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The Agency Model for Digital Goods

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ABSTRACT

While digital goods industries such as entertainment, software, and publishing are growing at a rapid pace, traditional supply chain contract models have failed to evolve with the new digital economy. To illustrate, the agency model utilized by the e-book publishing industry has recently received much negative attention brought by the U.S. Department of Justice's lawsuit against Apple, Inc. The emerging agency model in the e-book industry works as follows: the publisher sets the price of the digital goods and the retailers who serve as agents retain a percentage of the revenue associated with a consumer purchase. The regulators claim that the agency model is hurting this industry as well as the consumer's welfare because e-book prices have increased after the introduction of the agency model. We investigate the strategic impact of the agency model by examining a digital goods supply chain with one supplier and two competing retailers. In comparison to the benchmark wholesale model, we find that the agency model can coordinate the competing retailers by dividing the coordinated profits into a prenegotiated revenue sharing proportion. Further, we also identify the Pareto improving region whereby both the supplier and the retailers prefer the agency model to the wholesale model. Our main qualitative insight regarding the agency model still holds even when we consider the presence of the printed books in the marketplace. Thus, contrary to current press presaging the negative impact of the agency model on the e-books industry, we find the agency model to be superior to the traditional wholesale contracts for publishers, retailers and consumers in this digital goods industry. [Submitted: December 11, 2013. Revised: April 27, 2015. Accepted: July 20, 2015.]

Subject Areas: Coordination Mechanism, E-book Industry, Pricing, and and Supply Chain Contracts.

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INTRODUCTION

The Internet and digital technologies have transformed many aspects of businesses and the global marketplace. The leading market research firm International Data Corporation (IDC) estimates that the global business-to-business and business-to-consumer e-commerce will approach $16 trillion in 2013 (www.idc.com). Including the global market for digital products and services estimated at $4.4 trillion, the digital economy is expected to account for $20.4 trillion of the world economy in 2013. The media, entertainment, and publishing industries face one of the largest challenges from the digital transformation of the economy as old working models become obsolete. Hayes (2002) gives an overview of these problems associated with the utilization of traditional operations management theories in the digital economy. Meanwhile, these industries have the potential to become major beneficiaries of such a transformation. The case in point is the sales of Kindle books from Amazon.com surpassing those of hardcover and paperback books combined in May 2011 (Olivarez-Giles, 2011). Note that the net sales revenue from the e-books industry has exceeded that of hardcover books for the first time in the first quarter of 2012.[i]

This trend necessitates that both business and industry policy makers reconsider the old rules and strategy governing physical goods in the old economy that may no longer apply in the new digital economy. A case in point is highlighted by the U.S. Department of Justice's lawsuit against Apple, Inc. The agency model utilized by the e-book publishing industry is at the center of this lawsuit. Prior to e-book availability, retailers and publishers traditionally utilized a wholesale model where the publisher sets a wholesale price to the retailer and subsequently the retailer determines the retail price for the printed books to consumers. When Amazon initially brought e-books to the marketplace, they set the price of all New York Times bestselling books to $9.99. Shortly thereafter, Apple proposed the controversial agency model to let the publishers set prices of e-books themselves. The U.S. Justice Department prosecutors argued that Apple used publishers' dissatisfaction with Amazon's aggressive e-book discounting to shoehorn itself into the digital book market in 2010. The prosecutors claim that (a) the average price of the digital version of New York Times bestselling books has increased after switching to the agency model, and (b) consumers suffer as a result of the increased prices. A federal judge ruled that Apple colluded with major publishers (Department of Justice, 2013), but Apple is still fighting the legal order by filing numerous appeals.

However, we believe these short-term observations are not sufficient to conclude that consumers' welfare has been compromised. Rather, a more complete assessment of the equilibrium of these pricing schemes shows that there are other benefits associated with the agency pricing model. U.S. Senator Charles E. Schumer wrote an op-ed article in the Wall Street Journal (Schumer, 2012) urging the Department of Justice to drop the suit against Apple and several major

[i] As reported by Los Angeles Times, since April 1, 2011, for every 100 print books sold on Amazon, 105 Kindle e-books have been sold. Further, according to another report by the Association of American Publishers (AAP), the e-books sales have reached $282.3 million in the first quarter 2012 while the Hardcover sales only amount to $229.6 million in the same time period.

publishers. The main focus of his article is to support the evolving agency model in which the publisher establishes a retail price and the retailers (e.g., Apple or Amazon) take a percentage cut of the sales. The chief argument for the senator's proposal is the fact that the average price (including New York Times bestselling and other books) for e-books actually decreased after the agency model replaced traditional wholesale model where the publisher sets a wholesale price to the retailer and subsequently the retailer determines the retail price. Thus, conflicting evidence is given in the popular press concerning the impact of the agency and wholesale pricing schemes on the e-book industry.

Hence, several natural and intriguing questions arise from our discussion above. Which model, the traditional wholesale model or the agency model, is better for the e-book industry as a whole? Which pricing model do the retailers and the publisher prefer? Are consumer surplus measures commensurate under these two pricing schemes? We study these issues and provide valuable managerial insights to executives in the related industry as well as the policy makers by formalizing a game theoretic model.

There are several key findings associated with our analysis. First and most importantly, we find that the agency model can coordinate the digital goods supply chain with competing retailers for any prenegotiated revenue sharing proportion. Essentially, the agency model shifts the supply chain decisions solely to the publisher thereby creating a "virtual vertical integration." In addition, there is no inventory risk reflecting the mismatch between the supply and demand for the digital goods market. This result is in sharp contrast to that from previous literature involving physical goods as no legal revenue sharing contract can coordinate the physical goods supply chain in the presence of competing retailers. Second, there exists a Pareto improving region of revenue sharing proportions such that the publisher and the retailers all prefer the agency model to the wholesale model, while these firms may have conflicting preferences outside this region. In contrast, it is impossible for both the publisher and the retailers to favor the traditional wholesale model at the same time. Third, consumer surplus measures are actually higher under the agency model than a traditional wholesale model. This result arises due to the fact that the equilibrium price of the e-book is lower in the agency model compared with the price under the wholesale model.

The rest of the article is organized as follows. In the next section, we review the relevant literature. In Section 3, we present the e-book supply chain model with one publisher and two competing retailers, where we analyze the baseline wholesale model followed by the agency model. Subsequently, in Section 4, we compare both profit and consumer surplus measures under these two pricing schemes. In Section 5, we extend our base model by taking physical counterparts into consideration and discuss the implications the e-book reader device. The last section concludes this study by highlighting future research directions and limitations.

LITERATURE REVIEW

This article is related to the literature on supply chain contracts as well as the digital goods pricing and distribution strategies. Supply chain contracts between suppliers and retailers of physical goods have been well documented in the literature (Tsay, Nahmias, & Agrawal, 1999; Cachon, 2003). Most of the extant research focuses on the coordination of the supply chain by different types of contracts (e.g., buy-back contracts, price-discount contracts, quantity flexibility contracts, sales-rebate contracts, franchise contracts, quantity discounts and revenue sharing contracts). However, little is known about the supply chain involving digital products where products such as software, movies, music and e-books are created and distributed in digital form. Digital product supply chains differ markedly from their physical product counterparts (Chellappa & Shivendu, 2003). Unlike the physical goods market which always faces the risk of a mismatch between the random demand and supply, the demand of the digital goods can always be perfectly fulfilled. As a result, there is no inventory decision to be made in the digital goods market. Further, the marginal production cost of the digital goods is negligible. We focus our study on the mechanism behind the agency model by incorporating these unique characteristics and utilize the wholesale model as a benchmark case.

The agency model for the digital goods also has some similarity with the traditional revenue sharing and franchise contracts. Previous literature on revenue sharing contracts often assumes that the revenue function is derived from the stochastic demand with a fixed retail price, that is, a newsvendor model (Cachon & Lariviere, 2005; Yao, Leung, & Lai, 2008; Linh & Hong, 2009). A crucial feature of these formulations is the firm's inventory management practices, as the retailer's profit suffers from difficulties of matching supply and demand perfectly in the physical goods market. Later, we show that this is not an issue in the agency model for the digital goods. In a typical revenue-sharing contract, a retailer pays the supplier a single wholesale price for each unit purchased (where in the agency model, this value is zero), plus a percentage of the overall revenue that the retailer generates. This contract has become prevalent in the video rental industry in the early 2000's. Motivated by the practice of the video rental industry, Cachon and Lariviere (2005) comprehensively investigate the revenue sharing contract for coordination of the distribution channel. While it's possible to coordinate the competing retailers through distinct contracts for different retailers, it's not clear whether there exists a legal contract with common terms that both satisfies the Robinson–Patman Act and coordinates the heterogeneous competing retailers in the physical goods market. Yao et al. (2008) further study revenue sharing contracts by incorporating a price dependent demand curve in the newsvendor problem framework. They numerically demonstrate that revenue sharing contracts improve the supply chain performance with two competing retailers. But the division of the profits is always in favor of the supplier under this contract. In this study, we show that the agency model not only can coordinate the competing retailers in the digital goods market but also can allocate the supply chain profit based on the revenue sharing proportion.

