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# BUNDLING WITH QUALITY CHOICE*

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## *Abstract*

Antitrust authorities consider commodity bundling as an extension of monopoly power to other markets which harms consumers. This paper analyzes quality competition and its effect on consumer surplus for the case of commodity bundling by a multi-product firm in a vertically differentiated industry. When the firm bundles a high quality good, we show that bundling negatively affects the quality of a competing good, consumer surplus, and welfare. When the firm bundles a low quality good instead, bundling raises the quality of a competing good, enhances consumer surplus, and may increase the welfare.

*Keywords*: bundling, vertical product differentiation, optimal quality, consumer surplus,

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## I. *Introduction*

Commodity bundling as a business practice is commonly observed in modern market economies. A great deal of research has been done investigating whether selling different products in a bundle is anti-competitive and whether it generates a perverse effect on consumer surplus.[1] This paper analyzes quality competition and its effect on consumer surplus for the case of commodity bundling by a multi-product firm in a vertically differentiated industry. We show that the firm bundling vertically with a high quality good negatively affect the quality of a competing good, consumer surplus, and welfare. When the firm bundles a low quality good instead, bundling raises the quality of a competing good, enhances consumer surplus, and may increase the welfare.

Kramer (2009) addresses several examples on vertically bundling in the several industries such as TV and video broadcasting, regional cable network industry, and telecommunication services. We use the telecommunications industry in Taiwan to explain such vertical bundling. Chunghwa Telecom is Taiwan's leading telecom service provider,[2] offering ADSL Internet service with a local phone connection as a package to customers. It is clear that Chunghwa Telecom exercises its monopoly power in local phone service into its ADSL Internet service.[3] In September 2011 the National Communications Commission (NCC), the authority responsible for regulating telecommunications and broadcasting services in Taiwan, decided that Chunghwa Telecom unlawfully bundled sales of ADSL along with its dominant local phone service. The NCC claimed that Chunghwa Telecom's competitive action harmed consumers and called for an end to the bundled sale.

This paper relates two important strands of the existing literature: vertical quality differentiation and bundling. The product quality literatures focus on the quality selection of a monopoly, for example, Sheshinski (1976) and Mussa and Rosen (1978). Gabszewicz and Thisse (1979), Shaked and Sutton (1982), Motta (1993), and Aoki and Prusa (1996) extend this model to an oligopolistic set-up, continuing to argue the issue of quality choices and showing that firms prefer to produce differentiated products. Following the line of an oligopolistic market structure, this paper studies how bundling affects the differentiated quality choice by a duopoly.

For the bundling literature, Stigler (1968) and Adams and Yellen (1976) examine the effects of bundling by a multi-product monopolist when consumers' valuations are negatively

[1] As Kobayashi (2005) pointed out, in order to judge whether or not bundling is violating the antitrust regulation, antitrust evaluations of bundling practices must simultaneously take into account both strategic and efficiency reasons.

[2] Chunghwa Telecom was formerly 100% owned by the government and monopolized the telecommunications industry until 1996. After privatization, the share of company stock owned by the government fell to less than 50% in August 2005. The telecommunications industry in Taiwan is no longer monopolized by Chunghwa Telecom and has few firms in the market, but the company is still the sole local phone service provider.

[3] ADSL Internet services in Taiwan are offered by Chunghwa Telecom, New Century InfoComm Tech, APOL, INFOSERVE, and TTN. Chunghwa Telecom monopolizes local phone service, but competes with other firms in internet service. Each ADSL company provides different service quality to consumers.

correlated. The authors show that bundling allows a monopolist to earn higher profits since it works to reduce product heterogeneity in terms of consumers' valuations. Bundling thus serves as a tool for a multi-product firm to extract more of surplus from consumers. Schmalensee (1982) considers the incentive for a single product monopolist to bundle a competitively supplied good and shows that if there is zero correlation between consumers' valuations, then Stigler's result does not hold. Even if two goods have independent valuations, McAfee et al. (1989) find that a monopolist is still able to make more profits by selling both goods as a bundle rather than independently. Whinston (1990) examines a bundling strategy as an entry-deterrence device from the perspective of market leverage. He presents that bundling as a mechanism enables a firm with monopoly power to leverage from its own market in order to foreclose its rival from accessing a second market. Carlton and Waldman (2002) and Nalebuff (2004) further investigate this use of commodity bundling for entry deterrence.

Viewed from the strategic perspective in Whinston (1990) and Seidmann (1991) indicate that the consumer-valuations models of bundling do not allow a rival firm to respond to the bundling. These authors emphasize that imperfect competition creates a strategic incentive to bundle that is absent under the traditional polar cases of a competitive and monopolized tied market. Carbajo et al. (1990) and Martin (1999) show that bundling allows a monopoly to extent its market power to other markets, causing the profits of rival firms in those markets to decline under the Cournot fashion. They conclude that bundling with quantity competition not only reduces the competitor's profit but also negatively affects the consumer's and social welfare. However, via the perspective of bundling in the presence of vertical differentiation, this paper finds that bundling may be welfare-improving when the bundling firm is a low-quality firm. This result differs from those in Carbajo et al. (1990) and Martin (1999). This is because this paper takes into account endogenous quality such that bundling by a low-quality firm improves the endogenous quality levels and hence may be welfare-improving.

Choi (2004) further builds a deterministic R&D model to analyze how bundling agreements affect the incentives of firms to invest in R&D. He finds that a bundling strategy increases the bundling firm's R&D level, but decreases the opponent's R&D level, making the industry's R&D level remain unchanged and bringing down social welfare.

Although most existing economic literature supports that bundling with extending the monopoly power reduces consumer surplus behavior, there are some exceptions. Choi and Stefanadis (2001) establish a three-firm, two product model. The market structures of these two products are both duopolies. When the potential entrant firm engages in R&D competition with the incumbent firm, an increase in the incumbent firm's R&D will reduce its competitor's R&D, making bundling being likely to increase both consumer surplus and social welfare. Chung et al. (2013) build up a two-firm, two-product model in which good 1 (monopoly product) is produced only by the bundling firm and good 2 (competing good) is produced by both firms. There are different degrees of substitution between the intrabrand as well as interbrand products. Under Cournot competition bundling always reduces the opponent's profit and social welfare, but may increase consumer surplus.

The common feature of the above papers is that they examine commodity bundling under the assumption of horizontal production differentiation. In this paper we investigate how strategic bundling affects the quality competition and welfare in the context of a vertically differentiated market.

Few studies recently focus on the economic effects of strategic bundling in a model of vertical product differentiation. Using the model of vertically differentiated quality with sales discount and exogenous quality, Diallo (2006) finds that bundling is the dominant strategy for both firms and reduces the consumer surplus while increasing the social surplus. Kovac (2007) builds up a three-firm, four-product model in which their quality is exogenous. He finds that bundling firms can use mixed sales to defend their monopoly status while reducing the social surplus. Gilbert and Riordan (2007) emphasize the competition between two-system products and firms engaging in R&D to improve quality. The vertically integrated firm is a monopoly of the essential component and its competitor has to purchase this essential component from the integrated monopoly in order to sell a system product. They assume that consumers have the same preference over quality and conclude that technology bundling can force the competitor to exit the market and hence reduce the consumer and social surpluses. Unlike Gilbert and Riordan (2007), Kramer (2009) assumes that consumers have different preferences over same the quality and the market is uncovered under both monopoly and duopoly. The two firms move sequentially. If the bundling firm provides a sum of quality levels higher than its competitor's, then bundling increases the bundling firm's quality while reducing the competitor's quality. On the contrary, if the sum of quality of the bundled goods is smaller than the competitor's, then there is no equilibrium quality level since the bundling firm always has an incentive to increase its own quality. However, Kramer (2009) does not examine the effect of bundling on consumer surplus. Brito and Vasconcelos (2011) construct a two-product, four-firm model and find that when all firms offer a bundling discount, the consumer and social surpluses both decrease.

