

The Economics of Pricing Add-on Products under Duopoly Competition

Full paper

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Abstract

Firms often offer a variety of add-on products in addition to their core information goods. How should firms offer such add-on products? When should they offer them as a bundle versus à la carte? How does competition impact firms' bundling choice? What is the impact of regulators' decision to limit add-on pricing on consumers' surplus? Motivated by these questions, we develop an analytical model to examine asymmetric firms' bundling and pricing strategy. We identify the critical role of competition in firm's bundling decision. When there is more competition from the inferior firm, the superior firm has more incentive to bundle its add-on, even when the add-on is costly to offer. When the ratio of cost to quality is sufficiently low, the superior firm bundles as opposed to the monopoly case wherein the superior firm unbundles. We show that consumers are unlikely to be better off when add-on pricing is prohibited by regulators.

Keywords

add-on bundling, duopoly competition, vertical differentiation, asymmetric firms, information goods

Introduction

Firms often offer add-on products or services in addition to their core products. Generally add-on product refers to any ancillary or complementary product that is offered in addition to firms' core product. For example, software vendors offer technical support and training in addition to packaged software. Telecommunication providers promote additional data plans besides voice calling service. Banks offer debit card and overdraft protection in addition to the basic checking service. By definition, the purchase of an add-on product is contingent on the purchase of the core product. Our primary focus is on the information goods industry, though broadly both core and add-on can be information goods or physical goods.

We observe firms that have asymmetric qualities adopt different add-on bundling strategies across industries. While low-quality firms often adopt bundling strategy and charge a bundled price for its core and add-on product, high-quality firms generally have different bundling strategies. Some high-quality firms unbundle their add-ons while others bundle add-ons. In the following examples, *Adobe Systems Inc.*, *Amazon Web Services Inc.*, and *SolarWinds* are high-quality (superior) firms while *Nitro Corp.*, *BMC Software Inc.*, and *PRTG* are low-quality (inferior) firms¹. In the software industry, a high-quality software vendor such as *Adobe Systems Inc.* charges for Adobe Acrobat software (core product) and expert-level technical support (add-on product) separately, whereas a lower functionality software vendor such as *Nitro Corp.* offers technical support such as discussion forum and online Q&A with the software for a bundled price. Other lower quality vendors such as *Foxit Software Inc.* also bundle technical support

¹ Based on prices and reviews, we classify these firms as high quality vendors and low quality vendors, respectively

with their software offering. One can also find such asymmetric bundling strategies in other software categories. For example, a superior software vendor such as *Amazon Web Services Inc.* offers technical support separately from their data analytics software, while an inferior software vendor such as *BMC Software Inc.* bundles technical support with their data analytics software. In IT security industry, a low quality vendor such as *PRTG* network monitor offers all-in, no add-ons price for both its core network monitoring functions and add-on features such as cluster failure solution and security SSL encryption. In this industry, a high quality vendor *SolarWinds* offers the network performance monitor v11 for one bundled price including additional features such as route monitoring and packet analysis. How can we explain the different add-on bundling strategies adopted by the superior firms? When should they offer such add-on products as a bundle or à la carte? How does competition impact a firm's pricing decision? Addressing these questions will help draw insights on the role of competition in driving firms' pricing strategy, and offer guidance to firms who are looking to optimally bundle add-on products in a competitive environment. Prior add-on literature has not completely explained such asymmetric bundling strategies for add-on products and this is the primary focus of this study.

Our second focus is to examine the impact of regulating add-on pricing on consumer surplus. Add-on pricing has been widely adopted across different industries and firms benefit from charging additionally for their add-on products or services. For example, software vendors make great amount of revenue from charging technical support (PWC 2007). Consumer Financial Protection Bureau (CFPB) reported that in 2012, banks took in \$32 billion in overdraft service up \$400 million from the previous year (Touryalai 2013). Given the hefty revenues generated from various kinds of add-on services, general concerns prevail in public and among consumer groups who fear companies are over charging through various add-on services. Hence, government and regulators have incentive to regulate the add-on services market to protect consumers, sometimes even prohibit the add-on pricing practices. For example, British government has banned travel companies and retailers from charging extra fees when consumers use their credit cards to pay online (Ensor 2013). Although it seems necessary for government intervention and industrial regulation of add-on pricing in some circumstances, it is not clear whether such regulation can benefit consumers. In this study, we explicitly examine the implication of prohibiting add-on pricing policy on consumer surplus. We provide insights on the impact of well-intentioned regulators' intervention on add-on pricing under different conditions.