The traditional franchise contract includes a franchisor and a franchisee, where the franchisor produces the inputs to the final product sold at the retail outlet owned by the franchisee. The franchisee buys the inputs from the franchisor, adds value to the inputs and sells the product at a price decided by the franchisee (Lal, 2009). The franchisor collects a fixed fee as well as a percentage of gross sales from the franchisee (i.e. two-part tariff). Compared with this contract, in the agency model, the pricing decision is fully controlled by the upstream publisher. Another difference between the contemporary agency model and the franchise contract concerns the commitment of the franchisee to the franchisor. The agency model does not require the retailer to adhere to this type of exclusivity. Interested readers in traditional supply chain contracts should refer to Tsay et al. (1999) and Cachon (2003) for reviews of the recent research related to the contracts and supply chain coordination of the physical goods.

There is another important literature stream which addresses the digital goods pricing and distribution strategies. Sundarajan (2004) analyzes the fixed-fee and usage-based pricing schemes for information goods and shows that offering fixed-fee pricing in addition to a nonlinear usage-based pricing scheme will improve the profits. Fan, Kumar, and Whinston (2007) study the trade-off between the pricing and advertising strategies for media providers utilizing online channels to distribute digital media. Several recent studies address different issues germane to the e-book industry. Jiang and Katsamakas (2010) examine the impact of the entry of an e-book retailer where there is an online retailer of physical books and another offline retailer of physical books. They identify the conditions where the book prices may increase and total readership will decrease after the introduction of the e-book. In contrast, our model (a) extends their work in a more realistic setting where both competing retailers have their own digital goods distribution channel and (b) focuses on the impact of different contracts on the publisher and competing retailers. Hu and Smith (2011) empirically analyze the impact of digital goods channels on traditional good sales where the publisher makes the decision on whether or not to release the digital format. They find that delaying the release of an e-book can cause a significant decrease in e-book sales, but does not cause a significant decrease in sales of the traditional goods. Johnson (2013a,b) investigates the strategic interactions of the agency model and wholesale model and shows that consumers are better off under the agency model. Hao and Fan (2014) compare the wholesale model and agency model in a monopoly setting. In their seminal work, they identify the complementary consumption of e-reader and e-book as the main reason of price change under different pricing models. Finally, Tan and Carrillo (2015) analyze a monopolist that sales both printed books and e-books taking into account both vertical and horizontal differentiation in these channels.

Our study contributes to the literature by identifying the circumstances under which the agency model can (1) mitigate the double marginalization effect and (2) coordinate the digital goods supply chain with competing retailers. This result is in sharp contrast to the previous literature involving physical goods as no legal revenue sharing contract can coordinate physical goods supply chain in the presence of competing retailers. Essentially, our results are driven by the unique characteristics of the digital goods. The production cost associated with each unit is negligible, and also the demand and supply can always be perfectly matched in the digital goods market. While we use the e-book industry as our motivating example, our results can resonate beyond e-books, with broader implications for providers of other digital goods including music, games and movies.

In addition, we identify several positive characteristics of the agency model not previously investigated. One key feature of the agency model is that the supplier determines the optimal price that the consumer pays for the digital good. We compare the agency model to a "modified" version of the agency model where the

Table 1: Model variables.

Variable	Description
A	Demand facing the retailer if prices are zero
p_i	Priced charged by the *i*th retailer
$\theta_{j,i}$	Cross-price sensitivity from the price of retailer j to the demand for retailer i, $0 < \theta_{j,i} < 1$
w	Wholesale price charged to retailers under the wholesale model
α	Proportion of the revenue the retailer keeps from the sale of digital goods, $0 < \alpha < 1$
D_i	Market demand for retailer i
f_i	Fixed cost incurred by the retailer i, this cost includes infrastructure investment
ε_i	Randomness of demand for retailer i
CS	Consumer surplus
SW	Total social welfare

retailers determine the optimal prices. We find that when the retailers determine the price instead of the publisher the supply chain efficiency diminishes.

MODELS

In this study, we consider a supply chain consisting of one digital media publisher and two price-competing retailers. Capturing a key feature of the digital goods (Sundararajan, 2004), we set the marginal production cost of the digital goods to zero. We explore the impact of the agency model by utilizing the traditional wholesale model as a benchmark. The wholesale model denotes the traditional price setting game between the publisher and retailers in which the publisher offers each book to the retailers at a wholesale price w. Following the Robinson–Patman Act, we assume the wholesale price is common among the competing retailers. Then retailer i chooses the retail price p_i to sale the book to consumers. Under the agency model setting, the publisher determines the price of the e-book and the retailer serves as an "agent" who retains a fixed percentage α of the book's retail price. According to a recent media report (Schumer, 2012),[ii] the current value of α is set at 30% in the book publishing industry, which denotes the situation where the retailer keeps 30% of the revenue associated with each book that they sell and 70% of the sales revenue goes to the publisher. The notation for the model is summarized in Table 1. For convenience, we use subscript "*P*" and "*R*" to denote the publisher and retailer, respectively.

We assume that the market demand for retailer i $(i, j \neq i)$ is as follows:

$$D_i\left(p_i, p_j\right) = A - p_i + \theta_{j,i}\, p_j + \varepsilon_i, \quad 0 < \theta_{j,i} < 1, \quad i, j \in \{1, 2\}.$$

This classical downward sloping form of demand curve has been widely used in the marketing and operations literature (McGuire & Staelin, 1983, 1986; Jeuland

[ii]http://blogs.wsj.com/digits/2012/04/11/what-is-agency-pricing/

& Shugan, 1988; Ingene & Parry, 1995; Lus & Muriel, 2009). In this context, it captures both product differentiation and competition between the retailers. Without loss of generality, we assume that both retailers face the same potential market size denoted by the variable A. Our results can be further generalized to the case where different retailers face distinct market potentials. The variable ε_i represents the randomness in demand for retailer i and is distributed as $G_i(.)$.

The cross-price sensitivity parameter $\theta_{j,i}$ denotes the impact of a change in price of product j on the demand for product i. The cross-price sensitivity parameter $\theta_{j,i} > 0$ reflects the substitutability of the two products where a higher value of $\theta_{j,i}$ implies a higher substitutability between the retailers and vice versa. Following the assumption of Ingene and Parry (1995), we let $\theta_{j,i} < 1$ ($\forall\, i, j$), which reflects that the impact of the competing product price on demand is smaller than that of the primary product price.

The $\theta_{j,i}$ parameter is important in the e-book industry because it captures the intensity of the competition between the two retailers. Specifically, this parameter captures consumers' channel choice and brand preference effects. To illustrate, Kurataa, Yao, and Liu (2007) comment that, "It is plausible to assume that (this parameter) decreases as channel loyalty increases." Thus, a digital good with increased brand loyalty may effectively shield itself from price competition. Another key factor driving the value of the cross-price sensitivity parameter for the e-book industry is the portability of the product which can be accessed by multiple devices. To illustrate, a customer who utilizes a platform which supports many different types of e-book formats (such as Android) may be more price sensitive to the sale of the e-book via the Apple Store or Amazon. However, a Kindle user may be more committed to the Amazon store, as the books offered from Apple or Barnes and Noble may not be readable on the Kindle device. Consequently, the Kindle user may be less price sensitive to changes in the price for the same e-books sold in the Apple Store.

Our modeling framework stems from the classical newsvendor model with a price-dependent demand function. In the physical goods market utilizing a wholesale model, retailer i chooses the optimal order quantity Q_i^* and optimal retailer price p_i^* to maximize his/her expected profit:

$$\pi_i(Q_i, p_i) = \begin{cases} p_i D_i - wQ_i - h_i(Q_i - D_i) & \text{if } Q_i \geq D_i \\ p_i Q_i - wQ_i - s_i(D_i - Q_i) & \text{if } Q_i < D_i \end{cases},$$

where h_i and s_i represent the salvage (disposal) value and shortage penalty for each unit, respectively. For physical goods with the newsvendor model, Petruzzi and Dada (1999) show a method to solve for optimal price and quantity levels under a single retailer setting with linear additive random demand. However, we can characterize the optimal solutions for our problem by taking advantage of the unique features of digital goods. First, there is no "physical" inventory for the digital goods and the retailers do not need to make a quantity commitment in advance. This simplifies the problem from two-dimensions to one where the retailers only need to make the decision on the retail price p_i as the demand will always be satisfied without incurring overstocking or loss of sales in the physical goods market. Further, we assume the mean of the random component ε_i equals to zero and as our objective function is to maximize the expected profit, thus the newsvendor framework from the physical goods simplifies to the deterministic model in the digital goods context.

During the selling season of a new book, two price competing retailers announce their preferred retail price simultaneously after the publisher declares the wholesale price. We thus model this situation as a Stackelberg competition for both wholesale and agency models. In addition to profit measures for the retailers and the supplier, we also calculate supply chain profit and social welfare measures. Note that the social welfare measure is defined as the sum of the supply chain profit and consumer's surplus. We next introduce the benchmark wholesale model.

Wholesale Model

In the wholesale pricing model, the publisher as the Stackelberg game leader charges both of the retailers the same wholesale price w. After observing the wholesale price provided by the publisher, the retailers decide their best response retail price p_i individually. The publisher faces the following problem,

$$\max_{w} \pi_P = w \sum_{i,j} \left(A - p_i + \theta_{j,i}\ p_j\right) \tag{1}$$

$$\text{s.t.} \quad p_i \in \text{argmax} \left\{(p_i - w)\left(A - p_i + \theta_{j,i}\ p_j\right) - f_i\right\} \quad \forall i, j \in \{1, 2\},$$

where f_i denotes the fixed cost (i.e., infrastructure and technology investment) incurred by the retailer i. In the physical goods market, the retailer's variable cost is typically proportional to the market demand (Cachon & Lariviere, 2005; Xiao & Qi, 2008); however, this value becomes negligible after the significant initial investment in the e-book industry.