In order to analyze the effects of bundling on product quality, profits, consumer surplus, and social surplus, we adopt a model of vertically differentiated products in which the two firms engage in quality competition. Being different from Gilbert and Riordan (2007) in which there is technology bundling, this paper considers the commonly seen product bundling in which the monopoly power in one market can be extended to another through the bundling of products. Generally speaking, consumer preferences toward product provided by a firm are differentiated. In order to fit reality, consumer preferences are assumed to be heterogeneous herein. Moreover, we assume that the two firms simultaneously choose their quality, which is different from Kramer (2009) where the two firms choose their quality sequentially. This paper finds that when the bundling firm is of high quality, bundling will always lower both firms' quality, and this result differs from that in Kramer (2009). Moreover, in this paper bundling by a high-quality firm always reduces the consumer and social surpluses. On the contrary, when bundling firm is of low-quality, bundling will increase firms' quality as well as the consumer surplus, and maybe the social surplus. This result differs from Gilbert and Riordan (2007), because they assume homogenous consumer preferences. In Gilbert and Riordan (2007), via technology bundling the vertically integrated firm can reduce its opponent's quality level, increase its own R&D, and finally make the opponent exit the market. No matter whether there is a bundled high- or low-quality product, bundling will not change the degree of quality differentiation and always reduces the competitor's profit. The analysis in this paper is relatively close to Choi (2004).

The remainder of the paper is organized as follows. Section II presents our vertical quality differentiation model in the presence of bundling and not bundling cases. Section III analyzes the market equilibrium of the two cases in which the multi-product firm produces a high-quality product and the rival firm offers a low-quality product in the competitive market.

This section examines the optimal quality level, profits, consumer surplus, and welfare. Section IV investigates the other regime when the multi-product firm offers a low-quality good and the rival firm offers a high-quality good in the competitive market. Section V concludes.

## II. *The Model*

We assume that good 1 is produced by firm A as a monopolist; good 2, which is a group of vertically differentiated products, is produced by firms A and B, and goods 1 and 2 are independent. Firms A and B produce only one quality for good 2, i.e., either high or low quality. In the analysis we consider a simple three-stage game. At stage one, firm A decides whether to bundle or not to bundle goods 1 and 2 in a single package.[4] At stage two, firms A and B determine their quality investment simultaneously. We discuss two cases. In case 1, the multi-product firm A (hereafter firm A) is a high quality good producer, and firm B is a low quality good producer for the market in good 2. The situation is opposite in case 2. At stage three, the firms engage in Bertrand competition. We use backward induction to solve for the sub-game perfect Nash equilibrium.

Suppose there is a continuum of consumers who are uniformly distributed on the unit interval $[b-1, b]$ with $b \in (5/4, 2]$.[5] A consumer, identified by $\theta$, will get surplus of $u_1(q_1, p_1)=\theta q_1 - p_1$ if he buys a unit of good 1 solely produced by firm A, where $q_1$ and $p_1$ indicate the quality and price of good 1, respectively. The taste parameter $\theta$ represents consumers' marginal willingness to pay for quality. The marginal consumer who is indifferent between buying and not buying good 1 is defined as $\theta_1 = p_1/q_1$, and the market demand for good 1 is $x_1 = b - \theta_1$.

The reservation values of consumers for good 2 are sufficiently large so that the market for good 2 is fully covered.[6] In other words, each consumer is assumed to buy one unit of good 2. A consumer's net surplus of buying good 2 from firm $i$ is given by $u_{i2}(\theta)=\theta q_{i2} - p_{i2}$, $i=A, B$, where $q_{i2}$ and $p_{i2}$ are the respective quality and price of good 2 produced by firm $i$. The marginal consumer, $\theta_2$, who is indifferent between buying good 2 from firms A and B is $\theta_2 = (p_{A2} - p_{B2})/(q_{A2} - q_{B2})$. Since only two qualities (high and low) are produced for good 2 and each firm produces one quality, assuming that firm $i$ produces high quality and the other firm $k$ produces low quality, then the market demand for the two varieties of good 2 are $x_{i2}^H = b - \theta_2$ and $x_{k2}^L = 1 - x_{i2}^H$, $i, k = A, B$, $\forall i \neq k$.

We next describe the market demand when the bundling strategy adopted by firm A is to sell both goods 1 and 2 in a package. We assume consumers' preference and the marginal cost of firm A do not change during the bundling process. We denote $\tilde{x}_i^H$, $\tilde{x}_k^L$, and $\tilde{q}_{i2}$, $\tilde{q}_{k2}$ as the respective output and quality of good 2 under high quality and low quality in the case of bundling, $i, k = A, B$, $\forall i \neq k$, and $\tilde{p}$ and $\tilde{p}_{B2}$ are respectively the price of the bundled package and the price of good 2 supplied by firm B. In the bundling case, a consumer will buy either a

[4] Most existing literature on bundling arranges the decision to bundle in the first stage of the game, for example, Carbajo et al. (1990), Choi and Stefanadis (2001), Choi (2004), Diallo (2006), and Chung et al. (2013).

[5] This condition ensures the existence of the duopoly equilibrium as indicated by Cremer and Thisse (1994) and Ecchia and Lambertini (1997). Kovac (2007) and Kramer (2009) also adopt this assumption.

[6] The covering market assumption for market 2 follows those in Choi (2004) and Lee (2002).

bundled package supplied by firm A or good 2 supplied by firm B. A consumer will achieve the surplus of $\tilde{u}_A(\theta)=\theta(q_1+\tilde{q}_{A2})-\tilde{p}$ if he buys the bundled good, whereas the surplus of buying $B_2$ is $\tilde{u}_B(\theta)=\theta\tilde{q}_{B2}-\tilde{p}_{B2}$. The marginal consumer with bundling is defined as $\tilde{\theta}=(\tilde{p}-\tilde{p}_{B2})/(q_1+\tilde{q}_{A2}-\tilde{q}_{B2})$. The demand for the two varieties (high quality and low quality) is respectively $\tilde{x}_i^H=b-\tilde{\theta}$ and $\tilde{x}_k^L=1-\tilde{x}_i^H$, $i, k=A, B, \forall i\neq k$.

For analysis simplicity, we assume that there is no production cost and the quality of good 1 is exogenously given with and without bundling.[7] The costs of quality improvement for firms A and B in producing good 2 are assumed to be $C_i(q_{i2})=q_{i2}^2/2$, $i=A, B$.[8] This cost function is convex in quality, which implies that high quality is more expensive, i.e., $\partial C_i/\partial q_{i2}>0$ and $\partial C_i/\partial q_{i2}^2>0$. We next analyze the cases in which firm A is a high quality producer and firm B is a low quality producer in good 2 in the presence of bundling and not bundling regimes, respectively.

## III. *Firm A as a High-quality Producer*

In this section we assume that firm A is a high quality producer and firm B is a low quality producer. We consider the no bundling and bundling regimes adopted by firm A. We analyze the no bundling regime first.

### 1. Equilibrium without Bundling

Let us denote $\pi_i^j$ as the profit of firm $i$ ($i=A$ and $B$) producing with $j$-type ($j=H$ and $L$) quality. Firm A sells goods 1 and 2 individually, and both firms choose a price for each good to maximize their profit function:

$$\underset{\{p_1,\, p_{A2}\}}{Max}\ \pi_A^H=p_1x_1+\left(p_{A2}-\frac{q_{A2}^2}{2}\right)x_{A2}^H,\ \underset{\{p_{B2}\}}{Max}\ \pi_B^L=\left(p_{B2}-\frac{q_{B2}^2}{2}\right)x_{B2}^L. \tag{1}$$

The first-order conditions are respectively:

$$\frac{d\pi_A^H}{dp_1}=\underbrace{x_1}_{\text{direct effect }(+)}+\underbrace{p_1\frac{\partial x_1}{\partial p_1}}_{\text{indirect effect }(-)}=\frac{bq_1-2p_1}{q_1}=0, \tag{2.1}$$

$$\frac{d\pi_A^H}{dp_{A2}}=x_{A2}^H+\left(p_{A2}-\frac{q_{A2}^2}{2}\right)\frac{\partial x_{A2}^H}{\partial p_{A2}}=\frac{2(p_{B2}-2p_{A2})+2b(q_{A2}-q_{B2})+q_{A2}^2}{2(q_{A2}-q_{B2})}=0, \tag{2.2}$$

$$\frac{d\pi_B^L}{dp_{B2}}=x_{B2}^L+\left(p_{B2}-\frac{q_{B2}^2}{2}\right)\frac{\partial x_{B2}^L}{\partial p_{B2}}=\frac{2(p_{A2}-2p_{B2})-2(q_{A2}-q_{B2})(1-b)+q_{B2}^2}{2(q_{A2}-q_{B2})}=0. \tag{2.3}$$

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[7] Treating $q_1$ as an exogenous variable here makes the mathematics easier without losing generality (see Subsection III.2) such that we do not need to resort to numerical simulation. Moreover, this paper studies how bundling affects the equilibrium quality, consumer surplus, and social welfare when the qualities levels of the competing goods are endogenously chosen. In order to highlight the equilibrium qualities for competing goods with and without bundling, the monopoly good's quality is simplified to be exogenously given.