We study these questions by building an analytical model in a duopoly setting wherein competing firms have asymmetric qualities for their core and add-ons. We also assume firms have asymmetric marginal cost for add-ons. Our model incorporates the heterogeneity in consumers' taste for quality for both core and add-on. While most studies in add-on literature (Ellison 2006, Shulman and Geng 2013) assume consumers have discrete taste for qualities, we assume consumers are continuously differentiated in their taste for qualities, and consumers' heterogeneous willingness to pay (WTP) for core and add-on are correlated. In addition, whereas prior add-on literature assumes a segment of boundedly rational consumers and their main results rely on this segment of consumers, we focus on the case in which all consumers are rational and fully informed about prices of core and add-on products.

Our analysis yields several interesting results. First, we identify the critical role of competition in firm's add-on bundling decision. Specifically, when there is more competition from the inferior firm, the superior firm will have a stronger incentive to bundle its add-on, even when the add-on product is costly to offer. Second, while in the benchmark case, the monopolistic firm will unbundle the add-on, we show in duopoly that the superior firm will bundle its add-on, as long as the ratio of cost to quality is not sufficiently high. Third, distinct from prior literature, our results show that consumers' surplus is never higher when regulators prohibit add-on pricing.

Our findings help researchers and practitioners better understand the competing effects of cost and competition on firms' bundling strategy. One managerial insight is that if competition is weak, the superior firm may unbundle to gain revenue from the add-on product. However, if competition is very strong, the superior firm may be better off bundling its add-on with the core product to soften competition and increase profit. An important policy implication is that government and policy makers need more discretion in regulating firms' practice of add-on pricing, because prohibiting add-on pricing may change the market equilibrium and thus lessen price competition, this in turn may reduce the total consumer surplus. This result calls for the design of an appropriate policy framework that enhances firms'

profits together with consumer surplus. Finally, our closed-form solution offers guidance to firms looking to optimize their pricing strategy in a competitive environment.

The most closely related research to this study is the add-on literature. The first stream of the add-on literature studies the profit and price implications for a monopoly that offers a core and an add-on product. Fruchter et al (2010) examines when a monopolistic firm should charge a supplementary fee for add-on. They find that it is profit-equivalent for the monopoly to bundle or unbundle the add-on when both types of consumers value the add-on similarly, and it is optimal to charge the add-on when only the low type of consumers value the add-on. Adachi et al (2011) shows that the monopoly should unbundle the add-on when the range of the add-on product valuation exceeds a threshold value. Our monopoly case shows that even when the add-on valuation is small, as long as the marginal cost for the add-on is positive, then it is optimal for the monopoly to unbundle the add-on.

Prior research in add-on literature also studies the profit and price implications of add-on pricing by incorporating a segment of boundedly rational consumers. Verboven (1999) studies firms' add-on pricing strategy when there is a group of myopic consumers in the market who are unaware of the add-on information. Gabaix and Laibson (2006) examines firms' profitability when facing a segment of boundedly rational consumers who did not consider the add-on price, and they generate the profit-irrelevancy result of add-on prices with the existence of boundedly rational consumers. Our research is distinct from this stream of research in that we assume all consumers are fully rational and informed. Therefore, our bundling result doesn't rely on the existence of boundedly rational consumers.

Another stream of add-on literature examines price and profit implications of add-on pricing in duopolistic markets. Ellison (2006) finds the optimal profits for symmetric firms in unbundle case are higher than that in the bundle case when there is sufficient asymmetry in price sensitivity between the high valuation and low valuation consumers. Shulman and Geng (2013) model horizontally differentiated firms and assume discrete segments of consumers in the market. They find the superior firm is better off by unbundling add-on when add-on qualities are asymmetric. Our research models vertically differentiated firms facing a market of consumers who have continuously heterogeneous valuations for core and add-on products. We find that the superior firm will bundle when competition is strong or the magnitude of marginal cost of add-on relative to quality is relatively small.