We solve the above problem by utilizing backward induction. Details of the proofs are in Appendix A. Because the demand curve is linear in price, the consumer surplus is characterized by $CS = \sum_i^j \frac{(p_i^{\max} - P_i^*)}{2} D_i^*$, where p_i^* and D_i^* are the equilibrium price and market demand captured of retailer i, respectively. Table 2 summarizes the results of the individual retailers and the whole supply chain for the case of wholesale model where $\Delta = 4 - 2\theta_{1,2}\, \theta_{2,1}\ - \theta_{1,2}\ - \theta_{2,1}$ indicates the relative price sensitivity intensity between the two retailers. Note that lower levels of Δ reflect higher competition intensity between the two retailers. In addition, Table 2 also has the results for the integrated (i.e., coordinated) supply chain.

Proposition 1: *Under a wholesale pricing model with a symmetric cross-price sensitivity coefficient (i.e., $\theta_{j,i} = \theta_{i,j}\ = \theta$), the retailers' profit, the publisher's profit, the supply chain profit, the consumer surplus and social welfare are strictly increasing in the cross-price sensitivity coefficient for the digital goods.*

***Proof*:** See Appendix B. Our result for the digital goods is consistent with the previous work addressing physical goods with a constant production cost (Van Ryzin & Mahajan, 1999; Yao et al., 2008) where the increase in cross-price sensitivity θ can improve the channel efficiency. The intuition behind this result in the e-book industry is the following: as the cross-price sensitivity θ is growing, the portability of digital goods from distinct retailers increases, which effectively increases the competition between the two e-book markets. In this case, the consumers will be

Table 2: Wholesale model with asymmetric substitutability coefficient.

	Decentralized Case	Integrated Supply Chain
Sales price (Retailer 1)	$\frac{A(2+\theta_{2,1})(2\Delta+4+\theta_{1,2}+\theta_{2,1})}{2\Delta(4-\theta_{1,2}\theta_{2,1})}$	$\frac{A}{2-\theta_{1,2}-\theta_{2,1}}$
Wholesale price	$\frac{A(4+\theta_{1,2}+\theta_{2,1})}{2\Delta}$	n/a
Total demand	$\frac{A(4+\theta_{1,2}+\theta_{2,1})}{8-2\theta_{1,2}\theta_{2,1}}$	A
Retailer 1's profit	$\frac{A^2[(\theta_{2,1}-6)\theta_{2,1}+\theta_{1,2}(6+\theta_{2,1}(5+3\theta_{2,1}))-\theta_{1,2}{}^2\theta_{2,1}-8]^2}{4(4-\theta_{1,2}\theta_{2,1})^2\Delta^2}-f_1$	n/a
Publisher's profit	$\frac{A^2(4+\theta_{1,2}+\theta_{2,1})^2}{4(4-\theta_{1,2}\theta_{2,1})\Delta}$	n/a
Supply chain profit	$A^2(4\theta_{1,2}\theta_{2,1}+\theta_{1,2}+\theta_{2,1}-12)\frac{[\theta_{1,2}{}^3(1+3\theta_{2,1})-\theta_{1,2}{}^2(2\theta_{2,1}{}^2-9\theta_{2,1}+4)+\theta_{1,2}(3\theta_{2,1}{}^3+9\theta_{2,1}{}^2+32\theta_{2,1}-8)+\theta_{2,1}{}^3-4\theta_{2,1}{}^2-8(4+\theta_{2,1})]}{4(4-\theta_{1,2}\theta_{2,1})^2\Delta^2}-f_1-f_2$	$\frac{A^2}{2-\theta_{1,2}-\theta_{2,1}}-f_1-f_2$
Consumer surplus	$\frac{A^2((8-6\theta_{1,2}+6\theta_{2,1}+(\theta_{1,2}-5)\theta_{1,2}\theta_{2,1}-(1+3\theta_{1,2})\theta_{2,1}{}^2)(6\theta_{1,2}-8-(14+\theta_{1,2})\theta_{2,1}+(7+\theta_{1,2}(8+3\theta_{1,2}))\theta_{2,1}{}^2-\theta_{1,2}\theta_{2,1}{}^3))}{8(4-\theta_{1,2}\theta_{2,1})^2\Delta^2(\theta_{1,2}\theta_{2,1}-1)}+\frac{A^2(6\theta_{2,1}-8+\theta_{1,2}(\theta_{1,2}-(\theta_{2,1}-3)(\theta_{2,1}-2)+3\theta_{1,2}\theta_{2,1}))(8-6\theta_{2,1}+\theta_{1,2}(14+\theta_{2,1}+\theta_{1,2}(-7+(\theta_{1,2}-8-3\theta_{2,1})\theta_{2,1}))}{8(4-\theta_{1,2}\theta_{2,1})^2\Delta^2(\theta_{1,2}\theta_{2,1}-1)}$	$\frac{A^2}{4}$
Social welfare	$\frac{A^2(-\theta_{1,2}(192+\theta_{1,2}(136+\theta_{1,2}(9\theta_{1,2}-88)))+\theta_{1,2}(2128+\theta_{1,2}(424+\theta_{1,2}(218+3(\theta_{1,2}-27)\theta_{1,2})))\theta_{2,1}+(-136+\theta_{1,2}(424+\theta_{1,2}(-1498+\theta_{1,2}(\theta_{1,2}(17\theta_{1,2}-130)-323))))\theta_{2,1}{}^2}{8(4-\theta_{1,2}\theta_{2,1})^2\Delta^2(\theta_{1,2}\theta_{2,1}-1)}+\frac{(88+\theta_{1,2}(218+\theta_{1,2}(-323+\theta_{1,2}(342+\theta_{1,2}(67+24\theta_{1,2})))))\theta_{2,1}{}^3-(9+\theta_{1,2}(81+\theta_{1,2}(130+\theta_{1,2}(16\theta_{1,2}-67))))\theta_{2,1}{}^4+\theta_{1,2}(1+3\theta_{1,2})(3+8\theta_{1,2})\theta_{2,1}{}^5-64(14+3\theta_{2,1}))}{8(4-\theta_{1,2}\theta_{2,1})^2\Delta^2(\theta_{1,2}\theta_{2,1}-1)}-f_1-f_2$	$\frac{A^2(3-\theta_{1,2}-\theta_{2,1})}{4(2-\theta_{1,2}-\theta_{2,1})}-f_1-f_2$

more sensitive to the price of each e-book, and while prices increase, the total demand also increases. If retailers only offer their exclusive digital formats, some consumers may be reluctant to make the purchase because they cannot read/use another format once they make commitments to one of the specific retailers. From a practical point of view, this implies that if the similar format of the digital book is adopted across the different retailers (i.e., high cross-price sensitivity), all of the parties in the e-book supply chain enjoy a much higher total market coverage compared with the case when an exclusive format is provided by each retailer. Further, in the duopoly market, the competition between the retailers can also benefit the consumers.

This result holds only in the case where the cross-price sensitivity parameter is symmetric. Proposition 2 addresses the situation when the cross-price sensitivity parameters are different for alternate retailers.

Proposition 2: *Under a wholesale pricing model with asymmetric cross-price sensitivity coefficients, a decentralized supply chain, and equivalent fixed costs, the equilibrium profit of retailer i is less than the profit of retailer j if* $\theta_{i,j} > \theta_{j,i}$.

Proof**:** See Appendix C for the proof, as well as an alternate sensitivity analysis. Proposition 2 indicates that the retailer with the lower cross-price sensitivity will earn a higher profit. Essentially, the retailer with a lower value of $\theta_{j,i}$ enjoys a higher exclusivity. To illustrate, consider e-books offered by both Amazon and Apple. A book bought from Amazon can be read on an iPad, while a book bought from the Apple store cannot be utilized on a Kindle reader. Therefore, the impact of the price of a particular digital book from Amazon on the demand for that same digital book from the Apple store is likely to be relatively lower. If the total market for this book (A) and the fixed costs (f_i) for these two retailers are roughly equal, Apple should earn a higher profit due to the higher exclusivity.

Combined with Proposition 1, this result provides a partial explanation of the current electronic format practice in the e-book industry. First, both of the competing retailers have a strong motivation to increase their portability (i.e., adopting the similar electronic formats) in the e-book market, which essentially induces higher market coverage and higher overall profit for both of the retailers. However, each of the retailers "has his own axe to grind." Both retailers would like to raise their portability, but neither of them wants to increase to a level higher than the other retailer. This provides an explanation as to why different digital book retailers prefer introducing their exclusive formats to sharing the same electronic format in the e-book industry. Other reasons may include better market segmentation and/or a lack of an official third party organization dictating industry standards.

Agency Model

In the agency model, the publisher sets the price of the e-book and the retailers who serve as agents retain a percentage of the revenue. To further explore the agency model, we also investigate the situation when the retailers instead of the publisher determine the price of e-books, which we call the "modified agency model" in this study.[iii] The agency model for digital goods is similar to the revenue sharing contract and franchise contract in the physical goods market, where the retailer shares a percentage of his/her revenue with the publisher (Cachon & Lariviere, 2005). Another interpretation of the agency model is as a special case of the linear price-discount sharing (PDS) scheme proposed by Bernstein and Federgruen (2005). These authors propose a buy-back contract combined with a PDS scheme to coordinate the physical goods supply chain. One can show that their contract is equivalent to the agency model in the e-book industry.