[8] This specific cost function is taken from Aoki and Prusa (1996).

There are direct and indirect effects in the first-order condition of Equation (2.1). The direct effect is the effect of increasing the price to increase firm A's profit, which is a positive effect; the change in magnitude is exactly the output. The indirect effect is that an increase in price reduces the demand quantity and hence decreases the profit, which is a negative effect. The second-order and stability conditions for these two firms in the price competition stage are: $d^2\pi_A^H/dp_1^2=-2/q_1<0$, $d^2\pi_A^H/dp_{A2}^2=d^2\pi_B^L/dp_{B2}^2=-2/(q_{A2}-q_{B2})<0$ and $D_1=-6/q_1(q_{A2}-q_{B2})^2<0$.

Solving Equations (2-1) to (2-3) yields the equilibrium prices $p_1=bq_1/2$, $p_{A2}^H=[2(1+b)(q_{A2}-q_{B2})+2q_{A2}^2+q_{B2}^2]/6$, and $p_{B2}^L=[2(2-b)(q_{A2}-q_{B2})+q_{A2}^2+2q_{B2}^2]/6$. Substituting the equilibrium prices into the market demand for high and low qualities, we obtain the equilibrium quantities: $x_1=b/2$, $x_{A2}^H=2[2(1+b)-q_{A2}-q_{B2}]/6$, and $x_{B2}^L=[2(2-b)+q_{A2}+q_{B2}]/6$.[9] From the equilibrium price and quantity of good 1, we know that the monopolist's surplus is $\pi_1=b^2q_1/4$.

Totally differentiating Equation (2), we obtain the following comparative statics under a duopoly:

$$\frac{dp_1}{dq_{i2}^H}=\frac{dp_1}{dq_{i2}^L}=0, \tag{3.1}$$

$$\frac{dp_{A2}^H}{dq_{A2}}=(1+b+2q_{A2})/3>0\ ;\ \frac{dp_{B2}^L}{dq_{A2}}=(2-b+q_{A2})/3>0, \tag{3.2}$$

$$\frac{dp_{A2}^H}{dq_{B2}}=(-1-b+q_{B2})/3<0\ ;^{10}\ \frac{dp_{B2}^L}{dq_{B2}}=(b-2+2q_{B2})/3\gtrless 0,\ if q_{B2}\gtrless(2-b)/2. \tag{3.3}$$

Because the model assumes that goods 1 and 2 are independent, Equation (3.1) implies that raising the quality of good 2 will not affect monopoly pricing. We further use the direct and indirect effects in Equation (2) to explain Equation (3). Equation (3.2) shows that an increase in quality increases both firms' prices of good 2. The economic intuitions behind it are as follows. Given the price of a low-quality competitor, an increase in high quality shifts the marginal consumer to the left, causing an increase (decrease) in the demand for the high (low) quality good. The further increases (decreases) the direct effect of the high (low) quality firm, hence inducing the high (low) quality firm to raise (reduce) its price. On the other hand, such a rise in the high quality expands the difference in good quality, reduces the intensity of competition between the two firms, lowers the indirect effects, and induces both firms to increase their prices.

The above analysis shows that an increase in the high quality shifts firm A's best response curve to the right. Since the indirect effect on the low quality firm is higher than the direct effect, an increase in the high quality shifts firm B's response curve to the left. Consequently, an increase in the high quality raises both firms' prices. Similarly, the analysis process can be applied to Equation (3.3).

Substituting the optimal pricing of firm A without bundling into Equation (1), we obtain $\pi_A^H=\pi_A^H(q_{A2}, q_{B2})$ and $\pi_B^L=\pi_B^L(q_{A2}, q_{B2})$. In stage two the two firms engage in quality

[9] In order to have a positive output, we impose the condition for the parameter $b$ as $(q_{A2}+q_{B2}-2)/2<b<(q_{A2}+q_{B2}+4)/2$.

[10] The derivative $dp_{A2}^H/dq_{B2}$ is negatively related to $b$. Substituting the condition for a positive quantity in Footnote 9 and the lower bound of $b$ as $(q_{A2}+q_{B2}-2)/2$ into the above derivative, we obtain that $dp_{A2}^H/dq_{B2}=-(q_{A2}-q_{B2})/6<0$.

competition and simultaneously choose their own quality. The first-order conditions for profit maximization in the stage of quality competition are:

$$\frac{d\pi_A^H}{dq_{A2}}=\underbrace{\left(\frac{\partial p_{A2}}{\partial q_{A2}}-q_{A2}\right)x_{A2}^H}_{\text{unit profit effect }(+)}+\underbrace{\left(p_{A2}-\frac{q_{A2}^2}{2}\right)\frac{\partial x_{A2}^H}{\partial q_{A2}}}_{\text{output effect }(-)}=\frac{[2(1+b)-q_{A2}-q_{B2}][2(1+b)-3q_{A2}+q_{B2}]}{36}=0, \tag{4.1}$$

$$\frac{d\pi_B^L}{dq_{B2}}=\underbrace{\left(\frac{\partial p_{B2}}{\partial q_{B2}}-q_{B2}\right)x_{B2}^L}_{(-)}+\underbrace{\left(p_{B2}-\frac{q_{B2}^2}{2}\right)\frac{\partial x_{B2}^L}{\partial q_{B2}}}_{(+)}=\frac{-[2(b-2)-q_{A2}-q_{B2}][2(b-2)+q_{A2}-3q_{B2}]}{36}=0. \tag{4.2}$$

Assume that the second-order and stability conditions hold. Simultaneously solving the first-order conditions in Equations (4.1) and (4.2), we obtain the equilibrium qualities as $q_{A2}^{H*}=b+1/4$ and $q_{B2}^{L*}=b-5/4$. Therefore, at an interior solution of quality levels, the best response functions of these two firms are respectively: $q_{A2}=f_A^H(q_{B2})=[2(1+b)+q_{B2}]/3$ and $q_{B2}=f_B^L(q_{A2})=[2(b-2)+q_{A2}]/3$. In order to assure that in equilibrium the low quality level is positive, the condition $b>5/4$ is needed, under which the second-order and stability conditions all hold.[11] Denote firm $i$'s unit profit without bundling by $\gamma_i$. Substituting the optimal quality levels into the price and quantity response functions in the price competition stage, we obtain that the unit profit functions of these two firms are both $\gamma_i^*=[p_{i2}-(q_{i2})^2/2]=3/4$, $i=A, B$ and good 2's equilibrium quantities are $x_{A2}^{H*}=x_{B2}^{L*}=1/2$.[12] Figure 1 can be used to depict the equilibrium in the quality competition stage when firm A produces the high quality good.

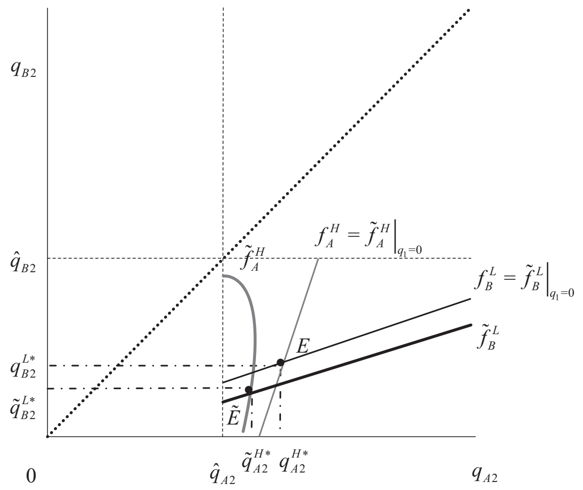
Without bundling, the best response functions in the quality competition stage are $R_A^H$ and $R_B^L$, respectively. The first-order conditions show that the best response curves of these two firms in the quality competition stage are both upward-sloping - that is, their quality strategies are strategic complements. The equilibrium in the quality competition stage is point E in Figure 1. In Figure 1, $\hat{q}_{B2}$ ($\hat{q}_{A2}$) is firm B's (A's) quality level when firm A (B) has the same profits of producing a high or low quality good.[13] The next subsection discusses the equilibrium with bundling and compares it, shown as $\tilde{E}$, to point E.