Our study is broadly related to the stream of literature on mixed bundling (Stigler 1963, Adams and Yellen 1976, McAfee et al 1989, Reisinger 2006). Our model differs from these bundling research in that the realization of add-on is related to core product in a specific manner. That is, add-on product is purchased contingent on the purchase of core product. In other words, add-on is only valuable together with core product offering.

Benchmark monopoly case

The central focus of the paper is to study how quality differentiated firms bundle and price their core and add-on product in a duopolistic competition and implications of such add-on pricing. We first start with the monopoly case which serves as a benchmark.

A monopolistic firm offers a core product with quality q_c and an add-on product with quality q_a . The monopoly can offer core product only, or offer core and add-on as à la carte, or offer core and add-on as a bundle. Without loss of generality, we assume $q_c > q_a > 0$, and q_c is normalized to 1. The monopoly offers a core information good which is assumed to have negligible marginal cost and an add-on product which has non-negative marginal cost (c_a). All qualities and cost are assumed to be exogenous.

The market consists of a unit mass of consumers who have heterogeneous taste for quality. Consistent with prior literature (Bakos et al., 1999, Verboven 1999), we assume consumers' taste parameter $\theta \sim U[0,1]$. θ is consumer's private information, although the distribution for the entire consumer population is common knowledge.

The sequence of the game is that first, the monopoly sets the bundling strategy and the prices, then consumers decide whether and which firm to purchase from based on their surplus. If the monopoly bundles, then consumers can either buy the bundle or not buy; if the monopoly unbundles, then consumers can buy either core product only or both core and add-on or nothing. The consumer's utility

function is $U = \theta q - p$. We allow consumer's WTP for core product to be positively correlated with her WTP for the add-on. For example, consumers who appreciate higher quality of an ERP system are also likely to appreciate higher quality of after-sales support.

Each consumer can buy at most one unit of core and one unit of add-on. Note that by nature of add-on, one cannot buy add-on only without buying core first. Examples can be found across industries, i.e. software users find no value for technical support without purchasing the software first; consumers cannot consume WiFi without purchasing the hotel room first.

If the monopoly bundles and offers p_B , then a consumer buys the bundle if her individual rationality (IR)

constraint is met: $\theta_B(1+q_a) - p_B \geq 0$. The firm's profit function is $\pi_B = (p_B - c_a)(1 - \frac{p_B}{1+q_a})$. If the firm

unbundles and offers p_c for core product and p_a for add-on, then consumers buy core good if her IR constraint is met: $\theta_c - p_c \geq 0$, or buy both core and add-on if the incentive compatibility (IC) constraint is

met: $\theta_a(1+q_a) - p_c - p_a \geq \theta_a - p_c$. The firm's profit function is $\pi_N = p_c(\frac{p_a}{q_a} - p_c) + (p_c + p_a - c_a)(1 - \frac{p_a}{q_a})$. The

monopoly optimizes the profit functions to get optimal price and profit for each case. Comparing results from the two cases, we get the equilibrium for the monopoly.

LEMMA 1. *The monopoly unbundles in equilibrium ($\pi_B^* < \pi_N^*$) when $c_a > 0$. The monopoly bundles when $c_a = 0$.*

Lemma 1 shows the monopoly unbundles as long as the marginal cost is positive. The unbundling strategy serves as a price discriminate mechanism such that only high valuation customers are willing to buy the add-on. This result extends prior literature in add-on pricing (Adachi et al. 2011). We now turn to our main analysis of duopoly competition, and compare the results with the benchmark case.