Although the revenue sharing, franchise and PDS contracts are very effective in a wide range of supply chains, they also have several limitations. One of the major implementation concerns associated with revenue sharing and franchise contracts in the physical goods market is the high administrative expense (Cachon & Lariviere, 2005). The upstream supplier must audit the retailer's revenue to verify that the retailer split the profit appropriately. In the digital goods market, the necessary monitoring technology has long been in place, as publishers and e-book retailers can easily share and validate information concerning the sales of digital goods. Another important limitation which may keep the supplier from engaging in the revenue sharing contract lies in the fact that the supplier typically quotes a transfer price to the retailer that is likely below the production cost (Koulamas, 2006). However, in the digital goods market, because the reproduction cost is negligible, the publisher is willing to accept a zero transfer price to the retailers, which facilitates the implementation of the agency model.

In our model, either the publisher or the retailer (i.e., agency model and modified agency model) can set the price of e-book. When the publisher sets the price (i.e., agency model), the sequence of events is as follows: First, the publisher declares the retail prices p_i and p_j simultaneously and then the retailers act as agents to sell the digital book while retaining α proportion of the revenue. Finally, the publisher gets the remaining $(1-\alpha)$ of the sales revenue as his/her profit. Thus, the publisher faces the following optimization problem:

$$\max_{p_i, p_j} \pi_P = (1-\alpha) \sum_{i,j} p_i \left(A - p_i + \theta_{j,i}\, p_j\right) \quad \forall i, j \in \{1, 2\}. \tag{2}$$

We summarize the results in the left column of Table 3 and the proof is given in Appendix D. The right column of Table 3 shows the results of the "modified agency model" where the retailers instead of the publisher set the sales price of the e-book simultaneously. Note that for the "modified agency model," the publisher does not have any control over the pricing of the goods.

Proposition 3: *When the publisher decides the price, the agency pricing model coordinates the digital goods supply chain with price competing retailers.*

***Proof*:** See Appendix E. This result is new to the literature where for the physical goods, there does not exist a simple legal contract with common terms that coordinates the heterogeneous competing retailers (Cachon et al., 2005; Yao et al.,

[iii]There are two main features of the agency model, which are revenue sharing as well as the publisher's control over the price. Comparing the agency model with the modified agency model allows us to identify the exact factors driving the result.

Table 3: Agency model results.

	Agency Model (Publisher Decides the Price)	Modified Agency Model (Retailers Decide the Price)
Sales price (Retailer 1)	$\frac{A}{2-(\theta_{1,2}+\theta_{2,1})}$	$\frac{A(2+\theta_{2,1})}{4-\theta_{1,2}\ \theta_{2,1}}$
Total demand	A	$\frac{A(4+\theta_{1,2}+\theta_{2,1})}{4-\theta_{1,2}\ \theta_{2,1}}$
Retailer's profit (Retailer 1)	$\frac{A^2\alpha(1-\theta_{1,2})}{(2-\theta_{1,2}-\theta_{2,1})^2} - f_1$	$\frac{A^2\alpha\ (2+\theta_{2,1})^2}{(4-\theta_{1,2}\ \theta_{2,1})^2} - f_1$
Publisher's profit	$\frac{A^2(1-\alpha)}{2-\theta_{1,2}-\theta_{2,1}}$	$\frac{A^2(1-\alpha)[8+\theta_{1,2}\ (4+\theta_{1,2})+\theta_{2,1}(4+\theta_{2,1})]}{(4-\theta_{1,2}\ \theta_{2,1})^2}$
Supply chain profit	$\frac{A^2}{2-\theta_{1,2}-\theta_{2,1}} - f_1 - f_2$	$\frac{A^2(8+\theta_{1,2}\ (4+\theta_{1,2})+\theta_{2,1}(4+\theta_{2,1}))}{(4-\theta_{1,2}\ \theta_{2,1})^2} - f_1 - f_2$
Consumer surplus	$\frac{A^2}{2(2-\theta_{1,2}-\theta_{2,1})}$	$\frac{A^2(8+\theta_{1,2}{}^2(3+\theta_{1,2})+\theta_{2,1}(8+3\theta_{2,1})+\theta_{1,2}\ (8+\theta_{2,1}(4+\theta_{2,1})))}{2(4-\theta_{1,2}\ \theta_{2,1})^2(1-\theta_{1,2}\ \theta_{2,1})}$
Social welfare	$\frac{3A^2}{2(2-\theta_{1,2}-\theta_{2,1})} - f_1 - f_2$	$\frac{A^2(8+\theta_{1,2}{}^2(3+\theta_{2,1})+\theta_{2,1}(8+3\theta_{2,1})+\theta_{1,2}\ (8+\theta_{2,1}(4+\theta_{2,1})))}{2(4-\theta_{1,2}\ \theta_{2,1})^2(1-\theta_{1,2}\ \theta_{2,1})} + \frac{A^2(8+\theta_{1,2}\ (4+\theta_{1,2})+\theta_{2,1}(4+\theta_{2,1}))}{(4-\theta_{1,2}\ \theta_{2,1})^2} - f_1 - f_2$

2008). The decentralized digital goods supply chain achieves "virtual integration" with the agency model when the publisher decides the price. Essentially, the publisher makes all of the supply chain decisions in the agency model and shares the revenue with the retailers whereas in the wholesale model, the publisher and the retailers share the pricing decisions, which cause the double marginalization effect. It's worthwhile to point out that it's relatively simple to implement for the digital goods due to the negligible production cost and also the demand and supply can always be perfectly matched.

There are several important differences between the agency model and both revenue sharing and franchise contracts. To begin with, the retailer sets the price instead of the supplier in both revenue sharing and franchise contracts. Under the agency model, the upstream publisher (instead of the retailer) sets the price. Second, the monetary transactions between the supplier and the retailers are dissimilar among these contracts. In both revenue sharing and franchise contracts, the retailers typically pay an upfront fee for the units from the supplier. However, in the agency model, the retailer does not to pay such an upfront cost to the publisher.

The particular revenue sharing proportion value α is exogenously determined before the selling season starts. In practice, the value of α may depend on the firms' relative bargaining power, outside opportunity profit and other factors to allocate the profit between the publisher and retailers. As the e-book retailers' bargaining power becomes stronger, one would expect a higher value of α. The current value of α is 30% where the publisher keeps the majority portion of the e-book sales. It's possible that the value α will increase as the retailers keep improving their e-book technology capabilities and earn additional bargaining power by allowing some authors to publish directly through the retailers, and thereby bypassing the publishers.

In order to further delineate the specific mechanism driving the results for the agency model, we also consider a variant whereby the retailer determines the retail price of e-books. We explore this intriguing case in the following proposition.

Proposition 4: *Comparing the agency model with the modified agency model, we find that if the retailers set the digital goods prices (i.e., modified agency model) instead of the publisher, then*

(a) *the optimal retail price p_i decreases and the total market coverage increases,*
(b) *the retailer i with a lower value of $\theta_{i,j}$ will suffer a greater loss than the "relative gain" of the retailer j with a higher value of $\theta_{j,i}$, and*
(c) *the publisher's profit and total supply chain profit decrease.*

***Proof*:** See Appendix F. We find that alternating the decision sequence where the retailers determine the price instead of the publisher will diminish the supply chain efficiency. The root reason of this distortion is a result of the competition between the price competing retailers. If the retailers set the retail prices, they tend to set the price lower compared with the integrated scenario. Although the retailer will lose some market coverage due to the price decrease of the competing retailer, our assumption that $\theta_{i,j} \in (0, 1)$ guarantees that the retailer's own price change has a dominant effect on the market coverage. As a result, the total market coverage for both retailers will increase.

Further, we discover that reversing the pricing sequence will only "benefit" the retailer j with relative high value of $\theta_{j,i}$ despite the fact it hurts the retailer i who enjoys a higher exclusivity at the same time. Essentially, the "weak" retailer (i.e., retailer j with high value of $\theta_{j,i}$) is inclined to set the price sufficiently low to mitigate his/her weakness in the competition which forces the "strong" retailer to lower his/her optimal retail price. In the aggregate, the loss from the "strong" retailer outweighs the benefit from the "weak" retailer. Hence the total retailers' profit is lower as compared with the integrated supply chain case. Moreover, although the publisher gains from the higher market coverage, their loss from the lower margin outweighs the gains. As a result, the publisher's profit is also lower due to the competition between the retailers. We have also compared the consumer surplus and social welfare when $\theta_{i,j} = \theta$. In line with our expectation, we find that the consumer surplus and social welfare are higher under the modified agency model due to the downstream competition between the retailers.

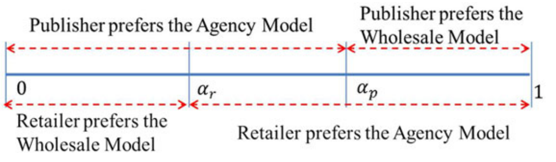
BENEFITS OF THE AGENCY MODEL

In this section, we compare and contrast the wholesale model with the agency model to illustrate the benefits of the agency model. To gain structural insights, we first focus on the symmetric cross-price sensitivity parameter case (i.e., $\theta_{i,j} = \theta_{j,i} = \theta$) and generalize the results to the asymmetric case, where our main qualitative insights still hold.

