Negative effect of price-matching policy on traditional retailers in a dual-channel supply chain with different content formats[*]

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Abstract

We investigate a model in which a monopoly supplier distributes two types of its product, physical and electronic products, through a traditional/brick-and-mortar retailer with a wholesale price contract and an online retailer with an agency contract, respectively. The supplier and the online retailer negotiate the royalty rate, which is a ratio of the online retailer's revenue to the entire revenue of the channel. We also discuss the case in which the supplier imposes the following self-regulation to balance its dual-channel supply chain: the retail price of the online retailer is not lower than the wholesale price for the traditional retailer. What will happen if the supplier employs such self-regulation? Is self-regulation beneficial to the two retailers? To answer these questions, we first derive the equilibrium without such self-regulation. Second, we investigate what happens if the supplier employs such self-regulation. We obtain the following results. First, in the baseline model, an increase in the online retailer's bargaining power over the supplier benefits the two retailers but harms the supplier. Second, under self-regulation, the wholesale price *is strictly higher* than that in the baseline model. Third, the retailers' equilibrium prices are also strictly higher than those in the baseline model. Self-regulation always benefits the online retailer. It benefits the traditional retailer if the online retailer's bargaining power is sufficiently weak. Furthermore, self-regulation benefits the supplier if the substitutability between the two retailers is not high. However, it reduces consumer and social welfare.

Keywords: Agency contract, Price-quantity competition, Dual-channel supply chain, Royalty rate.
JEL Classification: L22, L13, C72, C78.

1 Introduction

The recent advancement of online platforms facilitates selling digital content, including books, games, movies, and music, and purchasing such content without leaving home. The facilitation of selling and buying digital content is a competitive threat to the traditional brick-and-mortar retailers handling physical content. For instance, in the US book industry, the sales share of e-books was about 20% in 2015 (Gilbert, 2015), and in 2018, 34% of younger consumers, aged 18–29 years, had read e-books in the previous 12 months (Pew Research Center, 2019a).[1] Contrary to this trend, many consumers still chose only paper books in 2019. According to Pew Research Center (2019b), among consumers who read books, the ratios of purchasing only paper books, only e-books including audiobooks, and both types are, respectively, 51%, 9.8%, and 39%. Thus, consumers still purchase both traditional paper books and e-books, depending on preferences, situations, and places (see, for instance, Bergström and Höglund (2020) for the recent trend in e-books in Sweden). In sum, it is reasonable to investigate a market in which consumers can purchase both physical and digital content.

In the distribution of such content, online and brick-and-mortar retailers often face different contract types: agency contracts and wholesale price contracts, respectively. For instance, in the US book industry, some online retailers (e.g., Apple) use agency contracts, although brick-and-mortar book retailers employ standard wholesale price contracts (Dantas et al., 2014; Gilbert, 2015).[2] Publishers directly determine the downstream prices of such online retailers using agency contracts, contrary to wholesale price contracts in which brick-and-mortar retailers choose their downstream pricing at their discretion. The online retailers receive profits based on a prenegotiated percentage of revenues (the royalty rate). Employing agency contracts eliminates the double-marginalization problem and allows the trading pair to be a quasi-integrated firm.[3] The quasi-integrated nature of the trading pair with agency contracts could cause (partial) foreclosure of brick-and-mortar retailers through offering higher wholesale prices to those brick-and-mortar retailers, which is reminiscent of encroachment issues in the supply chain problem (Chiang et al., 2003;

[1] The penetration of devices for reading e-books, such as e-readers, smartphones, and tablet PCs, is constantly increasing (Deloitte, 2018). In 2015, smartphones were the most popular devices for reading e-books (Maloney, 2015). Therefore, the e-books market share is now substantial.

[2] In the Appendix (Section 8.3), we briefly describe the practices of the major publishers in the US before employing agency contracts became a common practice.

[3] Another advantage of distributing digital content over physical content is lower production costs.

Arya et al., 2007; Zennyo, 2019; Zheng and Yu, 2021) and the discussion of price/margin squeeze in economics (see, e.g., Bouckaert and Verboven, 2004; Sidak, 2008; Jullien et al., 2014).[4] Given the imbalance between brick-and-mortar retailers and online retailers, content suppliers need to consider balancing their dual channels, to keep better threat points (outside profits) in bargaining with online retailers by ensuring brick-and-mortar retailers are profitable outside options (Shen et al., 2019; Wang and Miller, 2020).[5]

Given the disadvantage of brick-and-mortar retailers over online retailers, which are quasi-integrated with suppliers, we can borrow an idea from regulation economics (e.g., Bouckaert and Verboven, 2004; Jullien et al., 2014) to balance content suppliers' dual-channel supply chains: *an integrated firm does not set its retail price lower than wholesale prices for its independent trading downstream firms* (henceforth, *self-regulation*).[6] At first glance, self-regulation seems to give brick-and-mortar retailers competitive power over (quasi-integrated) online retailers in the downstream market because content suppliers will increase the retail prices of the (quasi-integrated) online retailers and lower the wholesale prices for the brick-and-mortar retailers to meet the requirement of self-regulation. Besides, the idea seems less likely to cause antitrust concerns intuitively because it is reminiscent of the remedy in the discussion of price/margin squeeze in economics (Bouckaert and Verboven, 2004; Jullien et al., 2014).

Related to such commitment to pricing, one may think that a retail-level equal pricing policy is a direct and plausible way to help independent retailers (Zheng and Yu, 2021). This policy is effective if independent (large-size) e-retailers compete with manufacturers' direct e-channels because the comparison of those retail prices is easy, and they easily detect the deviation of the price-matching policy through web scraping (Castrillo-Fernández, 2015). In our context, gathering price information about brick-and-mortar retailers is not easy because of the ways they post their prices (posting in their stores offline), making retail price comparison difficult.

As an alternative to retail price matching, we consider the self-regulation mentioned earlier. The integrated firm under self-regulation knows completely the price information required for self-regulation. Furthermore, independent trading downstream firms can de-

[4] See Rey and Tirole (2007) for a review of market foreclosure issues.

[5] This matter aligns with issues in channel coordination problems (see the seminal work by Jeuland and Shugan (1983), review articles (Cachon, 2003), direct channel in Chiang et al. (2003), and revenue sharing contracts in Cachon and Lariviere (2005)).

[6] This idea is related to the price discount contracts investigated in Section 5.1 of Cai et al. (2009).

tect the violation only by gathering the online information of the integrated firm's online price through web scraping (Castrillo-Fernández, 2015). Therefore, in the competition between brick-and-mortar retailers and direct e-retailers, the feasibility of implementing self-regulation is higher than that of using the retail-level equal pricing policy.

Although the abovementioned *self-regulation* seems useful to balance the dual-channel supply chain with a brick-and-mortar retailer and an online retailer, what really happens if the supplier employs such a pricing policy? Is self-regulation beneficial for the supplier and retailers? Does self-regulation benefit consumers and social welfare?

We investigate a model in which a monopoly supplier distributes two types of its product through a traditional retailer with a wholesale price contract and an online retailer with an agency contract.[7] We also consider the impact of the abovementioned *self-regulation* on the three players and the consumer and total surpluses.

In the baseline model, we consider the following three-stage game. First, the supplier and the online retailer negotiate the royalty rate through Nash bargaining, which is a key element in our model. Second, the supplier unilaterally determines the wholesale price for the traditional retailer. The sequence of the first and second stages follows those in the related papers that endogenize royalty rates (e.g., Abhishek et al., 2016; Zennyo, 2019, 2020; Tsunoda and Zennyo, 2021). Third, observing the trading terms determined before, the traditional retailer and the supplier simultaneously set their own strategic variables. By taking into account the nature of physical and digital content, we assume that the traditional retailer and the supplier via the online retailer compete in quantity and price, respectively (e.g., a subgame of the model with endogenous choices of strategic variables in Singh and Vives (1984)). We call the competition mode "*price-quantity competition*."

In the self-regulation case, the supplier cannot set a retail price that is lower than the wholesale price for the traditional retailer in the third stage (Bouckaert and Verboven, 2004; Jullien et al., 2014).

Note that we can classify the research method in our paper as a "closed-form analytical operational analyses," which are standard in the supply chain management literature,

[7] The literature of closed-loop supply chains investigates the distribution of multiple types of products, as in our paper (Savaskan et al., 2004; Atasu et al., 2008; Taleizadeh et al., 2018; Taleizadeh and Moshtagh, 2019; Taleizadeh and Sadeghi, 2019; Alizadeh-Basban and Taleizadeh, 2020; Xiao et al., 2020; Dou and Choi, 2021; Qiao and Su, 2021; Sheu et al., 2021; Taleizadeh et al., 2021).

following the explanation in footnote 2 of Choi and Guo (2020).[8]

The assumption of price-quantity competition is consistent with the standard view on when price and quantity are strategic variables of firms (e.g., see the textbooks by Belleflamme and Peitz (2015, Section 3.3.3, p. 67) and Cabral (2017, Section 8.3, pp. 200–201)). Before we consider this view, we discuss an interpretation of quantity setting in oligopoly models. Setting a quantity in oligopoly models is interpreted as a reduced form of the following procedure: a firm precommits its production capacity, then sets its retail price by considering its precommitted capacity. In this procedure (capacity-then-price decision), the retail price equalizes the capacity (the supply) to the market demand for its product (the demand). Thus, the market is clear, and there is no inventory problem. The logic holds even when more than one firm simultaneously conducts such procedures. The seminal work by Kreps and Scheinkman (1983) provides a micro-foundation for the interpretation. Since then, many researchers have relied on this interpretation to formulate oligopoly models with capacity-then-price decisions. The operations research and management science (OR/MS) literature is no exception. For instance, Arya et al. (2007), David and Adida (2014), Shulman (2014), and Yang et al. (2018) employ quantity-setting models in supply chain problems. Furthermore, Farahat et al. (2019) provide a micro-foundation of quantity competition in the context of OR/MS. Our modeling approach follows the stream of quantity competition models in the context of OR/MS.

We now explain the plausibility of our price-quantity competition using a well-cited textbook on industrial organization by Belleflamme and Peitz (2015), who summarize the discussion of Kreps and Scheinkman (1983) (Belleflamme and Peitz, 2015, pp. 61–65) and then explain how to use strategic variables in oligopoly models. Belleflamme and Peitz (2015) mention that when capacity is unlimited, assuming a firm is a price setter is appropriate; when capacity is limited, assuming a firm is a quantity setter is appropriate. Case 3.4 on page 68 in Belleflamme and Peitz (2015) explains the change in product characteristics in the publishing industry: "it seems that the quantity competition model fits better with the batch printing technology (because prices will adjust to selling the existing capacity) and the price competition model with the POD technology (because

[8] Because the purpose of this methodology is to derive closed-form solutions theoretically, the analytical frameworks are not complex (Choi and Guo, 2020), which is in contrast to the mathematical programming-based operational research studies. Even in recent years, many papers in operations research studies employ closed-form analytical operational analyses (e.g., Taleizadeh et al., 2019; Choi, 2021; Dou and Choi, 2021; Xu and Choi, 2021; Cao and Choi, 2021; Sheu et al., 2021).

quantity can be adjusted immediately at the announced prices)" (POD in the quotation is "publish on demand"). Thus, we think that the market structure discussed in our paper properly captures the nature of product characteristics in real-world industries, including books, games, movies, and music.

First, we obtain the following results in the baseline model. The equilibrium royalty rate positively correlates with the online retailer's bargaining power over the supplier. The wholesale price for the traditional retailer is higher than the online retailer's retail price in equilibrium if the bargaining power is lower than a threshold value, which is larger than 0.3 but lower than 0.5. An increase in the online retailer's bargaining power over the supplier benefits the two retailers but harms the supplier. Furthermore, such an increase in bargaining power lowers the wholesale price and the online retailer's retail price, enhancing consumer and social welfare.

Second, we also obtain the following results in the self-regulation case. The equilibrium royalty rate positively correlates with the online retailer's bargaining power over the supplier as in the baseline model. The online retailer's retail price is always binding to the wholesale price for the traditional retailer under self-regulation because the supplier can mitigate the downstream competition by setting a higher wholesale price, leading to a higher retail price of the online retailer. The wholesale price under self-regulation is strictly higher than that in the baseline model, contrasting to the intuition that the supplier decreases the wholesale price but increases the retail price of the online retailer to meet the self-regulation. The retail prices under self-regulation are also strictly higher than those in the baseline model. The royalty rate under self-regulation is strictly higher than that in the baseline model. In particular, the incremental level of the royalty rate increases as the product substitutability between the two contents increases.

Furthermore, self-regulation always benefits the online retailer because it weakens the downstream competition and increases the royalty rate. The self-regulation benefits the traditional retailer if the online retailer's bargaining power is sufficiently weak because the self-regulation limits the supplier's strong dependency on the online retailer with weak bargaining power, which dominates the cost from increasing the wholesale price. In addition, the self-regulation benefits the supplier if the substitutability between the two retailers is not sufficiently high because the benefit from mitigating the downstream competition dominates the cost from augmenting the royalty rate (see the abovementioned relation between the royalty rate and the product substitutability).

