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TWO ANALYTICAL ESSAYS IN DISTRIBUTION CHANNELS

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The Hong Kong Polytechnic University

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The Hong Kong Polytechnic University

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Two Analytical Essays in Distribution Channels

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CERTIFICATEOFORIGINALITY

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Abstract

Essay 1: A Signaling Model of Co-Branding with an Ingredient Supplier

In the real world, product quality may not be readily observable to consumers. For example, without actually using a computer for a long time, consumers are unlikely to be able to assess its durability. In such situations, consumers often use brand name (as well as price) as a cue to infer quality. In the PC industry, co-branding strategy is commonly observed. Producers such as Lenovo, Dell and Hewlett-Packard display not only their own brand name ("host brand") on their computers, but also those of some key ingredients provided by independent suppliers ("ingredient brand") (e.g., a Intel CPU sticker and a Nvidia Graphics sticker). Consumers therefore may use both the host brand and the ingredient brand to infer the quality.

The objective of this research is to investigate a manufacturer's incentives to co-brand with an ingredient supplier for signaling purposes. To explore the optimal conditions for co-branding and their implications for quality signaling we develop a series of game theoretical models. In our model, while a manufacturer produces a final product, the quality of the product is determined by an ingredient and unobservable to some consumers. We consider two possibilities for the ingredient: it is of high quality and has brand equity, and it is of low quality and has no brand equity. We also consider two addtional costs associated with manufacturer's co-branding strategy: a lump sum cost of contracting with the ingredient supplier, and a variable cost of labeling the ingredient brand on the final product. We derive the manufacturer's optimal strategies under the scenarios with ingredient co-branding or without it (i.e., price signaling only). Our model provides the conditions under which the manufacturer prefers to facilitate an ingredient co-branding strategy over the non-cobranding strategy when ingredient co-branding is an available option for the manufacturer. In the process, we address the following questions: What are the advantages of ingredient co-branding in quality signaling when it compares to non-cobranding signaling? How manufacturer capitalize the ingredient brand equity? How does wholesale price and two additional cost in co-branding make impact on manufacturer's strategy equilibrium?

Our research makes following contributions to the literature. First of all, this paper enriches the quality signaling literature by provide an analytical model to signaling quality through ingredient branding, and add one more framework to adopt quality signaling in channel context. Second, we demonstrate how manufacturer facilitate ingredient co-branding strategy to signaling the product quality, and how brand equity is capitalized in the process. Third, our findings provide theoretical and managerial implications for the rational behind ingredient co-branding strategy.

(Key words: Co-branding, Ingredient, brand awareness, siganling, channel)

Essay 2: Advance Selling in a Supply Chain

Advance selling has gained much popularity in recent years. Developing closely alongside Internet technology, advance selling enables sellers to expand the market by serving consumers who are not accessible with traditional spot selling. Conversely, due to the temporal separation between purchasing and consumption, consumers incur a disutility in advance buying, which puts a downward pressure on price and makes advance buying particularly appealing to price-sensitive, low-end consumers. In this paper, based on these two stylized facts and abstract from capacity and information issues, we develop a direct seller model and a bilateral-monopoly supply chain model to investigate a seller's advance selling strategy (i.e., spot selling only, advance selling only, or both spot and advance selling) and how the seller's decision is affected by a supplier. Analysis shows that because a supplier is motivated to induce the market equilibrium that is most favorable to itself, it has important impact on the downstream firm's advance selling strategy. The two firms consider different factors when making their respective decisions. The seller will adopt it only if advance selling is able to yield a positive margin, whereas the supplier's decisions on the wholesale price and whether to use the wholesale price to change the seller's strategy are dependent on advance selling's ability to expand the market size. Conventional wisdom suggests that due to the double marginalization problem, a seller in a supply chain is faced with a high marginal cost that discourages the seller to adopt advance selling to expand the market and price-discriminate consumers. We show that this is not necessarily the case in our model. We elucidate the conditions under which a seller in a supply chain has greater incentives to adopt a spot and advance selling strategy than a direct seller.

(Key words: advance selling, pre-order, supply chain, coordination, Internet)

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Contents

Chapter 1
The first Essay: A Signaling Model of Co-Branding with an Ingredient Supplier

1.1 Introduction

Product quality can be very difficult or costly to measure (Nelson 1970, 1974). For example, the quality of a laptop, which is an "experience goods", is hard to inspect until after actual consumption. In such a situation, because consumers may use information such as advertising, brand and price to infer its quality, firms are motivated to use this information as signals for quality. In the real world, PC producers use their brands (i.e., Lenovo) to distinguish itself from other brands (i.e., Apple et al.), and academic researchers provide the rationale. It has been well examined that a manufacturer can use brand name (Shapiro 1983, Wernerfelt 1988) to signal quality. However, producers such as Lenovo, Dell and Hewlett-Packard also display ingredient brand names on their laptops using label stickers (i.e., Intel for its CPU). There is no doubt that ingredient is one conventional attribute to measure the quality of a final product. With a well-known brand name to ensure the high quality of ingredient, consumers may use those label stickers incorporating with host brand to infer the quality of product accordingly. This is an example of "co-branding" for producers. Nevertheless, some other PC producers, in contrast, adopt a "non-cobranding" strategy, serving consumers with unobservable ingredient information. For instance, Apple Inc. uses a tidy cover on its laptops without any label sticker.

It is well documented that co-branding with a well-known brand name can improve the image and enhance consumer's quality perception of the final product (Tirole 1988). A manufacturer produces a final product which needs an ingredient from a supplier. The supplier can provide its brand name for co-branding. One rather illustrative example is GORE-TEX and the North Face. The North Face, one of the largest manufacturers and distributors for outerwear and sportswear. But when the North Face start its business, it is an unnamed manufacturer in its industry. At the meantime, GORE-TEX fabrics has led the industry in providing durable waterproof, breathable protection for decades. The North Face is successful to deliver the industry's most innovative and highest performance water-proof, wind-proof and breathable weather protection by co-branding with GORE-TEX and using its materials. In this case, GORE-TEX appears in the North Face in form of material. Such example provides a typical case of manufacturer leveraging vast brand awareness from ingredient supplier (i.e., The North face opens its market in waterproof outerwear with awareness of GORE-TEX). In this research, however, we abstract from the quality signal with the host brand and focus on the role of ingredient brand. We assume that the quality of ingredient can be either high or low and unknown to consumers. The quality of other parts is constant and known to all. In other words, we ignore the signal role of host brand and the product quality is only determined by the quality of ingredient. The ingredient supplier can be one of two following types: a high quality ingredient supplier with brand awareness of β ($\beta \in [0,1]$), and a low quality ingredient supplier without brand awareness.

Consumers differ in their ability to inspect product quality and they can be divided into three types. Informed consumers know the quality of the product, semi-informed consumers do not know about the product quality but they are aware of the ingredient brand and uninformed consumers know nothing about quality. The proportion of the semi-informed consumers is related to the brand awareness of the ingredient brand. For instance, in the example of *Cadillac* vehicle and in-car audio system “*Bose*”, informed consumers (i.e., with special knowledge about automobiles) are informed of a Cadillac vehicle’s quality while both semi-informed and uninformed consumers are not. But semi-informed consumers have been exposed to "Bose"’s market effect (acknowledge a high quality for "Bose" in-car audio system) and infer a high quality for the Cadillac vehicle. Hence, brand awareness of supplier plays an important role in consumers’ ability to inspect product quality and this role motivates a manufacturer to co-brand with a supplier, especially with one owns brand awareness.

To adopt a co-branding strategy, the manufacturer incurs "labeling cost" and "contract cost". "Labeling cost" refers to a marginal cost that a manufacturer incurs to display the ingredient brand (e.g., logo stickers). "Contract cost" refers to a lump-sum cost which is incurred due to the negotiation and contracting between the manufacturer and the supplier to adopt the co-branding strategy. We also assume that both "labeling cost" and "contract cost" are constant.

The objective of this research is to investigate a manufacturer’s incentives to adopt ingredient co-branding strategy for signaling purposes. Although prior research has indicated a signaling role of cobranding (Rao et al. 1999, Rao and Ruekert 1994), there has been no analytical endeavour. We conduct this research by developing a series of game theoretical models follow the above context. We first examine a model in which product quality is known to all. We show that a manufacturer will use a high quality ingredient to serve the market when the wholesale price scheme matches the ingredient quality (i.e., a high quality ingredient supplier never charges an irrational premium on wholesale price). We next extend to a model in which quality is unknown to the consumers and the manufacturer can only use retail price to signal its product quality. It is well accepted that a manufacturer can signal its high quality through a high price (Bagwell and Riordan 1991). However, signaling through prices may require an upward "distortion" in price. Take this price signaling only model (Also known as non-cobranding model) as the benchmark, then we explore a model where ingredient co-branding is introduced. Thus, by comparing those two models, we are able to present the conditions under which manufacturer prefers an ingredient co-branding strategy over a non-cobranding strategy. Such comparison enables us to address the following questions: What are the advantages of ingredient co-branding in quality signaling? Why not all manufacturers adopt the ingredient co-branding strategy? What's the role of the proportion of uninformed/semi-informed consumer, "labeling cost", "contract cost" in the mechanism of ingredient co-branding signaling? How important is the ingredient's brand equity to a manufacturer's cobranding strategy? What are the optimal conditions for a manufacturer to leverage the ingredient's brand equity?

In the following sections, we first examine the case without co-branding, where price serves as the only signal for quality. Then we study the case with co-branding, where both price and co-branding are signals. We develop two heterogeneous belief system for the semi-informed consumers and yield with difference equilibrium strategies. Further, we compare the scenarios between non-cobranding and co-branding to achieve manufacturer's equilibrium strategy.

1.2 Related Literature

1.2.1 Quality signaling

This paper is related to the vast literature on quality signaling. Consumers may not be informed about product quality when making a purchase, because quality can be very difficult or costly to measure. Moreover, many products are experience goods, with characteristics (e.g., quality) that can be ascertained only after consumption (Nelson 1970, 1974). In these circumstances, consumers may use "signals" such as store image, services, and price to make the inference to assist the purchase decision. The literature has identified several mechanisms that a firm can use to distinguish itself such as high price (Bagwell and Riordan 1991), advertising (Milgrom and Roberts 1986), product warranty (Jiang and Zhang 2011; Boudling and Kirmani 1993; Cooper and Ross 1985; Grosman 1981;Spence 1977), money-back guarantees (Moorthy and Srinivasan 1995), retailer reputation (Chu and Chu 1994; Biglaiser 1993), brand ally (Rao et al 1999; Rao et al 1994), specialization (Kalar and Li 2008) or some combinations of above strategies (i.e., Zhao (2000) and Erdem et al (2008) use price-advertising for signaling and Desai (2000) uses slotting allowance and advertising). However, some mechanisms other than price are often not available to small or start-up manufacturers. For example, umbrella branding (Wernerfelt

1988) cannot be a signal of quality for the manufacturer if its brand awareness has not been well-established. Advertising (Milgrom and Roberts 1986) and money-back guarantees (Moorthy and Srinivasan 1995) also cannot be feasible tools when manufacturer's capital is not sufficient enough for such "money burning". Nor an extended warranty, which is provided by a relatively unknown manufacturer, because consumers would also suspect the unknown manufacturer may already bankrupt during the extended warranty period. Among above mechanisms, renting reputation from a retailer (Chu and Chu 1994; Biglaiser 1993) and brand ally (co-branding) are a low entry mechanism for the manufacturer to signal its product. In our model, a manufacturer can use a co-branding strategy with its ingredient supplier to signal its product quality.

1.2.2 Co-branding

Co-Branding refers to a situation when two brands are combined in some way as part of a product or some other aspect of the marketing program (Rao 1994, Rao et al. 1999), coordinated as business allies and have become prevalent marketing phenomena. As a joint-marketing activity in which two or more brands are simultaneously presented to the consumer, both positive and negative impact of co-branding has been explored by prior researchers.

Park et al. (1996) compared co-brands to the notion of conceptual combinations in psychology and showed how carefully selected brands could be combined to overcome potential problems of negatively correlated attributes (e.g., rich taste and low calories). Co-branding is happening depends on several possible bases of fits: category fit, brand associations, culture, product usage, self-representation and consumer goals (Loken, Barsoaloou, & Joiner, 2008; Martin & Stewart, 2001). Such fits of co-branding reduce the risk of entering a new product category, in which host branding may be a lack of expertise (Aaker and Keller, 1990; Aaker, 1996). Image reinforcement is also one of the most important advantages of co-branding. Geylani, Inman and Hofstede (2008) exam the effect of co-branding on attribute uncertainty when co-branding drives image reinforcement versus image impairment for the partner brands. Their finding suggests that it is not necessarily a brand's optimal strategy to choose a co-branding partner that is the highest performance, while co-branding is more likely happening with lower attribute uncertainty.

Besides, there is considerable research in the branding literature which demonstrates an association between brand names and consumers' abilities to recall product information (Janiszewski and Osselaer, 2000). This point of view is well applied in quality signaling that partner brands can be beneficial if they can signal high-quality cues that transfer to the host brand or provide information on product attributes that benefits the alliance (Rao & Ruekert, 1994, Rao et al. 1999). Rao et al (1999) offer an example of allying with a credible ally to signal quality for a manufacturer whose host brand is unable to provide a credible quality communication for consumers. In their model, they argue firm's vulnerability to economic losses is the central issue and use vulnerability rather than reputation or advertising as a measurement of brand equity. For instance, high vulnerability ensures a firm has no incentive to fake the claimed quality. Similarly, a brand name with no reputation can also communicate unobservable quality credibility if it is able to demonstrate a vulnerability to future economic sanctions. Hoegg and Alba (2011) also shows that consumers prefer to assimilate visual cues, in our case is co-branding name, into their judgments of product evaluation. The perceived fit between pre-existing attitudes and external cues makes an important influence on customer perceptions.

Unfortunately, prior research also found some potential risks and disadvantages with co-branding strategies. Simonin and Ruth (1998) show that evaluations of the co-branded product may have an impact on consumers' perceptions of the partner brand. Simonin and Ruth (1998) give an example when Intel experienced quality problems with its Pentium microprocessors, Dell and Gateway were concerned about negative spillover effects on their brands. Similarly, Berthon, Pitt, and Campbell (2009) argue that consumers' existing knowledge plays an important role in how they interpret brand communications, such that a brand can have multiple meanings in the market depending on the stakeholder. Co-branding can also result in image suppress (Venkatesh and Mahajan 1997) for the host brand. Thus, a strategic approach for brand alliances is to use partner's brand equity as one conventional attribute to measure the quality of a co-branding product (Blackett and Boad 1999).

1.2.3 Ingredient branding

The marketing theory and industrial practice define ingredient branding as the marking or labeling of components or their industrial goods (Kotler and Pfoertsch 2010). Early research by Norris (1992) shows that ingredient branding can be very beneficial to both partner brands. Hillyer and Tikoo (1995) describe the impact of ingredient branding on consumer product evaluations. Rao and Ruekert (1994) and Rao, Lu, and Ruekert (1999) evaluate ingredient branding from the perspectives of multiple beneficiaries. Levin et al.

(1996) found that adding a well-known branded ingredient improved product evaluations of both unknown and well-known host brands more than when an unknown branded ingredient was added. Venkatesh and Mahajan (1997) consider a bundled product with two jointly consumed components with an analytical model. Their findings indicated that price levels, total revenues, and profits were affected by different types of brand alliances. McCarthy and Norris (1999) design two experiments to investigate the impact of branded ingredients on the host products. They find that branded ingredients consistently and positively affect moderate-quality host brands while branded ingredients only positively affect high quality host brands occasionally. Desai and Keller (2002) conduct a laboratory experiment to explore a comparison of different ingredient branding strategies (i.e., brand the ingredient as a self-branded ingredient versus a co-branded one) to show how ingredient branding strategy affects consumer acceptance in host brand's extension. Bartlett, Ghoshal, and Birkinshaw (2004) show that the co-branding strategy between the manufacturer and ingredient suppliers enables the host brand to establish and maintain its competitive advantages, and provides competitive attributes for their customers to differentiate.

Our model differs from prior researchers, i.e., Venkatesh and Mahajan (1997) and Desai and Keller (2002), in the following important aspects. First, our paper is the first study that explores manufacturer's strategic consideration for the role of the ingredient brand in an analytical model, but Venkatesh et al and Desai et al seek their evidence from empirical data. Second, our model uses both co-branding and price as a signal for quality while both Venkatesh et al and Desai et al ignore the signal role of price. Third, our model conducts the analysis explicitly in a channel context. Venkatesh et al and Desai et al's empirical works are not able to provide any channel interaction.

1.2.4 Ingredient Co-branding

Ingredient Co-branding is a special form of alliance between two brands, based on their cooperation for designing and delivering the product, with particular emphasis on the possibility to recognize and identify the used components in the final product (Pfoertsch and Mueller, 2006; Luczak et al. 2007). It is an accepted marketing concept (Norris, 1992; Dover, 1997) that has started to emerge not long ago (Kotler and Keller, 2006; Kotler and Pfoertsch, 2006).

The concept of Ingredient Co-branding, including both Co-branding and Ingredient Branding (In-branding), is built on multiple research streams, including bundling, branding, information integration theory, and attitude accessibility theory. Information integration theory and attitude accessibility theory provide a theoretical foundation for understanding consumers' consideration of a brand alliance. Information integration theory describes the process by which stimuli are combined to form beliefs or attitudes (Anderson 1981). In our study, brands, are combined to form consumers' attitudes toward a product. The theory of attitude accessibility suggests that the more salient or accessible a brand attitude, the more likely it is that the individual will access that attitude upon observing cues associated with the brand (Fazio 1986, 1989). It means the positive attributes of ingredient co-branding strategy can induce consumer's purchase decision to that product (Simonin and Ruth, 1998).

Extant literature on ingredient co-branding is not only directed at tangible products but also consider the role of services as ingredients. Tangible products like The North Face with GORE-TEX (water-proof membranes), PC producer Dell or early IBM with Intel (Microprocessors) are the common examples which repeatedly mentioned by the prior researchers (Rao & Ruekert, 1994, Simonin and Ruth 1998, Rao et al. 1999, Desai and Keller, 2002). Later, such context is extended from tangible products to the services: FedEx's delivery services can be regarded as an ingredient services provided by the online retailing platform, such as Amazon.com. Ghosh and John (2009) describe how Fasturn (ingredient brand) and Andersen Consulting (host brand) joined in creating a sales-pitch emphasizing the value of the ingredient service delivered by Fasturn if incorporated in Andersen Consulting's services. Helm & Özergin (2015) also conduct an experiment on ingredient service, find a positive effect of the presence of an ingredient service brand on buyers' perception of the end product's service quality. their findings indicate that ingredient service brands provide a cue to product quality of the end product, indirectly improving purchase intentions.

An extensive search of the literature reveals only two published studies conduct analytical research on ingredient co-branding. Erevelles et.al. (2008) provide an analytical model to examine why ingredient co-branding relationships occur and to examine if they are beneficial for supplier and manufacturer relationships. Their research highlight several potential benefits of ingredient co-branding relationships and focus its model on B2B stage. their results suggest that the ingredient co-branding relationship can benefit both participating manufacturers and suppliers, as well as the downstream buyer. As their model sets the potential entry in supplier's end, a co-branding relationship set up a barrier to the competing suppliers. In return, the co-branding supplier can reward the manufacturer with lower prices. Some of these rewards are passed down-channel to the final buyer, which in turn benefits the manufacturer in the marketplace. In the model extension, they develop a pull effect of the supplier by advertising support. They find that advertising support by the supplier to the manufacturer shifts the demand curve, which suggests that the ingredient co-branding relationship is made superior by additionally specifying an advertising support investment in the co-branding contract. Similarly, Zhang et.al (2013) consider an ingredient co-branding strategy under which the supplier and the OEM form a brand alliance. Their study provides a dynamic ingredient co-branding and co-op advertising strategy between two ingredient supplier.

In this research, we focus on the manufacturer's quality signaling strategy of price and ingredient co-branding. Quality signaling issue is common but rare in a context of a channel. Erevelles et.al. (2008) is the first analytical work for an ingredient co-branding strategy, but the function of such strategy is used to maintain the B2B relationship between supplier and manufacturer. The signaling role of the B2C end is not been explored. Zhang et.al (2013) also construct an ingredient co-branding strategy in the channel context, but their research focus is also the pull effect of co-advertising strategy instead of signaling role of co-branding. Jiang and Zhang (2011) use a signaling mechanism to develop an issue of extended warranty in a channel context. In their model, they focus on warranties as a role of quality signaling and the manufacturer's product quality and base-warranty decision would affect downstream retailer's extended warranty policy and pricing strategy to signal the product quality to the end consumers. Our research is aim to investigate the signaling role of ingredient co-branding in a channel context.

In this paper, we link the empirical evidence of a positive association between consumer's perception and branded ingredient to the manufacturer's B2B co-branding decision. After abstracting the signaling role of ingredient branding and ignoring the signaling role of host brand to consumer's perception, we propose an analytical model to study the signaling mechanism of ingredient co-branding strategy in a channel context. To our best knowledge, this is the first analytical model to investigate the joint decisions of ingredient co-branding and price signaling in a channel context. We offer a number of insights that have not been addressed in the previous literature. Our results provide quantitative guidelines for marketing brands and supply chain managers.