Theorem 1: *When the cross-price sensitivity parameter is symmetric, the supply chain profit and consumer surplus under the agency model is strictly higher than under the wholesale model. Moreover, both the profit and consumer surplus differentials are decreasing in the level of the cross-price sensitivity coefficient θ.*

***Proof*:** See Appendix G. After comparing the profit under the agency model and the wholesale model, we find that the supply chain profit under the agency model will always be higher than that under the wholesale model. This result is expected due to the double-marginalization effect when using the wholesale model. Under the wholesale model, each party in the supply chain independently seeks to optimize its own profit. Thus, the retail price becomes higher and demand and profits achieved through the wholesale model are lower as compared with a coordinated supply chain achieved through the agency model. Also we find that the consumer surplus under the agency model is always higher than the wholesale model, which implies that consumers actually gain when firms switch from the wholesale model to the agency model. Essentially, in the equilibrium, the price from the wholesale model is higher than the price under the agency model. The reason that we have observed a low selling price (i.e., \$9.99) from the wholesale model is that the retailer (i.e., Amazon) has set prices low so as to lock-in the consumers into its digital platform for future gain (i.e., lower than that which is optimally determined utilizing the traditional wholesale model). Selling the digital books at such a low price clearly is not a viable strategy in the long run. The regulators should take this important

Figure 1: Critical revenue sharing proportion with symmetric $\boldsymbol{\theta}$.



factor into consideration when they make the policy decisions. It can also be shown that the above result holds with asymmetric cross-price sensitivity parameters.

Further, we find that the profit and consumer surplus differentials under the agency as opposed to the wholesale model are strictly decreasing in the cross-price sensitivity coefficient θ. This result is due to the fact that the increase in the sensitivity coefficient θ can improve the channel efficiency under the wholesale model. As θ approaches to one under the wholesale model, the e-book supply chain becomes closer to coordination. We have also numerically explored the case where the retailers face asymmetric cross-price sensitivity parameter and show the above results regarding the supply chain profit and consumer surplus remain the same.

Theorem 2: *Comparing the profits of both retailers and the publisher under the wholesale model and the agency model, we find:*

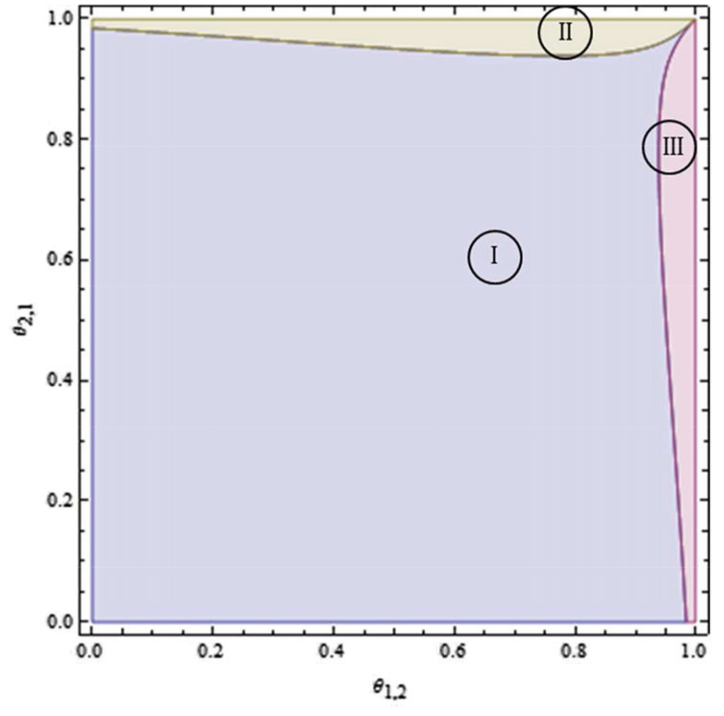
(a) *There exists a critical retailer revenue sharing proportion, $\alpha_r = \frac{1-\theta}{(2-\theta)^2}$, such that each retailer prefers the agency model when $\alpha > \alpha_r$ and the wholesale model when $\alpha < \alpha_r$. If $\alpha = \alpha_r$, the retailer is indifferent between these two pricing schemes.*

(b) *There exists a critical publisher revenue sharing proportion, $\alpha_p = \frac{1-\theta}{2-\theta}$ such that the publisher prefers the wholesale model when $\alpha > \alpha_p$ and the agency model when $\alpha < \alpha_p$. If $\alpha = \alpha_p$, the publisher is indifferent between these two pricing schemes.*

(c) *If the revenue sharing proportion $\alpha \in (\frac{1-\theta}{(2-\theta)^2}, \frac{1-\theta}{2-\theta})$, then both the publisher and retailers prefer the agency model.*

Proof: See Appendix H. Intuitively, it appears that the retailers and the publisher may have conflicting preferences for the different pricing models. A higher value of the revenue sharing proportion α will motivate the retailers to prefer the agency model while discouraging the publisher to adopt the same pricing scheme. Of course, the publisher and retailers prefer to keep a higher proportion of the revenue from the e-book sales. Interestingly, there always exists a Pareto-improving region of the revenue sharing proportion α as shown in Figure 1. When $\alpha \in (\frac{1-\theta}{(2-\theta)^2}, \frac{1-\theta}{2-\theta})$, the publisher and retailers benefit by switching from the wholesale model to the agency model, which leads to a more efficient supply chain with higher profits as well as higher levels of social welfare. So an appropriate revenue sharing proportion

Figure 2: Regions of preference for publisher and retailers under the agency model.



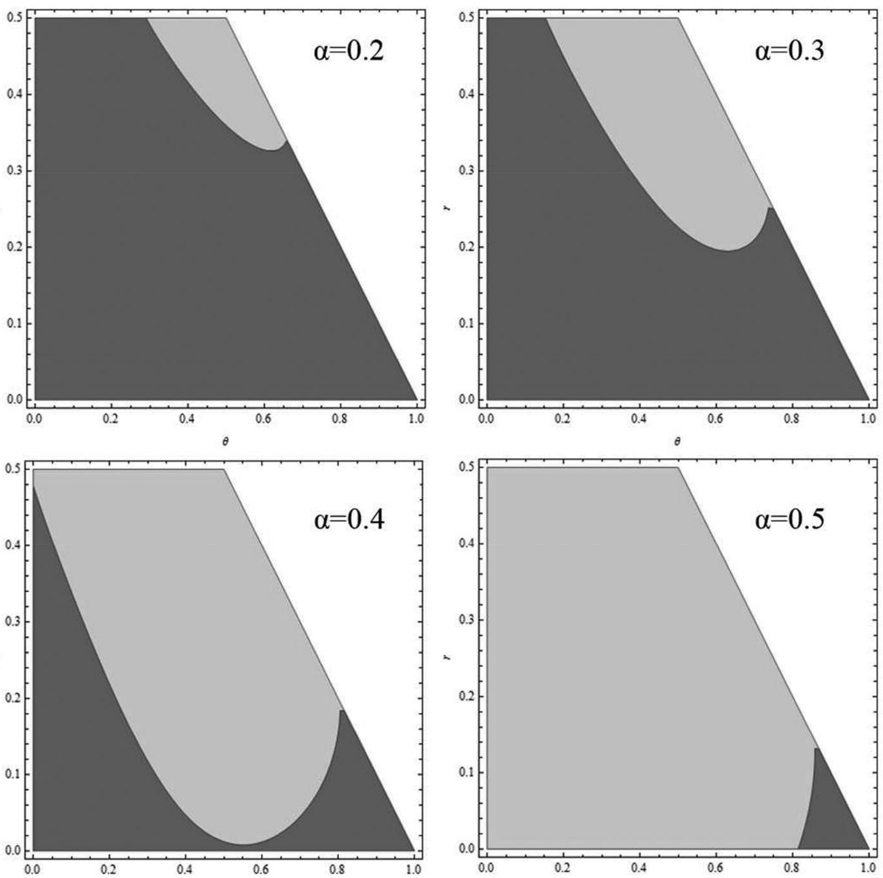
α will incentivize both the publisher and retailers to switch from the wholesale model to the agency model.

We further explore our analysis to address the case when the retailers have different cross-price sensitivity parameters and show that our main qualitative insights still hold. We find that Region I in Figure 2 depicts the area where there exist a range of αs that both retailers and publisher strictly prefer the agency model. Regions II and III in Figure 2 reflect the situation where there exists a range of αs such that one retailer and the publisher have the same preference for the contract scheme, while the other retailer has the opposite preference. The corresponding ranges of αs for each region of Figure 2 are characterized in Appendix I. We summarize the results when retailers have asymmetric cross-price sensitivity parameters in Theorem 3.