The results of our analyses have an important managerial implication for content suppliers. Our model fits the distribution problems in copyrighted content industries, including books, games, movies, and music. A content supplier's bargaining power over online retailers can be stronger if the originality/uniqueness of its content is higher. Our theoretical model shows that self-regulation benefits all firms if the online retailer's bargaining power is sufficiently weak and the product substitutability between the two contents is not sufficiently high; in other words, if the royalty rate is sufficiently low and the two contents are horizontally differentiated. The suppliers/providers of content with high originality can commit to the self-regulation discussed here without causing complaints by brick-and-mortar retailers. However, if content suppliers/providers do not have content with high originality, imposing the pricing constraint can cause conflicts with brick-and-mortar retailers because the constraint harms those retailers. In sum, the bargaining power of content suppliers/providers is one of the key factors in determining whether implementing the pricing constraint discussed here is feasible. However, we discuss another important factor in implementing the pricing constraint below.

Note that implementing the price constraint might cause concern on competition policy if the competition authority follows our welfare analysis. The pricing constraint intuitively seems acceptable from the viewpoint of competition policy because it is similar to the remedy in the discussion of price/margin squeeze in economics (e.g., Bouckaert and Verboven, 2004; Jullien et al., 2014). However, our results show that the pricing constraint harms consumer and social welfare because of the increases in the wholesale price and the online retailer's retail price. Those price increases stem from the structure of price-quantity competition, which captures competition modes in the content industries. Therefore, given that content suppliers employ the pricing constraint discussed here, if the competition authority recognizes that capacity constraints of the traditional retailers influence their pricing policies, it might apply our results to the conduct of the content suppliers. This concern is the other factor in determining whether implementing the pricing constraint discussed here is feasible.

The remainder of this paper is organized as follows. Section 2 surveys the related papers. Section 3 constructs the model. Section 4 analyzes the game and presents the results. Section 5 analyzes the effect of self-regulation on retail prices. Section 6 discusses the case in which two retailers compete in price. Section 7 offers concluding remarks.

2 Related literature

Because the market structure in our model is the dual-channel supply chain in which the monopoly supplier distributes two types of its product through a traditional retailer under linear wholesale pricing and an online retailer under an agency contract, our paper is related to the numerous studies on dual-channel supply chain management issues in the context of OR/MS based on game theory (earlier works, Chiang et al., 2003; Arya et al., 2007; Cai, 2010; Li et al., 2014, 2015b; Matsui, 2016; recent works, Guan et al., 2020; He et al., 2020; Xu et al., 2020; Xue et al., 2020; Zhen et al., 2020; Zhang et al., 2021; Zhang and Hezarkhani, 2021; Zheng and Yu, 2021). Except for a few papers discussed in the main text, the focus of our paper differs from those in other papers, although the market structures in those papers are similar to ours.

In particular, our paper contributes to the literature on dual-channel supply chains with agency contracts (e.g., Abhishek et al., 2016; Tan et al., 2016; Tan and Carrillo, 2017; Lu et al., 2018; Tian et al., 2018; Yan et al., 2018; Shen et al., 2019; Zennyo, 2019, 2020; Zhang and Zhang, 2020; Chen et al., 2021; Fu et al., 2021; Song et al., 2021; Tsunoda and Zennyo, 2021; Zhen and Xu, 2022).[9] We can classify the themes of those papers into the following: endogenous contract forms (wholesale or agency) (Abhishek et al., 2016; Tan et al., 2016; Tan and Carrillo, 2017; Lu et al., 2018; Tian et al., 2018; Yan et al., 2018; Zennyo, 2019, 2020; Fu et al., 2021; Tsunoda and Zennyo, 2021); optimal channel structure (Shen et al., 2019; Zhang and Zhang, 2020; Song et al., 2021; Zhen and Xu, 2022); and multiperiod sales problem (Chen et al., 2021). We investigate (i) the relation between the bargaining power of the online retailer and the equilibrium royalty rate, (ii) the effect of the online retailer's bargaining power on the profits and consumer and social welfare, (iii) the effect of self-regulation imposed by the supplier on the profits and consumer and social welfare, and (iv) how the competition mode (price-quantity competition) influences the effect of self-regulation.[10] Although our main focus listed above does not overlap with

[9] See also Foros et al. (2017); Johnson (2017); Maruyama and Zennyo (2020). Our paper also complements the literature on store-within-store formats in traditional retailers (Jerath and Zhang, 2010; Netemeyer et al., 2012).

[10] Among the papers listed in the main text, only Tan and Carrillo (2017) and Shen et al. (2019) explicitly investigate the relationship between the retailer's bargaining power and the endogenous royalty rate in extension sections. The other papers, which endogenize royalty rates, assume that e-retailers unilaterally set royalty rates (Abhishek et al., 2016; Zennyo, 2019, 2020; Fu et al., 2021; Tsunoda and Zennyo, 2021).

those of the previous papers, the market structures of Shen et al. (2019) and Zennyo (2019) partially overlap with that of ours. We discuss the difference between Zennyo (2019) and our paper in Section 6 because the demand system in that paper is closer in nature to ours than that in Shen et al. (2019).[11]

Our paper also contributes to the literature on price parity clauses (price-matching policies) with agency contracts by providing a different mechanism behind the welfare-reducing price parity,[12] although we consider the parity of different tier prices (wholesale and retail prices).

We review several models dealing with price-matching policies under the dual-channel supply chain in the context of operations management and marketing. Cattani et al. (2006) is the seminal work that discusses a retail price-matching policy in a dual-channel supply chain in which a direct retail channel and an indirect retail channel compete. Such a price-matching policy benefits the indirect channel. Cai et al. (2009) discuss a pricing constraint related to ours in Stackelberg price-setting games with direct and indirect channels. They discuss a price discount contract that ensures that the wholesale price for the indirect channel should be lower than the retail price of the direct channel by some exogenous ratio.[13] When the manufacturer is the leader, such a price discount contract is beneficial to the retailer if the exogenous ratio is lower than a threshold value.[14] Their price-matching policies are different to that in our paper. Furthermore, agency contracts are beyond the scope of their paper. Ding et al. (2016) also consider price-matching constraints related to Cattani et al. (2006) and show that such constraints benefit the retailer, contrasting to our result. Zhou et al. (2018) discuss a price-matching policy in a dual-channel supply chain with investments for services and show that such a policy benefits the indirect channel.

[11] Tsunoda and Zennyo (2021) incorporate uncertainty into Zennyo (2019). Note that Shen et al. (2019) also consider Nash bargaining to derive the royalty rate in an extension section. One technical advantage of our analysis is that we analytically obtain the royalty rate in the single-part contract, although Shen et al. (2019) also obtain the equilibrium royalty rate, which is independent of the bargaining power, under a two-part contract form with a royalty rate and a lump-sum payment. The nature of the equilibrium royalty rate in their paper is reminiscent of the standard two-part tariff contract (setting the royalty rate to maximize the total channel profits and then splitting them through the lump-sum payment, which depends on the bargaining power).

[12] The related works in economics are, for instance, Johnson (2017), Wang and Wright (2020), and Bisceglia et al. (2021).

[13] They also consider the case in which the reference retail price is that of the indirect channel.

[14] If the retailer is the leader, the manufacturer can completely exploit the retailer's rent by equalizing its wholesale price to the predetermined retail price when no price discount contract exists. The channel members can escape the problem by employing the price discount contract.

Recently, Zheng and Yu (2021) consider a bilateral monopoly model in which the manufacturer can open its direct channel, which is less efficient than the indirect channel (the encroachment option). They assume that the manufacturer can employ a price-matching policy requiring the direct channel to equalize its price to the indirect channel's price and show that the availability of the policy enhances the incentive to encroach, harming the indirect channel. The key factor of their result is the enhanced incentive of the manufacturer to encroach through the price-matching policy. This fact implies that the encroachment option is necessary, contrasting to our model's fixed dual-channel supply chain. Zhen and Xu (2022) investigate three channel structures: (i) The monopoly manufacturer sells its product to a retailer, which resells it in the retailer's own channel and through a third-party platform under an agency contract, as in the encroachment subgame of Zheng and Yu (2021) and our paper; (ii) the manufacturer sells its product to the retailer that resells it in the retailer's own channel and uses the third-party platform under the agency contract; (iii) the manufacturer also sells its product through the third-party platform under structure (ii). Under the three structures, they consider two pricing strategies: offering discriminatory retail prices and offering a uniform price set by the retailer. They show that a higher exogenous royalty rate makes uniform pricing profitable for the two firms in the third channel structure (Proposition 7), contrasting to our result, which shows that self-regulation is more likely to benefit the supplier and the traditional retailer when the bargaining power of the online channel is lower (the endogenous royalty rate becomes lower).

There are several further differences between those two papers and ours. First, we introduce an online platform employing an endogenous agency contract with a monopoly supplier. The two players negotiate the contract term based on a percentage of the platform's revenue. Second, the constraint is looser than those in the related papers in that we assume that the retail price on the online platform should be greater than or equal to the wholesale price for the indirect channel. That is, we allow the possibility that the retail price is strictly higher than the wholesale price, although the constraint is always binding in equilibrium. The looser restriction is technically richer than the restrictions in the related papers. Third, the tiers of matched prices are different as mentioned earlier. Finally, the competition mode in our paper is the price-quantity competition, which is suitable for the content markets, including books, games, movies, and videos.

Technically, our modeling approach is related to the literature on price-quantity competition. Although there are many papers discussing price-quantity competition in various contexts since the seminal works by Bylka and Komar (1976) and Singh and Vives (1984) (e.g., Askar, 2014; Bian et al., 2018; and the comprehensive survey of Tremblay and Tremblay (2019)), only a few papers discuss price-quantity competition with vertical relations (e.g., Yang et al., 2015; Fanti and Scrimitore, 2019). The main themes in the latter two papers are the endogenous choices of strategic variables (price and quantity) differing from ours.

The modeling approach in the supplementary appendix in Lei (2019) is the closest to ours. The market structures in her model and ours use price-quantity competition. The difference between her model and ours is threefold. First, the main focuses of the two models are different. She investigates the optimal channel structure for a monopoly manufacturer, as in Chiang et al. (2003) and Arya et al. (2007). We investigate the equilibrium royalty rate and the impact of self-regulation by an upstream firm, but fix the dual-channel supply chain. Second, the properties of the realized royalty rates in the two models differ from each other. The endogenous royalty rate in her model binds at the exogenous upper bound because the retailer unilaterally sets the royalty rate. The endogenous royalty rate in our model is flexible because we consider Nash bargaining. Third, self-regulation by the supplier is only discussed in our model. In this sense, we should regard our model as an extension of price-quantity competition in a direction different from her extension.

Table 1 summarizes the literature that is closely related to our research.

3 Problem description

We introduce three players below. A monopolistic supplier produces two versions of a good, physical and digital versions, and distributes through two retailers: (i) a traditional retailer who resells the physical version of the good, and (ii) an e-commerce retailer who handles the digital version of the good. For the sake of clarity, we focus on a book market where a monopolistic *supplier* publishes a book and sells it through a traditional bookstore (henceforth referred to as T-*retailer*) and an e-commerce platform (E-*retailer*). T-retailer sells a traditional paper version of the book (hereafter, we refer to it as *paper book*), and E-retailer sells an electronic version of the book (*e-book*). The market structure is similar

Table 1: Summary of the related literature

Article	Agency model	Price matching	price-quantity competition
Cattani et al. (2006)	(direct)	✓	
Cai et al. (2009)	(direct)	✓	
Yang et al. (2015)	(direct)		✓
Abhishek et al. (2016)	✓		
Ding et al. (2016)	(direct)	✓	
Tan and Carrillo (2017)	✓		
Bian et al. (2018)			✓
Lu et al. (2018)	✓		
Fanti and Scrimitore (2019)	(direct)		✓
Lei (2019)	✓		✓
Shen et al. (2019)	✓		
Tsunoda and Zennyo (2021)	✓		
Zheng and Yu (2021)	(direct)	✓	
Fu et al. (2021)	✓		
Zhen and Xu (2022)	✓	✓	
This research	✓	✓	✓

to those in the papers discussing e-books (Li et al., 2015a; Lu et al., 2018).[15]

We assume that the product characteristics of the paper book and the e-book are different, as explained in Sections 1 and 2. Hereafter, the subscripts t and e denote the T-retailer and E-retailer, respectively. For the paper book, T-retailer determines its sales quantity, q_t, because it must consider the capacity of the book in the physical store (Kreps and Scheinkman (1983), Farahat et al. (2019), and the discussion in Section 1). By contrast, for the e-book, the monopolistic supplier and E-retailer sign an agency contract that allows the supplier to set its retail price, p_e, at the E-retailer directly without worrying about the capacity of the book thanks to the unlimited capacity of the electronic format (Kreps and Scheinkman (1983) and the discussion in Section 1). These assumptions are consistent with the standard view on when price and quantity are strategic variables of firms (e.g., Kreps and Scheinkman (1983); Belleflamme and Peitz (2015), Section 3.3.3 on p. 67; Cabral (2017), Section 8.3 on pp. 200–201; Yang et al. (2018); Farahat et al. (2019)). From the assumptions, the competition mode in the retail market is the price-quantity competition (Singh and Vives (1984), Askar (2014), Bian et al. (2018, Section 3.3)). T-retailer and the supplier simultaneously determine q_t and p_e, respectively.