1.3 Signaling without Co-branding

We consider a market where a monopolist manufacturer procures a key ingredient (or component) from a supplier to make a final product. The quality of the final product is $Q = Q_s + Q_m$, where Q_s is the quality of the ingredient and Q_m is the quality determined by all the other input of the manufacturer. Consumers differ in product knowledge: we assume that Q_m is fixed and known to all and Q_s is not readily observable to some consumers before the purchase. These consumers are called "uninformed" consumers, comprising a proportion, α, of the market, where $1 > \alpha > 0$. The other proportion, $1-\alpha$, are "informed" consumers; they are experienced or experts and thus readily tell the quality of the product. We normalize $Q_m = 1$ and assume Q_s to be either high ($Q_s = q$) or low ($Q_s = 0$). Thus, the manufacturer is of high-quality if it uses a high-quality ingredient (so $Q = 1 + q$), or low-quality if it uses a low-quality ingredient (so $Q = 1$). Due to the presence of the uninformed consumers, a high-quality firm is motivated to signal and the consumers, in turn, will utilize the signal as a cue to make inference about product quality.

In this research we focus on two possible signals in two scenarios. When the manufacturer does not co-brand with the ingredient supplier, the uninformed consumers use product price as the only signal for quality. However, when the manufacturer co-brands with the ingredient supplier, both price and co-branding (including both the act of co-branding itself and branding of the ingredient) are signals for quality, because then the ingredient brand is also exposed to consumers and becomes salient. With these assumptions, our model abstracts from other possible signals such as the manufacturer branding and supply chain members' advertising—such cases have been extensively studied in the literature. Our assumptions are plausible in situations where the manufacturer's brand is weak or new (while the ingredient brand can be either weak or strong). Our model can also be applicable to situations where the manufacturer's brand is strong: although the brand has been well established, some critical attributes of the manufacturer's product are dependent on an ingredient and so consumers may use the information about that key ingredient—if the information is available—to assess the manufacturer's product. For example, in the apparel industry, although many brands have developed the general reputation for producing good quality products, when it comes to high-end outdoor outwear or sportswear, consumers may seek a brand that use Gore-tex fabrics for water- and wind-proof and breathability.

In addition to product quality knowledge, consumers also differ in willingness to pay for quality. We assume that a consumer with a quality evaluation index, x, derives a utility of $u = Qx - p$, where x is uniformed distributed along $[0, 1]$ and p is the price of the product. For the ease of exposition and without much loss of generality, we assume that the manufacturer's marginal cost of the product is the wholesale price of the ingredient, and that the ingredient market is competitive and so the wholesale price is a constant, c_L for a low-quality ingredient, or c_H for a high-quality ingredient, where $c_H > c_L$. To simplify the exposition and without much loss of generality, we assume that $c_L = 0$.

Before moving to the signaling model, we first analyze a benchmark model in which all consumers are informed (i.e., $\alpha = 0$). In this case, knowing consumers' utility function $u = Qx - p$, the manufacturer will pick an ingredient that produces a higher profit. If it uses a low-quality ingredient, the demand will be $(1 - p_L)$, and thus the manufacturer is to maximize $\pi_L = (1-p_L)p_L$ with respect to p_L. F.O.C. yields $p_L = \frac{1}{2}$, which leads to a profit of $\pi_L = \frac{1}{4}$. Alternatively, if the manufacturer uses a high-quality ingredient, the demand will be $(1 - \frac{p_H}{1+q})$, and thus the manufacturer is to maximize $\pi_H = (1 - \frac{p_H}{1+q})(p_H - c_H)$ with respect to p_H. F.O.C. yields $p_H = \frac{1+q+c_H}{2}$, which leads to a profit of $\pi_H = \frac{(1+q-c_H)^2}{4(1+q)}$. We can show that the manufacturer prefers to use high-quality ingredients if the wholesale price is not too high, i.e., $\pi_H > \pi_L$ if $1 + q - \sqrt{1+q} > c_H$.

We now explore the signaling strategy by a high-quality manufacturer that does not co-brand. In this case, because information about the ingredient brand is not disclosed, the price is the only signal for uninformed consumers. In the signaling (separating) equilibrium that we construct in the following, the price must be such that it is optimal if the manufacturer is high-quality and suboptimal if it is low-quality, and because a low-quality manufacturer would not charge that price, uninformed consumers will (correctly) infer a product to be high-quality if the product is charged at that price. Formally, we are to construct an equilibrium, in which a manufacturer with a high-quality ingredient optimally charges a price of p^*, and the uninformed consumers' equilibrium belief is that the manufacturer is high-quality if its price is p^*, or low-quality otherwise.

To derive the signaling equilibrium, we note that in the equilibrium a high-quality manufacturer's profit is maximized, i.e., $\max \pi_H^P(p) = (1 - \frac{p}{1+q})(p - c_H)$ with respect to p, where π refers to profit, the superscript "P" refers to the current scenario of signaling with price alone, and the subscript "H" (or "L") refers to the case where the manufacturer is high-quality (or low-quality). The optimization problem has two constraints. The first constraint is the high-quality manufacturer's self-selection constraint that prevents it from deviating from the signaling equilibrium. That is, if the manufacturer is high-quality, the manufacturer's profit when charging that equilibrium price, $\pi_H^P(p^*)$, is greater than $\hat{\pi}_H$, the profit when charging a different price and thus being mistaken by uninformed consumers as a low-quality manufacturer, where $\hat{\pi}_H(\hat{p}_H) = ((1-\alpha)(1 - \frac{\hat{p}_H}{1+q}) + \alpha(1 - \hat{p}_H))(\hat{p}_H - c_H)$ and $\hat{p}_H \neq p^*$. The second constraint is a low-quality manufacturer's self-selection constraint that prevents it from mimicking. That is, if the manufacturer is low-quality, then the manufacturer's profit when charging a price other than p^* (so its low-quality type is revealed), $\pi_L^{revealing}$, is greater than $\pi_L^{mimicking}$, the profit when mimicking and charging the equilibrium price p^* and thus being mistaken by uninformed consumers as a high-quality manufacturer, where $\pi_L^{revealing} = \frac{1}{4}$, as we have derived for the complete information case, and $\pi_L^{mimicking} = (\alpha(1 - \frac{p^*}{1+q}) + (1-\alpha)(1-p^*))p^*$. Proposition 1 follows.

Proposition 1: *When a (high-quality) manufacturer does not adopt co-branding, there are two possible signaling equilibria:*

- If $\alpha \in [0, \alpha_1]$, *there is a unique (costless) signaling equilibrium in which the manufacturer charges* $p_H = \frac{1+q+c_H}{2}$ *and makes a profit* $\pi_H^P = \frac{(1+q-c_H)^2}{4(1+q)}$, *and the uninformed consumers' belief is that a manufacturer is high-quality iff it charges that price, where* $\alpha_1 = \frac{(1+q)(q+c_H)^2}{q(1+q+c_H)^2}$.

- If $\alpha \in (\alpha_1, 1]$, *there is a unique (costly) signaling equilibrium in which the manufacturer charges* $p_H = \frac{1+q+\sqrt{\alpha q(1+q)}}{2(1+q-\alpha q)}$ *and makes a profit*

$\pi_H^P = \frac{(2(1+q-\alpha q)(1+q)-(1+q+\sqrt{\alpha q(1+q)}))(1+q+\sqrt{\alpha q(1+q)}-2c_H(1+q-\alpha q))}{4(1+q)(1+q-\alpha q)^2}$, *and the uninformed consumers' belief is that a manufacturer is high-quality iff it charges that price.*

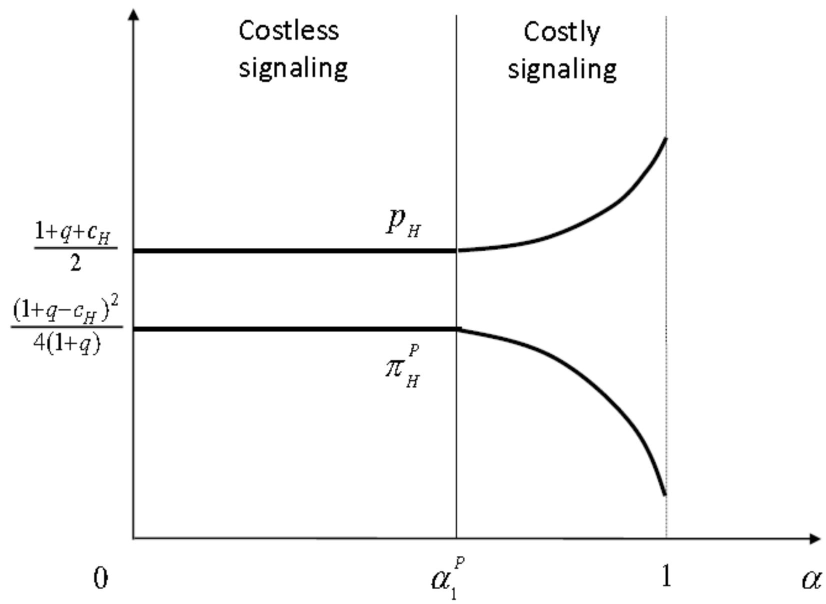

Figure 1: The equilibrium profit and price without co-branding

Proposition 1 shows that when the proportion of uninformed consumers is low (i.e. $\alpha \leq \alpha_1$), a high-quality manufacturer's pricing strategy is exactly the same as that under complete information. In this costless signaling equilibrium, the two foregoing self-selection constraints are not binding. Because a low-quality has no incentive to mimic to charge the same price as a high-quality manufacturer, a high-quality manufacturer faces no constraint in optimization, thereby obtaining the highest profit. When the proportion of uninformed consumers is sufficiently large (i.e. $\alpha > \alpha_1$), in contrast, a low-quality manufacturer has incentives to mimic now that the potential gain from exploiting the uninformed consumers becomes attractive. Nevertheless, faced with the threat of mimicking by a low-quality manufacturer, a manufacturer, if it is high-quality, will upwardly distort its price, such that the mimic is just deterred and thus the credibility of the price signal is warranted. Therefore, in this costly signaling equilibrium, the second self-selection constraint is binding and the first is not. Because a high-quality manufacturer's price is set to deter mimicking, the price is dependent on a low-quality manufacturer's cost c_L but not at its own cost c_H. Moreover, we can show that intuitively, $\frac{\partial p_H}{\partial \alpha} \geq 0$ and $\frac{\partial \pi_H}{\partial \alpha} \leq 0$, i.e., the greater the proportion of the uninformed consumers, the greater the price distortion and thus the smaller the manufacturer's profit.

It is useful to have a look at the boundary value $\alpha_1 = \frac{(1+q)(q+c_H)^2}{q(1+q+c_H)^2}$, which separates the costless and costly signaling equilibria. We can show that $\frac{\partial \alpha_1}{\partial c_H} > 0$. To understand this result, note that the higher the marginal cost c_H, the higher the price a high-quality manufacturer charges. Also note that a high price implies a small demand, which disappoints a low-quality manufacturer: with a low marginal cost this manufacturer is more willing to charge a low price to gain from a boosted sales volume. Because an increased c_H helps discourage mimicking by a low-quality manufacturer, it facilitates costless signaling, thereby expanding the parameter space of the costless signaling equilibrium.

1.4 Signaling with Co-branding?

In this section, we formally examine the signaling role of ingredient co-branding, under the assumption that consumers use both co-branding and price to infer product quality. The mere fact of co-branding can serve as a signal, because co-branding is generally well advertised in practice. In addition, because it is rather uncommon for manufacturers to show an ingredient brand side by side with their own, final product, the act of co-branding itself may be informative to consumers. In *Intel-inside* programs, for example, a PC maker displays the Intel-inside sticker on its PCs, making the ingredient brand (i.e., CPU by Intel) observable and salient to consumers. Consequently, consumers infer the product quality though whether the PC is equipped with an Intel CPU and its price, to infer its quality. In doing so, the manufacturer successfully leverages on the established brand equity of ingredient supplier.

A high-quality ingredient brand enjoys some positive brand equity. We capture brand equity in term of brand awareness, and denote it as $\beta \in [0, 1]$. Specifically, we assume that when the manufacturer co-brands with a high-quality ingredient supplier, a proportion, β, of the uninformed consumers become informed now that they are able to recognize the ingredient brand and correctly judge the product to be high-quality. We call these otherwise uninformed consumers "*semi-informed consumers*". The size of this group of consumers depends on the brand equity of the ingredient brand. The greater the brand equity β, the greater the proportion of the semi-informed consumers $\alpha\beta$, and thus the smaller proportion of the "truly" uninformed consumers $(1 - \alpha)$. That is, when co-branding with a high-quality ingredient brand, the proportion of informed consumers in the market is increased from $(1-\alpha)$ to $(1-\alpha+\alpha\beta)$ and the proportion of uninformed consumers is decreased from α to $\alpha(1 - \beta)$. In contrast, when co-branding with a low-quality ingredient supplier, there is no such reduction of uninformed consumers, because a low-quality ingredient brand has no brand equity (i.e., $\beta = 0$) and not recognizable by consumers.

While cobranding enables consumers to realize a high-quality ingredient, it comes at additional costs. We distinguish two types of costs. The lump sum costs of negotiation, contracting, marketing planning, etc. are referred to as "contracting cost" and denoted as

K. The marginal costs such as making and labeling the ingredient logo stickers are referred to as "labeling cost" and denoted as k. By definition, these costs are positive (while noting that they are be negative in modeling). It is apparent that K and k cannot be too large, otherwise, co-branding becomes a dominated strategy. For the ease of comparison, we assume that the wholesale price of a high-quality ingredient remains constant c_H.

We now construct a signaling equilibrium, in which a manufacturer co-brands with a high-quality ingredient and charges a price of p^*, and the uninformed consumers' equilibrium belief is that the manufacturer is high-quality if it adopts co-branding and charges p^*, or low-quality otherwise.[1] To derive this equilibrium, we note that in the equilibrium a high-quality manufacturer's profit is maximized at $\max \pi_H^{C\&P}(p) = (1 - \frac{p}{1+q})(p - c_H - k) - K$ with respect to p, where the superscript "$C\&P$" refers to the current scenario of signaling with both co-branding and price. Similar to the previous scenario, the optimization problem also faces two constraints. The first is a high-quality manufacturer's self-selection constraint: the manufacturer's profit, $\pi_H^{C\&P}(p^*)$, is greater than any other profits it can obtain if charging a different price and/or shedding co-branding and thus being mistaken as low-quality by uninformed consumers. If it deviates to adopt co-branding and charge a different price, it is to $\max \hat{\pi}_H(\tilde{p}_H) = ((1-\alpha+\alpha\beta)(1-\frac{\tilde{p}_H}{1+q})+\alpha(1-\beta)(1-\tilde{p}_H))(\tilde{p}_H-c_H-k)-K$, where $\tilde{p}_H \neq p^*$. If the high-quality manufacturer deviates to shed co-branding, it is to $\max \hat{\pi}_H(\hat{p}_H) = ((1-\alpha)\,(1 - \frac{\hat{p}_H}{1+q}) + \alpha(1 - \hat{p}_H))(\hat{p}_H - c_H)$.

The second constraint is a low-quality manufacturer's self-selection constraint: in equilibrium this manufacturer must be better off revealing its low-quality type than mimick-

[1] We focus on signaling equilibria. Pooling equilibria may exist, but are beyond the scope of this paper.

ing a high-quality manufacturer's co-branding and pricing strategies. Because co-branding entails additional cost, the best strategy for a low-quality manufacturer—when its low-quality type is revealed—is not to adopt co-branding. Thus, $\pi_L^{revealing} = \frac{1}{4}$, as in the complete information case. A low-quality manufacturer adopts a co-branding strategy only for mimicking and we assume that in this case, the manufacturer incurs the labeling cost k, but not the contracting cost K. This latter assumption is plausible since a mimicking manufacturer does not need to put much effort in contracting with a low-quality ingredient supplier.[2] When mimicking, a low-quality manufacturer makes a profit of $\pi_L^{mimicking} = (\alpha(1 - \frac{p^*}{1+q}) + (1-\alpha)(1-p^*))(p^* - k)$. Note that in this specification of a low-quality manufacturer's profit function, we explicitly assume that the semi-informed consumers behave the same as the uninformed consumers. That is, these consumers also believe a product that is co-branded and priced at the equilibrium level to be high-quality, even when the ingredient brand is not recognizable (we relax this assumption later).

Proposition 2: *When a (high-quality) manufacturer adopts co-branding, there are two possible signaling equilibria:*

- If $\alpha \in [\alpha_0^{C\&P}, \alpha_1^{C\&P}]$, there is a unique (costless) signaling equilibrium in which the manufacturer charges $p_H = \frac{1+q+c_H+k}{2}$, making a profit of $\pi_H^{C\&P} = \frac{(1+q-c_H-k)^2}{4(1+q)} - K$, and the uninformed consumers' belief is that a manufacturer is high-quality iff it co-brands and charges that price, where $\alpha_0^{C\&P} = \underset{\alpha}{\arg}\{\hat{\pi}_H = \pi_H^{C\&P\_Costless}\}$ and $\alpha_1^{C\&P} = \frac{(1+q)((c_H+q)^2+k(2-k))}{q(1+q+c_H+k)(1+q+c_H-k)}$.

[2] Because this assumption implies a reduced mimicking cost, it effectively encourages mimicking and thus results in tighter conditions for the co-branding equilibrium.

- If $\alpha \in (\alpha_1^{C\&P}, \alpha_2^{C\&P}]$*, there is a unique (costly) signaling equilibrium in which the manufacturer charges* $p_H = \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha q)}$*, making a profit of* $\pi_H^{C\&P} = (1 - \frac{(1+q-\alpha q)k+\left(1+q+A^{C\&P}\right)}{2(1+q)(1+q-\alpha q)})(\frac{k(1+q-\alpha q)+1+q+A^{C\&P}}{2(1+q-\alpha q)} - c_H - k) - K$*, and the uninformed consumers' belief is that a manufacturer is high-quality iff it co-brands and charges that price, where* $\alpha_2^{C\&P} = \underset{\alpha}{\arg}\{\pi_H^{C\&P} = \hat{\pi}_H^{C\&P}\}$ *if* $\beta \geq \beta^*$*, or 1 if* $\beta < \beta^*$*,* $\beta^* = \arg\{\hat{\pi}_H^{C\&P}|_{\alpha=1} = \pi_H^{C\&P}|_{\alpha=1}\}$ *and*
$A^{C\&P} \triangleq \sqrt{\left(1+q-k\left(1+q-\alpha q\right)\right)^2 - \left(1+q\right)\left(1+q-\alpha q\right)}$.

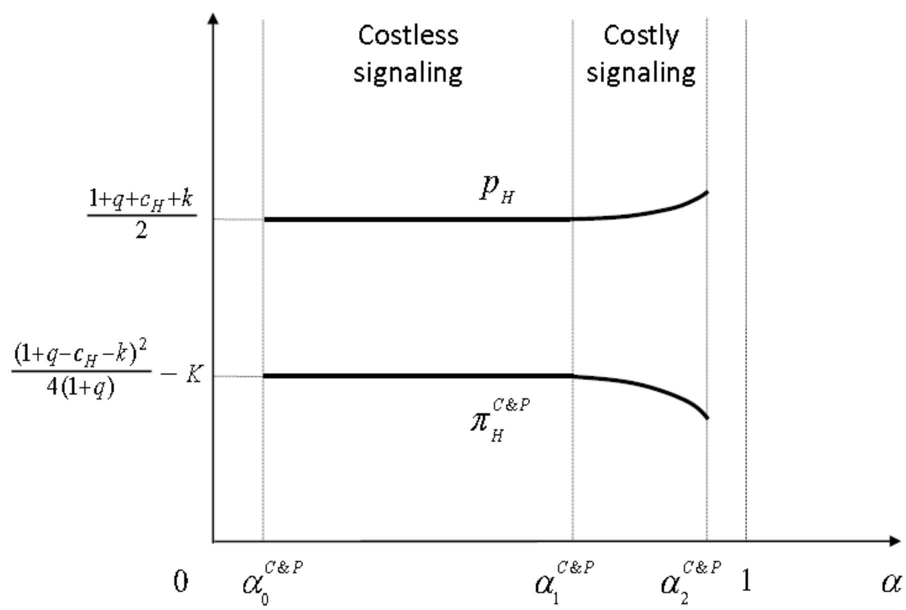

Figure 2: The equilibrium profit and price with co-branding

Proposition 2 produces a few results that are analogical to the scenario under non-co-branding. For instance, there is a critical value of the proportion of uninformed consumers, $\alpha_1^{C\&P}$, bellow which there is a costless signaling equilibrium and above which there is a costly signaling equilibrium. So, the manufacturer also needs to upwardly distort its price to signal, if the proportion of uninformed consumers α is sufficiently large (i.e., if $\alpha > \alpha_1^{C\&P}$). In this case, $\frac{\partial p_H}{\partial \alpha} > 0$ and $\frac{\partial \pi_H}{\partial \alpha} < 0$, i.e., the greater the proportion, the greater the price distortion and the smaller the manufacturer's profit. We can show that $\frac{\partial \alpha_1^{C\&P}}{\partial c_H} > 0$, which implies that an increased c_H expands the parameter space of the costless signaling equilibrium. The reason is that, as discussed before, a high c_H induces a high price, which can discourage mimicking, as a low-quality manufacturer may find it optimal to charge a low price and reveal its low-quality type.