Theorem 3: *Comparing the profits of both the retailers and the publisher under the wholesale model and the agency model with asymmetric cross-price sensitivity, we find:*

(a) *In Region I of Figure* 2*, the revenue sharing proportion* α *is such that both the retailers and the publisher prefer the agency model to the wholesale model.*

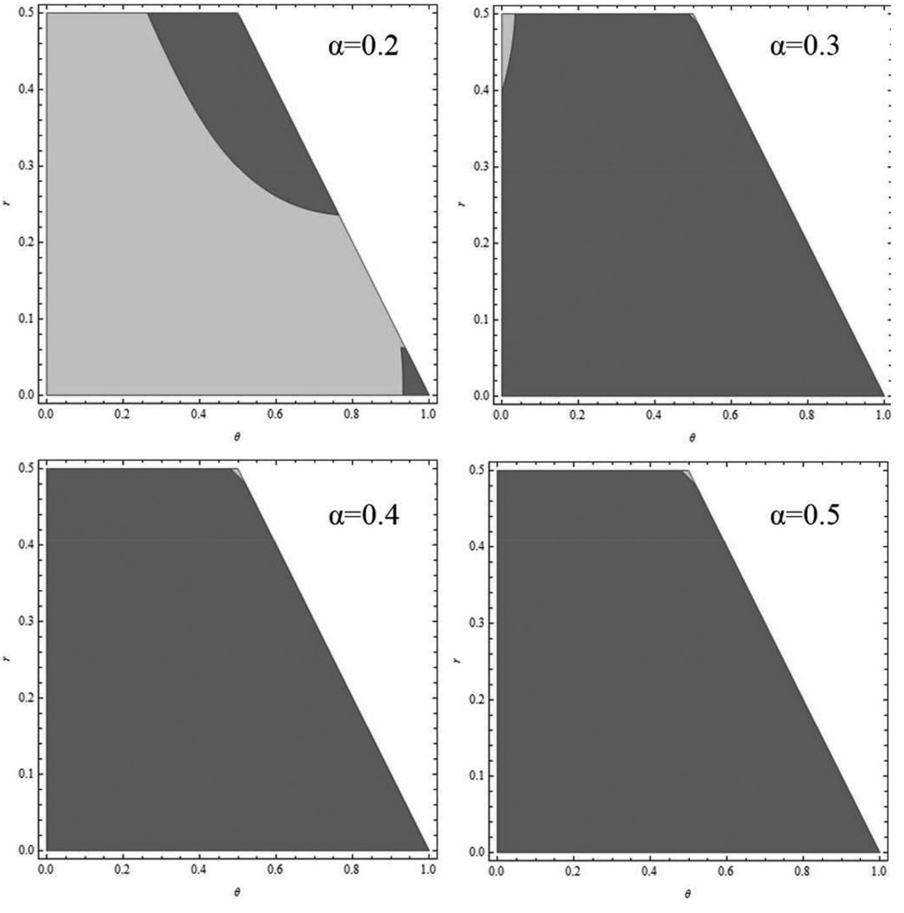
Figure 3: Illustrations of the comparison between agency model and wholesale model in the presence of printed books: publisher's profit.
Note: In each subfigure of Figure 3–5, the horizontal axis θ represents the cross-price sensitivity and the vertical axis r denotes the cross-price sensitivity between the physical books and the e-books. Figure 3 and 4 illustrate the parameter regions (in dark gray) when the publisher and retailers prefer the agency model. Figure 5 illustrates when the supply chain profit is higher under the agency model (in dark gray) compared with the wholesale model. To obtain the above illustrations, we vary the revenue sharing proportion $\alpha = \{0.2, 0.3, 0.4, 0.5\}$ in each case and set the potential market size $B = 100$.



(b) *In Regions II and III of Figure 2, the revenue sharing proportion α is such that the retailers have conflicting preferences for a contract scheme.*

Proof: See Appendix I. Essentially, Region I of Figure 2 is similar to Theorem 2 where there exists a Pareto-improving region of revenue sharing

Figure 4: Illustrations of the comparison between agency model and wholesale model in the presence of printed books: retailers' total profit.

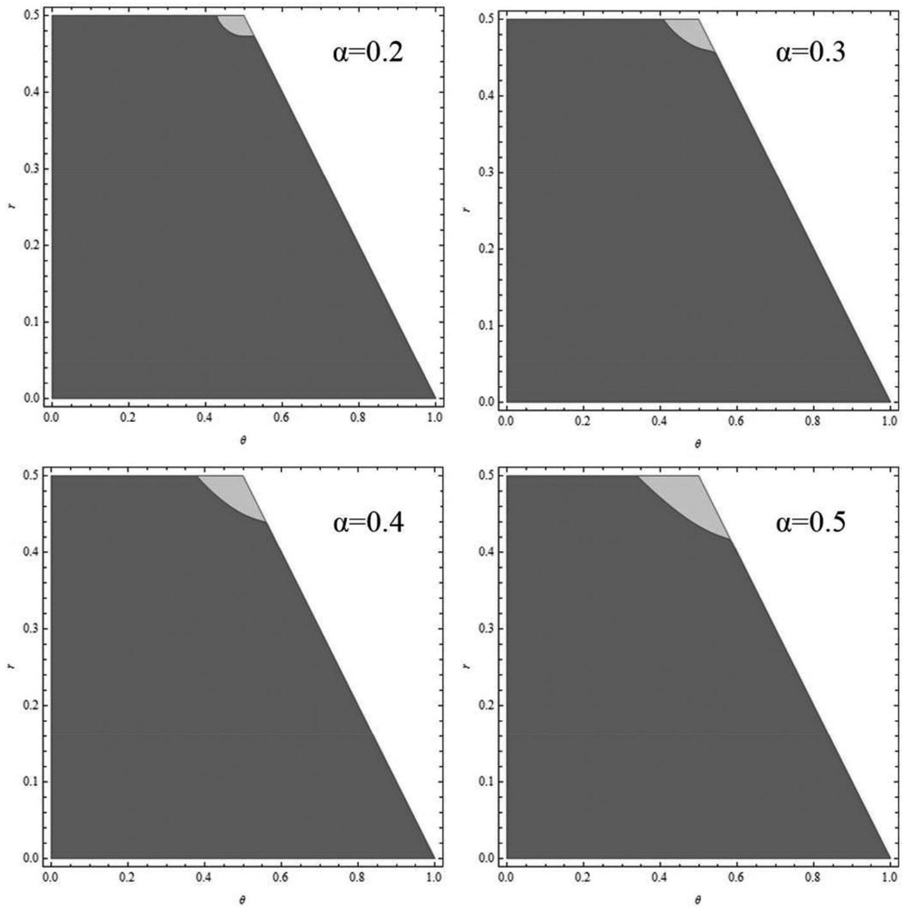


proportion α such that both the retailers and the publisher prefer the agency model. In general, the retailers prefer a higher revenue sharing proportion α while the upstream publisher favors the lower value of α. When α is in the middle range, the symmetric retailers prefer the agency model as well as the asymmetric retailers at large, but the asymmetric retailers may also have a conflicting preference over the contract schemes under certain conditions.

EXTENSIONS

We now consider extensions of the basic model in the previous sections to further assess the robustness our key findings. The analysis in this section further demonstrates the benefits of the agency model in the presence of physical counterparts or e-book readers in the marketplace.

Figure 5: Illustrations of the comparison between agency model and wholesale model in the presence of printed books: supply chain profit.



Printed Books

Our basic model focuses on the digital goods; we now take their physical counterparts into consideration. Although the agency model no longer coordinates the supply chain due to the presence of printed books, our main insights regarding the agency model still hold. Without loss of generality, we assume that Retailer 1 generates the revenue from the sales from both e-books as well as printed books. Retailer 2 is the pure e-book retailer as before. Our setting reflects the current market situation where Amazon competes with the e-book retailer Apple. In this section, we utilize the subscript/superscript "*T*" to denote the traditional printed book. The retail price of printed books is denoted as p_T and potential market sizes is denoted as B. Based on the above assumption, we modify our demand function for retailer i,

$$D_i{}^E\left(p_i, p_j, p_T\right) = B - p_i + \theta\, p_j + r p_T,$$
$$0 < \theta < 1, r < 1/2,\ \theta + r < 1\ \ i, j \in \{1, 2\},$$

$$D_1{}^T\left(p_i, p_j, p_T\right) = B - p_T + r p_i + r p_j, \qquad r < 1/2,\ \ i, j \in \{1, 2\},$$

where $D_i{}^E$ and $D_1{}^T$ represent the market demand of e-books for retailer i and traditional printed books for Retailer 1, respectively.[iv] We assume that the variable r represents the cross-price sensitivity between the physical books and the e-books. Furthermore, we assume that both θ and r are symmetric. Note that $\theta + r$ reflects the overall cross-price sensitivity effect faced by retailer i's e-book distribution channel and the condition $\theta + r < 1$ guarantees that each product's own price sensitivity outweighs the competing effects. In our extended wholesale model, after the publisher sets the wholesale price for electronic and printed books, both retailers decide their preferred e-book retail price and the Retailer 1 also determines the optimal printed book sales price. While under the agency model, the publisher determines both retail prices for the e-book and the wholesale price for the printed books. This is followed by decision of Retailer 1 on the retail price for printed books. Following the practice, the retailer and publisher will only share the revenue of the e-book. An overview of the derivation is provided in Appendix J. Due to the complexity of the results, we utilize numerical studies to present structural insights for this model extension as shown in Figures 3–5.

Observations: *When the revenue sharing proportion α is in the median range* (i.e.,$\alpha \in [0.2, 0.5]$) *and when comparing the agency model with the wholesale model in the presence of the printed book, we find that the agency model has higher supply chain profit than the wholesale model when the competition (i.e., reflected in cross-price sensitivities) is not extremely high.*

(a) *The publisher prefers the wholesale model for higher values of revenue sharing proportion* α.

(b) *The retailers prefer the agency model for higher values of revenue sharing proportion* α.

(c) *In terms of the supply chain profit, the agency model performs better than the wholesale model when the competition between retailers is not extremely high.*

In general, we find that the presence of physical counterparts does not affect the main qualitative insight obtained from the base model where the retailers and the publisher have conflicting preferences for the different pricing models. In addition, the agency model outperforms the wholesale model in terms of the supply chain profit for intermediate values of α. Different from the base model, we find that the agency model no longer coordinates the supply chain. In this case, the distribution of the printed book occurs via a traditional wholesale model framework regardless of the mechanism of distribution for the e-books. As a result, the agency model only

[iv]To focus on the strategic implication of the agency model as well as considering the growing popularity of the print on demand (POD) technology, we do not incorporate stochastic component into our demand function. Further we have verified that our result is robust to the different potential market size B.

partially alleviates the double marginalization effect. Further, when the price sensitivity between channels and retailers are extremely high (i.e., high values of θ and r), the agency model will decrease the level of competition between the downstream retailers by fixing the retail price of the e-book by the upstream publisher. Subsequently, the retailers may charge a higher sales price for printed books in the agency model compared with the wholesale model due to the decreased competition.