[15] The competition mode in their models (price competition) differs from ours (price-quantity competition).

To describe the price-quantity competition in the retail market, we use the demand system in the related papers (Singh and Vives (1984), Cai (2010), Askar (2014), Matsui (2017), Bian et al. (2018, Section 3.3), Fanti and Scrimitore (2019), Zhang and Zhang (2020), Zheng and Yu (2021)). The inverse demand functions for the paper book and the e-book are:

$$p_t = \alpha - q_t - \gamma q_e,$$
$$p_e = \alpha - q_e - \gamma q_t,$$

where $\alpha(> 0)$ is a positive constant and $\gamma \in (0, 1)$ is the degree of product substitutability between the two products. The demand system means that the product characteristics of the paper book and the e-book generate horizontal product differentiation (the first paragraph in Section 1).[16] We convert the demand system to meet the competition mode, the price-quantity competition (e.g., Askar, 2014; Bian et al., 2018, Section 3.3):[17]

$$\begin{aligned} q_e &= \alpha - p_e - \gamma q_t, && (1) \\ p_t &= \alpha - q_t - \gamma(\alpha - p_e - \gamma q_t) \\ &= (1-\gamma)\alpha - (1-\gamma^2) q_t + \gamma p_e. && (2) \end{aligned}$$

For analytical and notational simplicity, we assume that the market potentials for the two versions of the good (the constant terms α in the inverse demand functions) are symmetric and that their marginal costs are zero. In Section 4.5, we explain that those assumptions do not qualitatively affect the results of Section 4.

The monopolistic supplier transacts with T-retailer and E-retailer with a *wholesale contract* and an *agency contract*, respectively (e.g., Lu et al., 2018; Zennyo, 2020).[18] With a wholesale contract, the supplier determines its wholesale price, w_t, before T-retailer sets its sales quantity, q_t. With an agency contract, the supplier sets the retail price of the e-book, p_e, directly, and the supplier and E-retailer split sales revenues according to a royalty rate, r, that is determined in negotiation between them before the supplier

[16] If γ is close to zero (resp. one), the two versions are almost different (resp. homogeneous).

[17] Equation (2) in Askar (2014) contains a typo (the sign of the last term in the first line). Of course, the mathematical procedure is correct.

[18] Those papers consider endogenous choices of contract forms for E-retailers as in Hao and Fan (2014) and Abhishek et al. (2016).

determines w_t (and p_e). Concretely, the supplier pays r times its revenue earned via the E-retailer's channel to the E-retailer. The E-retailer's bargaining power over the supplier is $\beta \in (0, 1/2]$.[19] We formulate the bargaining problems in the subsequent sections. The timing for the royalty rate follows those in the related papers (e.g., Abhishek et al., 2016; Zennyo, 2019, 2020; Tsunoda and Zennyo, 2021). We believe that the assumptions on contract terms fit the reality where most publishers adopt wholesale contracts with brick-and-mortar bookstores, and those publishers adopt agency contracts with online retailers to sell e-books (see Dantas et al. (2014) and Gilbert (2015) who describe the pricing arrangements between publishers and retailers in book industries).[20]

From the discussions and equations (1) and (2), the profits of the supplier and the retailers are:

$$\begin{aligned} \pi_s &= w_t q_t + (1-r) p_e q_e = w_t q_t + (1-r) p_e (\alpha - p_e - \gamma q_t), \\ \pi_t &= (p_t - w_t) q_t = ((1-\gamma)\alpha - (1-\gamma^2) q_t + \gamma p_e - w_t) q_t, \\ \pi_e &= r\, p_e q_e = r\, p_e (\alpha - p_e - \gamma q_t), \end{aligned} \tag{3}$$

where the subscript s represents the supplier.

We define consumer surplus as:

$$CS \equiv \sum_{i=t,e} \left\{ \int_0^{q_i} (\alpha - x_i - \gamma q_j - p_i)\, dx_i \right\}, \tag{4}$$

where $j \neq i$, and social welfare is

$$SW \equiv CS + \pi_s + \pi_t + \pi_e. \tag{5}$$

Table 2 and Figure 1 summarize the problem description.

Under the market structure, we discuss the effect of the following self-regulation by the supplier: the price at E-retailer, p_e, must be higher than or equal to the wholesale

[19] We restrict the parameter range of β within $(0, 1/2]$ because the realized royalty rate under the range $(1/2, 1]$ is too high, which does not match the real-world royalty rates very closely.

[20] For instance, Amazon yearly enters Annual Vendor Negotiations with various vendors, including publishers (McLeod, 2018; The U.S. House of Representatives, 2019). In 2014, when the five famous publishers in the US (so-called the big five) changed the contract form from wholesale contracts to agency contracts with Amazon, two of the big five, Simon & Schuster and Hachette, initially engaged in negotiations with Amazon (Gilbert, 2015). Therefore, the bargaining scenario in our model reflects the reality. Jarsulic (2020) provides a useful comprehensive case study on the market power of platform monopolies.

Table 2: Notation and explanations

Notation	Description
q_t^j	The demand of traditional retailer (strategic variable), $j = \{A, B, C, D, R\}$
q_e^j	The demand of e-commerce platform/E-retailer
p_t^j	The retail price of traditional retailer
p_e^j	The retail price of E-retailer (strategic variable)
α	Market size (constant)
β	The bargaining power of E-retailer
γ	The degree of product substitutability
π_i^j	The profit of each player ($i = s, t, e$)
w_t^j	Wholesale price for traditional retailer (strategic variable)
w_e	Wholesale price for E-retailer (used only in Section 6)
r^j	The royalty rate for E-retailer (determined in negotiation)
O_s	The value of outside options for the supplier (defined in Section 4)
λ^j	The Lagrange multiplier (defined in Section 5)
CS	Consumer surplus (CS^R represents consumer surplus under supplier's self-regulation)
SW	Social welfare (SW^R represents social welfare under supplier's self-regulation)
Else	Superscript * denotes the equilibrium solution in the baseline model; superscript j represents different cases from the baseline model (used in Sections 5 and 6)

price for T-retailer, w_t; mathematically, $p_e \geq w_t$. The formulation of the self-regulation borrows the ideas of the remedy in the context of price/margin squeeze (see, e.g., Bouckaert and Verboven, 2004; Sidak, 2008; Jullien et al., 2014) and the price discount contracts investigated in Section 5.1 of Cai et al. (2009).[21]

We consider two games: (i) The game of the dual-channel supply chain without any self-regulation; (ii) the game of the dual-channel supply chain with self-regulation $p_e \geq w_t$. In both games, the timing is as follows.

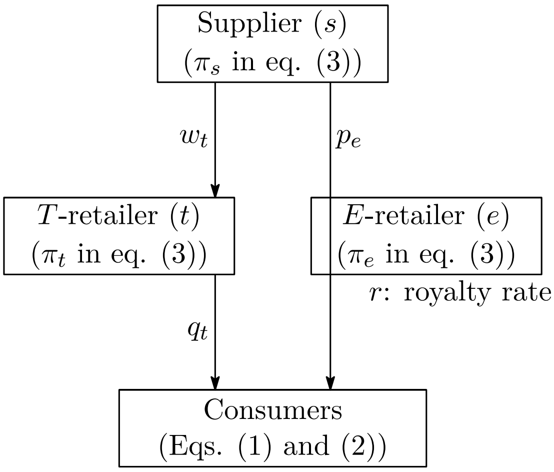
Stage 1. The supplier and E-retailer determine the royalty rate, r, through bargaining.

Stage 2. The supplier unilaterally sets a wholesale price, w_t, for T-retailer.

Stage 3. Observing the previous outcomes, T-retailer chooses the sales quantity, q_t, and the supplier chooses the price of the e-book, p_e, simultaneously.

We solve each game by backward induction. We have a remark on the assumption. Contract observability does not matter (we explain the reason for this in Section 4.1).

[21] Cai et al. (2009) also discuss different types of constrained pricing in Section 4.



Note: The arrows show the directions of the offers.

Figure 1: The market structure

4 Analysis

In this section, we analyze the game of the dual-channel supply chain without any self-regulation (hereafter, the baseline model).

4.1 Stage 3

To begin with, we derive the results of Stage 3. In this stage, T-retailer sets q_t and the supplier sets p_e simultaneously. They maximize their profits expressed in (3) given the wholesale price, w_t, and the royalty rate, r. The first-order conditions of T-retailer and the supplier are:

$$\frac{\partial \pi_t}{\partial q_t} = (1-\gamma)\alpha + \gamma p_e - 2(1-\gamma^2)q_t - w_t = 0, \quad \frac{\partial \pi_s}{\partial p_e} = (1-r)(\alpha - \gamma q_t - 2p_e) = 0. \quad (6)$$

$\partial \pi_s / \partial p_e$ in (6) provides three remarks on the pricing of the supplier. First, it does not internalize the profit through the wholesale price w_t, leading to fiercer competition in the downstream market. The discrepancy between the internalization and the first-order condition stems from the price-quantity competition discussed here.[22] If the strategic variable of T-retailer is also price (say p_t), T-retailer's quantity is a function of p_t and p_e (say $q_t(p_t, p_e)$), and then the supplier indirectly takes into account the wholesale profit, $w_t q_t(p_t, p_e)$, mitigating the discrepancy (we discuss this in Section 6). Second, the supplier

[22] This effect in itself is not new. Such a discrepancy occurs in the context of licensing under quantity competition (see, e.g., Faulí-Oller and Sandonís (2002), p. 195).

does not care about the royalty rate, r. As the royalty rate increases, the discrepancy mentioned above becomes serious. Third, the second remark implies that T-retailer need not know the realized r when it sets its quantity. Because both T-retailer and the supplier know w_t, our model does not have the matter of contract observability.

From (6), we obtain the optimal quantity and price:

$$q_t(w_t) = \frac{\alpha(2-\gamma) - 2w_t}{4-3\gamma^2}, \quad p_e(w_t) = \frac{\alpha\left(2-\gamma-\gamma^2\right) + \gamma w_t}{4-3\gamma^2}. \tag{7}$$

We can check that $\partial q_t(w_t)/\partial w_t < 0$ and $\partial p_e(w_t)/\partial w_t > 0$; that is, when the wholesale price of the paper book increases, T-retailer reduces its sales quantity of the paper book and the supplier raises its retail price for the e-book. Therefore, the supplier can intensify or weaken the retail competition by adjusting the wholesale price.

4.2 Stage 2

In Stage 2, given the quantity and price in (7), the supplier chooses the optimal w_t that maximizes its profit. The supplier tries to balance the wholesale revenue of the paper book and the sales revenue of the e-book.[23] The optimal wholesale price is:

$$w_t(r) = \frac{\alpha\left\{8 - 4r\gamma - 2(4-r)\gamma^2 + (1+2r)\gamma^3\right\}}{2\left\{8-\gamma^2(7-r)\right\}}. \tag{8}$$

From (8), it is straightforward that $\partial w_t(r)/\partial r < 0$. If, for example, the supplier's share of the e-book's revenue decreases, the supplier places weight on the wholesale revenue of the paper book and lowers the wholesale price to strengthen T-retailer's competitiveness.

Regarding the contract form, although we believe that assuming the nature of the wholesale contract is reasonable given real-world practices in the book industry (see, e.g., Dantas et al., 2014; Gilbert, 2015), it is reasonable to question what happens if the supplier employs a two-part tariff contract. Even under a two-part tariff contract, the supplier cannot set a low wholesale price to internalize the profit of T-retailer because such a low price unnecessarily intensifies the downstream competition in the third stage. Although the wholesale price under the two-part tariff contract is lower than that under the wholesale contract, the former wholesale price can be higher than the equilibrium retail price of E-

[23] This trade-off between the two sources of revenue is similar to that of vertically integrated producers who consider both wholesale revenue from independent retailers and sales revenue of their integrated retailers (see, e.g., Arya et al., 2008; Arya and Mittendorf, 2018).

retailer under the two-part tariff contract for some parameter range.