Proposition 2 also produces a number of new and important findings. First of all, there is no signaling equilibrium when α is very small (i.e., when $\alpha < \alpha_0^{C\&P}$), because then a high-quality manufacturer is better off shading co-branding and being mistaken by uninformed consumers as low-quality. To understand this result, note that co-branding entails both the labeling cost k and the contracting cost K. These costs make co-branding unappealing when the size of uninformed consumers is sufficiently small. On the other hand, there is no signaling equilibrium when α is sufficiently large (i.e., $\alpha > \alpha_2^{C\&P}$). In this case, the price distortion is so severe that the high-quality manufacturer is better off forgoing costly signaling. We can also show that $\frac{\partial \alpha_2^{C\&P}}{\partial \beta} < 0$; in other words, the greater the ingredient brand equity β, the more likely the costly signaling equilibrium collapse. To see this result, note that β influences the (off-the-equilibrium-path) profit of the high-quality manufacturer if it deviates from the costly signaling equilibrium. In this case, although the manufacturer will be mistaken by the truly uninformed consumers as low-quality, it will not by the semi-informed consumers because these consumers are able to recognize a high-quality ingredient brand. Naturally, the greater β, the greater the proportion of the semi-informed consumers $\alpha\beta$, and as a result, the greater the profit a high-quality manufacturer can obtain if it deviates, which in turn implies a reduced parameter space of the costly signaling equilibrium.

Second, the marginal, labeling cost k plays different roles in the signaling equilibria than the fixed, contracting cost K. Whereas the latter only adversely affects the profit, the former also influences the parametric space of the equilibrium. We can show that $\frac{\partial \alpha_1^{C\&P}}{\partial k} > 0$, which implies that the parametric space of the costless signaling equilibrium expands as k increases. This is because an increased k leads to an increased price (in the costless signaling equilibrium), which discourages a low-quality manufacturer from mimicking and thus facilitates a costless signaling equilibrium. The marginal, labeling cost k also influences the manufacturer's strategy and performance. Intuition suggests that an increased marginal cost raises the retail price and reduces the manufacturer's profit. Proposition 2 confirms this intuition, but only for the costless signaling equilibrium. When signaling is costly, the intuition is upended: we can show that $\frac{\partial p_H}{\partial k} < 0$ and we expect $\frac{\partial \pi_H}{\partial k}$ can be either positive or negative. To understand these surprising findings, note that in the costly signaling equilibrium, the high-quality manufacturer's price is set only to deter mimicking and thus is independent of the high-quality manufacturer's marginal cost k and c_H. As an increased k discourages mimicking, the greater k, the less price distortion the manufacturer needs to make and thus the lower the equilibrium price it charges. Because the parameter space of the costless signaling equilibrium expands with k and because price distortion decreases with k, it follows naturally that an increased k helps improve signaling efficiency and thus may result in an increased manufacturer profit. However, we are not able to find such parameter space for profit increasing when we use an numerical experiment[3]. This is unexpected but still reasonable. k is a cost for both high quality manufacturer and imitator, and increasing in k will only increasing the cost for both of them but no other functional rewards. Take the advertising as an example of "money burning", it can increase the demand when it incurs a larger cost. Thus, $\frac{\partial \pi_H}{\partial k}$ can only be negative suggest that k appears to be a cost more than signaling efficiency.

Surprisingly, Proposition 2 shows that the brand equity of the ingredient brand β does not help to improve a high-quality manufacturer's profit in spite of an increased proportion of informed consumers. In fact, the profit $\pi_H^{C\&P}$, the price p_H and the boundaries of the equilibria $\alpha_0^{C\&P}$ and $\alpha_1^{C\&P}$ are all independent of β (the only exception is $\alpha_2^{C\&P}$, which might decrease with β). Why is the manufacturer unable to capitalize on the ingredient brand's brand equity? To answer this questions, first note that in the signaling equilibrium that we have just derived, the uninformed consumers are able to correctly infer a high-quality manufacturer's type. Because the uninformed consumers behave exactly the same as the informed consumers in equilibrium, the proportions of informed and uninformed consumers in the market do not necessarily matter. Indeed, they do not matter in the costless signaling equilibrium. In this equilibrium, because the manufacturer optimally strategies the same way as if all the consumers are informed, the increased proportion of informed consumers due to the ingredient brand's brand equity (i.e., a proportion $\alpha\beta$ of the semi-uninformed consumers) has no effect. The proportions may matter when it comes to the costly signaling equilibrium. In this case, the manufacturer has to upwardly distort

[3] The range of parameter search: $\alpha = .05; .10; .15; ...0.95; 1.00$, $c_H = .05; .10; .15; ...0.95; 1.00$, $k = .01; .02; .03; ....09; .10$, $q = .5; 1.0; 1.5; 2; 2.5$

the price to credibly signal its high-quality type to uninformed consumers, and the greater the proportion of the uninformed consumers, the severer the price distortion and the lower the manufacturer's profit, as illustrated in Figure 2. Because the extent of price distortion is determined by the extent to which a low-quality is motivated to mimic, the question of how much an ingredient brand's brand equity can be capitalized by the high-quality manufacturer is equivalent to the question of how much that brand equity can help deter mimicking by a low-quality manufacturer. It turns out that the brand equity of the ingredient brand does not help deter mimicking in the present model, because we have assumed that both the semi-informed and uninformed consumers will believe a manufacturer to be high-quality as long as it adopts co-branding and charges the equilibrium price, even when the ingredient brand has no brand equity and is not recognizable by consumers. It is this assumption that disables the high-quality manufacturer from capitalizing on the ingredient brand's brand equity. We discuss an alternative assumption about the semi-informed consumers' belief and explore its implications in detail in the next section.

We are now ready to examine a manufacturer's optimal strategy choice between signaling with price alone ("non-co-branding" hereafter) and signaling with both price and co-branding ("co-branding" hereafter). Because a signaling equilibrium that yields a lower profit does not satisfy the intuitive criterion (Gibbons 1992, p. 188), the signaling equilibrium that yields a higher profit is the only equilibrium (for application of these concepts in marketing see Moorthy and Srinivasan 1995, Zhang and Cao 2014). We focus on the range of $\alpha \in [\alpha_0^{C\&P}, \alpha_2^{C\&P}]$, in which both the co-branding and non-co-branding signaling equilibria sustain.

According to the equilibrium profits we have obtained previously, it is easy to see that when signaling is costless, non-co-branding yields a higher profit than co-branding since $\pi_H^{P\_Costless} \geq \pi_H^{C\&P\_Costless}$, and $\pi_H^{P\_Costless} = \pi_H^{C\&P\_Costless}$ only when the co-branding costs, the lump sum contracting cost K and the marginal labeling cost k, are both zero. Therefore, when these two costs are sufficiently large, it is evident that the manufacturer is better off adopting non-co-branding and signaling with price alone. The following proposition shows that co-branding cannot arise in equilibrium even when these two costs are small.

Proposition 3: *Under the consumer belief as specified in Proposition 2, co-branding is a dominated strategy.*

Proposition 3 shows that co-branding is a dominated strategy even when both K and k are zero, despite that co-branding is able to increase the proportion of (semi)-informed consumers in the market. To understand this surprising result, note that in our co-branding model we assume that the semi-informed consumers believe a product to be high-quality as long as that product is co-branded and priced at the equilibrium price level, even if the ingredient brand is not recognizable (i.e., has no brand equity). This assumption is plausible in markets where there are many (high-quality) ingredient brands. In such markets, it is likely that even if consumers can recognize some particular high-quality ingredient brands, they do not exclude the possibility that other, unrecognizable brands to be high-quality as well. Note that under this assumption, the semi-informed consumers could also be fooled by a mimicking, low-quality manufacturer, if it adopts co-branding and charges the equilibrium price. Because the semi-informed consumers' knowledge about ingredient brands only helps them to recognize a high-quality ingredient brand, but not to prevent them from being deceived by a low-quality ingredient brand, from a mimicking, low-quality manufacturer's point of view, these consumers are virtually the same as the "pure" uninformed consumers. This is the very reason why a (high-quality) manufacturer cannot capitalize on a high-quality ingredient brand in our previous co-branding model, in which both the manufacturer's equilibrium price and profit are independent of β, the brand equity of the ingredient brand. Because co-branding incurs additional costs (i.e., K and k) and cannot contribute to profitability, it is suboptimal for the manufacturer has no incentive to adopt it—unless the supplier would subsidize the manufacturer by offering either a lump sum allowance or a lowered wholesale price.[4]

1.5 Capitalizing on Ingredient Brand

In this section, we present a more stringent (semi-informed) consumers' belief on high-quality ingredient and explore its implications. In the real world consumers can be very suspicious and risk averse; they only trust a reputed and recognizable ingredient brand. To effectively signal to these consumers, the act of co-branding is insufficient: co-banding is a credible signal only when the ingredient is a reputed and recognizable ingredient brand. As we show in the following, under this new, more stringent consumers' belief, the ingredient's brand equity can influence the retail price and improve the manufacturer's profit, thereby giving rise to co-branding as an equilibrium strategy for the manufacturer.

[4] Ingredient suppliers have been using both types of susidies to incentivize manufacturers to adopt co-branding in the real world. We leave these very interesting issues for future research, as in this research we take a manufacturer's point of view and focus on its signaling strategy.

Formally, we assume that the semi-informed consumers' belief is that a product is high-quality iff it is co-branded with a recognizable high-quality ingredient brand and priced at the equilibrium level. Other assumptions in the previous co-branding model are maintained. Now, because the proportion of consumers that can be exploited by a low-quality manufacturer is reduced from α to $\alpha(1-\beta)$, mimicking becomes less attractive, yielding a profit of $\pi_L^{mimicking} = (\alpha(1-\beta)(1-\frac{p^*}{1+q}) + (1-\alpha+\alpha\beta)(1-p^*))(p^*-k)$. As a result, a costless signaling equilibrium becomes more viable, as we can see from the following proposition.

Proposition 4: *When a (high-quality) manufacturer adopts a co-branding strategy, there are two possible signaling equilibria:*

- If $\alpha \in [\alpha_0^{C\&P}, \alpha_1^{C\&P}]$*, there is a unique (costless) signaling equilibrium in which the manufacturer charges* $p_H = \frac{1+q+c_H+k}{2}$*, making a profit of* $\pi_H^{C\&P} = \frac{(1+q-c_H-k)^2}{4(1+q)} - K$*, and that uninformed consumers' belief is that a manufacturer is high-quality iff it charges that price and the ingredient is a recognizable high-quality brand, where* $\alpha_0^{C\&P} = \arg\{\hat{\pi}_H = \pi_H^{C\&P\_Costless}\}$ and $\alpha_1^{C\&P} = \frac{(1+q)((c_H+q)^2+k(2-k))}{(1-\beta)q(1+q+c_H+k)(1+q+c_H-k)}$.

- If $\alpha \in [\alpha_1^{C\&P}, 1]$*, there is a unique (costly) signaling equilibrium in which the manufacturer charges*$p_H = \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha(1-\beta)q)}$*, making a profit of*

$\pi_H^{C\&P} = (1 - \frac{(1+q-\alpha(1-\beta)q)k+\left(1+q+A^{C\&P}\right)}{2(1+q)(1+q-\alpha(1-\beta)q)})(\frac{k(1+q-\alpha(1-\beta)q)+1+q+A^{C\&P}}{2(1+q-\alpha(1-\beta)q)} - c_H - k) - K$*, and that uninformed consumers' belief is that a manufacturer is high-quality iff it charges that price and the ingredient is a recognizable high-quality brand, where*

$A^{C\&P} \triangleq \sqrt{(1+q-(1+q-\alpha(1-\beta)q)k)^2 - (1+q)(1+q-\alpha(1-\beta)q)}$.

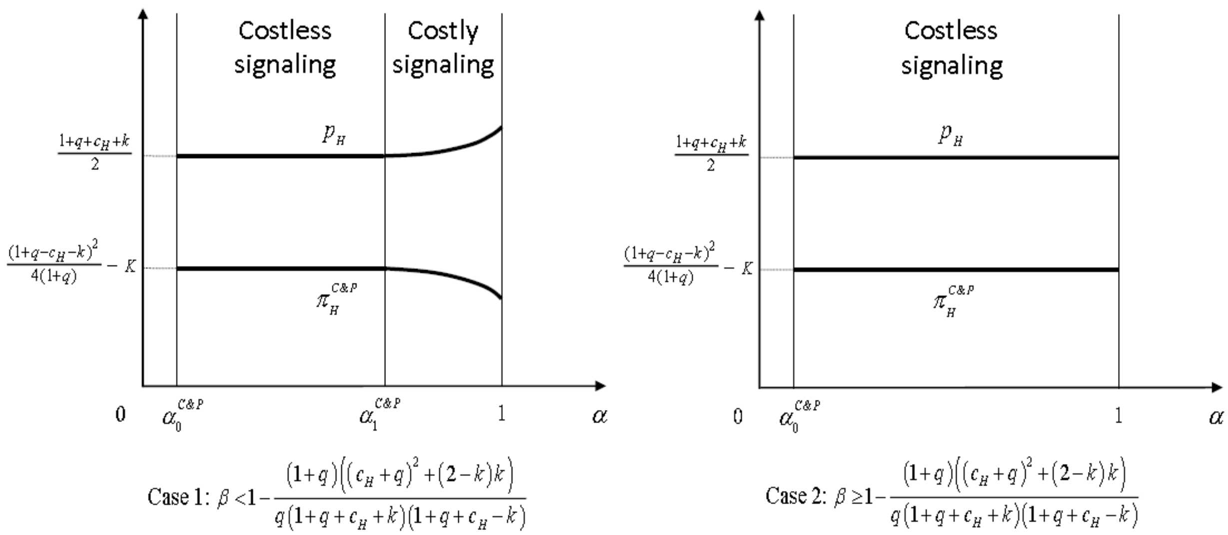

Figure 3: The equilibrium profit and price with co-branding under alternative belief

Proposition 4 shows that the new consumer belief brings about important changes in relation to Proposition 3: the manufacturer is now able to leverage on the ingredient's brand equity (i.e., β) to improve profitability. In general, due to the more strigent consumer belief on high-quality brand, mimicking by low-quality manufacturer is discouraged and more efficient (costless) signaling is facilitated. More specifically, we can show 1) that the equilibrium price in the costly signaling equilibrium is less distorted, leading to a higher manufacturer profit than in the previous co-branding model, 2) that the greater β, the smaller the price distortion and the greater the manufacturer profit in that equilibrium, and 3) that $\frac{\partial \alpha_1^{C\&P}}{\partial \beta} > 0$, i.e., the greater β, the greater the space of the costless signaling equilibrium and the smaller that of the costly signaling equilibrium. Indeed, when β is sufficiently large (i.e., when $\beta > \beta_2$, see case 2), signaling with co-branding becomes costless only, because the boundary that separates costly and costless signaling, $\alpha_1^{C\&P}$, approaches to 1 when β increases to $\beta_2 = 1 - \frac{(1+q)((c_H+q)^2+k(2-k))}{q(1+q+c_H+k)(1+q+c_H-k)}$.

Therefore, the role of β is the major difference between two semi-informed consumers' belief, and we address those changes with the following corollary.

Corollary 1(under an alternative consumer belief): *Increasing in the proportion of semi-informed consumers ($\alpha\beta$) through β can expand the space of co-branding. A large β can reduce price distortion and induce costless signaling with co-branding. But further increasing in β (i.e., $\beta \geq 1 - \frac{(1+q)\left((c_H+q)^2+k(2-k)\right)}{q(1+q+c_H+k)(q+c_H+1-k)}$) has no effect on co-branding signaling equilibrium.*

We now compare the manufacturer's profits under co-branding and non-co-branding, which are illustrated in Figure 4. We can see that when signaling is costless, non-co-branding yields a higher profit than co-branding since $\pi_H^{P\_Costless} \geq \pi_H^{C\&P\_Costless}$ and $\pi_H^{P\_Costless} = \pi_H^{C\&P\_Costless}$ only when the co-branding costs, the lump sum contracting cost K and the marginal labeling cost k, are both zero. When these costs are at a medium level, depending on the curvature of $\pi_H^{P\_Costly}$ and $\pi_H^{C\&P\_Costly}$ it becomes possible that $\pi_H^{P\_Costly} < \pi_H^{C\&P\_Costless}$ and $\pi_H^{P\_Costly} < \pi_H^{C\&P\_Costly}$, therefore giving rise to co-branding as an equilibrium strategy. When the costs are sufficiently large, co-branding is a dominated strategy by non-co-branding.

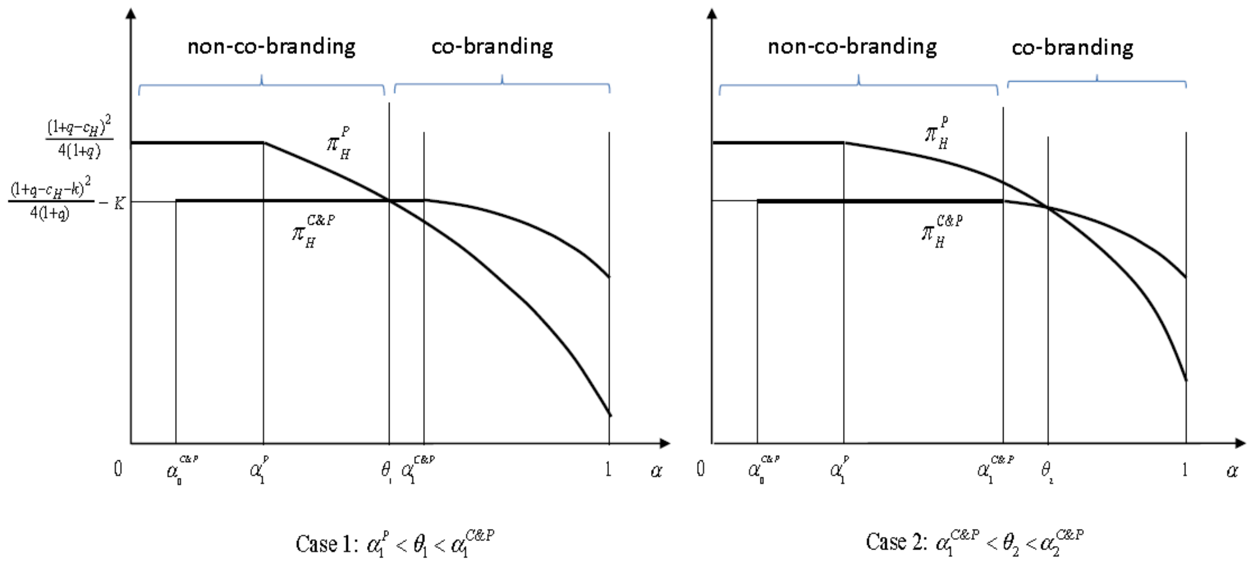

Figure 4: Comparison of the equilibrium profit with and without co-branding (under alternative belief)

We can also look at the manufacturer's strategy in relation to the proportion of uninformed consumers α. When α is small (i.e., $\alpha \leq \alpha_1^P$), both of the signaling equilibria are costless. In this case, co-branding yields a lower profit than non-co-branding because co-branding entails additional costs. So, when α is small, co-branding is disadvantaged due to its associated costs. These costs pay off only when α is sufficiently large. We can see in Figure 4 that when $\alpha \in (\alpha_1^P, \alpha_1^{C\&P}]$, signaling under non-co-branding is costly while signaling under co-branding is costless. In this case ("Case 1"), there exists a point $\theta_1 \in (\alpha_1^P, \alpha_1^{C\&P})$ such that $\pi_H^{C\&P\_Costless} > \pi_H^{P\_Costly}$ iff $\alpha > \theta_1$. When the signaling equilibria under non-co-branding and co-branding are both costly, it is also possible that $\pi_H^{C\&P\_Costly} \geq \pi_H^{P\_Costly}$, because price distortion is severer under non-co-branding than under co-branding and so the profit in the former scenario drops faster with α since $\frac{\partial \pi_H^{C\&P\_Costly}}{\partial \alpha} > \frac{\partial \pi_H^{P\_Costly}}{\partial \alpha}$. In this case ("Case 2"), there exists a point $\theta_2 \in (\alpha_1^{C\&P}, \alpha_2^{C\&P})$ such that $\pi_H^{C\&P\_Costly} > \pi_H^{P\_Costly}$ iff $\alpha > \theta_2$.

To better understand the conditions for co-branding to rise in equilibrium, we can also look at the manufacturer's optimal strategy in respect of the ingredient's brand equity β. When $\beta = 0$, there is no ingredient brand equity for the manufacturer to leverage. Thus, co-branding is a dominated strategy, consistent with Proposition 3. When β is at a medium level, because con-branding enables the manufacturer to capitalize on the ingredient's brand equity and facilitates more efficient signaling, a costly signaling under co-branding can result in a greater profit than a costly signaling under non-co-branding ("Case 2"). When β is sufficienly large, signaling under co-branding becomes so efficient and it is always costless, yielding a greater profit than a costly signaling under non-co-branding ("Case 1"). We summarize the above results, in respect to β, Proposition 5, and graphically illustrate the parametric spaces of the equilibrium strategies in Figure 5.