E-book Reader

Different from reading traditional printed books, e-books typically require a complementary electronic device to access them. The electronic device could be a dedicated e-book reader (e.g., Amazon's Kindle, Barnes, and Noble's Nook), a tablet computer, or software applications on PCs or smartphones. Previous literature (Hao & Fan, 2014) has investigated the influence of the e-book reader on the pricing in e-book market. They identify the complementary consumption between e-books and e-readers as the main reason for the differences in the e-book price under the wholesale model and agency model, which provides an important explanation of the pricing behavior of the early stage in the e-book market.

We do not incorporate the e-book reader into our model based on several recent developments in the e-reader market which we would like to highlight. First, there is now a significant established population which already owns a device that can be utilized to read e-books. According to a recent survey conducted by Princeton Survey Research (Zickuhr & Rainie, 2014), 50% of Americans now have access to a device (i.e., tablet or e-reader) for reading e-books. In addition, the number of people who own the e-book device has increased rapidly through the past few years. Second, as reported by Bookboon (2013), in the United States, there are only about 1.9% consumers planning to purchase the e-reader in the near future. Third, more people are using their smartphone as an e-reader. According to a survey of 1,420 respondents in United Kingdom (Ward, 2013), 25% used their smartphone as an e-reader, while 22% use Kindle and 15% use iPad. In the United States, approximately 32% of people surveyed read e-books through free mobile applications on their smartphones (Zickuhr & Rainie, 2014). More interestingly, many practitioners observe that e-book retailers do not earn a profit on their devices (Fiegerman, 2011). Note that this observation has also been confirmed by Amazon's CEO Jeff Bezos (Conlin, 2012).

In summary, the current e-book market is evolving very quickly and we believe our model is consistent with the current trend that the retailer no longer makes profit from the sales of e-book reader. As a result, we focus our attention on the comparison between wholesale model and agency model in current market situation.

CONCLUSIONS AND FUTURE RESEARCH

Motivated by the e-book industry, we investigate the impact of agency versus wholesale pricing schemes specifically for the digital goods market. By analyzing a scenario with two retailers and a single publisher, we identify situations under which the agency pricing scheme optimally coordinates the supply chain. Specifically, when the publisher determines the prices for the e-book in the marketplace, then the supply chain can be optimally coordinated. In contrast to the previous literature on physical goods, two key characteristics of digital goods causing this result are: (a) the lack of inventory and advanced commitments, and (b) zero marginal cost.

In our model, we assume that the percentage of revenue that both the retailers (α) and publisher ($1 - \alpha$) keep is exogenously given. To illustrate, in the e-book industry, the retailers typically retain 30% of the revenue from each book sold, while the publisher earns the remaining 70%. Our results show that when utilizing an agency pricing model whereby the publisher sets the prices for the e-book, there exists a range for this revenue sharing parameter (α) for which both retailers and the publisher earns more profit than that which they would have earned utilizing a traditional wholesale model. Moreover, contrary to popular press, consumer surplus and social welfare are also enhanced with the utilization of the agency pricing model. Thus, our research indicates that the in the equilibrium, the agency model may be a better pricing model for the digital goods market. We believe the initial price increase after introducing the agency model (i.e., from $9.99 to $12.99 and $14.99) is not because the agency model demands a high selling price but instead that the original retail price under the wholesale model was too low (i.e., lower than that predicted by the traditional wholesale model). One possible reason for the very low wholesale price is merely that Amazon undertook a strategic move to lock-in consumers and build market share, which is not viable in the equilibrium. Moreover, others may argue that Amazon also wanted to subsidize the e-book sales so that they could sell more reader devices.

In addition, we develop interesting results regarding the impact of the cross-price sensitivity of demand on profits for all parties. When utilizing a traditional wholesale model, it appears that the party associated with the smallest cross-price sensitivity parameter earns higher profits. Therefore, retailers have an incentive to differentiate their product such that customer's do not perceive them as similar. This result also holds when utilizing an agency model where the publisher determines the optimal price. However, when each retailer determines the optimal price of the digital good in his own market, an increased cross-price sensitivity leads to a higher profits. In this situation, a higher cross-price sensitivity parameter simply increases the firm's price in the marketplace. Therefore, if the retailers maintain control over pricing while utilizing an agency scheme, they have more of an incentive to invest in a common platform.

Future research should address additional complicating factors for the e-book industry. For example, one can study the collusion issue between the publishers by incorporating additional publisher into the current model. Note that a limitation of our model is the utilization of a linear form of demand (Lus & Muriel, 2009). An analysis of the impact of stochastic demand on the inventory for physical books alongside digital books may produce further results regarding appropriate pricing models. Finally, more than two competing retailers in the marketplace may yield insights concerning increased competition for e-book retailers.

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APPENDIX A

PROOF FOR WHOLESALE MODEL

We solve the publisher's Stackelberg game by backward induction. Retailer i faces the following unconstrained optimization problem given the wholesale price w,

$$\max_{p_i} \pi_R = (p_i - w)\left(A - p_i + \theta_{j,i}\, p_j\right) - f_i. \tag{A1}$$

It's clear that the above problem is concave in the retailer's own sales price p_i, so the first-order condition (FOC) leads to the optimal solution. Taking the derivative with respect to p_i (or p_j) to both retailers' profit function and setting them equal to zero jointly, we find

$$p_1{}^*(w) = \frac{2A + A\theta_{2,1} + w\left(2 + \theta_{2,1}\right)}{4 - \theta_{1,2}\,\theta_{2,1}}, \quad p_2{}^*(w) = \frac{2A + A\theta_{1,2} + w\left(2 + \theta_{1,2}\right)}{4 - \theta_{1,2}\,\theta_{2,1}}.$$

After substituting the above expression into the publisher's problem, we find

$$\max_{w}\ \pi_P = \frac{w\left[A\left(4 + \theta_{1,2} + \theta_{2,1}\right) + w\Delta\right]}{\theta_{1,2}\,\theta_{2,1} - 4}, \tag{A2}$$

where $\Delta = 4 - 2\theta_{1,2}\,\theta_{2,1} - \theta_{1,2} - \theta_{2,1}$. We can show that the publisher's profit is concave in the wholesale price w by checking the second-order condition. So taking the derivative of π_P with respect to the wholesale price w will give us the optimal solution $w^* = \frac{A(4+\theta_{1,2}+\theta_{2,1})}{2\Delta}$. By substituting this value into previous expression of $p_i{}^*(w)$, we also find $p_1{}^* = \frac{A(2+\theta_{2,1})(2\Delta+4+\theta_{1,2}\,\theta_{2,1})}{2\Delta(4-\theta_{1,2}\,\theta_{2,1})}$ and $p_2{}^* = \frac{A(2+\theta_{1,2})(2\Delta+4+\theta_{1,2}\,\theta_{2,1})}{2\Delta(4-\theta_{1,2}\,\theta_{2,1})}$.

APPENDIX B

PROOF FOR PROPOSITION 1

If both retailers have the same cross-price sensitivity coefficient, then we replace $\theta_{1,2}, \theta_{2,1}$ with θ and simplify the results in Table 2.

It's straightforward to prove that the retailer's profit and the publisher's profit are strictly increasing in the value of the cross-price sensitivity coefficient θ, thus the supply chain's profit (the sum of retailers' and publisher's profit) is also strictly increasing in θ. We prove the consumer surplus is increasing in θ by taking the first order condition and find:

$$\frac{dCS_{Wholesale}}{d\theta} = \frac{A^2(3\theta - 4)}{4(\theta - 2)^3(\theta - 1)^2}. \tag{B1}$$

Clearly the above expression is greater than zero under our assumption that $0 < \theta < 1$. Further we can conclude that the social welfare is also increasing in the value of θ.

APPENDIX C

PROOF FOR PROPOSITION 2

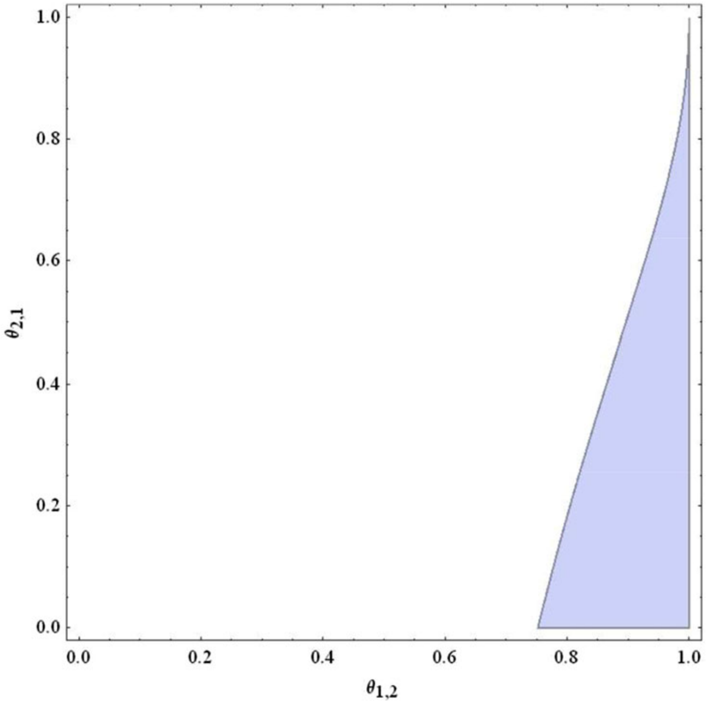
Without loss of generality, we subtract the Retailer 2's profit from Retailer 1's to obtain the following:

$$\pi_{Difference} = \frac{A^2(\theta_{1,2} - \theta_{2,1})(4 + \theta_{1,2} + \theta_{2,1})(\theta_{1,2} + \theta_{2,1} + 4\theta_{1,2}\theta_{2,1} - 12)}{4(\theta_{1,2}\theta_{2,1} - 4)^2\Delta} + f_2 - f_1. \tag{C1}$$

By our assumption, the fixed costs of two retailers are equivalent. As a result the sign of the $\pi_{Difference}$ will depends on the sign of the first term in the above expression. Thus the retailer i with lower value of $\theta_{i,j}$ will have a higher profit than retailer j.