Duopoly case

The market consists of two competing firms with heterogeneous qualities for their core and add-on products. The superior firm (H) offers its core product q_c^H (normalize to 1) and add-on q_a^H ($q_a^H < 1$), and the inferior firm (L) offers its core product q_c^L and add-on q_a^L ($q_a^L < q_c^L$). Typically, valuation of add-on is sufficiently smaller than core product, so we assume $q_c^L + q_a^L < 1 + q_a^H$, and the sum of the qualities of the inferior firm's core and add-on product is still less than the superior firm's core quality ($q_c^L + q_a^L < 1$)². And we assume that both firms have negligible marginal cost for their core products. The superior firm has non-negative marginal cost for its add-on product while the inferior firm has negligible marginal cost for its add-on. This abstraction is consistent with anecdotal evidence. For example, Adobe Systems Inc. offers digital document editing and sharing software, i.e. Adobe Acrobat series, and associated expert support over phone and on site³. Adobe incurs significant cost for providing labor and transportation for its expert support. So Adobe has non-negligible marginal cost for its add-on service. In contrast, Adobe's competitors such as Nitro Corp. offers lower quality versions of pdf editing software, i.e. Nitro Pro, with technical support via online community and Q&A. Since this technical support is provided online and does not include on-site support, this add-on service has negligible marginal cost.

Consumers

The market consists of one unit mass of consumers. Consumers' taste θ follows the same assumption as in the monopoly case. Distinct from add-on literature (Shulman and Geng 2013, Ellison 2006), we allow all consumers to be rational. That is, they know full information of prices and qualities of both firms.

² The equilibrium result remains the same when $q_c^L + q_a^L > 1$, as long as $q_c^L + q_a^L < 1 + q_a^H$.

³http://www.adobe.com/support/expert_support/product.html

Consumers can buy core product only or both core and add-on from either firm or buy nothing. A consumer's generic utility function is the same as in the monopoly setting.

We model a two-stage game. In stage 1, firms simultaneously choose bundling strategy and correspondingly, offer either bundle price or separate prices for its core and add-on to maximize their profits. In stage 2, consumers decide whether and which firm to purchase to maximize their utility.

Analysis and results

Each firm needs to decide whether to bundle or unbundle its core and add-on product. Hence, there are four cases that may occur: both firms bundle (BB case), the superior firm (H) unbundles and the inferior firm (L) bundles (NB case), firm H bundles and firm L unbundles (BN case), and both firms unbundle (NN case). Each firm compares the optimal profit derived from its bundling strategy, given the rival's bundling strategy.

Both firms bundle

When both firms bundle, a consumer buys firm L's bundle if his individual rationality (IR) constraint is met, i.e. $\theta^L(q_c^L + q_a^L) - p_{BB}^L \geq 0$, and buys firm H's bundle if his incentive compatibility (IC) constraint is met, i.e. $\theta^H(1 + q_a^H) - p_{BB}^H \geq \theta^H(q_c^L + q_a^L) - p_{BB}^L$

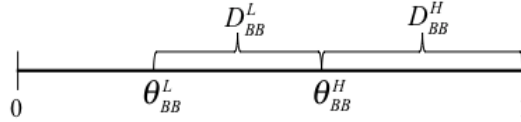


Figure 1: demand for firm L's bundle (D_{BB}^L) and for firm H's bundle (D_{BB}^H)

The indifferent consumer valuation points ($\theta_{BB}^H, \theta_{BB}^L$) can be derived by solving the above two equations. Firm L's demand is $\theta_{BB}^H - \theta_{BB}^L$ and Firm H's demand is $1 - \theta_{BB}^H$. Accordingly, firm H's profit is $\pi_{BB}^H = (p_{BB}^H - c_a^H)(1 - \theta_{BB}^H)$ and firm L's profit is $\pi_{BB}^L = p_{BB}^L(\theta_{BB}^H - \theta_{BB}^L)$. We derive the optimal prices in this subgame by taking the first order condition for the profit functions and solving them simultaneously (p_{BB}^{H*}, p_{BB}^{L*}), and then we get the optimal profit for each firm ($\pi_{BB}^{H*}, \pi_{BB}^{L*}$). The constraints for this case to be feasible is: $0 < \theta_{BB}^{L*} < \theta_{BB}^{H*} < 1$. The complete expressions for prices and profits are available upon request.