[11] Substituting the optimal quality levels into second-order and stability conditions, we obtain the second-order conditions as $d^2\pi_A^H/dq_{A2}^2=d^2\pi_B^L/dq_{B2}^2=-1/4<0$ and the stability conditions as $(d^2\pi_A^H/dq_{A2}^2)(d^2\pi_B^L/dq_{B2}^2)-(d^2\pi_A^H/dq_{A2}dq_{B2})(d^2\pi_B^L/dq_{B2}dq_{A2})=1/18>0$.

[12] Substituting firm A's optimal quality without bundling into the price competition stage, we know that optimal prices under endogenous quality choice are respectively: $p_1=bq_1/2$, $p_{A2}^{H*}=[8b(1+2b)+25]/32$, and $p_{B2}^{L*}=[8b(2b-5)+49]/32$. Thus, we obtain the equilibrium profits as $\pi_A^{H*}=(2b^2q_1+3)/8$ and $\pi_B^{L*}=3/8$.

[13] This paper uses $\pi_A^H(q_{A2}^H(\hat{q}_{B2}), \hat{q}_{B2})=\pi_A^L(q_{A2}^L(\hat{q}_{B2}), \hat{q}_{B2})$ and $\pi_B^H(\hat{q}_{A2}, q_{B2}^H(\hat{q}_{A2}))=\pi_B^L(\hat{q}_{A2}, q_{B2}^L(\hat{q}_{A2}))$ to find $\hat{q}_{A2}$ and $\hat{q}_{B2}$. Please refer to Aoki and Prusa (1996) for details.

Fig. 1. Optimal Quality Levels With and Without Bundling When Multi-product Firm A Is a High-quality Producer




## 2. Equilibrium with Bundling

To guarantee that firm B still has a positive output after firm A extends its monopoly power to market 2 by bundling, the quality of good 1 must be less than an upper bound, i.e., $q_1 < 3(5-4b)/8(b-2)$. In order to distinguish the equilibrium outcomes with and without bundling, a tilde (~) is used to label the variables with bundling. The demand functions with bundling for these two firms are $\tilde{x}_A^H$ and $\tilde{x}_B^L$, respectively. These two firms' profit functions are:

$$\underset{\{\tilde{p}\}}{Max}\ \tilde{\pi}_A^H = \left(\tilde{p} - \frac{\tilde{q}_{A2}^2}{2}\right)\tilde{x}_A^H,\ \underset{\{\tilde{p}_{B2}\}}{Max}\ \tilde{\pi}_B^L = \left(\tilde{p}_{B2} - \frac{\tilde{q}_{B2}^2}{2}\right)\tilde{x}_B^L. \tag{5}$$

The first-order conditions of profit maximization in the price competition stage with bundling are:

$$\frac{d\tilde{\pi}_A^H}{d\tilde{p}} = \tilde{x}_A^H + \left(\tilde{p} - \frac{\tilde{q}_{A2}^2}{2}\right)\frac{\partial \tilde{x}_A^H}{\partial \tilde{p}} = \frac{2b(\tilde{q}_{A2} - \tilde{q}_{B2} + q_1) + \tilde{q}_{A2}^2 - 4\tilde{p} + 2\tilde{p}_{B2}}{2(\tilde{q}_{A2} - \tilde{q}_{B2} + q_1)}, \tag{6.1}$$

$$\frac{d\tilde{\pi}_B^L}{d\tilde{p}_{B2}} = \tilde{x}_B^L + \left(\tilde{p}_{B2} - \frac{\tilde{q}_{B2}^2}{2}\right)\frac{\partial \tilde{x}_B^L}{\partial \tilde{p}_{B2}} = \frac{2(1-b)(\tilde{q}_{A2} - \tilde{q}_{B2} + q_1) + \tilde{q}_{B2}^2 + 2\tilde{p} - 4\tilde{p}_{B2}}{2(\tilde{q}_{A2} - \tilde{q}_{B2} + q_1)}. \tag{6.2}$$

Totally differentiating Equation (6), we find that when quality is exogenous, the effects of quality on pricing are the same with and without bundling. In order to compare the changes in firm A's price of good 2 with and without bundling, we re-write the best response functions in Equations (2.2) and (6.1) to be: $p_{A2} = \phi(p_{B2}) = [2b(q_{A2} - q_{B2}) + q_{A2}^2 + 2p_{B2}]/4$ and $\tilde{p} = \tilde{\phi}(\tilde{p}_{B2}) = [2b(\tilde{q}_{A2} - \tilde{q}_{B2} + q_1) + \tilde{q}_{A2}^2 + 2\tilde{p}_{B2}]/4$. Assume that the fictitious price of firm A's good 2 with bundling is $\tilde{p}_{A2}$. Given any quality level with and without bundling, the relation between firm A's prices of good 2 with and without bundling is:

$$\tilde{p}_{A2}=\tilde{\phi}(\tilde{p}_{B2})-bq_1/2=\phi(p_{B2}). \tag{7}$$

Equation (7) tells that when the quality level of good 1 is zero, firm A's monopoly price of good 1 is zero, i.e., if $q_1=0$, then $p_1=bq_1/2=0$; moreover, the first-order conditions with and without bundling are the same.[14] The economic meaning of Equation (7) can be interpreted by using the utility function with bundling.[15] Bundling goods 1 and 2 by firm A will promote the quality level from $q_{A2}$ to $q_{A2}+q_1$, hence increasing the utility of a consumer purchasing the bundled goods by $\theta q_1$ which can be called the 'intrinsic value'. This intrinsic value will affect the market demand functions and hence change the best response function of firm A in good A2. Therefore, if $q_1$ is zero in Equation (7), then the best response functions with and without bundling are the same. To simplify the analysis without loss of generality, in the following analysis the equilibrium without bundling can be obtained by simply assuming that the quality of good 1 is zero.

From further computation of Equation (6), we know that the second-order and stability conditions of profit maximization are all satisfied. The equilibrium prices and quantities with firm A's bundling are respectively: $\tilde{p}^H=[2(1+b)(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)+2\tilde{q}_{A2}^2+\tilde{q}_{B2}^2]/6$, $\tilde{p}_{B2}^L=[2(2-b)(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)+\tilde{q}_{A2}^2+2\tilde{q}_{B2}^2]/6$, $\tilde{x}_A^H=[2(1+b)(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)-(\tilde{q}_{A2}^2-\tilde{q}_{B2}^2)]/6(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)$, and $\tilde{x}_B^L=[2(2-b)(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)+\tilde{q}_{A2}^2-\tilde{q}_{B2}^2]/6(\tilde{q}_{A2}-\tilde{q}_{B2}+q_1)$.

Substituting the optimal pricing in stage 3 into Equation (5), we similarly obtain the profit functions as $\tilde{\pi}_A^H=\tilde{\pi}_A^H(\tilde{q}_{A2},\tilde{q}_{B2})$ and $\tilde{\pi}_B^L=\tilde{\pi}_B^L(\tilde{q}_{A2},\tilde{q}_{B2})$. The firms' first-order profit maximization conditions in the quality competition stage become:

$$\frac{d\tilde{\pi}_A^H}{d\tilde{q}_{A2}}=\underbrace{\left(\frac{\partial\tilde{p}}{\partial\tilde{q}_{A2}}-\tilde{q}_{A2}\right)\tilde{x}_A^H}_{(+)}+\underbrace{(\tilde{p}-\tilde{q}_{A2}^2/2)\frac{\partial\tilde{x}_A^H}{\partial\tilde{q}_{A2}}}_{(-)}=0, \tag{8.1}$$

$$\frac{d\tilde{\pi}_B^L}{d\tilde{q}_{B2}}=\underbrace{\left(\frac{\partial\tilde{p}_{B2}}{\partial\tilde{q}_{B2}}-\tilde{q}_{B2}\right)\tilde{x}_B^L}_{(-)}+\underbrace{(\tilde{p}_{B2}-\tilde{q}_{B2}^2/2)\frac{\partial\tilde{x}_B^L}{\partial\tilde{q}_{B2}}}_{(+)}=0. \tag{8.2}$$

Assume that the second-order and stability conditions all hold. Equations (8.1) and (8.2) tell that under positive quantities, these two firms' optimal quality level are respectively $\tilde{q}_{A2}^{H*}=[8q_1(1+b)+3(1+4b)]/4(3+4q_1)$ and $\tilde{q}_{B2}^{L*}=[8q_1(b-2)+3(4b-5)]/4(3+4q_1)$.[16] The previous analysis shows that there is an interior solution of quality levels and the best response functions of these two firms are: $\tilde{q}_{A2}=\tilde{f}_A^H(\tilde{q}_{B2})$ and $\tilde{q}_{B2}=\tilde{f}_B^L(\tilde{q}_{A2})$. The best response curves are

[14] Choi (2004) defines product A2's fictitious price as firm A's best response function of bundled products minus the monopoly price of product 1. He also shows that when the monopoly price of product 1 is zero, the first-order conditions with and without bundling are the same.