4.3 Stage 1

In Stage 1, based on their expectations of the results in the subsequent stages, the supplier and E-retailer negotiate over the royalty rate, r. We employ Nash bargaining to derive the negotiation outcome, following the formulations in the related papers on supply chain issues (e.g., Choi and Guo, 2020; Choi, 2020; Matsui, 2020, 2021).[24] For simplicity, we assume that E-retailer has no outside options. However, we assume that, if the negotiation breaks down, the supplier sells the paper book only through T-retailer. At that time, the supplier sets $w_t^o = \alpha/2$ and T-retailer chooses $q_t^o = \alpha/4$, where the superscript o indicates the case in which the supplier executes its outside option. Therefore, the disagreement profit of the supplier is:

$$O_s = \frac{\alpha^2}{8}. \tag{9}$$

The equilibrium royalty rate, r^*, solves the following problem:

$$\max_r \; [\pi_s(r) - O_s]^{1-\beta}[\pi_e(r)]^{\beta}, \quad \text{where} \tag{10}$$

$$\pi_s(r) = \frac{\alpha^2\left\{12 - 8\gamma - 3\gamma^2 - 4\left(2-\gamma-\gamma^2\right)r\right\}}{4\left\{8-(7-r)\gamma^2\right\}}, \quad \pi_e(r) = \frac{\alpha^2\left(8-2\gamma-5\gamma^2\right)^2 r}{4\left\{8-(7-r)\gamma^2\right\}^2}. \tag{11}$$

Solving the problem in (10), we obtain the equilibrium royalty rate:

Proposition 1 *In equilibrium, as a result of their Nash bargaining, the supplier and E-retailer set the royalty rate as:*

$$r^* = \frac{1}{\beta\gamma^2\left(16-8\gamma-7\gamma^2\right)}\Big\{(8-2\gamma-5\gamma^2)^2 - \sqrt{(8-2\gamma-5\gamma^2)^4 - \beta^2\gamma^2(16-8\gamma-7\gamma^2)(16-16\gamma+\gamma^2)(8-7\gamma^2)}\Big\}, \tag{12}$$

where the superscript "$*$" represents the equilibrium outcome in the baseline model. Figure 2 shows the royalty rates in the three cases ($\beta = 1/6, 1/3, 1/2$). Given the equilibrium royalty rate r^* under β, if the degree of product substitutability is moderate (around $\gamma = 0.5$), β around $1/3$ approximates the actual real-world royalty rate for e-books (e.g.,

[24] Matsui (2020) explains the theoretical foundation of using Nash bargaining in noncooperative games.

30% in Amazon). This might imply that publishers have reasonably strong bargaining power over online retailers thanks to the copyrights.

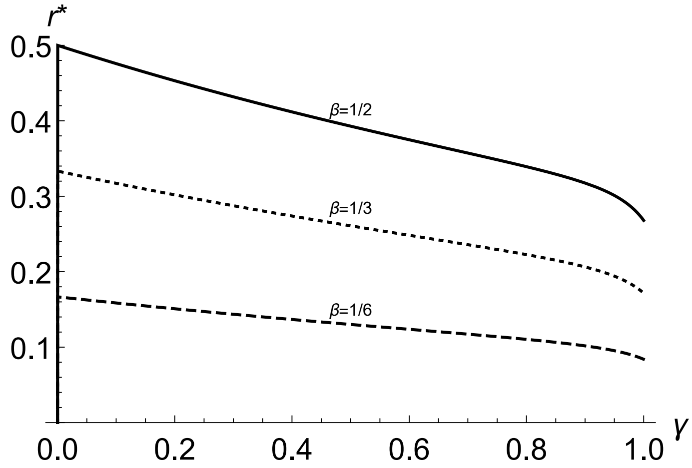


Figure 2: Equilibrium royalty rates ($\beta = 1/6, \beta = 1/3, \beta = 1/2$)

We obtain the equilibrium profit of the supplier, that of T-retailer, and that of E-retailer, π_s^*, π_t^*, and π_e^*, respectively. The other variables such as q_i^*, p_i^* for $i = t, e$, and w_t^* are also derived and shown in Table 3 in the Appendix.

The simple but tedious partial derivatives of r^* with respect to β and γ, respectively, lead to $\partial r^*/\partial\beta > 0$ and $\partial r^*/\partial\gamma < 0$ for any $\beta \in (0, 1/2]$ and $\gamma \in [0, 1)$. The former outcome is intuitive in that the stronger bargaining power of E-retailer leads to its higher profit share. We explain the latter outcome. The royalty rate r is based on the additional contribution of E-retailer, which is related to the two channels' relative profitability. An increase in γ has two contrasting effects: (i) intensifying retail competition, which diminishes E-retailer's profitability, and (ii) enhancing the direct channel advantage of E-retailer because of the nonexistence of double marginalization. The mixture of the two effects determines the sign of $\partial r^*/\partial\gamma$. When β is less than $1/2$, the first effect dominates the latter one, then $\partial r^*/\partial\gamma < 0$.

A simple comparison between p_e^* and w_t^* leads to Proposition 2:

Proposition 2 *In the equilibrium of the baseline model, the supplier sets the retail price of the e-book below the wholesale price of the paper book depending on* β *and* γ*, that is,*

$p_e^* < w_t^*$, *if and only if*

$$\begin{cases} 0 < \beta < \bar{\beta} \text{ and } 0 < \gamma < 1, \text{ or} \\ \bar{\beta} < \beta \leq \dfrac{12}{37} \text{ and } 0 < \gamma < \gamma_1(\beta),\ \gamma_2(\beta) < \gamma < 1, \text{or} \\ \dfrac{12}{37} < \beta < \dfrac{1}{2} \text{ and } 0 < \gamma < \gamma_1(\beta), \end{cases} \tag{13}$$

where $\bar{\beta} \simeq 0.306$*, and* $\gamma_1(\beta)$ *and* $\gamma_2(\beta)$ *are the first and the second root of* $128 - 256\beta - (32 + 64\beta)\gamma - (112 - 216\beta)\gamma^2 + (8 + 74\beta)\gamma^3 + (20 - 7\beta)\gamma^4$.

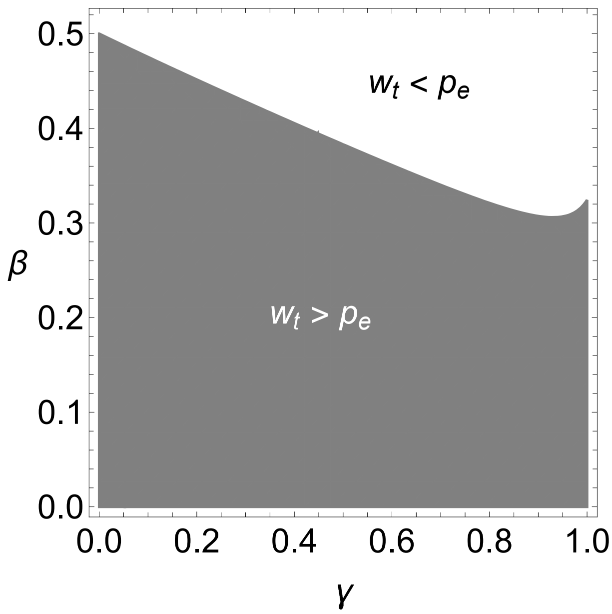


Figure 3: Parameter ranges where the supplier uses *below-wholesale-price retail pricing*

The supplier implements *below-wholesale-price retail pricing* when the parameters γ and β are in the shaded area in Figure 3. A small value of β means that the supplier's bargaining power over E-retailer is strong; therefore, $(1 - r^*)$ is large. At that time, the supplier prioritizes the sales revenue of the e-book, $(1-r^*)p_e q_e$, over the wholesale revenue of the paper book, $w_t q_t$; the supplier tries to soften the retail competition and earn larger sales revenue from the e-book by raising w_t and p_e. To sell the e-book well, the increase in p_e is moderate compared with that in w_t. Therefore, w_t^* exceeds p_e^* when β is small.

4.4 Effects of countervailing power

To take a more in-depth look at the equilibrium characteristics of the baseline model, we analyze how a change in β affects the equilibrium results in this subsection. Checking the simple comparative statics for each equilibrium outcome, we derive the following proposition (we omit the proof).

Proposition 3 *An increase in E-retailer's bargaining power lowers the retail price of the e-book. Moreover, this increases the profits of T-retailer and E-retailer, the consumer surplus, and the social surplus; however, it reduces the supplier's profit. Specifically,*

$$\frac{\partial p_e^*}{\partial \beta} < 0, \ \frac{\partial w_t^*}{\partial \beta} < 0, \ \frac{\partial \pi_t^*}{\partial \beta} > 0, \ \frac{\partial \pi_e^*}{\partial \beta} > 0, \ \frac{\partial \pi_s^*}{\partial \beta} < 0, \ \frac{\partial CS^*}{\partial \beta} > 0, \ \frac{\partial SW^*}{\partial \beta} > 0. \tag{14}$$

First, we can confirm that E-retailer's bargaining power leads to a lower retail price in our model. Second, it may be more surprising that T-retailer improves its profit from an increase in E-retailer's bargaining power. These two effects arise from the supplier's reaction to an increase in β. When β increases, the supplier places more weight on the wholesale revenue of the paper book over the retail revenue of the e-book. As a result, the supplier lowers w_t, inducing a low p_e; that is, $\partial p_e^*/\partial \beta < 0$ and $\partial w_t^*/\partial \beta < 0$.[25] Even though the retail price of the paper book, p_t, also decreases, both $(p_t - w_t)$ and q_t increase. Consequently, T-retailer can earn more profit when E-retailer's bargaining power becomes strong. This complementarity between T-retailer and E-retailer might be related to the recent empirical finding in Li (2021), who points out the complementarity between the offline print channel and the e-channel on the supply side.

As an aside, in addition to the supplier's profit, total sales of the e-book decrease in β, specifically, $\partial p_e^* q_e^*/\partial \beta < 0$. In our model, an increase in E-retailer's bargaining power does not promote e-book sales but rather suppresses e-book sales because, for its profit, the supplier comes to depend more on the wholesale revenue of the paper book when β becomes large.

Decreases in p_e^* and w_t^* through an increase in β improve the consumer and social surplus.

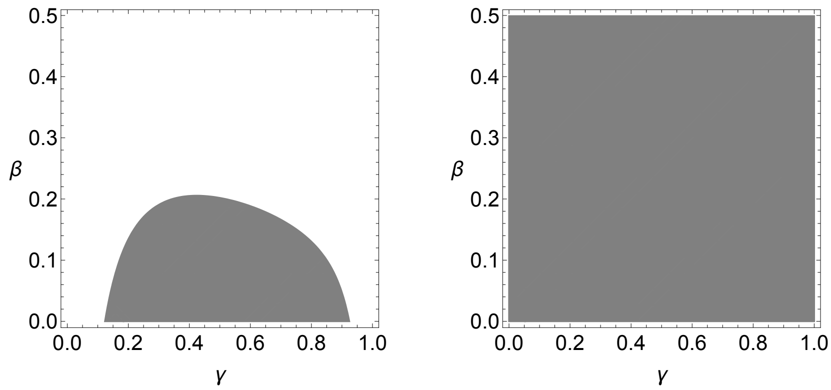
4.5 Heterogeneous market potentials

We discuss how the heterogeneity of market potentials and marginal costs of the two content formats influences the results in this section. The demand system is: $p_t = (1 +$

[25] This mechanism is very similar to those revealed in Chen (2003) and Matsushima and Yoshida (2018). In their papers, a supplier, which deals with a dominant retailer and fringe retailers under wholesale contracts, responds to an increase in the dominant retailer's bargaining power by lowering the wholesale price for fringe retailers to boost its sales through the fringe retailers.

$b)\alpha - q_t - \gamma q_e$ and $p_e = \alpha - q_e - \gamma q_t$, where $b(>0)$ is the market potential advantage of the paper book over the e-book. Furthermore, we incorporate the supplier's marginal cost of the paper book $c_t(>0)$ into the baseline model with the modified demand system.

In the modified model, we can summarize the additional components into the difference $\eta \equiv b\alpha - c_t$, which affects the profitability of the firms.[26] On the one hand, given the consumers' strong preference for paper books in the real world (see the first paragraph in Section 1), the market potential for the paper book (the constant term $(1+b)\alpha$ for the paper book) is higher than that for the e-book. On the other hand, the marginal cost of producing one unit of paper books is higher than that of e-books. If the former effect dominates (is dominated by) the latter one, an equilibrium wholesale price is more (less) likely to be higher than an equilibrium supplier's retail price. In other words, as the value of η increases, the price of the e-book is more likely to be lower than the wholesale price of the paper book.



$\eta = -0.025$ $\eta = 0.025$

Figure 4: Parameter ranges where $(w_t^* - c_t) - p_e^* > 0$

We calculate $(w_t^* - c_t) - p_e^*$ in the modified model.[27] If this difference is positive, $p_e^* < w_t^*$. We can numerically show that $(w_t^* - c_t) - p_e^* > 0$ if $\eta \geq 0$ and $\beta < 0.305$. The shaded areas in Figure 4 show the parameter regions in which $(w_t^* - c_t) - p_e^* > 0$ for $\eta = -0.025$ and $\eta = 0.025$ under $\alpha = 1$. Figure 4 shows that this inequality is more likely to hold as η becomes larger. We can conclude that the result here is qualitatively similar to that in Proposition 2 when the paper book is advantageous over the e-book (when $\eta \geq 0$).