Proposition 5: *The (high-quality) manufacturer's optimal strategies are as follow:*

- *if* $\beta \in [0, \beta_0)$, *non-cobranding is the equilibrium strategy;*

- *if* $\beta \in [\beta_0, \beta_1)$, *it adopts non-cobranding if* $\alpha \in [0, \theta_2)$ *and co-branding if* $\alpha \in [\theta_2, 1]$;

- *if* $\beta \in [\beta_1, 1]$, *it adopts non-cobranding if* $\alpha \in [0, \theta_1)$ *and co-branding if* $\alpha \in [\theta_1, 1]$, *where* $\theta_1, \theta_2, \beta_0,$ and β_1 *are defined in the Appendix..*

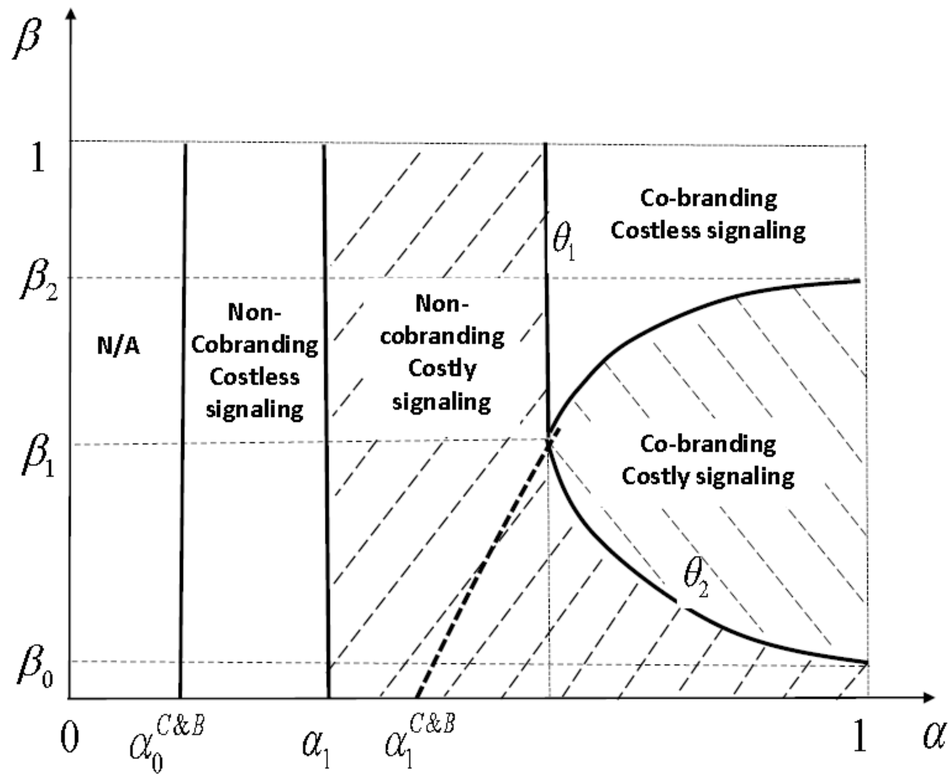

Figure 5: The parametric spaces of the manufacturer's equilibrium strategies

The above results have suggested that co-branding is more likely to arise in equilibrium when the proportion of uninformed consumers in the market is large; under such conditions, the benefit from improved signaling efficiency can overweigh the additional costs associated with it. The effect of the contracting cost K on the incidence of co-branding is also straight forward. As it is a fixed cost, an increase of it only shifts the profit curve downward, without changing the curvature of the profit function. Hence, as K increases, θ (either θ_1 or θ_2) shifts to the right, thereby shrinking the parameter space of the co-branding equilibrium.

The impact of the wholesale price of the ingredient c_H on the parameter spacaaaaaaaaae of the co-branding equilibrium is more involved. While an increased c_H always reduces the manufacturer's profit, we can show that $\frac{\partial \pi_H^{C\&P}}{\partial c_H} > \frac{\partial \pi_H^P}{\partial c_H}$ when $\alpha \in (0, \alpha^*)$ and $\frac{\partial \pi_H^{C\&P}}{\partial c_H} < \frac{\partial \pi_H^P}{\partial c_H}$ when $\alpha \in (\alpha^*, 1)$ where $\alpha^* = \frac{(1+q)\left(q(q+2c_H+2k)+(c_H+k)^2\right)}{q\left((c_H+k)^2+(1+q)(1+q+2c_H+2k)\right)}$ and $\alpha^* < \theta$. However, co-branding is more likely to be adopted only when the negative effect of c_H on profit is weaker. Thus, increasing in c_H can only shrink the space of co-branding. The reason is that when non-cobranding turns to a costly signaling, its demand will not affect by the c_H. c_H only plays a role of marginal cost. However, non-cobranding signaling is more distorted in price, and it creates less demand than co-branding signaling case Thus, we can observe a weaker effect of c_H from non-cobranding.

Finally, the effects of the labeling cost k are multifaceted. An increased k generally puts a downward pressure on profit as it increases the manufacturer's marginal cost. However, there are also counteracting forces. As noted in the previous section, $\frac{\partial \alpha_1^{C\&P}}{\partial k} > 0$, i.e., the parameter space of the costless signaling equilibrium expands with k, and $\frac{\partial p_H}{\partial k} < 0$, i.e., price distortion in the costly signaling equilibrium decreases with k. Because an increased k can help improve signaling efficiency, it turns out that the parameter space of the co-branding equilibrium can either shrink or expand as k increases. However, similar to the previous belief, only shrink cases are survived. See detailed proof in the Appendix. These results are summarized in Proposition 6.

Proposition 6: *The parameter space of the co-branding equilibrium a) expands with β; b) shrinks with K, c_H* and k.

In this co-branding model, the semi-informed consumers, who have some knowledge about ingredient brand, behave differently from those uninformed consumers when they face an unnamed ingredient brand. The semi-informed consumers are a lack of security and refuse to accept any unrecognizable brand to be a high quality ingredient. We address such assumption by abstracting the features of risk-averse consumers. Such insecurity is the very reason why brand equity is so important and plays an important role in manufacturer's co-branding strategy.

1.6 Discussion

Most products contain more than one components and many manufacturers co-brand with their ingredient suppliers to create synergy. In this research, focusing on the role of co-branding in signaling product quality we develop analytical models to investigate the optimal conditions for a manufacturer to adopt a co-branding strategy. In our model, the quality of the manufacturer's product is critically dependent on a component whose quality is not readily observable to some consumers and the manufacturer chooses between a non-co-branding strategy and a co-branding strategy. The previous analysis elucidates the conditions under which a co-branding strategy yields a higher profit than a non-cobranding strategy. To facilitate the analysis, our model is more parsimonious with two belief system of semi-informed consumers. For instance, we make the first belief of semi-informed consumers to be the same as uninformed consumers when they face a co-branded product beyond their recognition. In practice, not all the consumers, who recognize a particular ingredient brand, still do not exclude the possibility that other unrecognizable brands to be high-quality as well. Our first belief abstracts such practice from one extreme scenario that all semi-informed consumers admit the possibility of a high quality ingredient from other unrecognizable brands. Our alternative belief, pick the another side of extreme scenario that all semi-informed consumers exclude the possibility that the ingredient from other unrecognizable brands can be high-quality.

Under the first belief: The manufacturer is unable to capitalize the ingredient supplier's brand equity. The brand equity fails to either improve consumers' ability in deterring mimicking or help manufacturer to facilitate costless signaling. Indeed, brand equity does not affect in the costless signaling equilibrium. Further, a sufficient high brand equity even makes a counter effect, it reduces the ceiling of equilibrium space and shrinked the space of co-branding equilibrium. More surprised, co-branding is dominated when it compare to the non-cobranding strategy.

Under the alternative belief: The manufacturer now is able to capitalize on the ingredient supplier's brand equity. Increasing in brand equity can cut the proportion of consumers of getting cheated which directly reduces the profit of mimicking manufacturer. Although brand equity still not shows its position in the costless signaling profit, it expands the space of facilitating costless signaling emerges. In this scenario, the space ceiling of equilibrium space is unconditional expanded to a full space ($\alpha = 1$) and profit of costly signaling is also increasing with brand equity. What's more, when brand equity is high enough, the manufacturer is free from costly signaling. Although further increasing in brand equity cannot further improve manufacturer's profit, costless signaling only benefits the manufacturer to achieve the highest profit.

Though two scenarios, our analysis also highlights some robust results to understand how other factors affect manufacturer's co-branding strategy:

- Signaling with co-branding is not as good as signaling with price alone when there are not many uninformed consumers ($\alpha < \theta$), due to its additional cost of contracting and labeling. Signaling with co-branding becomes efficiency and takes advantage when the proportion of uninformed consumers is large enough ($\alpha \geq \theta$).

- Contracting cost K and labeling cost k play different roles in facilitating co-branding signaling: K only acts as a cost that prevents the use of co-branding. But k can deter mimicking and thus reduces price distortion. It is out of our expectation that there is no parameter space to address the positive effect on manufacturer's profit.

- Wholesale price c_H is also an important factor as it is the major cost for host manufacturer. Increasing in c_H brings disadvantage to prevent mimicking as it increases the cost of host brand. However, it's major function in facilitating manufacturer's equilibrium strategy is to prevent the adoption of co-branding, because it only affects with manufacturer's marginal profit when its optimal strategy is non-cobranding with costly signaling. Non-cobranding with a low demand is less sensitive to the marginal cost.

1.7 Conclusion

Prior empirical researchers provide a solid foundation about how branded ingredient improves consumer's perception of product quality (Norris 1992, McCarthy and Norris 1999, Desai and Keller 2002). Despite this, there is also some researchers that address the issue of B2B ingredient co-branding relationship and outcome (Erevelles et.al. 2008, Zhang et.al. 2013). We use an analytical model to investigate the signaling role of ingredient co-branding in a channel context. Our approach tries to explain why and how manufacturer engages an ingredient co-branding strategy in a supply chain. Our model provides the conditions under which the manufacturer prefers to facilitate an ingredient co-branding strategy over the non-cobranding strategy. We find that ingredient co-branding is not an efficiency strategy for the manufacturer when it faces a small proportion of uninformed consumers. Contracting cost, labeling cost and wholesale price all can be the liabilities unless the manufacturer faces a sufficiently high proportion of uninformed consumers, which adds enough advantage for co-branding signaling in deterring mimicking and facilitating costless signaling emerges. We also find that capitalizing on ingredient brand equity is not automatic if all semi-informed consumers admit the possibility of high quality for other unrecognizable ingredient brands. In the extension part, we also provide answers for how brand equity can be capitalized by the manufacturer in the ingredient co-branding with an alternative semi-informed consumers' belief.

This paper makes several contributions to the extant literature. First, it provides a theoretical and managerial reason for the rational behind ingredient co-branding strategy. We link the prior empirical evidence of a positive association between consumer's perception and branded ingredient to the manufacturer's B2B co-branding decision. We use a signaling mechanism to model the relationship between consumers' knowledge of quality and the ingredient's brand equity. Second, our findings also show that customers can enjoy a lower price from ingredient co-branding equilibrium. This finding consistent with the counter-intuitive notion from Erevelles et.al. (2008), they give the credit to the elimination of double marginalization in the channel for such price reduce. However, our model votes price reducing to the signaling price distortion mitigation in the ingredient co-branding.

Third, we provide theoretical support for the brand equity capitalization. Past literature prefers to use the cooperative advertising program (Zhang et.al. 2013) to measure brand investment and create more demand from consumers. Our model abstracts such feature to a single measurement of brand equity which can transfer to actual demand though ingredient co-branding signaling strategy. Fourth, we provide two different beliefs of semi-informed consumers. With those two distinctive beliefs, we characterize the role of brand equity in manufacturer's co-branding decision. And more surprise, we find that capitalization on ingredient brand equity is not automatic. This is an important initial contribution, and to the best of our knowledge, is the first time to be captured by our model. Fifth, our model also enriches the quality signaling literature by providing an analytical model of ingredient co-branding signaling. Also, our model adds one more framework to adopt quality signaling in channel context.

A few limitations and a future extension of the model should be noted. In this study, it assumes that the wholesale price is the same before and after the adoption of co-branding strategy. However, the practice may not just go this easy way to meet our simplification purpose. In the future research, we can use an alternative model to capture the scenario with the wholesale price change. Besides, our model uses a signaling mechanism and focus more on the relationship between manufacturer and consumers. Although we keep emphasizing that our model is developed in a channel context, the role of ingredient supplier is defaulted to be exogenous. Thus, it would be a natural extension to address an endogenous supplier in the future research.

Chapter 2
The second Essay: Advance Selling in a Supply Chain

2.1 Introduction

Advance selling occurs when a seller sells a product or service at a time ahead of the consumption time. For example, a hotel might sell on the Internet a room to a guest for future accommodation. With advances in Internet and information technology, advance selling has been used widely for many product categories (e.g., books, CDs, video games, software, smart phones, fashion products, sports events, travel services, etc.) and has attracted increasing attention from practitioners. Academics have identified several compelling reasons for advance selling. The economics literature demonstrates the ability of advance selling to implement price discrimination (Dana 1998, Nocke et al. 2011). For instance, in the travel industry, price-sensitive leisure travelers purchase in advance at discounted prices, whereas price-insensitive business travelers often pay much higher spot prices. Largely focusing on the B2B context, the operations literature shows that advance selling can reduce demand uncertainty and inventory risk, update demand information and secure purchases (Gale 1993, Moe and Fader 2002, McCardle et al. 2004, Tang et al. 2004, Liu and Ryzin. 2008, Prasad et al. 2011, Boyaci and Ozer 2010, Li and Zhang 2010). Marketing scientists, on the other hand, incorporate into their models such behavioral elements as uncertainty about future consumption states, risk aversion (Shugan and Xie 2000, Xie and Shugan

2001) and regret (Nasiry and Popescu 2012). Advance selling can improve sales and profit, even without price discrimination (Xie and Shugan 2001).

Despite the vast literature, few studies have focused on advance selling as a tool to expand the market beyond the reach of spot selling. Advance selling is made possible by technological advances such as electronic tickets, smart cards, online prepayments, etc. These technologies greatly reduce the costs of making complex transactions far away from sellers' physical sites, enabling sellers to serve consumers who cannot be served by traditional spot selling services (Xie and Shugan 2001). Because market expansion is one of the major strategies to improve sales and profitability, it is important for firms to have a good understanding of the conditions for advance selling. The vast literature has also neglected the implications of a supply chain structure for advance selling. In the real world, Best Buy offers hundreds of items that can be ordered in-store or online before they are released by suppliers such as video game titles, movies, and mobile phones. JD.com, a leading e-tailer in China, allows consumers to pre-order not only digital products and mobile phones, but also liquor and food, books, furniture, and household electrical appliances. Because these retailers' advance selling strategy change consumers' purchase behavior and product sales, their suppliers' decisions (e.g., wholesale prices) are likely to be affected. Hence, although advance selling is a decision made by a seller, the impact of a supplier should also be considered. Indeed, as advance selling becomes increasingly popular among retailers, suppliers are eager to know how best to respond to maximize their own profits.

In this paper, we investigate a seller's advance selling strategy (i.e., spot selling only, advance selling only, or both spot and advance selling) and how this decision is affected by a supplier. We start with a benchmark direct seller model to explore a seller's incentives to adopt advance selling. In our model, due to the temporal separation between purchasing and consumption, advance buying entails a consumer disutility and thus is a particularly effective sales channel to serve price-sensitive, low-end consumers. To capture advance selling's ability to expand the reach of a seller's services, we assume that there are two separate markets, a "local" market and a "remote" market. Whereas spot selling only covers the local market, advance selling covers both. Thus, the seller in our model considers four cases. It can adopt spot-selling-only to serve the local market only, or advance-selling-only to serve both the local and the remote markets. It can also adopt both spot and advance selling. In this situation, there are two cases. In an "unrelated-advance-and-spot-selling" case, the local market is served only by spot selling and thus the local and remote markets are two separated markets. In a "related-advance-and-spot-selling" case, the seller uses both advance selling and spot selling to serve the local market (while using advance selling to serve the remote market), thus enjoying the synergy between advance selling and spot selling. In this context, we address two questions. Which strategy is optimal: advance selling only, spot selling only, or both advance selling and spot selling? And what conditions are optimal for each of these market outcomes? We then extend the benchmark model to a bilateral-monoploy supply chain model to examine whether and how a supplier can affect the market outcome. We ask the questions, Which market outcome is most beneficial to the supplier? and how the supplier can use its wholesale price to induce that optimal market outcome? To focus on the implications of the supply chain structure for advance selling, we abstract from production and inventory capacity issues and demand information issues.

Our analysis shows that advance selling arises in equilibrium when its cost is small relative to that of spot selling and when the associated consumer disutility is not too large. The supplier has an important impact on market equilibrium, and interestingly, the firms in the supply chain consider different factors when making decisions. The seller will employ advance selling only if it is able to yield a positive margin. As a result, the seller's equilibrium selling strategy is independent of the size of the market expanded by advance selling (i.e., the size of the remote market), although this size affects its profit. In contrast, this market size is vital to the supplier's wholesale price decision; there is an equilibrium in which the optimal wholesale price decreases as the size increases. Conventional wisdom suggests that due to the double marginalization problem, the seller in a supply chain is faced with a higher marginal cost than a direct seller, and thus is less motivated to expand the market and price-discriminate consumers. Consistent with this rationale, we show that the presence of a supply chain structure expands the parametric space of the spot-selling-only equilibrium. Nevertheless, a supply chain structure does not necesssarily shrink the parametric space of advance selling; it has no effect on the parametric space of the advance-selling-only equilibrium, and more interestingly, the parametric space of the unrelated-advance-and-spot-selling equilibrium can be either shrunk or expanded.

Considering the fact that advance selling is simply an additional outlet to serve consumers to the more traditional, spot selling outlet, it is no surprising that in this research we model spot selling and advance selling in a way similar to that in the multichannel retailing literature in which a firm determines whether to employ both online and offline sales channels (Balasubramanian 1998, Zhang 2009). However, it is important to note that in this research we are not concerned with such a channel decision. In our view, a channel decision involves more and higher-level strategic considerations such as firm image, product assortment, consumer contacts, etc., and such a decision is unlikely to be much affected by suppliers (this is particularly true when the seller carries products from a large number of suppliers). By contrast, advance selling strategy is a lower-level decision. Given the fact that most retailers have already established both online and offline channels and they often carry different product assortments in different channels (Grewal et al. 2010), we investigate how a strategic manufacturer can use a wholesale price to influence the way its product is sold by a retailer, namely, advance selling (e.g., online), spot selling (e.g., offline), or both online and offline (e.g., both advance and spot selling). In such a context, the manufacturer may greatly improve its profitability if it takes into account its retailer's channel outlet designation decisions (Wall Street Journal 2005).

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 develops a benchmark model to examine a direct seller's incentives for adopting advance selling. Section 4 extends the model and incorporates a supply chain structure. Section 5 compares the two models and sheds light on the impact of a supply chain structure on the market equilibrium. Section 6 discusses the results of the models and Section 7 provides a conclusion. All proofs appear in the appendix.

2.2 Related Literature

Because advance selling is normally conducted on Internet platforms and because advance selling is an endogenous decision in our model that enables market expansion and segmentation, our research is closely related to the Internet retailing literature which generally addresses the question of whether a firm should use the Internet as a sales channel (in addition to traditional offline sales channels). In this stream of literature, Chiang et al. (2003) and Kumar and Ruan (2006) look at a supplier's decision to complement its seller's bricks-and-mortar channel with a direct online channel. More recently, Yoo and Lee (2011) show that Internet channel entry does not always lead to lower retail prices and enhanced consumer welfare, and an independent retailer might become worse off after adding an Internet outlet under certain market conditions. They also find that the impact of introducing an Internet channel varies substantially across channel structures and market environments. Our model has important differences from these studies. They focus on whether a firm should use the Internet to sell to end users. We are not concerned with such a channel decision. In our view, a channel decision involves more and higher-level strategic considerations such as firm image, product assortment, consumer contacts, etc., and such a decision is unlikely to be much affected by a particular supplier's wholesale price. In contrast, advance selling strategy is a lower-level decision, and a strategic supplier can use a wholesale price to affect whether a seller would like to sell a product before it is released to market. Perhaps for this reason, the role of the supplier in a seller's advance selling is important, as discussed in this research, but not so for a channel decision and thus not addressed in the Internet channel literature. In addition, a major issue examined in the Internet channel literature is channel conflicts and coordination, as a supplier's direct channel will encroach on existing sellers' business (Chiang et al. 2003, Kumar and Ruan 2006, Arya et al. 2007, Dumrongsiri et al. 2008, Yoo and Lee 2011). In our model, in contrast, the supplier does not sell directly to consumers. Advance selling and spot selling are alternative selling strategies to the seller, and they can cannibalize each other's sales when they are both adopted by the seller.

It has long been known that advance selling enables consumer segmentation and price discrimination (Dana 1998, Chu and Zhang 2011, Moller and Watanabe 2010). For instance, Moller and Watanabe (2010) explain why some goods are sold cheaply to early buyers while others offer discounts to late buyers. They show that the optimality of advance-purchase discounts or clearance sales depends on price commitment, temporal capacity limits, the rationing rule and resale. Prasad et al. (2011) divide consumers into informed ones and uninformed ones, based on their accessibility to pre-order information, whereas Zhao and Stecke (2010) classify consumers into two groups according to whether they are loss averse or not. More recent research by Nocke et al. (2011) shows that advance-purchase discounts can serve to price-discriminate consumers who are heterogeneous in their expected valuations of the product. In their model, consumers with a high expected valuation purchase the product before learning their actual valuation at the offered advance-purchase discount; consumers with a low expected valuation will wait and purchase the good at the regular price only when their realized valuation is high.

Several studies focus on a mechanism in which advance selling improves consumer participation. In many markets, consumers are uncertain of the value of a product or service when making a purchase decision, because their consumption utility depends on future circumstances or state-dependent factors such as future moods, opportunities, conflicts, demands on buyer time or simply uncertainty surrounding the consumption occasion (Hauser and Wernerfelt 1990). Xie and Shugan (2001) provide conditions for when and how the seller should advance-sell in such circumstances. In their model, advance selling increases overall demand as it enables the seller to utilize consumers' uncertainty regarding valuations by selling a product at an early stage when consumers are less certain about their valuations.