[15] The utility function of purchasing good A2 with bundling is $\tilde{u}_A(\theta)=\theta(q_1+\tilde{q}_{A2})-\tilde{p}$, which is obviously different from that without bundling as $u_{A2}(\theta)=\theta q_{A2}-p_{A2}$. That is, bundling gives an extra utility of $\theta q_1$ to a consumer, which may be called the 'intrinsic value'. Note that the unit production cost of A2 is the same with and without bundling. However, bundling gives a consumer a totally different utility level while incurs the same production cost to firm A. We thank a referee for providing this economic intuition.

[16] The first-order conditions for the optimal quality levels with bundling are: $(\tilde{q}_{A2}-\tilde{q}_{B2})[3\tilde{q}_{A2}-\tilde{q}_{B2}-2(1+b)]-2q_1(1+b-2\tilde{q}_{A2})=0$ and $(\tilde{q}_{A2}-\tilde{q}_{B2})[\tilde{q}_{A2}-3\tilde{q}_{B2}-2(2-b)]+2q_1(b-2-2\tilde{q}_{B2})=0$.

described in Figure 1. The $\tilde{E}$ point in Figure 1 is the quality equilibrium. Comparing the equilibrium points $E$ without bundling and $\tilde{E}$ with bundling, we know that bundling makes both firms' quality levels drop in equal magnitudes of change - that is, $\Delta q^H_{A2} \equiv \tilde{q}^{H*}_{A2} - q^{H*}_{A2} = -q_1(2b-1)/(3+4q_1) < 0$ and $\Delta q^L_{B2} \equiv \tilde{q}^{L*}_{B2} - q^{L*}_{B2} = \Delta q^H_{A2} < 0$.

The two firms' equilibrium unit profit and quantities are respectively: $\tilde{\gamma}^{H*}_A = (\tilde{p}^{H*} - p_1) - (\tilde{q}^{H*}_{A2})^2/2 = [8q_1^2(2-b) + 6q_1(b+7) + 27]/12(3+4q_1)$, $\tilde{\gamma}^{L*}_B = \{(2q_1+3)[8q_1(2-b)+9]\}/12(3+4q_1)$, $\tilde{x}^{H*}_A = [8q_1(1+b)+9]/6(3+4q_1)$, and $\tilde{x}^{L*}_B = [8q_1(2-b)+9]/6(3+4q_1)$.[17] We define $\Delta x_1 \equiv \tilde{x}^{H*}_A - x_1$ as changes in good 1's quantity, and $\Delta x^H_A \equiv \tilde{x}^{H*}_A - x^{H*}_{A2}$, $\Delta x^L_B \equiv \tilde{x}^{L*}_B - x^{L*}_{B2}$, $\Delta p_T \equiv \tilde{p}^{H*} - (p_1 + p^{H*}_{A2})$, $\Delta p_{B2} \equiv \tilde{p}^{L*}_{B2} - p^{L*}_{B2}$, $\Delta \gamma^H_A \equiv \tilde{\gamma}^{H*}_A - \gamma^{H*}_A$, and $\Delta \gamma^L_B \equiv \tilde{\gamma}^{L*}_B - \gamma^{L*}_B$ as changes in good A2's, good B2's quantity, prices, and unit profits, respectively. Comparing these changes due to bundling, we come up with the following lemma.[18]

***Lemma 1*** *When multi-product firm A is the high quality firm, bundling lowers the quantity of the monopoly product, raises good A2's quantity and unit profit, and lowers the competitor's quantity, price, and unit net profit of good B2. Moreover, the price of bundled goods is lower than the sum of the prices for individually purchased goods A1 and A2;* $\Delta p_T < 0$.

Substituting the optimal quality levels into Equations (1) and (5) and letting $\Delta\Pi^H_A$ be firm A's profit difference with and without bundling, we express $\Delta\Pi^H_A$ as:

$$\begin{aligned}\Delta\Pi^H_A &= \tilde{\pi}^H_A - \pi^H_A = \underbrace{p_1(\tilde{x}^{H*}_A - x_1)}_{\substack{\text{profit discrepancy}\\ \text{in product 1 } (-)}} + \underbrace{[(\tilde{p}^H - p_1 - \tilde{q}^2_{A2}/2)\tilde{x}^H_A - (p^H_{A2} - q^2_{A2}/2)x^H_{A2}]}_{\text{profit discrepancy in product 2 } (+)} \\ &= \frac{q_1\delta_1}{36(3+4q_1)^2} > 0\end{aligned}, \qquad (9)$$

where $\delta_1 = -40b^2q_1(2q_1+3) + 64q_1^2(1+2b) + 24b(14q_1+9) - 3[9(1+3b^2) - 8q_1] > 0$.[19] Equation (9) shows that bundling is the dominant strategy for firm A. Lemma 1 presents that bundling lowers firm A's profit in good 1 while increases its profit in good A2. The above analysis generates Proposition 1.

***Proposition 1*** *When the multi-product firm is a high quality firm, bundling is the dominant*

[17] Substituting the optimal quality levels with bundling into the equilibrium prices in the price competition stage, we obtain the optimal prices as $\tilde{p}^{H*} = \{12b[18(1+6q_1) + 13b^2(3+4q_1)] + 64q_1^2[30 + 3b(8+b) + 8q_1(1+b)] + 3(672q_1 + 225)\}/96(3+4q_1)^2$ and $\tilde{p}^{L*}_{B2} = [512q_1^3(2-b) + 192bq_1^2(b-10) + 144bq_1(4b-17) + 216b(2b-5) + 48q_1(81+76q_1)]/96(3+4q_1)^2$. Furthermore, substituting the equilibrium quality levels with endogenous quality into Equations (5.1) and (5.2), we obtain the equilibrium profits as $\tilde{\pi}^{H*}_A = (8bq_1 + 8q_1 + 9)^2(2q_1+3)/72(3+4q_1)^2$ and $\tilde{\pi}^{L*}_B = (8bq_1 - 16q_1 - 9)^2(2q_1+3)/72(3+4q_1)^2$.

[18] When $q_1 > 3(5-4b)/8(b-2)$, the following results can be obtained: (1) $\Delta x_1 = -[4q_1(b-2) + 9(b-1)]/6(3+4q_1) < 0$; (2) $\Delta x^H_A = -\Delta x^L_B = 2q_1(2b-1)/3(3+4q_1) > 0$; (3) $\Delta p_T = -q_1[72b^2(1+q_1) + 32q_1^2(b-2) - 9(10q_1 + 4b+3)]/12(3+4q_1)^2 > 0$; (4) $\Delta p_{B2} = -q_1[72b^2(1+q_1) + 64q_1^2(b-2) - 9(18q_1 + 6b + 5)]/12(3+4q_1)^2 < 0$; (5) $\Delta\gamma^H_A = -q_1[4q_1(b-2) - 3(1+b)]/6(3+4q_1) > 0$; and (6) $\Delta\gamma^L_B = -q_1[8q_1(b-2) - 3(5-4b)]/6(3+4q_1) < 0$.

[19] The properties of the $\delta_1$ function are: $\partial\delta_1/\partial q_1 = 32q_1(5b+2)(2-b) + 24(-5b^2 + 14b + 1) > 0$ and $\partial^2\delta_1/\partial q_1^2 = 32(5b+2)(2-b) > 0$.