[26] The mathematical procedure is available in the Supplementary Appendix.

[27] We include c_t to make the numerical calculation work well. If the difference is positive, the inequality $w_t^* - p_e^* > 0$ also holds because $c_t > 0$.

We also obtain outcomes qualitatively similar to those in Proposition 3 when $\eta \geq 0$. Moreover, except for the sign of $\partial\pi_t/\partial\beta$ when $\eta < 0$, the outcomes of comparative statics in Proposition 3 hold even for $-1/10 \leq \eta \leq 0$ under $\alpha = 1$.

5 Self-regulation on below-wholesale-price retail pricing

Proposition 2 in the previous section shows the possibility that the wholesale price for T-retailer is higher than the retail price of E-retailer even if we have assumed that the marginal costs of the two books are zero.

In this section, we consider a simple way to escape the imbalance between the wholesale price for T-retailer and the retail price of E-retailer by following the insights in the context of price/margin squeeze (Bouckaert and Verboven, 2004; Jullien et al., 2014) and the price-matching policy in Cai et al. (2009).

We impose the following self-regulation regarding w_t and p_e on the supplier: $w_t \leq p_e$, which prevents the supplier from setting w_t that is higher than p_e. We derive new equilibrium results with this self-regulation and compare them with those of the baseline model.

In the same vein as the baseline model, we derive a subgame perfect Nash equilibrium of the self-regulation case by backward induction. Therefore, at first, we solve the retail competition in Stage 3.

5.1 Stage 3 with self-regulation

The maximization problems of T-retailer and the self-regulated supplier in Stage 3 are:

$$\max_{q_t} \ \pi_t = (p_t - w_t)q_t, \quad \max_{p_e} \ \tilde{\pi}_s = w_t q_t + (1-r)p_e q_e + \lambda(p_e - w_t), \tag{15}$$

where $\lambda \geq 0$ is a Lagrange multiplier. The first-order conditions are:

$$\begin{aligned} \frac{\partial \pi_t}{\partial q_t} &= (1-\gamma)\alpha + \gamma p_e - 2(1-\gamma^2)q_t - w_t = 0, \\ \frac{\partial \tilde{\pi}_s}{\partial p_e} &= (1-r)(\alpha - \gamma q_t - 2p_e) + \lambda = 0. \end{aligned} \tag{16}$$

From equation (16), we obtain the optimal retail quantity and price and the condition that the constraint, $w_t \leq p_e$, is binding. The constraint is binding if and only if:

$$\lambda = \frac{(1-r)(-\alpha(2+\gamma)+(4+3\gamma)w_t)}{2(1+r)} > 0,$$

in other words, if and only if

$$w_t > \frac{(2+\gamma)\alpha}{4+3\gamma}. \tag{17}$$

5.2 Stage 2 with self-regulation

Following the outcome in (17), we consider two cases in Stage 2: (Case A) $w_t > (2+\gamma)\alpha/(4+3\gamma)$ (the constraint in Stage 3 is binding); (Case B) $w_t \leq (2+\gamma)\alpha/(4+3\gamma)$ (the constraint in Stage 3 is not binding).

Case A ($w_t > (2+\gamma)\alpha/(4+3\gamma)$) In this case, the optimal retail quantity and price are:

$$\begin{aligned} q_t^A(w_t) &= \frac{\alpha - w_t}{2(1+\gamma)}, \\ p_e^A(w_t) &= w_t. \end{aligned} \tag{18}$$

Taking the quantity and the price as given, the supplier sets w_t to maximize its profit subject to the constraint (17). The supplier solves the following maximization problem:

$$\max_{w_t} \ \pi_s(q_t^A(w_t), p_e^A(w_t)) + \lambda^A \left(w_t - \frac{(2+\gamma)\alpha}{4+3\gamma} \right), \tag{19}$$

where $\lambda^A \geq 0$. The optimal wholesale price and the Lagrange multiplier in this case are:

$$\begin{aligned} w_t^A &= \frac{\alpha}{2}, \\ \lambda^A &= 0. \end{aligned} \tag{20}$$

We find that this w_t^A is greater than the lower bound of (17), $(2+\gamma)\alpha/(4+3\gamma)$.

Case B ($w_t \leq (2+\gamma)\alpha/(4+3\gamma)$) When $w_t \leq (2+\gamma)\alpha/(4+3\gamma)$, the constraint in Stage 3, $w_t \leq p_e$, is not binding. The optimal retail quantity and price are derived by substituting $\lambda = 0$ into the first-order conditions in equation (16):

$$\begin{aligned} q_t^B(w_t) &= \frac{(2-\gamma)\alpha - 2w_t}{4-3\gamma^2}, \\ p_e^B(w_t) &= \frac{(2-\gamma-\gamma^2)\alpha + \gamma w_t}{4-3\gamma^2}. \end{aligned} \tag{21}$$

Given the quantity and the price, the supplier solves the following problem:

$$\max_{w_t} \ \pi_s(q_t^B(w_t), p_e^B(w_t)) + \lambda^B \left(\frac{(2+\gamma)\alpha}{4+3\gamma} - w_t \right), \tag{22}$$

where $\lambda^B \geq 0$. We can obtain both a corner solution and an interior solution in this case. The supplier chooses the corner solution ($w_t = (2+\gamma)\alpha/(4+3\gamma)$ and $\lambda^B > 0$) when $0 \leq r < (2-\gamma)/(4+2\gamma)$, and the interior solution ($w_t < (2+\gamma)\alpha/(4+3\gamma)$ and $\lambda^B = 0$) when $(2-\gamma)/(4+2\gamma) \leq r < 1$. However, the former corner solution is dominated by the outcome of Case A from the viewpoint of the supplier's profit. Therefore, we show only the optimal wholesale price and the Lagrange multiplier of the latter. They are:

$$\begin{aligned} w_t^B &= \frac{\alpha\left\{8 - 4r\gamma - 2(4-r)\gamma^2 + (1+2r)\gamma^3\right\}}{2\left\{8 - \gamma^2(7-r)\right\}}, \\ \lambda^B &= 0. \end{aligned} \tag{23}$$

Note that this w_t^B is consistent with that in the baseline model without self-regulation.

Comparison of the profits under Cases A and B We can now compare the supplier's profit under Cases A and B: $\pi_s(q_t^A(w_t^A), p_e^A(w_t^A))$ and $\pi_s(q_t^B(w_t^B), p_e^B(w_t^B))$. We find that the former is larger (smaller) than the latter if and only if the royalty rate, r, is smaller (larger) than $(1+\sqrt{9-4\gamma-4\gamma^2})/2(2+\gamma)$. Moreover, the threshold value under this condition is higher than $(2-\gamma)/(4+2\gamma)$. To sum up, we derive the following subgame equilibrium:

$$\begin{cases} w_t = w_t^A & \text{if } \ 0 < r \leq \dfrac{1+\sqrt{9-4\gamma-4\gamma^2}}{2(2+\gamma)} \\ w_t = w_t^B & \text{if } \ \dfrac{1+\sqrt{9-4\gamma-4\gamma^2}}{2(2+\gamma)} < r. \end{cases} \tag{24}$$

5.3 Stage 1 with self-regulation

We move on to Stage 1, the bargaining stage. We have assumed that $\beta \leq 1/2$ to focus on realistic equilibrium outcomes. In the Appendix, we show that the Nash product in (10) is maximized at a royalty rate that leads the supplier to set w_t^A in the following subgame. The equilibrium is as follows:

Proposition 4 *When the supplier imposes self-regulation, $w_t \leq p_e$, and when $\beta \in (0, 1/2]$, then the supplier and E-retailer choose the royalty rate $r^R = 2\beta/(2+\gamma)$. The supplier sets $w_t^R = \alpha/2$ and the constraint is binding, $p_e^R = w_t^R = \alpha/2$. The quantities are*

$q_e^R = (2+\gamma)\alpha/(4(1+\gamma))$ *and* $q_t^R = \alpha/(4(1+\gamma))$.

The superscript "R" represents the equilibrium outcome in the self-regulated supplier case.

We also obtain the equilibrium profit of the supplier, that of T-retailer, and that of E-retailer, π_s^R, π_t^R, and π_e^R, respectively (see Table 3 in the Appendix).

As in Section 4.4, we conduct comparative statics. Except for π_s^R and π_e^R, the outcomes are independent of β (Proposition 4). We find that $\partial\pi_s^R/\partial\beta < 0$ and $\partial\pi_e^R/\partial\beta > 0$ as in Proposition 3.

5.4 Comparison of the results with and without self-regulation

By comparing the royalty rate and the prices in Section 5 with those of the baseline model, we derive the following proposition (we omit the proof because of the simple comparisons).

Proposition 5 *In the equilibrium of the self-regulated supplier case with* $\beta \in (0, 1/2]$, *for* $\gamma \in (0, 1)$,

- *the royalty rate with self-regulation,* r^R, *is always higher than that of the baseline model,* r^*, *and the difference,* $r^R - r^*$, *increases as* γ *increases;*
- *the wholesale price with self-regulation,* w_t^R, *is higher than that of the baseline model,* w_t^**;*
- *the retail prices with self-regulation,* p_e^R *and* p_t^R, *are also higher than those of the baseline model,* p_e^* *and* p_t^*.

Specifically, for $\gamma \in (0, 1)$ *and* $\beta \in (0, 1/2]$,

$$r^R > r^*, \; w_t^R > w_t^*, \; p_e^R > p_e^*, \; p_t^R > p_t^*. \tag{25}$$

Figure 5 shows a graphical comparison between the royalty rates in the baseline and self-regulation cases.

Proposition 5 states that self-regulation, which seemingly lowers the wholesale price w_t, has anticompetitive effects on the retail competition. The supplier anticipates the expected outcome of Stage 3, in which the wholesale price set in Stage 2 is the lower bound of its retail price set in Stage 3. Setting a higher wholesale price allows the supplier to commit itself to setting a high retail price of the e-book in Stage 3.

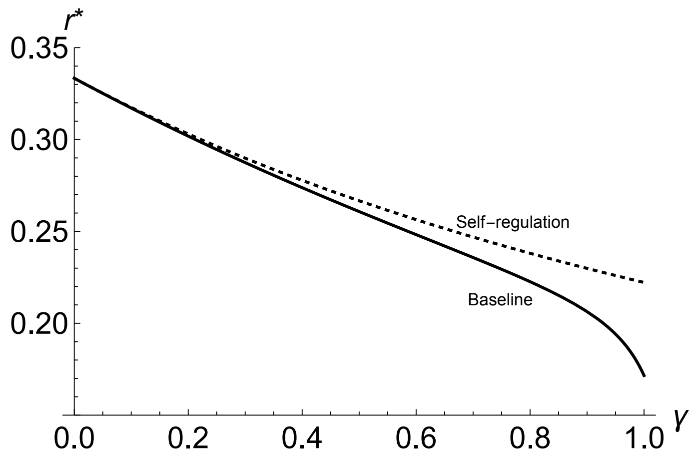


Figure 5: Equilibrium royalty rates in the two cases ($\beta = 1/3$)

Furthermore, the royalty rate under self-regulation becomes higher than that in the baseline model as the degree of product substitution γ increases. The reason is that the relative profitability of T-retailer shrinks because of the higher wholesale prices, giving E-retailer a better bargaining position over the supplier. This profit shrinkage of T-retailer is higher when the downstream competition is effective; in other words, when γ is higher.

We check the effects of self-regulation on the firms' profits. Comparing π_e^*, π_t^*, and π_s^* with π_e^R, π_t^R, and π_s^R, respectively, we have (we omit the proof because of the simple comparisons):

Proposition 6 *When $\beta \in (0, 1/2]$, the supplier's self-regulation, $w_t \leq p_e$,*

- *always increases the profit of E-retailer;*
- *increases the profit of T-retailer iff $0 < \gamma < 1$ and $0 < \beta < \beta_1(\gamma)$;*
- *increases the profit of the supplier iff $0 < \gamma \leq \tilde{\gamma}$, where $\tilde{\gamma} \simeq 0.631$, or $\tilde{\gamma} < \gamma < 1$ and $0 < \beta < \beta_2(\gamma)$;*

where

$$\begin{aligned} \beta_1(\gamma) &= \frac{32\gamma + 16\gamma^2 - 26\gamma^3 - 15\gamma^4}{128 + 96\gamma - 120\gamma^2 - 86\gamma^3 + 7\gamma^4}, \\ \beta_2(\gamma) &= \frac{1}{2}\sqrt{\frac{16 - 8\gamma - 21\gamma^2 + 6\gamma^3 + 7\gamma^4}{8 - 7\gamma^2}}. \end{aligned} \tag{26}$$

From Proposition 6, the impact of self-regulation on E-retailer is clear. The self-regulated supplier can commit to setting a higher p_e when it sets a higher w_t. The supplier controls the competitive environment in the downstream market by setting a higher w_t, which leads to a weaker competitive position of T-retailer. Furthermore, the weaker competitive position of T-retailer increases the royalty rate r, which is significant when γ is high. As a result, self-regulation benefits E-retailer.