The superior firm unbundles and the inferior firm bundles

When the superior firm unbundles and the inferior firm bundles (NB case), a consumer buys firm L's bundle if $\theta_{NB}^L(q_c^L + q_a^L) - p_{NB}^L \geq 0$, and buys firm H's core product if $\theta_{NB}^{Hc} - p_{NB}^{Hc} \geq \theta_{NB}^{Hc}(q_c^L + q_a^L) - p_{NB}^L$, and buys firm H's both core and add-on product if $\theta_{NB}^{Ha}(1 + q_a^H) - p_{NB}^{Ha} \geq \theta_{NB}^{Ha} - p_{NB}^{Hc}$.

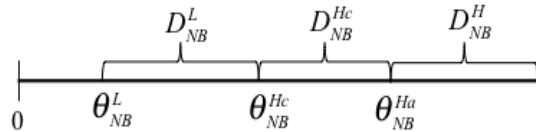


Figure 2: demand for firm L's bundle (D_{NB}^L), for firm H's core good (D_{NB}^{Hc}), and for firm H's core and add-on (D_{NB}^H)

Inferior firm's profit function is $\pi_{NB}^L = p_{NB}^L(\theta_{NB}^{Hc} - \theta_{NB}^L)$, and superior firm's profit function is $\pi_{NB}^H = p_{NB}^{Hc}(\theta_{NB}^{Ha} - \theta_{NB}^{Hc}) + (p_{NB}^{Hc} + p_{NB}^{Ha} - c_a^H)(1 - \theta_{NB}^{Ha})$. We use the same approach as §4.1 to derive the optimal price and profit for each firm. The detailed expressions are available upon request.

The analysis for the case that the superior firm bundles and the inferior firm unbundles (BN case) and for the case that both firms unbundle (NN case) follow a similar manner as §4.1 and §4.2. We omit it here for lack of space. After deriving the optimal demand and profit for these two cases, we find that when the inferior firm unbundles, all consumers who buy the inferior firm's core product also buy its add-on. The optimal demand for the inferior firm's core product is zero. Therefore, unbundling is not optimal for the inferior firm. We will focus on BB and NB cases to derive the equilibrium.

Equilibrium solution of bundling cases

The equilibrium solution of bundling cases is reported in the following lemma:

Lemma 2. *In equilibrium, both firms bundle (BB) when $c_a^H \leq \tilde{q}$. The superior firm unbundles and the inferior firm bundles (NB) when $c_a^H > \tilde{q}$.*

Lemma 2 shows duopolistic firms' bundling strategies in equilibrium. When the marginal cost of the superior firm's add-on is relatively small, both firms bundle; otherwise, the superior firm unbundles and the inferior firm bundles. The threshold (\tilde{q}) is a function of the inferior firm's bundle quality, and is increasing with the inferior firm's bundle quality.

PROPOSITION 1. Equilibrium cases. *Whereas the superior firm unbundles in the monopoly if $c_a^H > 0$, in duopoly competition, the superior firm bundles if $c_a^H \in (0, \tilde{q})$, and unbundles if $c_a^H > \tilde{q}$. The inferior firm bundles in both monopoly and duopoly.*

Proposition 1 highlights the changes in the superior firm's bundling strategy when an inferior firm competes in the market. In the monopoly, the superior firm will always unbundle as long as the marginal cost of add-on is positive. In contrast, in duopoly, the superior firm bundles when the marginal cost of add-on is positive, as long as it is not sufficiently large. The intuition is the following. When quality-based competition exists and marginal cost of add-on is not sufficiently large, firm H will bundle to make their bundle quality more differentiated with its competitor, and thus soften competition and obtain a higher profit. When marginal cost of add-on is above the threshold, it will become more costly for firm H to serve the add-on, thus firm H only serves add-on to higher valuation consumers, and serve core product only to relatively low valuation consumers. The increased pressure of add-on cost dominates competition effect, thus superior firm unbundles to avoid serving costly add-on to relatively low valuation consumers. Basically, in duopoly case superior firm will decide its bundling strategy by balancing competition effect and marginal cost effect.