*strategy and lowers the quality levels of both firms.*

Proposition 1 can be further explained by Figure 1. First, a comparison of the best response curves with and without bundling (i.e., $\tilde{q}_{A2}=\tilde{f}^H_A(\tilde{q}_{B2}), q_{A2}=f^H_A(q_{B2})$, $\tilde{q}_{B2}=\tilde{f}^L_B(\tilde{q}_{A2})$, and $q_{B2}=f^L_B(q_{A2})$) shows that $\tilde{q}^H_{A2}=\tilde{f}^H_A(\tilde{q}^L_{B2})<q^H_{A2}=f^H_A(q^L_{B2})$ and $\tilde{q}^L_{B2}=\tilde{f}^L_B(\tilde{q}^H_{A2})<q^L_{B2}=f^L_B(q^H_{A2})$. Through bundling, firm A's best response curve $\tilde{f}^H_A$ is to the left of $f^H_A$, while firm B's best response curve $\tilde{f}^L_B$ with bundling is down below $f^L_B$. In other words, the quality equilibrium point with bundling must be located to the left and down below the quality equilibrium point without bundling. Therefore, bundling lowers both firms' quality levels.

We can further use the first-order conditions with and without bundling to interpret the effects of bundling on endogenous quality choice. Equations (4.1) and (8.1) show that the unit profit effect makes firm A raise its quality level while the output effect lowers its quality level. Moreover, bundling enhances the magnitudes of both unit profit (positively) and output (negatively) effects. Since the effect of bundling on the unit profit effect is smaller than that on the output effect, bundling induces firm A to bring down its own quality level.

Comparing the first-order conditions for firm B in the quality competition stage (i.e., Equations (4.2) and (8.2)), the unit profit effect lowers firm B's quality while the output effect promotes its quality. Bundling shrinks the unit profit (negatively) and output (positively) effects for firm B. Since the unit profit effect is smaller than the output effect for firm B, in total bundling induces firm B to reduce its own good quality.[20] The main reason is that firm A uses bundling to extend its monopoly power to the competitive market in order to get more profits from firm B by means of lowering its own quality. In order to alleviate the competition, the best response of firm B is to further differentiate the quality levels, which induces firm B to bring down its own quality level, too.

### 3. Bundling Effects on Profits and Social Surplus

Following the model set-up in Section II, here we further analyze the effects of firm A's bundling on firm B's profit, consumer surplus, and social surplus. First, we substitute the equilibrium outcomes with and without bundling into firm B's profit function, define $\Delta\Pi^L_B=\tilde{\pi}^L_B-\pi^L_B=(\tilde{p}_{B2}-\tilde{q}^2_{B2}/2)\tilde{x}^L_B-(p_{B2}-q^2_{B2}/2)x^L_{B2}$ as the change in firm B's profits with and without bundling, and find that $\Delta\Pi^L_B<0$.

We further discuss the effect of bundling on consumer surplus. Without bundling, the consumer surplus is the sum of the surplus for consumers from monopoly good 1, good A2,

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[20] Comparing the unit profit and output effects with and without bundling, we know that the change in unit profit effect is: $\{[(\partial\tilde{p}/\partial\tilde{q}_{A2})-\tilde{q}_{A2}]\tilde{x}^H_A-[(\partial p_{A2}/\partial q_{A2})-q_{A2}]x^H_{A2}\}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=q_1(2b-1)/12(3+2q_1)>0$ and the change in output effect is: $\{|[\tilde{p}-(\tilde{q}^2_{A2}/2)]\partial\tilde{x}^H_A/\partial\tilde{q}_{A2}|-|[p_{A2}-(q^2_{A2}/2)]\partial x^H_{A2}/\partial q_{A2}|\}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=q_1(2b-1)[2q_1(4b+7)+27]/36(3+2q_1)^2>0$. Therefore, bundling enhances both the unit profit and output effects. The total effect for firm A then is: $d\tilde{\pi}^H_A/d\tilde{q}_{A2}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=-q_1(2b-1)[4q_1(1+b)+9]/18(3+2q_1)^2<0$ - that is, the unit profit effect is less than the output effect. For firm B the change in the unit profit effect is: $\{|[(\partial\tilde{p}_{B2}/\partial\tilde{q}_{B2})-\tilde{q}_{B2}]\tilde{x}^L_B|-|[(\partial p_{B2}/\partial q_{B2})-q_{B2}]\tilde{x}^L_{B2}|\}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=-q_1(2b-1)/12(3+2q_1)<0$ and the change in the output effect $\{[\tilde{p}_{B2}-(\tilde{q}^2_{B2}/2)]\partial\tilde{x}^L_B/\partial\tilde{q}_{B2}-[p_{B2}-(q^2_{B2}/2)]\partial x^L_{B2}/\partial q_{B2}\}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=q_1(2b-1)(8bq_1-22q_1-27)/36(3+2q_1)^2<0$. Therefore, for firm B bundling reduces both unit profit and output effects. For firm B the total effect is $d\tilde{\pi}^L_B/d\tilde{q}_{B2}|_{\tilde{q}^H_{A2}=q^{H*}_{A2},\ \tilde{q}^L_{B2}=q^{L*}_{B2}}=q_1(2b-1)[4q_1(b-2)-9]/18(3+2q_1)^2<0$ - that is, the unit profit effect is less than the output effect.

and good B2; i.e., $cs = cs_1 + cs_{A2} + cs_{B2} = \int_{\theta_1}^{b}(\theta q_1 - p_1)d\theta + \int_{\theta_2}^{b}(\theta q_{A2} - p_{A2})d\theta + \int_{b-1}^{\theta_2}(\theta q_{B2} - p_{B2})d\theta$. Similarly, with bundling the consumer surplus can be expressed as $\widetilde{cs} = \widetilde{cs}_A + \widetilde{cs}_B = \int_{\tilde{\theta}}^{b}[\theta(q_1 + \tilde{q}_{A2}) - \tilde{p}]d\theta + \int_{b-1}^{\tilde{\theta}}(\theta\tilde{q}_{B2} - \tilde{p}_{B2})d\theta$. Let us substitute the equilibrium outcomes into the consumers' surplus functions and define the changes in consumer surpluses from goods 1, A2, and B2 as $\Delta CS_1$, $\Delta CS_{A2}$, and $\Delta CS_{B2}$, respectively.

Lemma 1 implies that $\Delta CS_1 = -\int_{\theta_1}^{\tilde{\theta}}(\theta q_1 - p_1)d\theta < 0$. The consumer surplus change of good 2 due to bundling is then: $\Delta CS_2 = \Delta CS_{A2} + \Delta CS_{B2} = \int_{\theta_2}^{b}[\theta(\tilde{q}_{A2} - q_{A2}) - (\tilde{p}_{A2} - p_{A2})]d\theta + \int_{b-1}^{\tilde{\theta}}[\theta(\tilde{q}_{B2} - q_{B2}) - (\tilde{p}_{B2} - p_{B2})]d\theta + \int_{\tilde{\theta}}^{\theta_2}[\theta(\tilde{q}_{A2} - q_{B2}) - (\tilde{p}_{A2} - p_{B2})]d\theta$. The first and second items on the right-hand side of the above equation are the changes in consumer surpluses from goods A2 and B2 due to bundling, while the third item is the consumer surplus change due to consumers switching from good B2 to bundled goods.

First of all, we explore the change in consumer surplus of buying good A2 with bundling. Proposition 1 implies that for consumers with the highest quality preference, along with bundling the difference in the willingness to pay (i.e., $\theta(\tilde{q}_{A2} - q_{A2})$ ) reduced by lowered good A2's quality is larger than the actual price difference (i.e., $\tilde{p}_{A2} - p_{A2}$), resulting in the consumers' surplus to drop. As the consumer quality preferences go down, for consumers with the lowest quality preferences the decrease in actual payment may dominate the decrease in willingness to pay. Therefore, bundling may promote the surplus of the consumers with the lowest quality preferences, but it is likely that bundling decreases the consumer surplus from good A2.

Second, we explain the change in consumer surplus of buying good B2 with bundling. Lemma 1 and Proposition 1 imply that bundling worsens (promotes) consumer surpluses of the highest (lowest) quality preferences. Summing up the changes in consumer surpluses, we find that it is likely that bundling raises consumer surplus from good B2.