However, the impact of self-regulation on T-retailer and the supplier depends on the degree of product substitution γ. In the baseline model, the higher the degree of product substitution γ, the lower the royalty rate r, which increases the supplier's profitability from E-retailer. As a result, the supplier's incentive to weaken T-retailer becomes stronger as γ increases. The negative effect on T-retailer is stronger when the bargaining power of E-retailer is weaker because the supplier's profitability from E-retailer is higher. Self-regulation limits such an incentive of the supplier, benefiting T-retailer. The benefit dominates the cost of a high w_t if the bargaining power of E-retailer is sufficiently weak and the degree of product substitution is high (see the south-east area in the left-hand side of Figure 6). For the supplier, the increase in the royalty rate diminishes the positive effect of self-regulation on its profit. The higher the value of γ, the larger the increment of the royalty rate through self-regulation, completely offsetting the benefit of self-regulation (see the north-east area in the right-hand side of Figure 6). Figure 6 illustrates the ambiguous impact of self-regulation on the profits of T-retailer and the supplier.

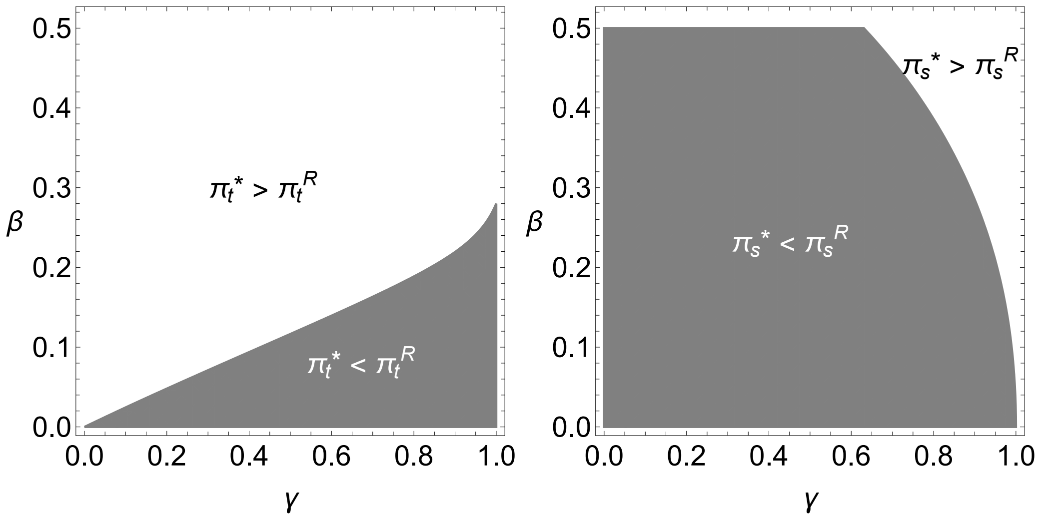


Figure 6: Effects of self-regulation on T-retailer's profit (left panel) and on the supplier's profit (right panel)

Our results provide an important managerial implication for content suppliers. Our model fits the distribution problems in the copyrighted content industries, including books, games, movies, and music.[28] We expect that a content supplier's bargaining power over

[28] For example, Capcom Co., Ltd. (2020, p.69) describes recent market trends and forecasts for the game

online retailers is stronger as the originality/uniqueness of its content is higher. Our theoretical model shows that self-regulation benefits all firms if the online retailer's bargaining power is sufficiently weak and the product substitutability between the two contents is not sufficiently high; in other words, if the royalty rate is sufficiently low and the two contents are moderately differentiated. The suppliers/providers of content with high originality can commit to the self-regulation discussed here without causing complaints by brick-and-mortar retailers. However, if content suppliers/providers do not have content with high originality, imposing the pricing constraint can cause conflicts with brick-and-mortar retailers because the constraint harms those retailers. In sum, the bargaining power of content suppliers/providers is a key factor in determining whether the pricing constraint discussed here is feasible.

5.5 Welfare analysis

Finally, we examine the effect of self-regulation on social welfare and consumer surplus. Before checking the welfare effect, we examine the effect on industry profits (the producer surplus) and show the following result (we omit the proof because of the simple comparison).

Proposition 7 *When $\beta \in (0, 1/2]$, the supplier's self-regulation, $w_t \le p_e$, increases industry profits when the degree of substitution is relatively high and the E-retailer's bargaining power over the supplier is relatively low, which is illustrated in Figure 7.*

Propositions 6 and 7 jointly demonstrate the profitability of self-regulation for the three firms and the producers' surplus. There is a parameter area in which self-regulation benefits all firms.

Comparing the consumer and social surpluses of the baseline model with those of the self-regulated supplier case, we have (we omit the proof because of the simple comparisons):

Proposition 8 *When $\beta \in (0, 1/2]$, the supplier's self-regulation, $w_t \le p_e$, decreases both consumer surplus and social welfare, that is, for $\gamma \in (0, 1)$,*

$$CS^* > CS^R, \quad SW^* > SW^R. \tag{27}$$

industry. The sales volumes of the mobile content and PC online markets globally are \$92.0 billion and \$38.4 billion (US), respectively, whereas that of the consumer (package + digital) market, which is the market for traditional home video game consoles, is \$35.1 billion (US). Online content dominates offline, contrary to the book industry.

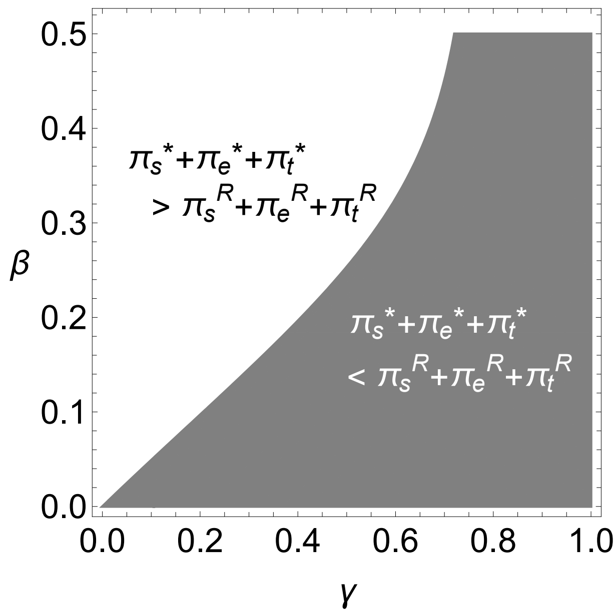


Figure 7: Effect of self-regulation on the industry profits

In addition to the increases in the retail prices, the retail quantities are lower for most values of γ. Therefore, self-regulation reduces the consumer surplus. Moreover, even though self-regulation can increase industry profits, it decreases social welfare for all γ.

Proposition 8 cautions the supplier to impose the price constraint, which may cause concern on competition policy if the competition authority follows our welfare analysis. Proposition 8 stems from the price-quantity competition, which captures competition modes in the content industries. Therefore, given that content suppliers employ the pricing constraint discussed here, if the competition authority recognizes that capacity constraints of the traditional retailers influence their pricing policies, it might apply our results to the conduct of the content suppliers. This concern is also a factor in determining whether implementing the pricing constraint discussed here is feasible.

In the Appendix (Section 8.4), we numerically confirm the propositions in the main text.

6 Retailers compete in price

We develop a modified model in which the two retailers compete in price instead of the price-quantity competition to clarify the importance of considering the price-quantity competition. Concretely, self-regulation, in which the supplier does not use below-wholesale-price retail pricing ($w_t \leq p_e$), does not have any effect on the outcome in the modified model, when we introduce price competition into the retail market. To examine the result, we solve the self-regulation case with price competition and show that the constraint is not binding, $w_t < p_e$, in equilibrium.

The maximization problems of T-retailer and the self-regulated supplier in the retail pricing stage are:

$$\max_{p_t} \ \pi_t = (p_t - w_t)q_t, \quad \max_{p_e} \ \tilde{\pi}_s = w_t q_t + (1-r)p_e q_e + \lambda(p_e - w_t), \tag{28}$$

where $\lambda \geq 0$ is a Lagrange multiplier. The first-order conditions are:

$$\begin{aligned} \frac{\partial \pi_t}{\partial p_t} &= \frac{\alpha(1-\gamma) - 2p_t + \gamma p_e + w_t}{1-\gamma^2} = 0, \\ \frac{\partial \tilde{\pi}_s}{\partial p_e} &= \frac{(1-r)\{\alpha(1-\gamma) - 2p_e + \gamma p_t\} + \gamma w_t}{1-\gamma^2} + \lambda = 0. \end{aligned} \tag{29}$$

Note that the supplier internalizes the wholesale revenue contrary to the price-quantity model; the supplier's first-order condition includes w_t, whereas it is not included in equation (6). This consideration for the wholesale revenue in the retail pricing stage differs from the supplier's pricing in the baseline model, and it increases the retail price of the E-retailer.[29] From equation (29), we obtain optimal retail prices, and the condition for the constraint, $w_t \leq p_e$, is binding. The constraint is binding if and only if:

$$\lambda = \frac{-\alpha(2-\gamma-\gamma^2)(1-r) + \{4 - 3\gamma - \gamma^2 - (4-\gamma-\gamma^2)r\}w_t}{2(1-\gamma^2)} > 0; \tag{30}$$

in other words, if and only if

$$\begin{aligned} 0 < r &\leq \frac{4-3\gamma-\gamma^2}{4-\gamma-\gamma^2} \equiv \bar{r}, \ \textit{and} \\ w_t &\geq \frac{\alpha(2-\gamma-\gamma^2)(1-r)}{4-3\gamma-\gamma^2-(4-\gamma-\gamma^2)r} \equiv \bar{w}_t. \end{aligned} \tag{31}$$

In Stage 2, we consider two cases: (Case C) $w_t \geq \bar{w}_t$ and $r \leq \bar{r}$ (the constraint in Stage 3 is binding); (Case D) $w_t \leq \bar{w}_t$ or $r > \bar{r}$.

[29] From equation (6), T-retailer's reaction function in the baseline case is $q_t(p_e) = \{(1-\gamma)\alpha + \gamma p_e - w_t\}/2(1-\gamma^2)$, and we can see that $\partial w_t q_t(p_e)/\partial p_e > 0$ for all $\gamma \in (0,1)$. Therefore, the lack of consideration for the wholesale revenue makes the supplier more aggressive and decreases p_e to less than the optimal level for the supplier who cares about the wholesale revenue.

Case C ($w_t \geq \bar{w}_t$ and $r \leq \bar{r}$) In this case, the optimal retail prices are:

$$\begin{aligned} p_t^C(w_t) &= \frac{\alpha(1-\gamma)+(1+\gamma)w_t}{2}, \\ p_e^C(w_t) &= w_t. \end{aligned} \tag{32}$$

Taking these prices as given, the supplier sets w_t to maximize its profit subject to the constraint (31); the supplier solves the following maximization problem:

$$\max_{w_t} \ \pi_s(p_t^C(w_t), p_e^C(w_t)) + \lambda^C (w_t - \bar{w}_t), \tag{33}$$

where $\lambda^C \geq 0$. Then, the optimal wholesale price and the Lagrange multiplier are:

$$\begin{aligned} w_t^C &= \frac{\alpha(2-\gamma-\gamma^2)(1-r)}{4-3\gamma-\gamma^2-(4-\gamma-\gamma^2)r} = \bar{w}_t, \\ \lambda^C &= \frac{\alpha\gamma\{1-\gamma+r(1+\gamma)\}\{3+\gamma-r(2+\gamma)\}}{2(1+\gamma)\{4-3\gamma-\gamma^2-(4-\gamma-\gamma^2)r\}}. \end{aligned} \tag{34}$$

We can also check that λ^C is always positive for any $r \in (0, \bar{r}]$. In the range $w_t \geq \bar{w}_t$, if $r \leq \bar{r}$, $w_t = \bar{w}_t$ is optimal in Stage 2, otherwise ($r > \bar{r}$), Case C is not sustainable.