Because advance selling takes many different forms, the literature is related to many other research areas. There have been a large number of studies devoted to a newsvendor seller that uses advance selling to obtain more accurate demand information and make better inventory planning (Gale 1993, McCardle et al. 2004, Tang et al. 2004, Chu and Zhang 2011, Prasad et al. 2011, Boyaci and Ozer 2010). For instance, Liu and Ryzin (2008) examine a firm's strategic capacity rationing for inducing early purchases. In their model, via its capacity choice the firm is able to control the fill rate and the rationing risk faced by customers. Customers behave strategically and weigh the payoff of immediate purchases against the expected payoff of delaying their purchases. Prasad et al. (2011) show that although advance selling helps to reduce demand uncertainty, implementing it is not always optimal but is contingent on parameters of the market (e.g., market potential and uncertainty) and of the consumers (e.g., valuation, risk aversion, and heterogeneity). We differ from these studies. We assume complete information and so there is no need for market information updates. We also assume that the seller has ample capacity to abstract from capacity issues. This assumption is plausible in many manufacturing industries and situations such as a Harry Potter book release, software upgrades, or a video game release.

2.3 Advance Selling by a Direct Seller

Consider a market in which a single seller serves consumers through spot selling and/or advance selling. To understand this context, consider two periods of time, which we label as advance period and spot period, respectively. Consumer consumption occurs only in the spot period, but purchase can occur in either period (i.e., advance buying if in the advance period, or spot buying if in the spot period). In this context, the seller has three possible selling strategies. With a spot-selling-only strategy (denoted by “S”), it sells only in the spot period, at a spot selling price p_S. With an advance-selling-only strategy (denoted by “A”), it sells only in the advance period, at an advance selling price p_A. With an advance and spot selling strategy (denoted by “AS”), it sells in both periods, at an advance selling price and a spot selling price, respectively. We focus on situations where the seller has ample capacity to serve its market.

There are two groups of consumers, who differ in their access to the seller. One group of consumers, of a unit size, can buy either in advance or on spot. The other group of consumers, with a size of m, can buy only in advance, where $m \geq 0$. These assumptions are plausible (Prasad et al. 2011 made a similar assumption) and suggest that a seller can expand its market through advance selling services. Advance selling is facilitated by electronic tickets, smart cards, online prepayments, and other technological advances. These technologies reduce the cost of making complex transactions at a significant distance from the seller’s physical site, enabling the seller to serve consumers who cannot be served by on-spot services (Xie and Shugan 2001). One can interpret the first group of consumers as a local market (“local consumers”), those that are close to the seller and thus can buy the product either in advance or on spot, and the second group of consumers as a remote market ("remote consumers"), those that are located at a distance and thus can buy only in advance via the Internet and smart card technologies. Consumers are risk-neutral.

Except for their access to the seller, the local and remote consumers are identical. We assume that each consumer buys one product at most, and that consumers are heterogenous in their willingness to pay (WTP) for the product. Their WTP, on spot, is $\theta v,$ where v is the intrinsic value of the product and θ follows a uniform distribution $\theta\tilde{}uniform[0,1]$. If consumers make their purchase in advance, however, they incur a disutility μ and thus we assume that their WTP is $\theta\left(v-\mu\right)$. Consumers incur a disutility in advance buying for the following reasons. First, the seller has no capacity constraint in our model and thus product availability is not a concern for consumers. The time value of money suggests that consumers incur a cost rather than a gain from paying in advance. Second, in advance buying consumers often cannot inspect the product physically and have immediate gratification, as commonly assumed in the multichannel retailing literature (Balasubramanian 1998, Chiang et al. 2003). Third, many consumers do not like to make plans and take actions ahead of time. They tend to wait until the last minute. Indeed, procrastination can directly contribute to consumer welfare by offering option flexibility (Reibstein et al. 1975, Smith 1983). Finally, according to the state-dependent utility theory, buyer valuations depend on future circumstances or state-dependent factors (Fishburn 1974), which implies that in the advance period consumers may be uncertain about their need for the product. This consumption state uncertainty also reduces consumers' expectations of the value of a product, as they may not need the product as much in the spot period (Xie and Shugan 2001).

Therefore, advance buying yields a lower utility to consumers than spot buying and when compared with spot selling, advance selling is more appealing to low-end consumers (i.e., consumers with a small value for θ), as they incur a small disutility in advance buying. This important feature of our model is consistent with the general observation that "early bird" rates are discounted prices. We acknowledge that there may be situations where consumers derive some positive utility from advance buying (particularly when product availability is not ensured with spot buying). Our results do not hold in such cases, as then advance selling will become a premium channel and target high-end customers instead.

The consumer utility function in advance buying, $\theta\left(v-\mu\right)$, implicitly assumes that consumers are substantially heterogeneous in their disutility in advance buying, and there is a positive correlation between consumers' product evaluation and their disutility. These assumptions are plausible. Consumers who have higher WTP generally have higher income and these consumers generally have a higher time value of money and suffer more from loss of option flexibility. The assumption of a positive correlation has been made by many analytical models of the online channels. In these models, there is an acceptance rate of the online channel across heterogenous consumers, at which consumers' utility from purchasing online is discounted (Chiang et al. 2003). We discuss the implications of this assumption in the discussion section of the paper.

In addition to a constant marginal cost c for each product, the seller incurs constant marginal costs in selling the product on spot and in advance, which are denoted as c_S and c_A and called "spot selling cost" and "advance selling cost", respectively, where the subscript

"S" refers to spot selling and "A" to advance selling. The advance selling cost can include the seller's shipping costs for physical products.

Both consumers and the seller are forward looking. We assume that the seller knows the distribution of consumers' WTP, and that the seller announces its selling strategy and the associated price(s) (in the advance period). The seller commits to the announced prices (as in Xie and Shugan 2001, Tang et al. 2004, Chen and Parlar 2005, Zhao and Stecke 2010, Prasad et al. 2011). This assumption is consistent with empirical observations. For instance, Apple adopts an advance selling strategy and announces prices well before releasing its iPhone products to market, and commits to these prices. Consumers are utility maximizers; when faced with two options, they pick the one that offers a greater (expected) utility. We assume that $v > c + c_S$ so that the seller can maintain spot selling at a positive profit margin.

2.3.1 Analysis

When the seller adopts a spot-selling-only strategy, S, and charges a price, p_S, it serves only the local market. Consumers buy if $\theta v - p_S \geq 0$, which means that consumers with $\theta \in [\frac{p_S}{v}, 1]$ make a purchase. Thus, the seller's problem is

$$\max_{p_S} \ \pi_S = (p_S - c - c_S)\left(1 - \frac{p_S}{v}\right).$$

FOC. yields $p_S = \frac{v+c+c_S}{2}$. Thus, the seller makes a profit of $\pi_S = \frac{(v-c-c_S)^2}{4v}$, with a market size of $\frac{v-c-c_S}{2v}$. Naturally, the higher the marginal cost of product c and the spot selling cost c_S, the smaller the market demand and the seller profit.

When the seller adopts an advance-selling-only strategy, A, and charges a price, p_A, consumers buy if $\theta(v-\mu)-p_A \geq 0$, which means that consumers with $\theta \in [\frac{p_A}{v-\mu}, 1]$, in both the local and the remote markets, make a purchase. Thus, the seller's problem is

$$\max_{p_A} \ \pi_A = (1+m)\,(p_A - c - c_A)\,(1 - \tfrac{p_A}{v-\mu}).$$

FOC. yields $p_A = \frac{v-\mu+c+c_A}{2}$, Thus, $\pi_A = \frac{(1+m)(v-\mu-c-c_A)^2}{4(v-\mu)}$, with a total demand of $\frac{(1+m)(v-\mu-c-c_A)}{2(v-\mu)}$. The higher the marginal product cost c and the advance selling cost c_A, the higher the retail price and thus the smaller the market demand and the seller profit. In addition, the greater the disutility μ, the lower the retail price and the seller profit. The greater the size of the remote market m, the greater the market demand and the seller profit.

When the seller adopts both spot and advance selling, consumers in the local market can buy either in advance or on spot, whereas consumers in the remote market can buy only in advance. There are two cases depending on whether or not local consumers buy in advance. In case 1 ("AS1"), spot selling and advance selling are unrelated; they serve the local and remote markets respectively. In this case, local consumers buy on spot if $\theta v - p_S \geq 0$ and remote consumers buy in advance if $\theta(v-\mu)-p_A \geq 0$. Because no local consumers buy in advance, we require that $\theta v - p_S \geq \theta(v-\mu) - p_A$ (i.e., $p_S - \theta\mu < p_A$). Thus, the seller's problem is

$$\max_{p_S, p_A} \ \pi_{AS1} = (p_S - c - c_S)\left(1 - \tfrac{p_S}{v}\right) + m\,(p_A - c - c_A)\,(1 - \tfrac{p_A}{v-\mu}),$$
$$\text{s.t. } p_S - \theta\mu < p_A, \text{ where } \theta = \tfrac{p_S}{v}.$$

FOC. yields $p_S = \frac{v+c_S+c}{2}$ and $p_A = \frac{c_A-\mu+v+c}{2}$. Thus, $\pi_{AS1} = \frac{(v-c-c_S)^2}{4v} + \frac{m(v-\mu-c-c_A)^2}{4(v-\mu)}$. The constraint implies that $c_S < \frac{c\mu+c_A v}{v-\mu}$; that is, local consumers do not buy in advance because c_A and μ are too large. Some remote consumers purchase in advance and gain a positive surplus, which requires that $c < v - c_A - \mu$. Because both selling strategies are operative, both the demand and the profit decrease with c, c_S and c_A, and increase with m. In addition, because the spot selling cost is relatively low, spot selling not only yields a higher profit margin than advance selling, but also serves a greater proportion of consumers in the local market than advance selling does in the remote market.

In case 2 ("AS2"), advance selling serves both local and remote consumers and thus the seller is able to enjoy the synergy between advance selling and spot selling. In this case, remote consumers purchase in advance if $\theta\,(v-\mu) - p_A \geq 0$. For local consumers, $\theta\,(v-\mu) - p_A \geq 0$ (i.e., $\theta > \frac{p_A}{v-\mu}$) is required for advance buying, and $\theta v - p_S \geq 0$ (i.e., $\theta > \frac{p_S}{v}$) is required for spot buying. Advance buying is preferred to spot buying iff $\theta\,(v-\mu) - p_A \geq \theta v - p_S$, i.e., iff $\theta \leq \frac{p_S - p_A}{\mu}$. This condition implies that to entice local consumers to buy in advance, the advance selling price must be no higher than the spot selling price, i.e., $p_S \geq p_A$. This condition also implies that local consumers with a low θ are more likely to choose to purchase in advance, because they incur a small disutility in advance buying. Thus, given the spot and advance selling prices p_S and p_A, remote consumers with $\theta \in [\frac{p_A}{v-\mu}, 1]$ buy in advance, whereas local consumers with $\theta \in [\frac{p_S - p_A}{\mu}, 1]$ buy on spot and those with $\theta \in [\frac{p_A}{v-\mu}, \frac{p_S - p_A}{\mu})$ buy in advance. So the seller's problem is

$$\max_{p_S, p_A}\ \pi_{AS2} = (p_A - c - c_A)\,(\tfrac{p_S - p_A}{\mu} - \tfrac{p_A}{v-\mu}) + (p_S - c - c_S)(1 - \tfrac{p_S - p_A}{\mu})$$
$$+\, m\,(p_A - c - c_A)\,(1 - \tfrac{p_A}{v-\mu}),$$
$$\text{s.t. } 1 > \tfrac{p_S - p_A}{\mu} \geq \tfrac{p_S}{v} \geq \tfrac{p_A}{v-\mu} > 0.$$

FOC. yields $p_S = \frac{v+c+c_S}{2}$ and $p_A = \frac{v+c_A-\mu+c}{2}$. Thus, $\pi_{AS2} = \frac{(1+m)(v-\mu-c-c_A)^2}{4(v-\mu)} + \frac{(c_S-\mu-c_A)^2}{4\mu}$. In this equilibrium, there are local consumers who choose to buy in advance, which implies $\frac{p_S - p_A}{\mu} \geq \frac{p_A}{v-\mu}$, i.e., $p_S \geq p_A$ and $c_S \geq \frac{c\mu + c_A v}{v-\mu}$. To understand these conditions, note that local consumers would choose advance buying only if it is more attractive than spot buying. This implies that $p_S \geq p_A$, which is not necessarily the case in AS1. From the seller's point of view, although advance selling entails a consumer disutility $\theta\mu$, it produces a higher profit margin than spot selling if the associated selling cost c_A is sufficiently low. This implies that the advantages of advance selling can outweigh its disadvantages and advance selling becomes a viable strategy if c_A and μ are sufficiently small relative to c_S, i.e., if $c_S \geq \frac{c\mu + c_A v}{v - \mu}$.

In AS2, the same as in the AS1 case, spot selling produces a greater margin than advance selling. However, now it is advance selling that sets the market boundary in the local market, as the price is lower than the spot selling price (i.e., $p_S > p_A$). The advantage of advance selling in attracting low-end consumers and expanding to the remote market takes effect. The existence of local consumers who choose to buy on spot requires that $1 > \frac{p_S - p_A}{\mu}$, i.e., $\mu + c_A > c_S$. To understand this condition, note that c_A and μ cannot be too small, or advance selling would be so advantageous as to dominate spot selling. Indeed, we can show that as the value of $\mu + c_A$ decreases, the local market served by advance selling expands and that served by spot selling shrinks. When the value of $\mu + c_A$ is sufficiently small (i.e., when $c_S > \mu + c_A$), the seller optimally conducts advance selling only.

The above analysis indicates the impact of costs on the market equilibrium, as shown in Figure 1. When $c > v - \mu - c_A$, the advance selling cost c_A and consumer disutility μ are so high that advance selling yields a negative margin. Because we have assumed that $v > c + c_S$ (i.e., $c < v - c_S$) to ensure a positive margin in spot selling, regime S arises in equilibrium, in which the seller adopts spot selling only (the two conditions implicitly imply that $c_S \leq \mu + c_A$). When $c \leq v - c_A - \mu$, advance selling is able to produce a positive profit margin. In this case, the seller can employ advance selling in three ways. When $c_S < \frac{c\mu + c_A v}{v - \mu}$ (i.e., if $c > \frac{(v-\mu)c_S - v c_A}{\mu}$), μ and c_A are large. Because advance selling is not very attractive, the seller only uses it to serve the remote market and thus regime AS1 arises in equilibrium. In this equilibrium, with a low selling cost c_S, spot selling yields a greater profit margin and serves a greater proportion of consumers in the local market than advance selling does in the remote market. When $\frac{c\mu + c_A v}{v - \mu} \leq c_S \leq \mu + c_A$, the spot selling cost is medium (or μ and c_A are medium) and thus regime AS2 is the equilibrium. In this equilibrium, although spot selling still yields a greater profit margin than advance selling, its price is higher (i.e., $p_S > p_A$) and as a result, advance selling is also able to attract low-end consumers in the local market. When $\mu + c_A < c_S$, the spot selling cost is large (or μ and c_A are small). Advance selling is so attractive that it becomes a dominating strategy and is used to serve both the local and the remote markets. In this case, because spot selling makes no sales, the equilibrium space is independent of c_S.

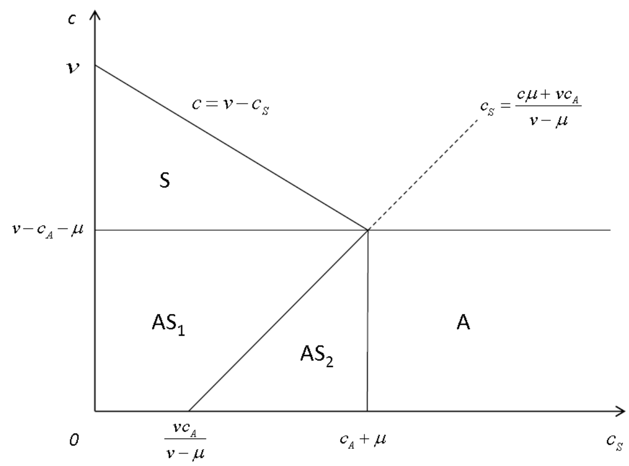

Figure 1: The market equilibrium in the direct seller model

Proposition 1: *A direct seller's equilibrium strategy is as follows:*

1) When $v - c_S > c > v - \mu - c_A$, the seller adopts S. It serves the local market only and charges $p_S = \frac{v+c_S+c}{2}$, making a profit of $\pi_S = \frac{(v-c-c_S)^2}{4v}$.

2) When $c_S < \frac{c\mu+c_A v}{v-\mu}$ and $c \leq v - \mu - c_A$, the seller adopts AS1, serving the local market with spot selling and serving the remote market with advance selling. It charges $p_S = \frac{v+c_S+c}{2}$ and $p_A = \frac{c_A-\mu+v+c}{2}$, making a profit of $\pi_{AS1} = \frac{(v-c-c_S)^2}{4v} + \frac{m(v-\mu-c-c_A)^2}{4(v-\mu)}$.

3) When $\frac{c\mu+c_A v}{v-\mu} \leq c_S \leq \mu + c_A$, the seller adopts AS2, serving the local market with both spot and advance selling and serving the remote market with advance selling. It charges $p_S = \frac{v+c_S+c}{2}$ and $p_A = \frac{c_A-\mu+v+c}{2}$, making a profit of $\pi_{AS2} = \frac{(1+m)(v-\mu-c-c_A)^2}{4(v-\mu)} + \frac{(c_S-\mu-c_A)^2}{4\mu}$.

4) When $c_S > \mu + c_A$, the seller adopts A, serving both local and remote markets with advance selling only. It charges $p_A = \frac{c_A-\mu+v+c}{2}$, making a profit $\pi_A = \frac{(1+m)(v-\mu-c-c_A)^2}{4(v-\mu)}$.

Proposition 1 indicates that the seller's equilibrium strategy depends on consumers' WTP, the marginal product cost c, on-spot selling cost c_S, advance selling cost c_A and consumer disutility μ. Interestingly, although the size of the remote market m affects the profit, it does not affect the market equilibrium (i.e., the parametric space and price). The reasons are as follows. Given that advance selling has a broader market reach than spot selling, the seller has only a minimum requirement for advance selling: it will employ advance selling only if advance selling is able to yield a positive profit margin (i.e., if $v - \mu - c_A - c > 0$). The seller's equilibrium price is independent of m, because it is set only on the basis of the seller's costs and the distribution of consumers' WTP. The parametric spaces of the A, AS1 and AS2 equilibria are also independent of m, because in these cases, the seller is serving both the remote and local markets and thus its only concern is about the relative costs associated with advance and spot selling. The irrelevance of the size of the remote market m to market equilibrium is an important finding in the direct seller model. This finding is, however, upended in the context of a supply chain, as examined in the following section.

2.4 Advance Selling in a Supply Chain

To explore a seller's equilibrium selling strategy in the context of a supply chain, we now consider a supplier that markets its products through a single, independent seller. We assume that the two firms use a single-wholesale-price contract. Such contracts are widespread in practice and their efficiency has been found to be considerably higher than previously thought (Cachon 2004). We assume that the supplier and the seller play a noncooperative 2-stage game, with the supplier being a Stackelberg leader. The supplier makes a take-or-leave-it wholesale price offer. Then, the seller determines whether to take the offer or not. If the seller rejects the offer, both parties make zero profit. If the seller accepts the offer, it then determines its selling strategy and the associated retail price(s). With a marginal cost of a constant c, the supplier exercises its influence on the seller only through the wholesale price p_w. As in the previous model, the seller's marginal selling costs are c_S and c_A in spot and advance selling, respectively. All the other assumptions are also maintained.

Using the technique of backward induction we start with the seller's problem. Given a wholesale price p_w, which becomes the seller's marginal cost for the product, the seller has four options: S, AS1, AS2 and A. It will choose the one that yields the highest profit. The analysis is the same as in the direct seller model. We substitute p_w for c in that model and obtain the seller's equilibrium strategy and the associated profit.

Being a Stackelberg leader, the supplier anticipates how the seller will best respond to p_w. In the following, we examine the supplier's problem. We first examine the four regimes and derive the supplier's highest profit in each. We then derive the equilibrium for the whole game.

2.4.1 Regime S

In this regime the supplier sets $v - c_S \geq p_w \geq v - \mu - c_A$ (this implicitly requires that $c_S < c_A + \mu$) and the seller responds with S and serves the local market at $p_S = \frac{v+c_S+p_w}{2}$. Thus, the supplier's problem is

$$\max_{p_w} \ \Pi_S = (p_w - c)\left(1 - \frac{p_S}{v}\right), \text{ where } p_S = \frac{v + c_S + p_w}{2},$$
$$\text{s.t. } v - c_S \geq p_w \geq v - \mu - c_A.$$

FOC. yields $p_w^* = \frac{v - c_S + c}{2}$. The constraint $v - c_S \geq p_w$ is not binding as we have assumed that $v > c_S + c$. The constraint $p_w \geq v - \mu - c_A$ is not binding if $c_S \leq 2(c_A + \mu) + c - v$. In this case, the supplier will optimally charge $p_w = \frac{v - c_S + c}{2}$, making a profit of $\Pi_S = \frac{(v - c_S - c)^2}{8v}$. However, if $c_S > 2(c_A + \mu) + c - v$ (this is likely to be true when v is large), the constraint is binding. Then, the supplier will charge $p_w = v - \mu - c_A$ to ensure no sales from the remote market, making a profit of $\Pi_S = \frac{(v - \mu - c_A - c)(\mu + c_A - c_S)}{2v}$. To understand the non-binding condition $c_S \leq 2(c_A + \mu) + c - v$, note that p_w^* decreases as c_S increases. That is, the supplier needs to reduce its wholesale price when the seller's spot selling cost is high. Hence, when c_S is sufficiently small, p_w^* will automatically be high enough to prevent the seller from advance selling.