Third, using the equilibrium outcomes, we know that terms $(\tilde{q}_{A2} - q_{B2})$ and $(\tilde{p}_{A2} - q_{B2})$ in the third items are both positive - that is, for the lowest preference person in the group of consumers switching from good B2 to bundled goods A2, bundling increases his/her willingness to pay and to actually pay. Nevertheless, the degree of change in the former is smaller than that in the latter, resulting in consumers' surplus to drop. However, as the quality preference increases, the change in willingness to pay may dominate that in actual payment, and hence bundling increases the consumer surplus with higher quality preferences in this group. Therefore, bundling lowers the consumer surplus for those switching from good B2 to a bundled good.

Summing up the above discussion, we find that bundling influences the consumer surpluses of goods 1 and A2 more than that of good B2. Consequently, when the bundling firm is the high quality firm, bundling always reduces the total consumer surplus; i.e., $\Delta CS = \widetilde{cs} - cs < 0$.

The social surplus is the sum of profits and consumer surplus. Denote the social surplus without and with bundling as $w = \pi_A^H + \pi_B^L + cs$ and $\tilde{w} = \tilde{\pi}_A^H + \tilde{\pi}_B^L + \widetilde{cs}$, respectively. Substituting the equilibrium outcomes into the social surplus and taking the difference, we find that

$\Delta W = \tilde{w} - w = \Delta\Pi_A^H + \Delta\Pi_B^L + \Delta CS < 0.$

***Proposition 2*** *When the multi-product firm is the high quality firm, bundling reduces the competitor's profit, consumer surplus, and social surplus.*

Lemma 1 notes that firm B's profit drops, because of firm A's bundling. Since bundling does not affect the price of monopoly good 1, bundling lowers the consumer surplus from good 1. Moreover, bundling lowers the two firms' quality levels as well as prices and shifts the marginal consumer to the left. The number of consumers buying good A2 (B2) increases (decreases). At the same time, bundling lowers the quality levels of both goods A2 and B2, hence resulting in a net decrease in market 2's consumer surplus.

When firm A is the high quality firm, bundling lowers the prices of bundled good and good B2, which promotes the social surplus. However, bundling lowers the quality in good 2, lowers the quantities of goods 1 and B2, and lowers the social surplus. In total, bundling lowers the social surplus when the bundling firm is the high quality firm.

## IV. *Multi-product Firm A as a Low-quality Producer*

In this section we assume that firm A is a low quality producer and firm B is a high quality producer. Again, we consider with and without bundling regimes adopted by firm A and analyze the without bundling regime first.

As illustrated in Equation (7), the first-order conditions evaluated at $q_1 = 0$ under a bundling regime are equal to the first-order conditions under without a bundling regime. Therefore, the comparative static results and second-order condition for the equilibrium without bundling are the same as shown in Section III.1 except that now firm A is a low quality producer. We will not repeat the analysis of the no bundling equilibrium and instead only examine the equilibrium of the bundling regime when firm A is a low-quality producer.

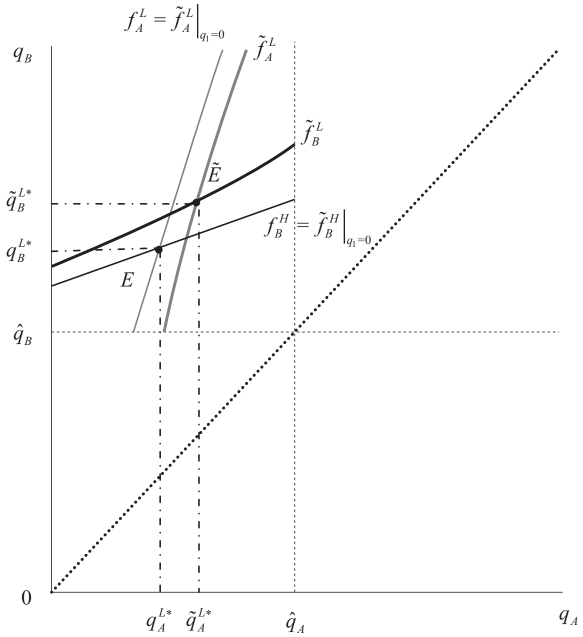
### 1. The Bundling Equilibrium

In this section we use the subscript A and superscript $L$ (subscript B and superscript $H$) to represent that firm A (B) is a low (high)-quality producer. To ensure that firm B produces positive quality and no firm will exit the market when firm A bundles goods 1 and 2 as a package, we assume that $q_1 < 9/8(1+b)$. The objective functions of firms A and B are the same as in Section III.2 except that we switch the superscript $H$ as $L$ and $L$ as $H$. Solving the first-order conditions yields the equilibrium prices under the bundling regime $\tilde{p}^L = [2(2-b)(\tilde{q}_{B2} - \tilde{q}_{A2} - q_1) + 2\tilde{q}_{A2}^2 + \tilde{q}_{B2}^2]/6$ and $\tilde{p}_{B2}^H = [2(1-2b)(\tilde{q}_{B2} - \tilde{q}_{A2} - q_1) + \tilde{q}_{A2}^2 + 2\,\tilde{q}_{B2}^2]/6$.

Using the similar approach in Subsection III.2, we proceed to the second stage of the quality chosen. After solving the first-order conditions in the second stage, we have the optimal quality level of the two firms as $\tilde{q}_{A2}^{L*} = [8q_1(2-b) + 3(4b-5)]/4(3-4q_1)$ and $\tilde{q}_{B2}^{H*} = 3(1+4b) - 8q_1(1+b)]/4(3-4q_1)$. The terms $\tilde{q}_{A2}^{L*}$ and $\tilde{q}_{B2}^{H*}$ are shown in Figure 2 at $\tilde{E}$.[21]

[21] Substituting the equilibrium quality into the prices and demand functions yields the equilibrium unit profits and quantities as $\tilde{\gamma}_A^{L*} = (\tilde{p}^{L*} - p_1) - [(\tilde{q}_{A2}^{L*})^2/2] = [4q_1(7-2b)(2q_1-3) + 27]/12(3-4q_1)$, $\tilde{\gamma}_B^{H*} = \{(2q_1-3)[8q_1(1+b)-9]\}/12(3-4q_1)$ and $\tilde{x}_A^{L*} = [8q_1(b-2)+9]/6(3-4q_1)$, $\tilde{x}_B^{H*} = [9-8q_1(1+b)]/6(3-4q_1)$.

FIG. 2. OPTIMAL QUALITY LEVELS WITH AND WITHOUT BUNDLING WHEN MULTI-PRODUCT FIRM A IS A LOW-QUALITY PRODUCER




In Figure 2, $\tilde{f}_A^L$ and $\tilde{f}_B^H$ are the respective reaction functions of firms A and B at the quality stage.[22] From a direct comparison of the quality levels between the no bundling equilibrium (point $E$) and the bundling equilibrium (point $\tilde{E}$), we can easily obtain that both firms yield high quality when firm A makes a bundle sell; i.e., $\Delta q_{A2}^L = \tilde{q}_{A2}^{L*} - \tilde{q}_{A2}^{L*}(q_1=0) = q_1(2b-1)/(3-4q_1) > 0$ and $\Delta q_{B2}^H = \tilde{q}_{B2}^{H*} - \tilde{q}_{B2}^{H*}(q_1=0) = \Delta q_{A2}^L > 0$.

Define $\Delta x_1 \equiv \tilde{x}_A^{L*} - x_1$, $\Delta x_A^L \equiv \tilde{x}_A^{L*} - x_{A2}^{L*}$, and $\Delta x_B^H \equiv \tilde{x}_B^{H*} - x_{B2}^{H*}$ as the changes in outputs of good 1, and those of good 2 produced by firms A and B, respectively, between the with and without bundling regimes. Similarly, we define $\Delta p_T \equiv \tilde{p}^{L*} - (p_1 + p_{A2}^{L*})$ and $\Delta p_{B2} \equiv \tilde{p}_{B2}^{H*} - p_{B2}^{H*}$ as the changes in prices, as well as $\Delta \gamma_A^L \equiv \tilde{\gamma}_A^{L*} - \gamma_A^{L*}$ and $\Delta \gamma_B^H \equiv \tilde{\gamma}_B^{H*} - \gamma_B^{H*}$ are the changes in unit profit between the two regimes. We thus have Lemma 2.[23]

***Lemma 2*** *When firm A is a low-quality producer, bundling (1) raises the output of A2, reduces the unit profit, and the price with bundling is lower than the sum of the two prices*

[22] The best response functions of firms A and B are $\tilde{q}_{A2} = \tilde{f}_A^L(\tilde{q}_{B2})$ and $\tilde{q}_{B2} = \tilde{f}_B^H(\tilde{q}_{A2})$.