Case D ($w_t \leq \bar{w}_t$ or $r > \bar{r}$) When $w_t \leq \bar{w}_t$ or $r > \bar{r}$, the constraint in Stage 3, $w_t \leq p_e$, is not binding. The optimal retail prices are derived by substituting $\lambda = 0$ into the first-order conditions in equation (29):

$$\begin{aligned} p_t^D(w_t) &= \frac{\alpha(2-\gamma-\gamma^2)(1-r)+\{2(1-r)+\gamma^2\}w_t}{(4-\gamma^2)(1-r)}, \\ p_e^D(w_t) &= \frac{\alpha(2-\gamma-\gamma^2)(1-r)+\gamma(3-r)w_t}{(4-\gamma^2)(1-r)} > w_t. \end{aligned} \tag{35}$$

Given these prices, the supplier solves the following problem:

$$\max_{w_t} \ \pi_s(p_t^D(w_t), p_e^D(w_t)) + \lambda^D (\bar{w}_t - w_t), \tag{36}$$

where $\lambda^D \geq 0$. We can obtain an interior solution in this case; the constraint, $w_t \leq \bar{w}_t$, is slack. The optimal wholesale price and the Lagrange multiplier are:

$$\begin{aligned} w_t^D &= \frac{\alpha(2-\gamma-\gamma^2)(1-r)\{4+2\gamma(1-r)-\gamma^2+\gamma^3\}}{2\{8(1-r)-\gamma^2(7-8r-r^2)-\gamma^4\}} < \bar{w}_t, \\ \lambda^D &= 0. \end{aligned} \tag{37}$$

From the discussions in Cases C and D, the supplier prefers the interior solution in Case D to the corner solution in Case C, which is the same as the corner in Case D.

This result implies that the supplier does not set w_t that induces the retail price at the E-retailer, p_e, to be binding to w_t. Therefore, the self-regulation, $w_t \leq p_e$, does not affect the equilibrium prices and profits in price competition. Furthermore, the retail price at the E-retailer is not lower than the wholesale price of the T-retailer, w_t, in equilibrium. We can conclude that the price-quantity competition is crucial in obtaining the counterintuitive effect of self-regulation.

Here, we briefly describe the model and results in Zennyo (2019), as well as the differences with our paper. Zennyo (2019) focuses on the equilibrium contractual form between the supplier and E-retailer in price–price competition under a similar market structure.

The channel structure is the same as in our paper: there is a monopoly supplier, a traditional retailer (T-retailer), and an e-commerce retailer (E-retailer). The game proceeds as follows. In Stage 1, E-retailer unilaterally offers the royalty rate r to the monopoly supplier. In Stage 2, if the supplier accepts it, the two firms employ the agency contract, in which the supplier sets the retail price for E-retailer in Stage 3, and the supplier unilaterally sets a wholesale price w_t for T-retailer. Otherwise, the supplier unilaterally sets wholesale prices w_t and w_e for both retailers under the wholesale contract, in which T-retailer sets its retail price in Stage 3. In Stage 3, T-retailer and the designated firm under the contract offer their retail prices simultaneously.[30]

In his study, because of the advantage of the agency contract, the supplier and E-retailer always employ the agency contract in equilibrium, and thus the realized market situation becomes the same as ours.[31] The differences between his study and ours are as follows. First, T-retailer's strategic variable is price in Zennyo (2019) and quantity in our paper; second, the procedure for determining the royalty rate is a unilateral offer in Zennyo (2019) and Nash bargaining in our paper; and third, the main focus is the equilibrium contract form in Zennyo (2019) and the market outcomes under price-quantity competition and self-regulation in our paper. Despite these similar situations, we emphasize that our different (but natural) assumptions yield very different outcomes and rich implications.

[30] He also endogenizes the choice of whether the supplier uses E-retailer and shows that the supplier always uses E-retailer in addition to T-retailer in equilibrium.

[31] In addition to the advantage of the agency contract discussed above, E-retailer prefers the agency contract to the wholesale contract because he can obtain a first-mover advantage. See Johnson (2017) for more details.

In this sense, we believe that his study and our own complement each other.

7 Conclusion

Following the recent advancement of online platforms facilitating digital content sales, we investigate a model in which a monopoly supplier distributes two types of its product through a traditional retailer with a wholesale price contract and an online retailer with an agency contract. The supplier and the online retailer negotiate the royalty rate through Nash bargaining. A notable feature of our model is assuming that the traditional retailer and the supplier, via the online retailer, compete in quantity and price, respectively. We believe that the assumption of price-quantity competition is consistent with the standard view on when price and quantity are strategic variables of firms (e.g., the textbook by Belleflamme and Peitz (2015), Section 3.3.3 on p. 67). We also discuss self-regulation by the supplier such that the retail price of the online retailer is not lower than the wholesale price for the traditional retailer, seemingly helping the traditional retailer.

The additional discussion on the abovementioned self-regulation by the supplier leads to the following results. The wholesale price under self-regulation is strictly higher than that in the baseline model. The retailers' prices under self-regulation are also strictly higher than those in the baseline model. The retail price of the online retailer is always binding by the constraint. The royalty rate under self-regulation is strictly higher than that in the baseline model because the negotiating party anticipates lower profitability of the traditional retailer, giving the online retailer a strong bargaining position over the supplier. The self-regulation benefits the online retailer. However, it benefits the traditional retailer if the bargaining power of the online retailer is sufficiently weak. Furthermore, the self-regulation benefits the supplier if the product substitutability between the two contents is not sufficiently high. The consumer and total surpluses under self-regulation are lower than those in the baseline model. In sum, the self-regulation can benefit all firms in some situations but always harms consumers.

We have shown that incorporating the heterogeneity of market potentials and marginal costs of the two content formats does not qualitatively change the results derived in Section 4. However, incorporating the heterogeneity makes the first stage analysis in the self-regulation case (Section 5) unsolvable.[32] Solving the self-regulation case with the het-

[32] The first-order condition in the bargaining problem becomes the fourth-order equation of r.

erogeneity of market potentials and marginal costs could be challenging future research.

We consider the cases where the monopoly supplier uses two different channels to distribute two different content formats: brick-and-mortar and online retailers. We can also consider a case in which an online retailer handles both content formats in addition to the existence of brick-and-mortar retailers. Considering the additional element is also important for future research.

8 Appendix

8.1 Proof of Proposition 4

In Stage 1, the supplier and E-retailer negotiate the royalty rate. Considering (24), we derive the optimal r that maximizes the Nash product in (10). The Nash product under the self-regulation case is:

$$\begin{cases} NP^A(r) & \text{if } 0 < r \le \frac{1+\sqrt{9-4\gamma-4\gamma^2}}{2(2+\gamma)}, \\ NP^B(r) & \text{if } \frac{1+\sqrt{9-4\gamma-4\gamma^2}}{2(2+\gamma)} < r < 1, \end{cases} \tag{38}$$

where

$$\begin{cases} NP^A(r) \equiv \left[\frac{\alpha^2(2-(2+\gamma)r)}{8(1+\gamma)}\right]^{1-\beta} \left[\frac{\alpha^2(2+\gamma)r}{8(1+\gamma)}\right]^{\beta}, \\ NP^B(r) \equiv \left[\frac{\alpha^2(16-16\gamma+\gamma^2-(16-8\gamma-7\gamma^2)r)}{8(8-(7-r)\gamma^2)}\right]^{1-\beta} \left[\frac{\alpha^2(8-2\gamma-5\gamma^2)^2 r}{4(8-(7-r)\gamma^2)}\right]^{\beta}. \end{cases} \tag{39}$$

For $0 < r \le (1+\sqrt{9-4\gamma-4\gamma^2})/2(2+\gamma)$, $r = r^A \equiv 2\beta/(2+\gamma)$ is optimal, which is characterized by $\partial NP^A(r^A)/\partial r = 0$. The second-order derivative of NP^A with r is negative; that is, $\partial^2 NP^A(r)/\partial r^2 < 0$. However, for $(1+\sqrt{9-4\gamma-4\gamma^2})/2(2+\gamma) < r < 1$, $\partial NP^B(r)/\partial r < 0$ for any r. Therefore, the corner solution, $r = r^B \equiv (1+\sqrt{9-4\gamma-4\gamma^2})/2(2+\gamma)$, is optimal in this case.

Finally, we compare $NP^A(r^A)$ and $NP^B(r^B)$ to derive the solution r to the Nash bargaining. As Figure 8 shows, $NP^A(r^A) > NP^B(r^B)$ for all $\beta \in (0, 1/2]$ and $\gamma \in (0, 1)$; r^A is the optimal royalty rate for the self-regulation case.

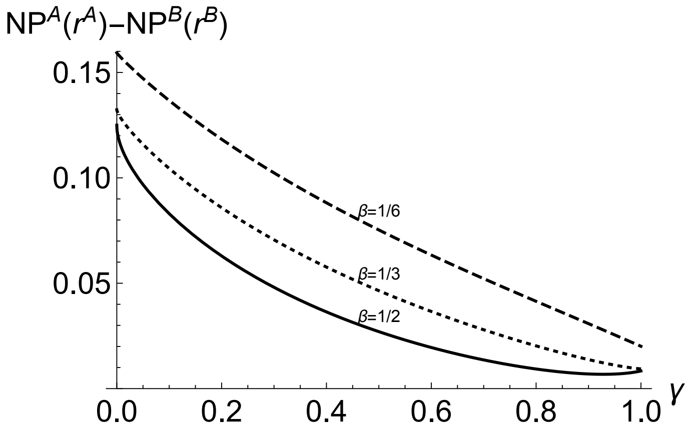


Figure 8: The difference between the equilibrium Nash products for Cases A and B in the self-regulation case ($\alpha = 1$)

8.2 Equilibrium results

Table 3: Equilibrium outcome for the baseline case and the self-regulation case

	Baseline case	Self-regulation case
r	$r^* = \frac{(8-2\gamma-5\gamma^2)^2-\sqrt{(8-2\gamma-5\gamma^2)^4-\beta^2\gamma^2(16-8\gamma-7\gamma^2)(16-16\gamma+\gamma^2)(8-7\gamma^2)}}{\beta\gamma^2\left(16-8\gamma-7\gamma^2\right)}$	$r^R = \frac{2\beta}{2+\gamma}$
w_t	$\frac{\alpha\left\{8-4\gamma r^*-2\gamma^2(4-r^*)+\gamma^3(1+2r^*)\right\}}{2\{8-\gamma^2(7-r^*)\}}$	$\frac{\alpha}{2}$
p_e	$\frac{\alpha(8-2\gamma-5\gamma^2)}{2\{8-\gamma^2(7-r^*)\}}$	$\frac{\alpha}{2}$
p_t	$\frac{\alpha\left\{12-2\gamma(2+r^*)-2\gamma^2(6-r)+5\gamma^3\right\}}{2\{8-\gamma^2(7-r^*)\}}$	$\frac{\alpha(3-\gamma)}{4}$
q_e	$\frac{\alpha(8-2\gamma-5\gamma^2)}{2\{8-\gamma^2(7-r^*)\}}$	$\frac{\alpha(2+\gamma)}{4(1+\gamma)}$
q_t	$\frac{\alpha\{2-\gamma(2-r^*)\}}{8-\gamma^2(7-r^*)}$	$\frac{\alpha}{4(1+\gamma)}$
π_s	$\frac{\alpha^2\left\{12-8r^*-4\gamma(2-r^*)-\gamma^2(3-4r^*)\right\}}{4\{8-\gamma^2(7-r^*)\}}$	$\frac{\alpha^2\left\{3-2r^R+\gamma(1-r^R)\right\}}{8(1+\gamma)}$
π_e	$\frac{\alpha^2\left(8-2\gamma-5\gamma^2\right)^2 r^*}{4\{8-\gamma^2(7-r^*)\}^2}$	$\frac{\alpha^2(2+\gamma)r^R}{8(1+\gamma)}$
π_t	$\frac{\alpha^2(1-\gamma^2)\{2-\gamma(2-r^*)\}^2}{\{8-\gamma^2(7-r^*)\}^2}$	$\frac{\alpha^2(1-\gamma)}{16(1+\gamma)}$
CS	$\frac{\alpha^2\left\{80+16\gamma r^*-4\gamma^2(35-4r^*-(r^*)^2)-4\gamma^3(1+2r^*)+5\gamma^4(13-4r^*)\right\}}{8\{8-\gamma^2(7-r^*)\}^2}$	$\frac{\alpha^2(5+3\gamma)}{32(1+\gamma)}$
SW	$\frac{\alpha^2\left\{304-48\gamma(4-r^*)-4\gamma^2(89-8r^*+(r^*)^2)+4\gamma^3(43-18r^*+2(r^*)^2)+75\gamma^4\right\}}{8\{8-\gamma^2(7-r^*)\}^2}$	$\frac{\alpha^2(19+5\gamma)}{32(1+\gamma)}$

8.3 A brief summary of the five major publishers' conduct

We briefly describe the actions of the five major publishers in the US when e-books entered the market.

We believe that the self-regulation discussed in our study is a realistic and reasonable strategy, taking into account the history of the US publishing industry, where the current five major publishers (Penguin Random House, HarperCollins, Simon & Schuster, Hachette, and Macmillan) have continued to attempt to raise the prices of e-books (Sang, 2017) (Penguin and Random House merged in 2013 and became Penguin Random House). We believe their conduct reflects concern for the sales of paper books and bookstores' profits.

Before e-books became widely accepted around 2010, Amazon adopted a strategy of selling e-books of best sellers and new releases at $9.99, which was lower than the wholesale prices of those e-books. This strategy aimed to promote sales of Kindle, an e-book reader released by Amazon.