2.4.2 Regime AS1

In this regime the supplier sets $v - \mu - c_A > p_w > \frac{(v-\mu)c_S - vc_A}{\mu}$ (this implicitly requires that $c_S < c_A + \mu$) and the seller responds with AS1, serving the local market with spot selling at $p_S = \frac{v + c_S + p_w}{2}$ and serving the remote market with advance selling at $p_A = \frac{c_A - \mu + v + p_w}{2}$. Thus, the supplier's problem is

$$\max_{p_w} \ \Pi_{AS1} = (p_w - c)\left(1 - \frac{p_S}{v} + m\left(1 - \frac{p_A}{v - \mu}\right)\right), \text{ where } p_S = \frac{v + c_S + p_w}{2} \text{ and } p_A = \frac{c_A - \mu + v + p_w}{2},$$
$$\text{s.t. } v - \mu - c_A > p_w > \frac{(v-\mu)c_S - vc_A}{\mu}.$$

FOC. yields $p_w^* = \frac{mv(v - \mu - c_A + c) + (v - \mu)(v - c_S + c)}{2(v - \mu + mv)}$. The constraints are not binding if $v - \mu - c_A > p_w$ (i.e., if $c_S > l'$) and if $p_w > \frac{(v-\mu)c_S - vc_A}{\mu}$ (i.e., if $c_S < l$), where

$l' = \frac{(v-2\mu-2c_A-c)(v-\mu)+mv(v-\mu-c_A-c)}{-(v-\mu)}$ and $l = \frac{mv\left(\mu v+2c_A v+\mu c-\mu^2-c_A\mu\right)+(v-\mu)(\mu v+\mu c+2c_A v)}{(v-\mu)(2v-\mu+2mv)}$. In this case, the supplier optimally sets $p_w = \frac{mv(v-\mu-c_A+c)+(v-\mu)(v-c_S+c)}{2(v-\mu+mv)}$, making a profit of $\Pi_{AS1} = \frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{8v(v-\mu+mv)(v-\mu)}$. We can show that $\frac{\partial p_w}{\partial m} < 0$, i.e., the greater the size of the remote market, the lower the wholesale price. If $c_S < l'$, the constraint is binding at $p_w = v - \mu - c_A$. Then, the supplier optimally sets $p_w = v - \mu - c_A$, making a profit of $\Pi_{AS1} = \frac{(\mu-c_S+c_A)(v-\mu-c_A-c)}{2v}$. If $c_S > l$, the constraint is binding at $p_w = \frac{(v-\mu)c_S-vc_A}{\mu}$. Then, the supplier optimally sets $p_w = \frac{(v-\mu)c_S-vc_A}{\mu}$, making a profit of $\Pi_{AS1} = \frac{(1+m)(c_A+\mu-c_S)(vc_S-\mu c_S-c_A v-\mu c)}{2\mu^2}$.

2.4.3 Regime AS2

In this regime, $c_S < c_A + \mu$, the supplier sets $p_w \leq \frac{(v-\mu)c_S-vc_A}{\mu}$ and the seller responds with AS2, charging $p_S = \frac{v+c_S+p_w}{2}$ and $p_A = \frac{c_A-\mu+v+p_w}{2}$. Because in AS2 advance selling serves both the local and the remote markets and because advance selling appeals to low-end consumers and thus sets the market boundary, the demands in the two markets are the same. Thus, the supplier's problem is

$$\max_{p_w} \ \Pi_{AS2} = (p_w - c)\left(1 - \tfrac{p_A}{v-\mu}\right)(1+m), \text{ where } p_A = \tfrac{c_A-\mu+v+p_w}{2},$$

$$\text{s.t. } p_w \leq \tfrac{(v-\mu)c_S-vc_A}{\mu}.$$

FOC. yields $p_w^* = \frac{v-\mu-c_A+c}{2}$. The constraint is not binding if $c_S \geq g$, where $g = \frac{\mu v-\mu^2-c_A\mu+c\mu+2c_A v}{2(v-\mu)}$. So, if $c_A + \mu > c_S \geq g$, the supplier optimally sets $p_w = \frac{v-\mu-c_A+c}{2}$, making a profit of $\Pi_{AS2} = \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}$. In this case, because the local and remote consumers are identical and because the supplier's optimal wholesale price is determined on the basis of costs and consumers' WTP distribution, p_w^* is independent of the market size

m. If $c_S < g$, the constraint is binding at $p_w = \frac{(v-\mu)c_S - vc_A}{\mu}$, and thus the supplier optimally sets $p_w = \frac{(v-\mu)c_S - vc_A}{\mu}$, making a profit of $\Pi_{AS2} = \frac{(1+m)(\mu - c_S + c_A)(c_S v - c_S \mu - c_A v - c\mu)}{2\mu^2}$.

2.4.4 Regime A

In this regime, $c_S > c_A + \mu$, the supplier sets $p_w \leq v - \mu - c_A$ and the seller responds with A, charging $p_A = \frac{c_A - \mu + v + p_w}{2}$. The supplier's problem is

$$\max_{p_w} \ \Pi_A = (p_w - c)\left(1 - \frac{p_A}{v-\mu}\right)(1+m), \text{ where } p_A = \frac{c_A - \mu + v + p_w}{2},$$
$$\text{s.t. } p_w \leq v - \mu - c_A.$$

FOC. yields $p_w^* = \frac{v - c_A - \mu + c}{2}$. The constraint is not binding since $c_S > c_A + \mu$. Thus, the supplier sets $p_w = \frac{v - c_A - \mu + c}{2}$, making a profit of $\Pi_A = \frac{(1+m)(v - \mu - c_A - c)^2}{8(v-\mu)}$. Intuitively, because the supplier faces the same demand as in AS2, its optimal wholesale price and thus profit are the same as in the AS2 regime.

2.4.5 Equilibrium of the whole game

The supplier anticipates the above results. It will compare the profits in the four regimes and set a wholesale price to induce the regime that yields the highest supplier profit. To derive the equilibrium of the whole game, recall that in the AS1 regime, if $c_S < l'$ then the constraint $p_w = v - \mu - c_A$ is binding. Because the supplier is constrained to set $p_w = v - \mu - c_A$ and because at this price it makes virtually no sales in the remote market, its profit cannot be higher than that when it is in the S regime and charges an optimal wholesale price without any constraints. This suggests that $\Pi_S \geq \Pi_{AS1}$ and thus S is the equilibrium strategy if $c_S \leq l'$. Hence, the line $c_S = l'$ (when $l' > 0$) separates the spaces of the S and AS1 equilibria, as shown in Figure 2.

We can show that $\Pi_{AS1} \geq \Pi_{AS2}$ if $c_S \leq h$. As discussed previously, the wholesale price in AS1 decreases as c_S increases, whereas it is independent of c_S in AS2. Thus, the greater c_S, the lower the supplier's profit margin in AS1. Hence, when c_S is sufficiently high, AS2 yields a greater profit than AS1 and becomes an equilibrium strategy.

The supplier faces the same demands and thus charges the same optimal wholesale price in A and AS2. As a result, it makes the same profit in the two regimes, i.e., $\Pi_{AS2} = \Pi_A$. Although the supplier is indifferent between AS2 and A, the seller strictly prefers AS2 to A when $c_S \leq c_A + \mu$. Therefore, in the spirit of Pareto optimality, when $c \leq v - \mu - c_A$, AS2 is the equilibrium if $c_S > c_A + \mu$, whereas A is the equilibrium if $c_S > c_A + \mu$.

Overall, these results imply that the greater c_S, the more the seller's business relies on advance selling. To understand the impact of the suppliers' marginal cost c on the seller's selling strategy, note that the greater c, the higher the wholesale price p_w, and thus the less likely it is that the necessary condition for advance selling $p_w \leq v - \mu - c_A$ is satisfied. Hence, a greater c implies a smaller likelihood of the S equilibrium. The market equilibrium is summarized in Proposition 2 and graphically illustrated in Figure 2.

Proposition 2: *In the supply chain model, the market equilibrium is as follows:*

1) When $c_S < \min(v - c, l')$, the supplier sets $p_w = \frac{v - c_S + c}{2}$ and the seller adopts S and charges $p_S = \frac{3v + c_S + c}{4}$. Their profits are $\Pi_S = \frac{(v - c_S - c)^2}{8v}$ and $\pi_S = \frac{(v - c_S - c)^2}{16v}$, respectively.

2) When $l' \leq c_S \leq h$, the supplier sets $p_w = \frac{mv(v - \mu - c_A + c) + (v - \mu)(v - c_S + c)}{2(v - \mu + mv)}$ and the seller adopts AS1 and charges $p_S = \frac{(v - \mu)(3v + c_S + c) + mv(3v + 2c_S - \mu - c_A + c)}{4(v - \mu + mv)}$ and $p_A =$

$\frac{mv(3v-3\mu+c+c_A)-(v-\mu)(2\mu+c_S-2c_A-3v-c)}{4(v-\mu+mv)}$, *where* $h = v - c - \frac{(v-\mu-c_A-c)(\sqrt{v(1+m)(mv+v-\mu)}-mv)}{v-\mu}$.
Their profits are $\Pi_{AS1} = \frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{8v(v-\mu+mv)(v-\mu)}$ *and* $\pi_{AS1} = \frac{((v-\mu)(-v+c_S+c)+mv(-v+2c_S-\mu-c_A+c))^2}{16v(v-\mu+mv)^2}$ $+ \frac{m((v-\mu)(-2\mu+v-c+c_S-2c_A)+mv(v-\mu-c_A-c))^2}{16(v-\mu)(v-\mu+mv)^2}$, *respectively.*

3) When $h \le c_S \le c_A + \mu$, *the supplier sets* $p_w = \frac{v-\mu-c_A+c}{2}$ *and the seller adopts AS2 and charges* $p_S = \frac{3v+2c_S-\mu-c_A+c}{4}$ *and* $p_A = \frac{c_A-3\mu+3v+c}{4}$. *Their profits are* $\Pi_{AS2} = \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}$ *and* $\pi_{AS2} = \frac{(\mu+c_A-c_S)^2}{4\mu} + \frac{(1+m)(v-\mu-c_A-c)^2}{16(v-\mu)}$, *respectively.*

4) When $c_S > \mu + c_A$ *and* $c \le v - \mu - c_A$, *the supplier sets* $p_w = \frac{v-\mu-c_A+c}{2}$ *and the seller adopts A and charges* $p_A = \frac{c_A-3\mu+3v+c}{4}$. *Their profits are* $\Pi_A = \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}$ *and* $\pi_A = \frac{(1+m)(v-\mu-c_A-c)^2}{16(v-\mu)}$, *respectively.*

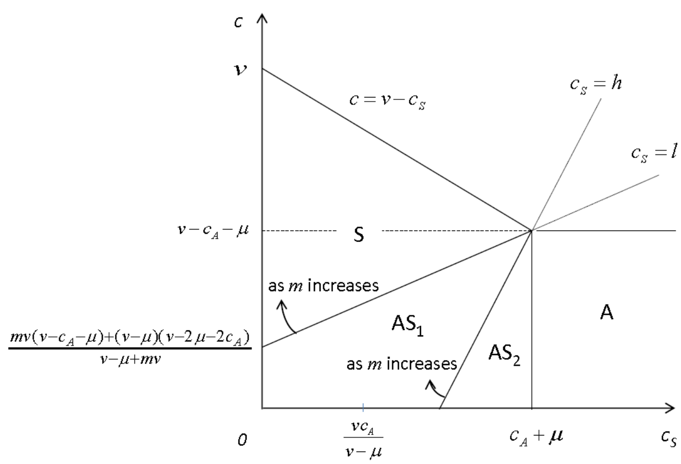

Figure 2: The market equilibrium in the supply chain model

The equilibrium wholesale prices are shown in Figure 3 (in bold lines). We can see that the supplier's optimal price function is not continuous and differs in three ranges along the c_S-axis. In both ranges $c_S \in [0, l']$ and $c_S \in [l', h]$, the optimal wholesale price decreases as c_S increases. In our model, even though the supplier does not bear the seller's selling cost, its wholesale decision is affected by it. The higher the cost, the higher the retail price(s), and thus the smaller the market demand, which will in turn put a downward pressure on the supplier's wholesale price. When $c_S > h$, in contrast, the optimal wholesale price is independent of c_S, because the demand faced by the supplier is no longer related to spot selling.

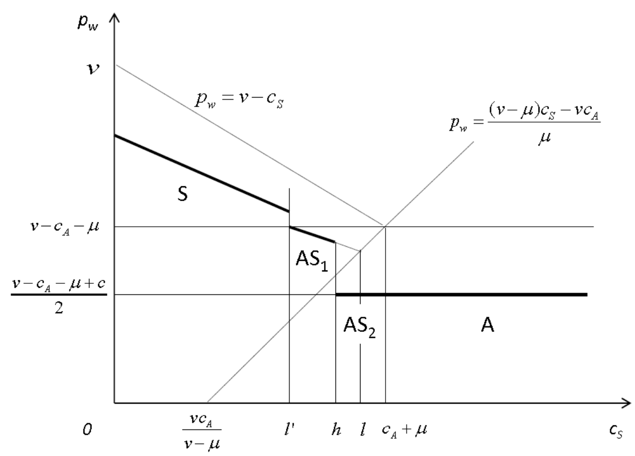

Figure 3: The supplier's equilibrium wholesale price

Figure 3 suggests how the supplier should use its wholesale price to change the seller's selling strategy and maximize its own profit. Note the two tipping points $c_S = l'$ and $c_S = h$ in the figure. As we have just discussed, when c_S is small, the supplier charges a high wholesale price. As a result, the seller adopts S and the wholesale price decreases with c_S. Once c_S reaches the tipping point $c_S = l'$, however, a small wholesale price drop is no longer optimal, because then the seller would still adopt S. The supplier is better off offering a substantial price cut to induce the seller to adopt AS1, thereby enjoying the benefits from expanding the business to the remote market. Similarly, once c_S reaches the tipping point $c_S = h$, a small wholesale price cut is likely to be suboptimal. The supplier is better off offering a heavy price cut to induce the seller to adopt AS2 instead of AS1.

The findings regarding the equilibrium wholesale price are important. They indicate that when suppliers change their wholesale prices according to sellers' costs and other influencing factors, a substantial price cut (or increase) may be optimal. In our model, because the seller has discrete options for its selling strategy, the optimal wholesale price arises in discrete ranges. Any wholesale prices that are not in these ranges are suboptimal.

Finally, we can show that compared with the situation in which advance selling is not allowed, the supplier makes the same or a greater profit when advance selling is allowed. The same is true for the seller as well. Proposition 3 follows.

Proposition 3: *In the supply chain model, both the supplier and the seller are better off when advance selling is available as an alternative selling strategy to the seller.*

2.5 Impact of the Supply Chain Structure

We can now compare the two models and investigate the impact of a supply chain structure on the seller's adoption of advance selling. This investigation is particularly useful for suppliers, as it provides indications for how they should develop different pricing strategies in markets with different distribution supply chain structures. Distribution channels generally suffer from the double marginalization problem. In our supply chain model, the supplier's marginal cost is c, and it charges a wholesale price higher than c to gain a positive profit margin. The seller then adds another positive margin to maximize its own profit.

The presence of the two margins results in higher price(s) to consumers and lower demand and channel profit than those in an integrated channel. Because the presence of a supply chain structure affects channel members' strategies and profits, it changes the parameter spaces of market equilibria.

Comparison and contrast of the direct seller model with the supply chain model highlights the different roles the remote market plays in determining the market equilibrium. In the direct seller model, as discussed previously, the market equilibrium is independent of the size of the remote market m. In the supply chain model, in contrast, because the size of the remote market affects the optimal wholesale price, it also affects the market equilibrium. To elucidate this impact, note the two curves in Figure 2, $c_S = h$ and $c_S = l'$, cross at $(v - \mu - c_A$, $c_A + \mu)$. We can show that the $c_S = l'$ curve rotates clockwise on the crossing point as m increases (this curve approaches the $c = v - \mu - c_A$ curve as $m \to +\infty$). This implies that the larger the size of the remote market, the smaller the parametric space of the S equilibrium. This result is intuitive. The larger the size of the remote market, the greater the incentive the supplier has to induce the seller to serve it through advance selling.

We can also show that the $c_S = h$ curve in Figure 2 also rotates clockwise on the crossing point as m increases (this curve joins the x-axis at $((\frac{vc_A}{v-\mu} - 1)c, 0)$ as $m \to +\infty$). This implies that the larger the size of the remote market, the greater the parametric space of the AS2 equilibrium that encroaches on the space of the AS1 equilibrium. To understand this result, recall that the wholesale price in AS1 decreases as m increases, whereas it is independent of m in AS2. Thus, as m increases, the supplier's profit margin in AS1 becomes narrower and AS2 becomes relatively more lucrative. Figure 4 illustrates the market equilibrium in parametric space with respect to m and c_S.

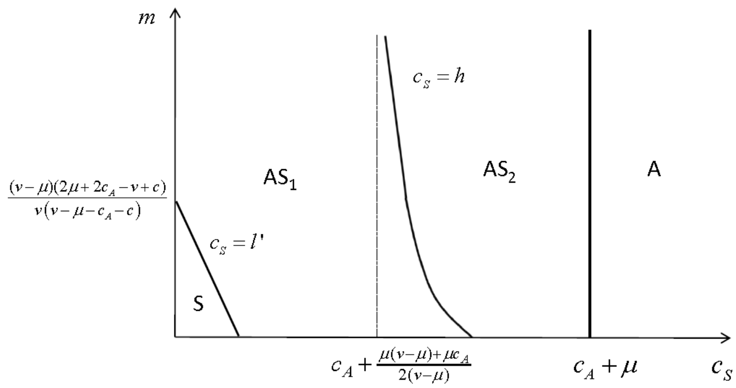

Figure 4: The market equilibrium with respect to m and c_S.

We summarize the changes of the parameter spaces of market equilibria in Proposition 4 as follows.

Proposition 4: *When compared with the direct seller model, the supply chain structure has the following effects:*

1) The space of the S equilibrium expands.

2) The space of the AS1 equilibrium is expanded when m is large and shrunk when m is small.

3) *The space of the AS2 equilibrium shrinks.*

4) The space of the A equilibrium remain unchanged.

To understand the impact of the supply chain structure on the seller's adoption of advance selling, note that the procurement cost of the direct seller (i.e., the marginal cost of the product) is a constant, whereas that of the seller in a supply chain is a decision variable of the supplier. In the supply chain model, due to the supplier's markup the seller is faced with a higher procurement cost than is the direct seller. This makes it difficult for advance selling to yield a positive margin in the supply chain context, resulting in an expanded parametric space of the S equilibrium. This finding is consistent with the conventional rationale that market expansion and price discrimination are more lucrative for a seller with a low marginal cost (Schmalenses 1981).

Proposition 4 also shows that the space of the AS1 equilibrium can either expand or shrink, depending on the size of the remote market m. When m is small, the benefit from expanding to the remote market is small. As a result, the space-shrinking effect of the double marginalization problem dominates. When m is large, however, the supplier has great motivation to reduce the wholesale price to boost sales. In this case, the double marginalization problem is mitigated, resulting in an expanded space for the AS1 equilibrium.

The parametric space of the A equilibrium, in contrast, is unaffected by the supply chain structure. When $c_S > c_A + \mu$, advance selling produces a higher profit margin than spot selling and thus becomes a dominating strategy for the seller, regardless of the wholesale price. As a result, the seller's adoption of A in the supply chain model coincides with the direct seller model.

2.6 Discussion

We have developed two models to investigate a seller's advance selling strategy. Our direct seller model shows that advance selling is adopted only if its associated selling cost and consumer disutility are sufficiently small to yield a positive profit margin (i.e., if $v > c +$

$c_A + \mu$). This condition is rather loose. In our model, there is a group of consumers who purchase only in advance. Advance selling can readily be lucrative simply due to its ability to expand the market. This finding is consistent with the real-world observation that advance selling is increasingly popular among sellers. As c_A and μ decrease (or, as the spot selling cost c_S increases), advance selling will serve local consumers as well, which enables the seller to make use of the synergy between advance selling and spot selling. Advance selling will dominate spot selling if c_A and μ are lower than c_S.

Our supply chain model explores the role of a supplier in a seller's advance selling strategy. Assuming the supplier to be the Stackelberg leader in the channel relationship, we elucidate why and how the supplier strategizes on wholesale price to change the seller's strategy so that the supplier's own profit is maximized. When the supplier's production cost c is very high, its wholesale price will be so high as to prevent the seller from selling in advance. As a result, S is the only equilibrium. When the production cost is low enough, however, advance selling is able to yield a positive profit margin. As a result, S, AS1, AS2 and A are all possible equilibria. Consistent with the direct seller model, advance selling contributes increasing sales and profit to the seller as c_A and μ decrease. More interestingly, we show that to induce the seller to move from S to AS1 and from AS1 to AS2, the supplier needs to offer some heavy price cuts. This behavior results in two price gaps in which no wholesale price is optimal.