[23] When $q_1 < 9/8(1+b)$, we have the following results: (1) $\Delta x_1 = [4q_1(5b-4) + 9(1-b)]/6(3-4q_1) \gtrless 0$, if $q_1 \gtrless 9(b-1)/4(5b-4)$; (2) $\Delta x_A^H = -\Delta x_B^L = 2q_1(2b-1)/3(3-4q_1) > 0$; (3) $\Delta p_T = -q_1[72b^2(q_1-1) + 32q_1^2(b+4) + 36b(3-4q_1) + 9(5-18q_1)]/12(3-4q_1)^2 < 0$; (4) $\Delta p_{B2} = -q_1[72b^2(q_1-1) + 64q_1^2(1+b) - 18q_1(8b-5) + 9(10b+3)]/12(3-4q_1)^2 > 0$; (5) $\Delta \gamma_A^L = q_1[4q_1(4+b) + 3(b-5)]/6(3-4q_1) < 0$; and (6) $\Delta \gamma_B^L = q_1[4q_1(b-2) + 3(4-5b)]/6(3-4q_1) < 0$.

*without bundling; (2) reduces the output and unit profit and increases the price of B2.*

We further calculate the changes in the profits of firm A between with and without bundling regimes as:

$$\begin{aligned}\Delta\Pi_A^L &= \underbrace{p_1(\tilde{x}_A^L - x_1)}_{\substack{\text{profit discrepency}\\ \text{in product 1 } (\pm)}} + \underbrace{[(\tilde{p}^L - p_1 - \tilde{q}_{A2}^2/2)\tilde{x}_A^L - (p_{A2}^L - q_{A2}^2/2)x_{A2}^L]}_{\text{profit discrepency in product 2 } (+)} \\ &= \frac{q_1\delta_2}{36(3-4q_1)^2}\end{aligned}, \qquad (10)$$

where $\delta_2 = -104b^2q_1(2q_1-3) - 256q_1^2(1-b) - 24b(22q_1-9) - 27(7+3b^2) + 456q_1$.

From Equation (10) we know that when $\delta_2 > 0$, the bundling strategy is the dominant strategy for firm A. The following analysis in this section focuses on the assumption $\delta_2 > 0$ where bundling is a dominant strategy for firm A. The changes in quality are also easily obtained from Figure 2. Here, $\tilde{f}_A^L$ and $f_A^L$ ($\tilde{f}_B^H$ and $f_B^H$) are the reaction functions of firm A (B) in the quality stage for the with and without bundling regimes, respectively. Clearly, in Figure 2 we find that $\tilde{q}_{A2}^L = \tilde{f}_A^L(q_{B2}^H) > q_{A2}^L = \tilde{f}_A^L(q_{B2}^H)$ and $\tilde{q}_{B2}^H = \tilde{f}_B^H(q_{A2}^L) < q_{B2}^H = f_B^H(q_{A2}^L)$. From the above analysis, we have Proposition 3.

***Proposition*** *3 When the multi-product firm is a low quality producer, the bundling strategy raises the quality level of the competitive good.*

The economic intuitions of Proposition 3 are as follows. When firm A is a low quality producer, it adopts a bundling strategy to extract more profits from firm B by raising its good quality. On the contrary, firm B attempts to mitigate the competition with firm A, and it also increases its quality level.

By Propositions 1 and 3, we are able to see that our results differ from those in Gilbert and Riordan (2007) and Kramer (2009). Gilbert and Riordan (2007) assume *homogeneous* consumer preferences and technology bundling for the vertically integrated firm can reduce its opponent's quality level. They conclude that technology bundling can increase the bundling firm's quality effectively, keep its opponent's R&D level unchanged, and finally force the opponent to exit the market. In our paper instead assumes *heterogeneous* consumer preferences and obtains the market structure of a duopoly even under bundling. Although Kramer (2009) also assumes heterogeneous consumer preferences, he considers different market scopes of competition goods and sequence of moves, concluding that bundling may increase the integrated firm's quality while reducing the opponent's quality.

## 2. Profit and Welfare Analysis

The analysis in this section is similar to that of Section III.3, except now firm A is a low-quality producer. The definitions of profit, consumer surplus, and welfare are analogous to those in Section III.3. From a direct comparison of the results in the previous section between with and without bundling regimes, we have the following results. First, from Equation (10) we know that firm A earns a higher profit, but firm B earns less profit since $\Delta\Pi_B^H = \tilde{\pi}_B^H - \pi_B^H = (\tilde{p}_{B2} - \tilde{q}_{B2}^2/2)\tilde{x}_B^H - (p_{B2} - q_{B2}^2/2)x_{B2}^H < 0$. Second, the consumer surplus increases, because $\Delta CS =$

$\widetilde{cs}-cs>0$.[24] Third, the welfare effect is ambiguous $\Delta W=\tilde{w}-w=\Delta\Pi_A^L+\Delta\Pi_B^H+\Delta CS \gtreqless 0$. We summarize the above results in Proposition 4.

***Proposition 4*** *When the multi-product firm is a low-quality producer, bundling reduces the rival's profit, increases consumer surplus, and may increase the welfare.*

The results in Proposition 4 differ from the existing literature. Choi (2004) concludes that bundling reduces the welfare in a model of horizontal product differentiation. Gilbert and Riordan (2007) find that technology bundling lowers the consumer surplus and welfare under a vertical product differentiation model. For example, in Gilbert and Riordan (2007) where consumers have the same preferences, the competition between firms is intensive such that technology bundling forces the opponent to exit the market and the consumer and social surpluses both to drop due to monopolization. From Propositions 2 and 4, we find that the effects of bundling on consumer surplus and welfare depend on the relative quality level of bundled goods. According to the results obtained by this paper, we suggest that the judgment of bundling by antitrust authorities should take into account the bundler's quality level.

## V. *Concluding Remarks*

The effects of bundling behavior on consumer surplus and social welfare raised the attention by the antitrust authorities. Without taking quality choice into account, most existing literature finds that bundling will harm the consumer surplus. However, via the perspective of bundling in the presence of vertical differentiation, this paper finds that bundling by a low-quality firm always improve the consumer surplus and may increase the social surplus.

With a theoretical model with vertical quality differentiation, we examine how a bundling strategy by a multi-product firm, which monopolizes one good and competes with a single-product firm in a competitive market in another good, affects the level of good quality chosen by firms. We analyze two cases in which the multi-product firm is a high (or low) quality producer and the rival firm is a low (or high) quality producer in a competitive good. We investigate how bundling affects good's quality level, profits, consumer surplus, and social welfare, taking into account the strategic interactions between the multi-product firm and its single-product rival in quality chosen.

In this paper we find that a bundling strategy hurts the rival firm after taking the endogenous quality choice into account. When the quality of the bundled good is high, we show that bundling lowers the quality levels of competitive goods for both firms and lowers consumer surplus and welfare as well. On the contrary, when the quality of a bundled good is low, bundling (i) raises the quality levels of competitive goods, (ii) increases consumer surplus, and (iii) may increase welfare. In other words, the effects of bundling on consumer surplus and

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[24] The consumer surplus in the no bundling regime is defined as $cs=cs_1+cs_{A2}+cs_{B2}=\int_{\theta_1}^{b}(\theta q_1-p_1)d\theta+\int_{b-1}^{\theta_2}(\theta q_{A2}-p_{A2})d\theta+\int_{\theta_2}^{b}(\theta q_{B2}-p_{B2})d\theta$; the consumer surplus in the bundling regime is $\widetilde{cs}=\widetilde{cs}_A+\widetilde{cs}_B=\int_{b-1}^{\tilde{\theta}}[\theta(q_1+\tilde{q}_{A2})-\tilde{p}]d\theta+\int_{\tilde{\theta}}^{b}(\theta\tilde{q}_{B2}-\tilde{p}_{B2})d\theta$.

welfare depend on the relative quality level of competing goods. We also find that although bundling alters the optimal quality level of the competitive good in these two cases, bundling does not change the quality differentials between the competitive goods.

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