Those publishers argued that selling e-books at such a low price would hurt the sales of paper books, damaging the profitability of bookstores and distributors. As a result, some publishers raised the wholesale price of e-books, which had originally been lower than that of paper books; others delayed the release of e-versions for weeks or months after the release of paper books. Furthermore, they considered strategies such as retail price maintenance, mandatory minimum advertised pricing, and a joint venture to sell e-books (Cote, 2013). However, these strategies were not enough to force Amazon to raise the prices of e-books.

The five publishers except for Random House in the US adopted agency contracts to directly set the prices of e-books when Apple entered the e-book market with the iPad launch in 2010.[33] These arrangements included most favored nations (price parity) clauses, which put pressure on Amazon to move to agency contracts. However, Apple and the five publishers were sued by the US Department of Justice in 2012 for conspiring to raise the prices of e-books. As a result, the agency contracts were prohibited for two years. In fact, De los Santos and Wildenbeest (2017) empirically show that the return to the wholesale contracts from the agency contracts lowered e-book prices by 18% at Amazon.

[33] Random House employed agency contracts in 2011 after the five publishers did.

8.4 Numerical examples

We numerically show how γ influences the equilibrium outcomes in Tables 4 and 5, confirming the propositions.

First, we confirm the propositions in Section 4. r^* in each table shows that r^* decreases in γ (Proposition 1 and Figure 2). Table 4 shows that the inequality $w_t^* > p_e^*$ holds for $\gamma \leq 0.7$; similarly, Table 5 shows that the inequality $w_t^* > p_e^*$ always holds (Proposition 2 and Figure 3). Comparing the values in Tables 4 and 5, we find that the values of w_t^*, p_e^*, and π_s^* in Table 4 are smaller than those in Table 5 and that the values of π_e^*, π_t^*, CS^*, and SW^* in Table 4 are higher than those in Table 5 (Proposition 3).

Second, we confirm the propositions in Section 5. r^R in each table shows that r^R decreases in γ, but the values of w_t^R and p_e^R remain the same irrespective of γ (Proposition 4). The difference $r^R - r^*$ is always positive and increases with γ in each table, and the differences, $w_t^R - w_t^*$ and $p_e^R - p_e^R$, are always positive in each table (Proposition 5 and Figure 5). For profits, $\pi_s^* < \pi_s^R$ holds for $\gamma \leq 0.8$ in Table 4, although $\pi_s^* < \pi_s^R$ always holds in Table 5; $\pi_e^* < \pi_e^R$ always holds in each table; $\pi_t^* > \pi_t^R$ always holds in Table 4, although $\pi_t^* < \pi_t^R$ hold for $\gamma \geq 0.8$ in Table 5 (Proposition 6 and Figure 6). The industry profit $\pi_s^* + \pi_e^* + \pi_t^*$ in the baseline model is higher than $\pi_s^R + \pi_e^R + \pi_t^R$ in the self-regulation case if $\gamma \leq 0.6$ in Table 4; and if $\gamma \leq 0.3$ in Table 5 (Proposition 7 and Figure 7). $CS^* > CS^R$ and $SW^* > SW^R$ always hold in both tables (Proposition 8).

γ	r^*	r^R	w_t^*	w_t^R	p_e^*	p_e^R	p_t^*	p_t^R	q_e^*	q_e^R	q_t^*	q_t^R
0.1	0.317132	0.31746	0.491678	0.5	0.488455	0.5	0.720262	0.725	0.488455	0.477273	0.230893	0.227273
0.2	0.301851	0.30303	0.483408	0.5	0.478526	0.5	0.689557	0.7	0.478526	0.458333	0.214738	0.208333
0.3	0.287438	0.289855	0.47522	0.5	0.469857	0.5	0.658089	0.675	0.469857	0.442308	0.200954	0.192308
0.4	0.273799	0.277778	0.467126	0.5	0.462173	0.5	0.625998	0.65	0.462173	0.428571	0.189133	0.178571
0.5	0.260803	0.266667	0.45913	0.5	0.455251	0.5	0.593378	0.625	0.455251	0.416667	0.178997	0.166667
0.6	0.248249	0.25641	0.451235	0.5	0.448884	0.5	0.560282	0.6	0.448884	0.40625	0.170387	0.15625
0.7	0.235788	0.246914	0.443451	0.5	0.442852	0.5	0.526724	0.575	0.442852	0.397059	0.163279	0.147059
0.8	0.222644	0.238095	0.435839	0.5	0.436861	0.5	0.492664	0.55	0.436861	0.388889	0.157847	0.138889
0.9	0.206355	0.229885	0.428746	0.5	0.430491	0.5	0.458094	0.525	0.430491	0.381579	0.154464	0.131579

γ	π_s^*	π_s^R	π_e^*	π_e^R	π_t^*	π_t^R	CS^*	CS^R	$\pi_s^* + \pi_e^* + \pi_t^*$	$\pi_s^R + \pi_e^R + \pi_t^R$	SW^*	SW^R
0.1	0.276449	0.276515	0.0756641	0.0757576	0.0527784	0.0511364	0.157228	0.150568	0.404892	0.403409	0.56212	0.553977
0.2	0.263673	0.263889	0.0691201	0.0694444	0.0442679	0.0416667	0.158101	0.145833	0.377061	0.375	0.535163	0.520833
0.3	0.252807	0.253205	0.0634563	0.0641026	0.0367482	0.0336538	0.1589	0.141827	0.353011	0.350962	0.511911	0.492788
0.4	0.243469	0.244048	0.0584847	0.0595238	0.0300478	0.0267857	0.159653	0.138393	0.332001	0.330357	0.491654	0.46875
0.5	0.235384	0.236111	0.0540523	0.0555556	0.0240299	0.0208333	0.160391	0.135417	0.313466	0.3125	0.473857	0.447917
0.6	0.22836	0.229167	0.0500214	0.0520833	0.0185804	0.015625	0.161155	0.132813	0.296962	0.296875	0.458116	0.429688
0.7	0.222282	0.223039	0.0462423	0.0490196	0.0135967	0.0110294	0.162005	0.130515	0.282121	0.283088	0.444126	0.413603
0.8	0.217153	0.217593	0.042491	0.0462963	0.00896969	0.00694444	0.163048	0.128472	0.268613	0.270833	0.431661	0.399306
0.9	0.213306	0.212719	0.0382423	0.0438596	0.00453324	0.00328947	0.164437	0.126645	0.256082	0.259868	0.420518	0.386513

Table 4: Numerical examples ($\alpha = 1$, $\beta = 1/3$)

γ	r^*	r^R	w_t^*	w_t^R	p_e^*	p_e^R	p_t^*	p_t^R	q_e^*	q_e^R	q_t^*	q_t^R
0.1	0.15855	0.15873	0.495555	0.5	0.488553	0.5	0.722205	0.725	0.488553	0.477273	0.22894	0.227273
0.2	0.150867	0.151515	0.490665	0.5	0.4789	0.5	0.693223	0.7	0.4789	0.458333	0.210997	0.208333
0.3	0.143594	0.144928	0.485464	0.5	0.470681	0.5	0.663334	0.675	0.470681	0.442308	0.195462	0.192308
0.4	0.136686	0.138889	0.480054	0.5	0.463642	0.5	0.632755	0.65	0.463642	0.428571	0.181788	0.178571
0.5	0.130071	0.133333	0.474524	0.5	0.457619	0.5	0.601667	0.625	0.457619	0.416667	0.169524	0.166667
0.6	0.123642	0.128205	0.468973	0.5	0.452529	0.5	0.570245	0.6	0.452529	0.40625	0.158238	0.15625
0.7	0.117202	0.123457	0.46355	0.5	0.448413	0.5	0.53872	0.575	0.448413	0.397059	0.147391	0.147059
0.8	0.110325	0.119048	0.458578	0.5	0.445607	0.5	0.507532	0.55	0.445607	0.388889	0.135982	0.138889
0.9	0.101704	0.114943	0.455134	0.5	0.445618	0.5	0.478095	0.525	0.445618	0.381579	0.120849	0.131579

γ	π_s^*	π_s^R	π_e^*	π_e^R	π_t^*	π_t^R	CS^*	CS^R	$\pi_s^*+\pi_e^*+\pi_t^*$	$\pi_s^R+\pi_e^R+\pi_t^R$	SW^*	SW^R
0.1	0.314293	0.314394	0.0378434	0.0378788	0.0518893	0.0511364	0.156734	0.150568	0.404025	0.403409	0.560759	0.553977
0.2	0.298274	0.298611	0.0346006	0.0347222	0.0427391	0.0416667	0.157142	0.145833	0.375614	0.375	0.532756	0.520833
0.3	0.284618	0.285256	0.0318119	0.0320513	0.0347668	0.0336538	0.157473	0.141827	0.351197	0.350962	0.50867	0.492788
0.4	0.27285	0.27381	0.0293825	0.0297619	0.0277593	0.0267857	0.157719	0.138393	0.329991	0.330357	0.487711	0.46875
0.5	0.262619	0.263889	0.0272389	0.0277778	0.0215537	0.0208333	0.157865	0.135417	0.311412	0.3125	0.469277	0.447917
0.6	0.253672	0.255208	0.0253197	0.0260417	0.016025	0.015625	0.157875	0.132813	0.295016	0.296875	0.452891	0.429688
0.7	0.245831	0.247549	0.0235664	0.0245098	0.0110793	0.0110294	0.157664	0.130515	0.280477	0.283088	0.43814	0.413603
0.8	0.239018	0.240741	0.0219067	0.0231481	0.00665684	0.00694444	0.157004	0.128472	0.267581	0.270833	0.424585	0.399306
0.9	0.233382	0.234649	0.0201959	0.0219298	0.00277485	0.00328947	0.155057	0.126645	0.256353	0.259868	0.41141	0.386513

Table 5: Numerical examples ($\alpha = 1$, $\beta = 1/6$)

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Supplementary Appendix

We explain the mathematical procedure in Section 4.5.

The profits of the supplier and the retailers are:

$$\begin{aligned}
\pi_s &= (w_t - c_t)q_t + (1-r)p_e q_e = (w_t - c_t)q_t + (1-r)p_e(\alpha - p_e - \gamma q_t), \\
\pi_t &= (p_t - w_t)q_t = ((1+b-\gamma)\alpha - (1-\gamma^2)q_t + \gamma p_e - w_t)q_t, \\
\pi_e &= r p_e q_e = r p_e(\alpha - p_e - \gamma q_t).
\end{aligned} \tag{40}$$

The first-order conditions in Stage 3 are:

$$\begin{aligned}
\frac{\partial \pi_s}{\partial p_e} &= (1-r)(\alpha - 2p_e - \gamma q_t) = 0, \\
\frac{\partial \pi_t}{\partial q_t} &= (p_t - w_t)q_t = (1+b-\gamma)\alpha - 2(1-\gamma^2)q_t + \gamma p_e - w_t = 0.
\end{aligned} \tag{41}$$

Solving the simultaneous equation, we have:

$$p_e(w_t) = \frac{(2-(1+b)\gamma - \gamma^2)\alpha + \gamma w_t}{4-3\gamma^2}, \quad q_t(w_t) = \frac{(2(1+b)-\gamma)\alpha - 2w_t}{4-3\gamma^2}. \tag{42}$$

Solving the first-order condition in Stage 2, we have:

$$w_t(r) = \frac{(8(1+b)(1-\gamma^2) + \gamma^3 - 2\gamma(2-(1+b)\gamma - \gamma^2)r)\alpha + 2(4-3\gamma^2)c_t}{2(8-(7-r)\gamma^2)}. \tag{43}$$

Using the outcomes in Stages 2 and 3, we have $\pi_s(r)$, $\pi_t(r)$, and $\pi_e(r)$.

Solving the maximization problems in the bilateral monopoly with the supplier and the E-retailer, we have the disagreement profit of the supplier:

$$O_s = \frac{((1+b)\alpha - c_t)^2}{8}.$$

We need to solve the following bargaining problem to obtain r:

$$\max_r \; [\pi_s(r) - O_s]^{1-\beta}[\pi_e(r)]^{\beta}.$$

To simplify the exposition, we define $\eta \equiv b\alpha - c_t$. The royalty rate r is:

$$r = \frac{(8-2\gamma-5\gamma^2)^2\alpha^2 - 4(8-2\gamma-5\gamma^2)\gamma\eta\alpha - 4\gamma^2\eta^2 + \sqrt{R}}{\beta\gamma^2((16-8\gamma-7\gamma^2)\alpha^2 - 2(4-\gamma)\gamma\eta\alpha + \gamma^2\eta^2)}, \tag{44}$$

where $R \equiv ((8-2\gamma-5\gamma^2)\alpha-2\gamma\eta)^4-\beta^2\gamma^2(8-7\gamma^2)((16-8\gamma-7\gamma^2)\alpha^2-2(4-\gamma)\gamma\eta\alpha+\gamma^2\eta^2)((16-16\gamma+\gamma^2)\alpha^2-2(8-7\gamma)\gamma\eta\alpha+7\gamma^2\eta^2)$. If $\eta=0$, the derived r is the same as that in (12).