Note that if the inferior firm's bundle quality is large and close to the superior firm's core quality, then $\tilde{q} > q_a^H$, this implies that the superior firm will bundle, even if marginal cost is high. This is because the strong competition will force superior firm to bundle to maximally differentiate with the rival's bundle. Even if marginal cost of add-on is high, competition effect will still outweigh the cost effect, so the superior firm bundles in equilibrium.

The above analysis helps explain the phenomena that more high quality hotels which previously charge separately for their Internet service now start to offer their WiFi service for free (Seminara 2012) to deal with the increased competition from low-end hotels which have already bundled their complementary WiFi service in room offering.

Proposition 1 contributes to the add-on literature. It is the first result to identify the difference of the superior firm's bundling strategies in duopoly versus in monopoly, and highlight the competition effect and cost effect for the superior firm's bundling decision. While Shulman and Geng (2013) find that in the case where firms have asymmetric quality for both core and add-on, the superior firm will unbundle and the inferior firm will bundle if its add-on quality is significantly lower than the superior firm's add-on quality, we find that the superior firm will either bundle or unbundle, depending on the magnitude of marginal cost of add-on relative to qualities, and the inferior firm will bundle, even when there is no significant asymmetry in add-on quality. In the case where there is symmetric add-on quality, whereas Shulman and Geng (2013) find both firms' profits are irrelevant of their bundling decisions, our results show that the inferior firm's profit is irrelevant of its bundling strategy while the superior firm's profit is depending on its bundling decision. One underlying reason for the differences of results is that the asymmetric add-on bundling strategy in Shulman and Geng (2013) is derived based on two exogenous

consumer segments, the core segment of consumers who has no value for add-on and the knowledgeable segment of consumers who has value for add-on (thus in equilibrium, knowledgeable segment always buys add-on while core segment never buys add-on). On the contrary, our results of asymmetric bundling strategy does not require exogenous segments of core and knowledgeable consumers but is based on consumers' heterogeneous valuation for qualities.

Gabaix and Laibson (2006) show that all consumers will buy both core and add-on products in equilibrium when there is no information asymmetry. In contrast, we show that with information symmetry, consumers buy either core product only or both core and add-on, based on their heterogenous WTP.

Implications of regulating add-on pricing

We examine the implications of industrial regulations and government intervention aimed to limit the ability to charge for add-on. In order to examine the impact of regulating add-on pricing on consumers, we compare consumer surplus between the scenarios in which firms are allowed to use add-on pricing and the scenario in which add-on pricing is prohibited.

PROPOSITION 2. *The prohibition of add-on pricing reduces consumer surplus when $c_a^H > \tilde{q}$; the prohibition of add-on pricing has no impact on consumer surplus when $c_a^H \leq \tilde{q}$.*

Proposition 2 highlights the negative impact of regulating add-on pricing on consumer surplus. That is, when marginal cost for superior firm's add-on is sufficiently large, consumer surplus is lower when add-on pricing is prohibited than the case when it is allowed. The intuition is as follows. If $c_a^H > \tilde{q}$, then when add-on pricing is allowed, the optimal strategy for the superior firm is to unbundle; when add-on pricing is prohibited, superior firm has to bundle the costly add-on with its core product, and it is a suboptimal strategy. As a result, superior firm's bundle price is higher than the sum of prices for core and add-on, and inferior firm's bundle price is higher than its bundle price had if add-on pricing were allowed. Therefore, consumers' WTP for each firm's core and add-on remains the same but each firm's price is higher, total demand is lower, so consumers' surplus is less than the case when add-on pricing was allowed.