Comparison of the two models sheds light on the impact of a supply chain structure on the market equilibrium. Because of the double marginalization problem, the seller in a supply chain is faced with a higher marginal product cost than is a direct seller. As a result, S is more likely to arise in equilibrium in the supply chain context. Nevertheless, the expanded space of the S equilibrium does not mean a reduced space for all the equilibria that involve advance selling. Analysis shows that the space of the A equilibrium is unaffected. More interestingly, although the space of the AS2 equilibrium shrinks in the presence of a supply chain structure, the space of the AS1 equilibrium can expand when the size of the remote market is large.

To obtain these results, our models are made parsimonious. We assume that consumers' WTP and their disutility in advance buying is positively and perfectly correlated. An ideal model would allow this correlation to not be perfect. We choose not to adopt such a model because it would greatly complicate the analysis without providing much additional insight. Similar approaches have been taken in the literature, and for the same reason (Varian 1980, Bagwell and Riordan 1991). We believe that the qualitative nature of our results does not hinge on the perfect-correlation assumption, as long as v and μ are not negatively correlated. We can show that in a model in which v and μ are independent, the key feature of our model that low-end consumers buy in advance and high-end consumers buy on spot is robust .

Our model predicts that A is the only equilibrium strategy if $c_S > c_A + \mu$. This result should be understood in the context of our model. We do not expect advance selling to completely replace spot selling in the real world even if $c_S > c_A + \mu$, because there are consumers who reject advance buying or have no access to it (in the same vein, Balasubramanian 1998 assumes that there is a proportion of consumers who have no access to the Internet). We can extend our model to incorporate a third group of consumers, who buy only on spot. In such a model, the parametric space of the A equilibrium is expected to shrink. The A equilibrium can even fall apart, if the size of this third group of consumers is sufficiently large.

In this paper, the seller and supplier are independent decision makers, they only aim to maximize their own profits, and their relationship is characterized by a wholesale price set by the supplier who plays as a Stackelberg leader. In practice, however, the wholesale price may be a result of negotiation between supply chain members and they may also engage in channel coordination behavior. Following Moorthy's (1987) argument, we can show that our supply chain model will perform as integrated if the supplier sets its wholesale price equal to its marginal cost c. In this case, the channel profit is maximized. We can then use Nash Bargaining to model the allocation of this profit between the supplier and the seller (the results and proof are available from the authors upon request). One should note that the impact of a supply chain structure, as discussed in this paper, is negated in such a model.

2.7 Conclusion

With the rapid development in information technologies, advance selling has gained popularity in recent years. In this paper, we develop two models to investigate a seller's incentives to adopt an advance selling strategy. We show that whether a seller adopts advance selling depends not only on the market situation, the nature of the product and the synergy between spot selling and advance selling, but also on the relationships between seller and supplier (e.g., the wholesale price and whether their strategies are coordinated). We highlight the role of the supplier in the seller's advance selling decision. We show that although a supply chain structure is likely to result in more incidences of spot-selling-only, it is unlikely to affect the incidence of advance-selling-only. More interestingly, a supply chain structure can even increase the incidence of the seller using advance and spot selling to serve the local and the remote markets, respectively.

These theoretical results have important managerial implications for whether and how firms in supply chains make use of advance selling. Advance selling can improve profit for both seller and supplier. But it is not effective for all products; it is more profitable for products with lower costs and lower consumer disutility. Our results also imply that when compared with their sellers, suppliers may have greater incentives to adopt advance selling due to their lower marginal costs of products. Indeed, an increasing number of manufacturers conduct advance selling before releasing their new products to markets. Nevertheless, many suppliers still rely on sellers to distribute their products. Given that nowadays most sellers have both online and offline channels and they often carry different assortments of products in different channels (Grewal et al. 2010), our analytical results shed light on when and how a supplier can induce a seller to designate the sales channels in its own interest. A seller's advance selling decision is independent of the size of the expanded market; it will employ advance selling as long as advance selling is able to yield a positive margin. In contrast, the size of the expanded market is vital to a supplier's wholesale price decision. To induce a seller to adopt a supplier's optimal strategy, the supplier may need to decrease its wholesale price as the seller's spot selling cost increases. There are two price gaps in which no wholesale price is optimal.

This study suggests several interesting areas for future research. First, in the supply chain model we assume that the supplier markets its products only through the seller. In reality, in addition to sellers' outlets, suppliers may have their own online and offline channels to sell directly to consumers. For example, Apple sells its product through a hybrid distribution channel system. Its products are sold not only through its authorized sellers' stores and websites, but also through its own stores and websites. This suggests that suppliers themselves can also offer spot selling and advance selling to their customers. There have been a number of studies that explore situations where a supplier opens its own direct channel and encroaches on its sellers' business, for example, Chiang et al. (2003), Arya et al. (2007), Dumrongsiri et al. (2008), and Yoo and Lee (2011). However, none allows the supplier to have both online and offline direct channels. Analysis of such a model is expected to produce interesting results. Second, in the present research, to highlight the impact of the supplier on the seller's advance selling strategy, we focus on a bilateral-monopoly distribution model. A number of studies have incorporated retail competition and shown that competing sellers may develop different advance selling strategies (McCardle et al. 2004, Shugan and Xie 2005). Future research can extend this stream of research by looking at the role of a supplier who markets its products through two competing sellers. In such a context, the supplier may have the power to determine whether to allow both, one or none of the sellers to offer advance selling. Because such a model incorporates both retail competition and a supply chain structure, it could make additional contributions to the literature. Finally, this study is theoretical, and we realize that empirical studies of advance selling have been extremely scarce. Such necessary research should prove to be of great interest when it eventually appears.

Appendix A
Appendix For The First Essay

A.1 Proof of Proposition 1

A high-quality manufacturer is to $\max \pi_H^P(p) = (1 - \frac{p}{1+q})(p - c_H)$, subject to $\pi_L^{mimicking} \leq \pi_L^{revealing}$ and $\hat{\pi}_H \leq \pi_H^P$, where $\pi_L^{mimicking} = (\alpha(1 - \frac{p^*}{1+q}) + (1-\alpha)(1-p^*))p^*$, $\pi_L^{revealing} = \frac{1}{4}$ and $\hat{\pi}_H(\hat{p}_H) = ((1-\alpha)(1 - \frac{\hat{p}_H}{1+q}) + \alpha(1 - \hat{p}_H))(\hat{p}_H - c_H)$. Foc., yields $p_H^P = \frac{1+q+c_H}{2}$ and $\pi_H^P = \frac{(1+q-c_H)^2}{4(1+q)}$. To prevent mimicking, $\pi_L^{mimicking} \leq \pi_L^{revealing}$, which requires that $p_H^P \geq \frac{1+q+\sqrt{\alpha q(1+q)}}{2(1+q-\alpha q)}$. The unrestricted price satisfies this condition only if $\alpha < \alpha_1^P$, so here it is a costless signaling equilibrium, where $\alpha_1^P \triangleq \frac{(q+1)(q+c_H)^2}{q(1+c_H+q)(q+c_H+1)}$. The manufacturer has to upwardly distort its price to $p_H^P = \frac{1+q+\sqrt{\alpha q(1+q)}}{2(1+q-\alpha q)}$ to signal if $\alpha \geq \alpha_1^P$; in this costly signaling equilibrium $\pi_H^P = \frac{(2(1+q-\alpha q)(1+q)-(1+q+\sqrt{\alpha q(1+q)}))(1+q+\sqrt{\alpha q(1+q)}-2c_H(1+q-\alpha q))}{4(1+q)(1+q-\alpha q)^2}$. If the manufacturer deviates, it will charge a price $\hat{p}_H$ other than p_H^P and be regarded by uninformed consumers as low-quality. In this case, it is to maximize $\hat{\pi}_H(\hat{p}_H)$ and we can show that the highest profit it can obtain is $\hat{\pi}_H = \frac{(q+1-(1+\alpha q)c_H)^2}{4(1+\alpha q)(q+1)}$. This profit is no more than π_H^P, noting that both $\hat{\pi}_H$ and π_H^P (weakly-)decrease with and are (weakly-)convex on α and that $\hat{\pi}_H|_{\alpha=1} < \pi_H^P|_{\alpha=1}$. As there are no better other strategies in the range of $\alpha \in [0, 1]$, the costless and costly signaling equilibria we have constructed are unique.

A.2 Proof of Proposition 2

A high-quality manufacturer is to $\max \pi_H^{C\&P}(p) = (1 - \frac{p}{1+q})(p - c_H - k) - K$, subject to $\pi_L^{mimicking} \leq \pi_L^{revealing}$, $\hat{\pi}_H^{C\&P} \leq \pi_H^{C\&P}$ and $\hat{\pi}_H \leq \pi_H^{C\&P}$, where $\pi_L^{mimicking} = \left(\alpha(1 - \frac{p^*}{1+q}) + (1-\alpha)(1-p^*)\right)(p^* - k)$, $\pi_L^{revealing} = \frac{1}{4}$, $\hat{\pi}_H^{C\&P}(\tilde{p}_H) = ((1-\alpha+\alpha\beta)(1 - \frac{\tilde{p}_H}{1+q}) + \alpha(1-\beta)(1-\tilde{p}_H))(\tilde{p}_H - c_H - k) - K$ and $\hat{\pi}_H(\hat{p}_H) = ((1-\alpha)(1 - \frac{\hat{p}_H}{1+q}) + \alpha(1 - \hat{p}_H))(\hat{p}_H - c_H)$. Foc. yields $p_H^{C\&P} = \frac{1+q+c_H+k}{2}$ and $\pi_H^{C\&P} = \frac{(1+q-c_H-k)^2}{4(1+q)} - K$. To prevent mimicking, $\pi_L^{mimicking} \leq \pi_L^{revealing}$, which requires that $p_H^{C\&P} \geq \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha q)}$, where $A^{C\&P} \triangleq \sqrt{(1+q-k(1+q-\alpha q))^2 - (1+q)(1+q-\alpha q)}$. The unrestricted price satisfies this condition only if $\alpha < \alpha_1^{C\&P}$, so here it is a costless signaling equilibrium, where $\alpha_1^{C\&P} \triangleq \frac{(1+q)((c_H+q)^2+k(2-k))}{q(1+q+c_H+k)(q+c_H+1-k)}$. The manufacturer has to upwardly distort the price to $p_H^{C\&P} = \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha q)}$ to signal if $\alpha \geq \alpha_1^{C\&P}$; in this costly signaling equilibrium $\pi_H^{C\&P} = (1 - \frac{(1+q-\alpha q)k+1+q+A^{C\&P}}{2(q+1)(1+q-\alpha q)})(\frac{k(1+q-\alpha q)+1+q+A^{C\&P}}{2(1+q-\alpha q)} - c_H - k) - K$.

There are two possible ways for the manufacturer to deviate. One is to adopt cobranding but charge a different price to maximize $\hat{\pi}_H^{C\&P}(\tilde{p}_H)$. In this case, only the really uninformed consumers and some of the semi-uninformed consumers who cannot recognize the ingredient brand will regard it as low-quality. The second way of deviation is to shed cobranding to maximize $\hat{\pi}_H(\hat{p}_H)$. In this case, both the really uninformed consumers and all the semi-uninformed consumers will regard it as low-quality. We can show that $\hat{\pi}_H^{C\&P} = \frac{(q+1-(1+\alpha(1-\beta)q)(c_H+k))^2}{4(1+\alpha(1-\beta)q)(q+1)} - K$, and so the manufacturer will not deviate in the first way if $\hat{\pi}_H^{C\&P} \leq \pi_H^{C\&P}$. This condition requires that $\alpha < \alpha_2^{C\&P}$, where $\alpha_2^{C\&P} = \begin{cases} \arg\limits_{\alpha}\{\pi_H^{C\&P} = \hat{\pi}_H^{C\&P}\} & \beta \geq \beta^* \\ 1 & \beta < \beta^* \end{cases}$ and $\beta^* = \arg\limits_{\beta}\{\hat{\pi}_H^{C\&P}|_{\alpha=1} = \pi_H^{C\&P}|_{\alpha=1}\}$. β^* is a threshold value; deviation happens only if $\beta \geq \beta^*$. We can show that $\hat{\pi}_H = \frac{(q+1-(1+\alpha q)c_H)^2}{4(1+\alpha q)(q+1)}$, and so the manufacturer will not deviate in the second way if $\hat{\pi}_H \leq \pi_H^{C\&P}$. This condition translates to $\alpha > \alpha_0^{C\&P}$, where $\alpha_0^{C\&P} \triangleq \underset{\alpha}{\arg}\{\frac{(1+q-c_H-k)^2}{4(1+q)} - K = \frac{(q+1-(1+\alpha q)c_H)^2}{4(q+1)(1+\alpha q)}\}$. Hence, we can show $0 < \alpha_0^{C\&P} < \alpha_1^{C\&P} < \alpha_2^{C\&P} \leq 1$ and the costless and costly separating equilibria we have derived exist and are unique equilibria, in range of $\alpha \in [\alpha_0^{C\&P}, \alpha_1^{C\&P})$ and $\alpha \in [\alpha_1^{C\&P}, \alpha_2^{C\&P}]$, respectively. The range of costly signaling equilibria is $\alpha \in [\alpha_1^{C\&P}, 1]$ if $\beta < \beta^*$.

A.3 Proof of $\frac{\partial p_H^{C\_costly}}{\partial k} < 0$

We can show that $\frac{\partial p_H^{C\&P}}{\partial k} = \frac{(1+q-\alpha q)(k+c_L)-1-q+A^{C\&P}}{2A^{C\&P}}$. The numerator is negative, noting that the demand of mimicking is nonnegative, i.e., $1 - P_H^{C\&P} \geq 0$, which implies that $\frac{1}{2}\frac{(1+q-\alpha q)(k+c_L)-1-q+2q\alpha+A^{C\&P}}{q-q\alpha+1} \leq 0$ and thus $(1+q-\alpha q)(k+c_L) - 1 - q + A^{C\&P} \leq -2q\alpha < 0$.

A.4 Proof of Proposition 3

According to Proposition 2, we can show that $\pi_H^{C\&P} \leq \pi_H^P$ if $K = 0$, and that $\pi_H^{C\&P}$ decreases with K and π_H^P is independent of it. Thus, $\pi_H^{C\&P} < \pi_H^P$ if $K > 0$. We can also show that $\pi_H^{P\_costless} \geq \pi_H^{C\&P}$, and that $\frac{\partial^2 \pi_H^{C\&P}}{\partial \alpha^2} < \frac{\partial^2 \pi_H^P}{\partial \alpha^2} < 0$. Hence, if we can show that $\pi_H^P|_{\alpha=1} > \pi_H^{C\&P}|_{\alpha=1}$ if $K = 0$, then it must be the case that $\pi_H^P \geq \pi_H^{C\&P}$ for $\alpha \in [\alpha_0^{C\&P}, \alpha_2^{C\&P}]$. We now prove that $\pi_H^P|_{\alpha=1} > \pi_H^{C\&P}|_{\alpha=1}$. $\pi_H^P|_{\alpha=1} = \frac{(q+1-\sqrt{q(1+q)})(q+1+\sqrt{q(1+q)}-2c_H)}{4(1+q)}$ and $\pi_H^{C\&P}|_{\alpha=1} = \frac{(1+q-k-\sqrt{(1+q-k)^2-(1+q)})(1+q-k+\sqrt{(1+q-k)^2-(1+q)}-2c_H)}{4(1+q)}$, noting that it is a costly signaling equilibrium for both cases if $\alpha = 1$. Denote $f(k) = \pi_H^{C\&P}|_{\alpha=1} = \frac{(1+q-k-\sqrt{(1+q-k)^2-(1+q)})(1+q-k+\sqrt{(1+q-k)^2-(1+q)}-2c_H)}{4(1+q)}$. So $f(0) = \frac{(q+1-\sqrt{q(1+q)})(q+1+\sqrt{q(1+q)}-2c_H)}{4(1+q)} = \pi_H^P|_{\alpha=1}$. Thus, $f(0) > f(k)$ is the sufficient condition for $\pi_H^P|_{\alpha=1} > \pi_H^{C\&P}|_{\alpha=1}$, which is true since $f'(k) = -\frac{2c_H(1+q-k-\sqrt{q-2k+q^2-2kq+k^2})}{4(1+q)\sqrt{q-2k+q^2-2kq+k^2}} < 0$. Thus, we must have $\pi_H^P|_{\alpha=1} > \pi_H^{C\&P}|_{\alpha=1}$ if $k > 0$, noting that $\pi_H^P|_{\alpha=1} = \pi_H^{C\&P}|_{\alpha=1}$ only if $k = 0$. Therefore, $\pi_H^P \geq \pi_H^{C\&P}$ for $\alpha \in [\alpha_0^{C\&P}, \alpha_2^{C\&P}]$ as long as $K \geq 0$ and $k \geq 0$, and they are equal only when $K = k = 0$.

A.5 Proof of Proposition 4

Under the new, alternative belief, a high-quality manufacturer is to $\max \pi_H^{C\&P}(p) = (1 - \frac{p}{1+q})(p - c_H - k) - K$, subject to $\pi_L^{mimicking} \leq \pi_L^{revealing}$, $\hat{\pi}_H^{C\&P} \leq \pi_H^{C\&P}$ and $\hat{\pi}_H \leq \pi_H^{C\&P}$, where $\pi_L^{mimicking} = (\alpha\,(1-\beta)\,(1-\frac{p^*}{1+q})+(1-\alpha+\alpha\beta)\,(1-p^*))\,(p^*-k)$, $\pi_L^{revealing} = \frac{1}{4}$, $\pi_H^{C\&P} = ((1-\alpha+\alpha\beta)(1-\frac{\tilde{p}_H}{1+q}) + \alpha(1-\beta)(1-\tilde{p}_H))(\tilde{p}_H - c_H - k) - K$ and $\hat{\pi}_H(\hat{p}_H) = ((1-\alpha)\,(1-\frac{\hat{p}_H}{1+q}) + \alpha(1-\hat{p}_H))(\hat{p}_H - c_H)$. Foc. yields that $p_H^{C\&P} = \frac{1+q+c_H+k}{2}$ and $\pi_H^{C\&P} = \frac{(1+q-c_H-k)^2}{4(1+q)} - K$. To prevent mimicking, $\pi_L^{mimicking} \leq \pi_L^{revealing}$, which requires that $p_H^{C\&P} \geq \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha(1-\beta)q)}$, where $A^{C\&P} \triangleq \sqrt{(1+q-(1+q-\alpha\,(1-\beta)\,q)\,k)^2 - (1+q)\,(1+q-\alpha\,(1-\beta)\,q)}$. The unrestricted price satisfies this condition only if $\alpha < \alpha_1^{C\&P}$ (so here it is a costless signaling), where $\alpha_1^{C\&P} \triangleq \frac{(1+q)\left((c_H+q)^2+k(2-k)\right)}{q(1-\beta)(1+q+c_H+k)(q+c_H+1-k)}$. The manufacturer has to upwardly distort the price to $p_H^{C\&P} = \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha(1-\beta)q)}$ to signal if $\alpha \geq \alpha_1^{C\&P}$ and such costly signaling makes profit of $\pi_H^{C\&P} = (1 - \frac{(1+q-\alpha(1-\beta)q)k+\left(1+q+A^{C\&P}\right)}{2(q+1)(1+q-\alpha(1-\beta)q)})(\frac{k(1+q-\alpha(1-\beta)q)+1+q+A^{C\&P}}{2(1+q-\alpha(1-\beta)q)} - c_H - k) - K$. Similar to the previous case, there are two possible ways for the manufacturer to deviate, resulting in a maximized profit, $\hat{\pi}_H^{C\&P}$ and $\hat{\pi}_H$, respectively. We can show that $\hat{\pi}_H^{C\&P} = \frac{(q+1-(1+\alpha(1-\beta)q)(c_H+k))^2}{4(1+\alpha(1-\beta)q)(q+1)} - K$. So the manufacturer will not deviate if $\hat{\pi}_H^{C\&P} \leq \pi_H^{C\&P}$. Now we have $\pi_H^{C\&P} = (1 - \frac{p}{1+q})(p - (c_H + k)) - K$ and $\hat{\pi}_H^{C\&P}(\tilde{p}_H) = ((1 - \alpha(1 - \beta))(1 - \frac{\tilde{p}_H}{1+q}) + \alpha(1 - \beta)(1 - \tilde{p}_H))(\tilde{p}_H - (c_H + k)) - K$. Note that $\hat{\pi}_H^{C\&P}(\tilde{p}_H)$ takes the same function form as in the proof of Proposition 1 if we redefine $c_H + k$ as c_H and $\alpha\,(1-\beta)$ as α. So we can show that $\hat{\pi}_H^{C\&P} \leq \pi_H^{C\&P}$ in the similar manner as in Proposition 1. We can also show that $\hat{\pi}_H = \frac{(q+1-(1+\alpha q)c_H)^2}{4(1+\alpha q)(q+1)}$. So the manufacturer will not deviate if $\hat{\pi}_H \leq \pi_H^{C\&P}$, which requires that $\alpha > \alpha_0^{C\&P}$, where $\alpha_0^{C\&P} \triangleq \underset{\alpha}{\arg}\{\frac{(1+q-c_H-k)^2}{4(1+q)} - K = \frac{(q+1-(1+\alpha q)c_H)^2}{4(q+1)(1+\alpha q)}\}$. Hence, if $\beta < \beta_2$, we can show $0 < \alpha_0^{C\&P} < \alpha_1^{C\&P} < 1$ and the costless and costly separating equilibria we have derived exist and are unique equilibria, in range of $\alpha \in [\alpha_0^{C\&P}, \alpha_1^{C\&P})$ and $\alpha \in [\alpha_1^{C\&P}, 1]$, respectively. If $\beta \geq \beta_2$, we can show that $0 < \alpha_0^{C\&P} < 1 \leq \alpha_1^{C\&P}$ and the range of the costless signaling equilibrium is $\alpha \in [\alpha_0^{C\&P}, 1]$ and the costless signaling is the only separating equilibria, where $\beta_2 = 1 - \frac{(1+q)((c_H+q)^2+k(2-k))}{q(1+q+c_H+k)(1+q+c_H-k)}$.

A.6 Proof of comparison of price distortion in the different cases

We can show that under non-cobranding, $p_H^{costless} = \frac{1+q+c_H}{2}$ and $p_H^{costly} = \frac{1+q+\sqrt{\alpha q(1+q)}}{2(1+q-\alpha q)}$, that under cobranding (as in Section 4), $p_H^{costless} = \frac{1+q+c_H+k}{2}$ and $p_H^{costly} = \frac{k}{2} + \frac{1+q+\sqrt{(1+q-k(1+q-\alpha q))^2-(1+q)(1+q-\alpha q)}}{2(1+q-\alpha q)}$, and that under cobranding , $p_H^{costless} = \frac{1+q+c_H+k}{2}$ and

$p_H^{costly} = \frac{k}{2} + \frac{1+q+\sqrt{(1+q-(1+q-\alpha(1-\beta)q)k)^2-(1+q)(1+q-\alpha(1-\beta)q)}}{2(1+q-\alpha(1-\beta)q)}$. It is easy to show that the price is higher under cobranding when signaling is costless, because cobranding incurs an extra marginal cost of k. However, when signaling is costly, the price distortion (relative to the price in the costless equilibrium) is reduced under cobranding and is the least in under cobranding with the alternative belief.

A.7 Proof of Proposition 5

We can show that $\pi_H^{P\_costless} > \pi_H^{C\&P\_costless}$. Both $\pi_H^{C\&P}$ and π_H^P decrease with α, and $\frac{\partial^2 \pi_H^{C\&P}}{\partial \alpha^2} < \frac{\partial^2 \pi_H^P}{\partial \alpha^2} < 0$. Hence, if we can show that $\pi_H^P|_{\alpha=1} < \pi_H^{C\&P}|_{\alpha=1}$, then it must be the case that $\pi_H^P < \pi_H^{C\&P}$ for $\alpha \in [\alpha_0^{C\&P}, 1]$. Notice that $\pi_H^P|_{\alpha=1} < \pi_H^{C\&P}|_{\alpha=1}$ when $K = 0$ is a sufficient condition for $\pi_H^P|_{\alpha=1} < \pi_H^{C\&P}|_{\alpha=1}$ when $K > 0$. We now prove that $\pi_H^P|_{\alpha=1} < \pi_H^{C\&P}|_{\alpha=1}$ when $K = 0$. Denote $f(k,\beta) =$
$\frac{((2q+2-k)(1+\beta q)-(1+q+\sqrt{(1+q-(1+\beta q)k)^2-(1+q)(1+\beta q)}))(1+q-(1+\beta q)(2c_H+k)+\sqrt{(1+q-(1+\beta q)k)^2-(1+q)(1+\beta q)})}{4(q+1)(1+\beta q)^2}$,
then $\pi_H^{C\&P\_costly}|_{\alpha=1} = f(k,\beta)$ and $\pi_H^{P\_costly}|_{\alpha=1} = f(0,0)$. We can show $f_1'(k,\beta) < 0$ and $f_2'(k,\beta) > 0$. It must be a case that $f(k,\beta) = \omega > f(0,0)$ and set $g(k,\beta) = f(k,\beta) - \omega = 0$, where ω is a constant. Then we can show $\frac{d\beta}{dk} = -\frac{g_1'(k,\beta)}{g_2'(k,\beta)} = -\frac{f_1'(k,\beta)}{f_2'(k,\beta)} > 0$. Thus we can have a β large enough to ensure that $f(0,0) < f(k,\beta)$ when $k > 0$. Thus, for a given k, there is a β such that $\beta_0 = \min_{\beta} \arg\{f(k,\beta) = f(0,0)\}$. When $K > 0$, $\beta_0 = \arg\{\pi_H^P|_{\alpha=1} = \pi_H^{C\&P}|_{\alpha=1}\}$, which ensures that $\pi_H^P|_{\alpha=1} < \pi_H^{C\&P}|_{\alpha=1}$.

For a given K and k, if $0 \leq \beta \leq \beta_0$, then non-cobranding is a dominating strategy. If $\beta > \beta_0$, then non-cobranding is a dominating strategy when $\alpha_0^{C\&P} \leq \alpha \leq \theta$, and cobranding is a dominating strategy when $\theta < \alpha \leq 1$, where $\theta = \arg\{\pi_H^P =$

$\pi_H^{C\&P}\}$. We denote θ according to the relative positions of θ and $\alpha_1^{C\&P}$: $\theta = \theta_1$ if $\theta < \alpha_1^{C\&P}$; and $\theta = \theta_2$ if $\theta \geq \alpha_1^{C\&P}$, where $\theta_1 = \arg\{\pi_H^{P\_costly}|_{\alpha=\theta_1} = \pi_H^{C\&P\_costless}\}$ and $\theta_2 = \arg\{\pi_H^{P\_costly}|_{\alpha=\theta_1} = \pi_H^{C\&P\_costly}|_{\alpha=\theta_1}\}$. It is the case of θ_1 if $\beta > \beta_1$ and the case of θ_2 if $\beta_1 \geq \beta > \beta_0$, where $\beta_0 = \underset{\beta}{\arg}\{\pi_H^{P\_costly}|_{\alpha=1} = \pi_H^{C\&P\_costly}|_{\alpha=1}\}$ and $\beta_1 = \underset{\beta}{\arg}\{\pi_H^{P\_costly}|_{\alpha=\alpha_1^{C\&P}} = \pi_H^{C\&P\_costless}\}$.

A.8 Proof of Proposition 6

We have shown that cobranding is more likely to arise in equilibrium if α is sufficiently large (i.e., if $\alpha > \theta$, see Proposition 4), and that θ decreases with β (more accurately, θ_2 decreases with β and θ_1 is independent of β). Thus, the parameter space of cobranding expands with α and β. Since K is a fixed cost and only reduces the profit under cobranding, the space of cobranding shrinks with K. As for c_H, we can show that: $\frac{\partial \pi_H^{P\_costless}}{\partial c_H} < \frac{\partial \pi_H^{C\&P\_costless}}{\partial c_H} < 0$ if $\alpha \leq \alpha_1^P$; $\frac{\partial \pi_H^{P\_costly}}{\partial c_H} < \frac{\partial \pi_H^{C\&P\_costless}}{\partial c_H} < 0$ if $\alpha \in \left(\alpha_1^P, \alpha^*\right)$; $\frac{\partial \pi_H^{C\&P\_costless}}{\partial c_H} < \frac{\partial \pi_H^{P\_costly}}{\partial c_H} < 0$ if $\alpha \in \left(\alpha^*, \alpha_1^{C\&P}\right)$; and $\frac{\partial \pi_H^{C\&P\_costly}}{\partial c_H} < \frac{\partial \pi_H^{P\_costly}}{\partial c_H} < 0$ if $\alpha > \alpha_1^{C\&P}$, where $\alpha^* = \frac{(1+q)(q(q+2c_H+2k)+(c_H+k)^2)}{q((c_H+k)^2+(1+q)(1+q+2c_H+2k))}$. We can show that $\frac{\partial \pi_H^{C\&P\_costly}}{\partial c_H} = \frac{\partial \pi_H^{P\_costly}}{\partial c_H}$ if $\alpha = \alpha^*$. Notice that θ exists only if $\beta > \beta_0$, that $\alpha_1^{C\&P}|_{\beta=0} - \alpha^* = \frac{2k(1+q)}{q(1+q+c_H-k)(1+q+c_H+k)^2} > 0$, and that $\min(\theta) = \alpha_1^{C\&P}|_{\beta=\beta_0}$ and $\alpha_1^{C\&P}|_{\beta=\beta_0} > \alpha_1^{C\&P}|_{\beta=0} > \alpha^*$. Because $\theta > \alpha^*$, the parameter space of the cobranding equilibrium shrinks with c_H since $\frac{\partial \pi_H^{C\&P}}{\partial c_H} < \frac{\partial \pi_H^{P}}{\partial c_H} < 0$ for $\alpha \in (\alpha^*, 1]$. (Note that when signaling is costly, the demands under cobranding and non-cobranding are both independent of c_H; specifically, they are $1 - \frac{p_H^{C\&P\_costly}}{1+q}$ and $1 - \frac{p_H^{P\_costly}}{1+q}$, respectively. The demand under cobranding is larger than that under non-cobranding since $p_H^{C\&P\_costly} < p_H^{P\_costly}$.) As for k, recall the objective function $\pi_H^{C\&P}(p_H) = (1 - \frac{p_H}{1+q})(p_H - c_H - k) - K$, where $p_H = \frac{k}{2} + \frac{1+q+A^{C\&P}}{2(1+q-\alpha q)}$. So $\frac{\partial \pi_H^{C\&P}}{\partial k} = \frac{\partial \pi_H^{C\&P}(p_H)}{\partial p_H}\frac{\partial p_H}{\partial k} + \frac{\partial \pi_H^{C\&P}(p_H)}{\partial k}$. We can show that $\frac{\partial p_H}{\partial k} < 0$, which means that an increase of k reduces the price distortion, and that $\frac{\partial \pi_H^{C\&P}(p_H)}{\partial p_H} < 0$, which means that the profit decreases with price (distortion). Thus, $\frac{\partial \pi_H^{C\&P}(p_H)}{\partial p_H}\frac{\partial p_H}{\partial k} > 0$, i.e., an increased k leads to higher profit by reducing price distortion and improving signaling efficiency. However, we can show that $\frac{\partial \pi_H^{C\&P}(p_H)}{\partial k} < 0$, indicating that as a cost, the labeling cost k reduces the profit directly. As we cannot formally prove $\frac{\partial \pi_H^{C\&P}}{\partial k}$ to be positive, we turn to numerical experiment, in the range of $\alpha = \{.05, .10, .15, ..., .95, 1.00\}$, $\beta = \{.05, .10, .15, ..., .90, .95\}$, $c_H = \{.05, .10, .15; ..., 1.95, 2.00\}$, $k = \{.01, .02, .03, ..., .19, .20, .30, .40, ..., 0.90, .1.00\}$, $q = \{.5, 1.0, 1.5, 2.0, 2.5\}$. The experiment results show that the parameter space of the cobranding equilibrium shrinks with k.

Appendix B
Appendix For The Second Essay

B.1 Proof of Proposition 1

The seller's objective functions in the four regimes are provided in the main text. Proposition 1 is proved noting that S has a constraint $c - c_s > c > v - \mu - c_A$; AS1 has a constraint $c_S < \frac{c\mu + c_A v}{v-\mu}$; AS2 has a constraint $c_S \geq \frac{c\mu + c_A v}{v-\mu}$; and AS2 becomes A if $c_S > \mu + c_A$.

B.2 Proof of Proposition 2

We substitute p_w for c in the direct seller model and obtain the seller's equilibrium strategy and the associated profit. Then we derive the supplier's objective functions, the equilibrium results (i.e., wholesale and retail prices) and the boundary constraints of the four regimes in the main text. Based on these results, we summarize the supplier's strategy options and payoffs as follows:

$$\Pi_S = \begin{cases} \frac{(v-c_S-c)^2}{8v}, \text{ if } c_S \leq g'; \text{ this is unconstrained} \\ \frac{(v-\mu-c_A-c)(\mu+c_A-c_S)}{2v}, \text{ if } c_S > g' \end{cases}$$

$$\Pi_{AS1} = \begin{cases} \frac{(\mu-c_S+c_A)(v-\mu-c_A-c)}{2v}, \text{ if } c_S < l' \\ \frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{8v(v-\mu+mv)(v-\mu)}, \text{ if } l > c_S > l'; \text{ this is unconstrained} \\ \frac{(1+m)(-c_S+\mu+c_A)(vc_S-\mu c_S-c_A v-\mu c)}{2\mu^2}, \text{ if } c_S > l \end{cases}$$

$$\Pi_{AS2} = \begin{cases} \frac{(1+m)(-c_S+\mu+c_A)(vc_S-\mu c_S-c_A v-\mu c)}{2\mu^2}, \text{ if } g > c_S \geq \frac{vc_A}{(v-\mu)} \\ \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}, \text{ if } c_A+\mu > c_S \geq g; \text{ this is unconstrained} \end{cases}$$

$$\Pi_A = \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}, \text{ if } c_S > c_A + \mu.$$

We can show that $\Pi_S > \Pi_{AS1}$ if $c_S < l'$, that $\Pi_{AS1} > \Pi_S$ if $l' \leq c_S \leq g'$, that $\Pi_{AS1} > \Pi_{AS2}$ if $l' \leq c_S \leq h$, and that $\Pi_{AS1} > \Pi_{AS2}$ if $c_A + \mu > c_S \geq h$. Because the supplier faces the same demands and thus charges the same optimal wholesale price in A and AS2, $\Pi_{AS2} = \Pi_A$. In the spirit of Pareto optimality, when $c \leq v - \mu - c_A$ (so advance selling must be employed by the seller), AS2 is the equilibrium if $c_S > c_A + \mu$, whereas A is the equilibrium if $c_S > c_A + \mu$.

Proof of clockwise rotation of the two lines in Figure 2

Easy to check that the two lines, $c_S = h$ and $c_S = l'$, cross the point of $(\mu + c_A, v - \mu - c_A)$. The line of $c_S = h \triangleq \frac{(v-\mu-c_A-c)(mv-\sqrt{(1+m)v(v-\mu+mv)})}{v-\mu} + v - c$ can be rewritten as $c = \frac{(v-\mu)(v-c_S+(v-\mu-c_A)\frac{mv-\sqrt{(1+m)v(v-\mu+mv)}}{v-\mu})}{v-\mu+mv-\sqrt{(1+m)v(v-\mu+mv)}}$. We can show that $\frac{\partial^2 c}{\partial c_S \partial m} = \frac{(2\sqrt{(1+m)v(v-\mu+mv)}-2v+\mu-2mv)(v-\mu)v}{2\left(v-\mu+mv-\sqrt{(1+m)v(v-\mu+mv)}\right)^2\sqrt{(1+m)v(v-\mu+mv)}} < 0$, which indicates that the line of $c_S = h$ rotates clockwise as m increases. The line of $c_S = l' \triangleq \frac{(2\mu+2c_A-v+c)(v-\mu)-mv(v-\mu-c_A-c)}{(v-\mu)}$ can be rewritten as $c = \frac{(v-\mu)(v-2\mu-2c_A+c_S)+mv(v-\mu-c_A)}{v-\mu+mv}$. We can show that $\frac{\partial^2 c}{\partial c_S \partial m} = \frac{-(v-\mu)v}{(v-\mu+mv)^2} < 0$, which indicates that the line of $c_S = l'$ rotates clockwise as m increases.

B.3 Proof of Proposition 3

We first look at the supplier. When advance selling is not allowed, its profit is $\Pi_S = \frac{(v-c_S-c)^2}{8v}$. When advance selling is allowed, its profit is $\Pi_S = \frac{(v-c_S-c)^2}{8v}$ when $c_S < l'$, $\Pi_A = \Pi_{AS1} = \frac{1}{8}\frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{v(v-\mu+mv)(v-\mu)}$ when $l' \leq c_S \leq h$, or $\Pi_{AS2} = \frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)}$ when $c_S > h$. We can show that $\Pi_{AS1}|_{m=0} = \frac{(v-c_S-c)^2}{8v}$ and that $\frac{\partial \Pi_{AS1}}{\partial m} > 0$ when $l' \leq c_S$. This indicates that $\Pi_{AS1} > \Pi_S$. When $c_S > h$, $\Pi_{AS2} > \Pi_S$ since we have shown that

$\Pi_{AS2} > \Pi_{AS1}$ (see proof of Proposition 2). It follows that $\Pi_A > \Pi_S$ when A arises in equilibrium since $\Pi_A = \Pi_{AS2}$.

When advance selling is not allowed, the seller's profit is $\pi_S = \frac{(v-c_S-c)^2}{16v}$. When advance sell is allowed, its profit is $\pi_S = \frac{(v-c_S-c)^2}{16v}$ when $c_S < l'$, $\pi_{AS1} = \frac{((v-\mu)(v-c_S-c)+mv(v-2c_S+\mu+c_A-c))^2}{16(v-\mu+mv)^2 v} + \frac{m((v-\mu)(v-2\mu-c+c_S-2c_A)+mv(v-\mu-c_A-c))^2}{16(v-\mu+mv)^2(v-\mu)}$ when $l' \leq c_S \leq h$, $\pi_{AS2} = \frac{(\mu+c_A-c_S)^2}{4\mu} + \frac{(1+m)(v-\mu-c_A-c)^2}{16(v-\mu)}$ when $h < c_S \leq c_A + \mu$, or $\pi_A = \frac{(1+m)(v-\mu-c_A-c)^2}{16(v-\mu)}$ when $c_S > c_A + \mu$. Thus, when $c_S \leq l'$, the seller's profit is the same. We can show that $\pi_{AS1}|_{m=0} = \pi_S$ and that $\frac{\partial \pi_{AS1}}{\partial m} > 0$. it implies that $\pi_{AS1} > \pi_S$ when $l' < c_S \leq h$. When $c_S > h$, we can show that $\frac{(1+m)(v-\mu-c_A-c)^2}{8(v-\mu)} > \frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{8v(v-\mu+mv)(v-\mu)}$. When $c_S > l'$, we can show $\frac{(mv(v-\mu-c_A-c)+(v-\mu)(v-c_S-c))^2}{8v(v-\mu+mv)(v-\mu)} > \frac{(v-c_S-c)^2}{8v}$. These implies that when $c_S > h$, $\pi_{AS1} > \pi_S$ and $\pi_{AS2} > \pi_S$, because $\frac{(1+m)(v-\mu-c_A-c)^2}{16(v-\mu)} > \frac{(v-c_S-c)^2}{16v}$. For the same reason, $\pi_A > \pi_S$.

B.4 Proof of Proposition 4

We can see that the space of the AS2 equilibrium in the direct seller model is confined by the lines of $c_S = \frac{c_A v}{v-\mu}$ and $c_S = c_A + \mu$, as shown in Figure 1, whereas that in the supply chain model is confined by the lines of $c_S = h$ and $c_S = c_A + \mu$, as shown in Figure 2. We can show that the line of $c_S = h$ joins the x-axis at (0, $\frac{v(v-\mu)+(v-\mu-c_A)(mv-\sqrt{(1+m)v(v-\mu+mv)})}{(v-\mu)}$) and $\frac{v(v-\mu)+(v-\mu-c_A)(mv-\sqrt{(1+m)v(v-\mu+mv)})}{(v-\mu)} > \frac{c_A v}{v-\mu}$. This proves a shrunk space of the AS2 equilibrium in the supply chain context and the area of the shrunk space is $\Delta\,(AS2) = \frac{1}{2}(\frac{v(v-\mu)+(v-\mu-c_A)(mv-\sqrt{(1+m)v(v-\mu+mv)})}{(v-\mu)} - \frac{c_A v}{v-\mu})\,(v-\mu-c_A)$. The total space of the advance and spot selling (i.e., both AS1 and AS2) is decreased by $\Delta\,(AS1\&AS2) = \frac{1}{2}(v - \mu - c_A - \frac{mv(v-\mu-c_A)+(v-\mu)(v-2\mu-2c_A)}{v-\mu+mv})\,(\mu + c_A)$. Thus, the space of the AS1 equilibrium is decreased by $\Delta\left(AS1\right) = \Delta\left(AS1\&AS2\right) - \Delta\left(AS2\right)$. The space of AS1 equilibrium shrinks if $\Delta\left(AS1\&AS2\right) > \Delta\left(AS2\right)$, i.e., if $\frac{(v-\mu)^2(\mu+c_A)^2}{(v-\mu-c_A)^2} > (v-\mu+mv)\left((m+1)\,v - \sqrt{(1+m)^2\,v^2 - (1+m)\,v\mu}\right)$. We can show that the right side of the inequality increases with m. Thus, the greater m, the less likely it is that $\Delta\left(AS1\&AS2\right) > \Delta\left(AS2\right)$. It implies that when m is large, the total space of AS1 and AS2 equilibria is likely to shrink to a smaller extent than the space of the AS2 equilibrium, indicating an expanded space of the AS1 equilibrium. Indeed, given that the line of $c_S = h$ is to the right of the line of $c_S = \frac{c_A v}{v-\mu}$ and that when $m \to +\infty$, the line of $c_S = l'$ approaches the line of $c = v - \mu - c_A$, it must be true that the space of AS1 is expanded when $m \to +\infty$. On the other hand, when m is small, the total space of AS1 and AS2 equilibria is likely to shrink to a greater extent than the space of the AS2 equilibrium, indicating a shrunk space of the AS1 equilibrium. We can show that it is the case if $v < 2\mu + 2c_A$ and $m \to 0$.

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