Our add-on pricing implication for consumer surplus is in contrast with the result in Ellison (2006), which shows the opposite result (i.e. consumer surplus is lower when add-on pricing is allowed than that without add-on pricing). The result in Ellison (2006) is driven by the fact that both firms price discriminate when add-on pricing is allowed, i.e. both firms unbundle and each firm offers two quality versions of products. Hence, in equilibrium consumers who have low valuation buy low quality product and high valuation consumers buy high quality product. More consumer surplus has been extracted than the case where all consumers buy high quality product (when add-on pricing is prohibited). In our study, the result of consumer surplus comparison is driven by firms' asymmetric quality and cost and competition effect. If superior firm's add-on is sufficiently large, then when add-on pricing is allowed, the superior firm unbundles and the inferior firm bundles, inferior firm's bundle quality is closer to superior firm's core quality. Each firm has to lower its price to compete with each other. When add-on pricing is prohibited, superior firm is forced to bundle its add-on, and the two firms are more quality differentiated, hence, competition is softened and each firm increases price for its core and add-on. Hence, consumer surplus is lower than the case if add-on pricing is allowed.

Discussion and conclusion

This study extends prior add-on literature in the following ways. First, we explicitly examine the asymmetric firms' add-on bundling and pricing problem when consumers are continuously differentiated in their taste for core and add-on products. Second, our model accommodates the asymmetry in qualities of core and add-on products between the competing firms and examines the impact of the quality asymmetry on competition and firms' pricing strategy. Third, we explicitly study the impact of public policy (i.e. industrial regulation and government intervention to prohibit the add-on pricing practice) on consumer surplus. We find the contrasting result with prior literature and explain the intuition for the differences.

Specifically, prior literature (e.g. Shulman and Geng 2013) shows the superior firm unbundles and the inferior firm bundles if there is significant asymmetry in add-on quality between the two firms. Our result shows that the superior firm will either bundle or unbundle, depending on the intensity of competition and the magnitude of marginal cost of add-on relative to quality. Our asymmetric bundling result in equilibrium helps explain the mixed phenomenon across industries that inferior firm bundles add-on while superior firm either bundles or unbundles their add-ons. Second, while prior research suggests the low-quality firm is more likely to price discriminate than the high-quality firm in the form of rebates (Dogan et al. 2010), we show the opposite result where high-quality firms rather than low-quality firm will price discriminate for their core and add-on products under asymmetric add-on marginal costs. We identify the competition effect to firms. Distinct from the benchmark case where the monopoly unbundles, in duopoly case, the superior firm bundles as long as the ratio of marginal cost to quality is not sufficiently large. Our results draw important policy implications of regulating firms' add-on pricing. We find that the well-intentioned government intervention on prohibiting add-on pricing may actually reduce consumer surplus, this may call for a more appropriate policy framework to account for the joint effect of regulation and market competition on consumer surplus.

This study can be extended in the following ways. First, an important extension related to the policy implication of limiting add-on pricing is to examine how government regulatory policy on prohibiting add-on pricing impacts firms' profitability and social welfare. And we will compare our findings with prior add-on literature on the policy implication, and provide more insights for government regulation on add-on pricing. Secondly, while we focus on analyzing the add-on bundling strategy for competing firms and its implications with fully informed consumers, it is interesting to see how the bundling and pricing strategy will change when there is a segment of uninformed or myopic consumers in the market. In addition, in current model we have assumed consumers' valuation on add-on product is positively correlated with core product. It is interesting to examine the case where consumers have independent valuations on core and add-on products, can compare with the current case to see how firms' competition and pricing strategy will change.

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Appendix: Proofs for Propositions and Lemmas

Proof for Lemma 1:

$\partial \pi_B / \partial p_B = 0 \rightarrow p_B^* = \frac{1}{2}(1 + q_a + c_a)$, $\pi_B^* = \frac{(1 + q_a - c_a)^2}{4(1 + q_a)}$. Similarly, take F.O.C with π_N , we get $p_c^* = \frac{1}{2}$, $p_a^* = \frac{1}{2}(c_a + q_a)$, $\pi_N^* = \frac{c_a^2 - 2c_a q_a + q_a(1 + q_a)}{4q_a}$. So $\pi_N^* - \pi_B^* = \frac{c_a^2}{4q_a(1 + q_a)} > 0$. When $c_a = 0$, $\pi_N^* = \pi_B^*$. •

Proof for Lemma 2:

Following the approach described in §5.1 and §5.2, we get $\pi_{NB}^{H^*}$ and $\pi_{BB}^{H^*}$, then

$$\pi_{NB}^{H^*} - \pi_{BB}^{H^*} = \frac{(q_a^H - c_a^H)^2}{4q_a^H} + \frac{4(1 - q_c^L - q_a^L)}{(4 - q_c^L - q_a^L)^2} - \frac{(2(1 + q_a^H)(1 + q_a^H - q_c^L - q_a^L) - c_a^H(2 + 2q_a^H - q_c^L - q_a^L))^2}{(1 + q_a^H - q_c^L - q_a^L)(4 + 4q_a^H - q_c^L - q_a^L)^2}$$

Solving it for c_a^H , we get two roots, one positive and one negative, the positive root we denote as \tilde{q} (see below), and the intercept is negative. Hence, if $c_a^H \in (0, \tilde{q})$, $\pi_{NB}^{H^*} < \pi_{BB}^{H^*}$; if $c_a^H > \tilde{q}$, $\pi_{NB}^{H^*} > \pi_{BB}^{H^*}$. •

Proof for Proposition 1:

Compare the results in Lemma 1 and 2, we get the difference in bundling strategy in the monopoly and in duopoly. •

Proof for Proposition 2:

We denote consumer surplus as CS^* when add-on pricing is allowed and consumer surplus as \overline{CS}^* when add-on pricing is prohibited. If $c_a^H > \tilde{q}$, the optimal strategy for the superior firm is to unbundle. When add-on pricing is allowed, we got

$$\overline{CS}^* = \int_{\theta_{NB}^{Hc^*}}^{\theta_{NB}^{Ha^*}} (\theta(q_c^L + q_a^L) - p_{NB}^{L^*}) + \int_{\theta_{NB}^{Hc^*}}^{\theta_{NB}^{Ha^*}} (\theta - p_{NB}^{Hc^*}) + \int_{\theta_{NB}^{Hc^*}}^1 (\theta(1 + q_a^H) - p_{NB}^{Hc^*} - p_{NB}^{Ha^*}), \text{ plug in } \theta_{NB}^{Hc^*}, \theta_{NB}^{Ha^*}, \text{ and } \theta_{NB}^{L^*},$$

we get \overline{CS}^* . When add-on pricing is allowed, we get

$$CS^* = \int_{\theta_{BB}^{L^*}}^{\theta_{BB}^{H^*}} (\theta(q_c^L + q_a^L) - p_{BB}^{L^*}) + \int_{\theta_{BB}^{H^*}}^1 (\theta(1 + q_a^H) - p_{BB}^{H^*}) = \frac{1}{2}(q_c^L + q_a^L)(\theta_{BB}^{H^*} + \theta_{BB}^{L^*})(\theta_{BB}^{H^*} - \theta_{BB}^{L^*})$$

, plug in

$$-p_{BB}^{L^*}(\theta_{BB}^{H^*} - \theta_{BB}^{L^*}) + \frac{1}{2}(1 + q_a^H)(1 + \theta_{BB}^{H^*})(1 - \theta_{BB}^{H^*}) - p_{BB}^{H^*}(1 - \theta_{BB}^{H^*})$$

$\theta_{BB}^{H^*}$ and $\theta_{BB}^{L^*}$, we get CS^* . Then compare the two consumer surplus results, we get

$$\overline{CS}^* - CS^* = -\frac{(c_a^H - q_a^H)^2}{8q_a^H} - \frac{4(4 + 5q_c^L + 5q_a^L)}{8(-4 + q_c^L + q_a^L)^2} +$$

$$4(1 + q_a^H)((c_a^H)^2(4 + 4q_a^H - 3q_c^L - 3q_a^L) - 2c_a^H(1 + q_a^H - q_c^L - q_a^L)(4 + 4q_a^H + q_c^L + q_a^L) + (1 + q_a^H)(1 + q_a^H - q_c^L - q_a^L)(4 + 4q_a^H + 5q_c^L + 5q_a^L)) / 8(1 + q_a^H - q_c^L - q_a^L)(-4 - 4q_a^H + q_c^L + q_a^L)^2$$

for c_a^H , the intercept can be shown is negative.