Moreover, we have conducted additional sensitivity analysis to better understand the mechanism of Proposition 2. Without loss of generality, we keep the value of $\theta_{1,2}$ unchanged and examine the effect of a change on $\theta_{2,1}$ by taking the derivative of Retailer 1's optimal profit with respect to $\theta_{2,1}$ and find $\frac{\partial \pi_1}{\partial \theta_{2,1}} \geq 0$. This indicates that if Retailer 2 decreases $\theta_{2,1}$ then Retailer 1's profit will decrease. We have also taken the derivative of Retailer 2's optimal profit with respect to $\theta_{2,1}$ and the sign of this derivative depends on the relative magnitude of $\theta_{1,2}$ and $\theta_{2,1}$, which we have illustrated in the following A1. In the A1, horizontal axis represents the value of $\theta_{1,2}$ and the vertical axis represents the value of $\theta_{2,1}$. The blue region specify the parameter zone where $\frac{\partial \pi_2}{\partial \theta_{2,1}} \geq 0$, while the remaining parameter zone represents the case where $\frac{\partial \pi_2}{\partial \theta_{2,1}} \leq 0$.

Figure A1: The parameter region for $\theta_{1,2}$ and $\theta_{2,1}$ where $\frac{\partial \pi_2}{\partial \theta_{2,1}} \geq 0$.



Essentially, this result reinforces our finding that the retailer is hesitant to increase their portability. We can tell from the sensitivity analysis that increasing the value of $\theta_{2,1}$ (which is controlled by the Retailer 2) will always benefit the Retailer 1 and hurts the Retailer 2 itself in most situations. We have also investigated the change of $\theta_{2,1}$'s impact on the difference between Retailers 1 and 2. We find that $\frac{\partial \pi_{Difference}}{\partial \theta_{2,1}} \geq 0$, where $\pi_{Difference}$ is defined as the difference between Retailer 1's optimal profit and Retailer 2's optimal profit. Without loss of generality, we have shown that an increase of $\theta_{2,1}$ will translate to an increase of the profit of Retailer 1 but may decrease or increase of the profit of Retailer 2.

APPENDIX D

PROOF FOR AGENCY MODEL

Because the publisher decides the retail price of the digital goods, we solve the following problem: $\max_{p_i, p_j} \pi_P = (1-\alpha) \sum_{i,j} p_i(A - p_i + \theta_{j,i}\ p_j)$.

In order to show the problem is strictly and jointly concave in p_i and p_j, it is necessary to show that the determinants of the Hessian alternate in sign. The Hessian and its determinants are

$$H = \begin{bmatrix} 2(\alpha - 1) & (1-\alpha)\left(\theta_{1,2} + \theta_{2,1}\right) \\ (1-\alpha)\left(\theta_{1,2} + \theta_{2,1}\right) & 2(\alpha - 1) \end{bmatrix},$$

$$\left|H_1^1\right| = \left|H_2^1\right| = 2(\alpha - 1) < 0,$$

$$\left|H_{12}^2\right| = (\alpha - 1)^2 \left(4 - \left(\theta_{1,2} + \theta_{2,1}\right)^2\right) > 0.$$

We conclude the problem is strictly and jointly concave in p_i and p_j. The first-order conditions are necessary and sufficient to determine the optimal value of p_i and p_j, which we summarize in Table 3.

APPENDIX E

PROOF FOR PROPOSITION 3

We prove the theorem by comparing the solution when the publisher and retailers are integrated with the decentralized case. Further, we notice that the publisher's profit is an affine transformation of the supply chain profit in the left column of Table 3. Thus, the agency model with a single revenue sharing proportion parameter can coordinate the digital goods supply chain and allocate the profit based on the predetermined revenue sharing proportion.

APPENDIX F

PROOF FOR PROPOSITION 4

(a) We subtract the optimal retail price ${p_i}^P$ when the publisher decides the price from the price ${p_i}^R$ when the retailers lead the game by setting the price:

$$\begin{aligned} {p_i}^R - {p_i}^P &= A\left(\frac{1}{\theta_{i,j} + \theta_{j,i} - 2} + \frac{2 + \theta_{j,i}}{4 - \theta_{i,j}\theta_{j,i}}\right) \\ &= \frac{A\left({\theta_{j,i}}^2 + 2\theta_{i,j}\right)}{\left(4 - \theta_{i,j}\theta_{j,i}\right)\left(\theta_{i,j} + \theta_{j,i} - 2\right)}, \quad \forall i, j. \quad \text{(F1)} \end{aligned}$$

Because the cross-price sensitivity coefficient $\theta_{i,j} \in (0, 1)$, the sign of the above expression is negative, which shows that the optimal retail price becomes lower when the retailers choose the digital goods price. Meanwhile the demand function is price dependent, so the total market demand will increase after the retail price drops.

(a) Without loss of generality, we assume $\theta_{1,2} < \theta_{2,1}$ to prove the result. For Retailer 1, the loss in the profit is $\pi_{loss} = \frac{A^2\alpha[(2+\theta_{2,1})^2(\theta_{1,2}\ \theta_{2,1}-2)^2+((\theta_{1,2}\ -1)(\theta_{1,2}\ \theta_{2,1}\ -4)^2]}{(\theta_{1,2}\ \theta_{2,1}\ -4)^2(\theta_{1,2}\ \theta_{2,1}-2)^2}$, while the relative gain (in some extreme scenarios, the "gain" may be negative) for Retailer 2 is $\pi_{gain} = \frac{A^2\alpha[(2+\theta_{1,2}\ )^2(\theta_{1,2}\ \theta_{2,1}-2)^2+(\theta_{2,1}\ -1)(\theta_{1,2}\ \theta_{2,1}\ -4)^2]}{(\theta_{1,2}\ \theta_{2,1}\ -4)^2(\theta_{1,2}\ \theta_{2,1}-2)^2}$. As a result, the retailers' total profit change is

$$\Delta_\pi = A^2\alpha \frac{-\left(\theta_{1,2}{}^3 + \theta_{2,1}{}^3 + 2\theta_{1,2}{}^2 + 2\theta_{2,1}{}^2 + \theta_{1,2}\ \theta_{2,1}\left(\theta_{1,2} + \theta_{2,1} + \theta_{1,2}\ \theta_{2,1}\right)\right)}{\left(\theta_{1,2}\ \theta_{2,1} - 4\right)^2(\theta_{1,2}\ \theta_{2,1} - 2)^2} < 0. \quad \text{(F2)}$$

(b) We subtract publisher's profit when publisher moves first π_P^P from the publisher's profit when retailer moves first π_P^R and find

$$\pi_P^R - \pi_P^P = \frac{A^2(\alpha - 1)\left[\theta_{1,2}{}^3 + \theta_{2,1}{}^3 + 2\theta_{1,2}{}^2 + 2\theta_{2,1}{}^2 + \theta_{1,2}\ \theta_{2,1}\left(\theta_{1,2} + \theta_{2,1} + \theta_{1,2}\ \theta_{2,1}\right)\right]}{\left(4 - \theta_{1,2}\ \theta_{2,1}\right)^2}. \quad \text{(F3)}$$

Because the revenue sharing proportion value $\alpha \in (0, 1)$, we conclude that the publisher's profit will decrease when the retailers (instead of the publisher) choose the retail price. Further, because both the total retailers' profit and the publisher's profit decrease when retailers decide the price of the digital goods, then the supply chain profit also drops.

We have also compared the consumer surplus and social welfare but can only derive analytical results when $\theta_{1,2} = \theta_{2,1} = \theta$. We subtract the consumer surplus and social welfare of the modified agency model from the agency model and obtain,

$$CS_{diff} = \frac{A^2(\theta - 4)\theta}{4(\theta - 2)^2(1 - \theta)} < 0, \quad \text{(F4)}$$

$$SW_{diff} = \frac{A^2(4 - 3\theta)\theta}{4(2 - \theta)^2(\theta - 1)} < 0. \quad \text{(F5)}$$

APPENDIX G

PROOF FOR THEOREM 1

We subtract the equilibrium supply chain profit under the wholesale model from the one under the agency model. We find

$$\pi_{Difference} = \frac{A^2}{2(1 - \theta)} - f_1 - f_2 - \left(\frac{A^2(2\theta - 3)}{2(\theta - 2)^2(\theta - 1)} - f_1 - f_2\right)$$
$$= \frac{A^2(1 - \theta)}{2(\theta - 2)^2} > 0. \quad \text{(G1)}$$

We then take the derivative of $\pi_{Difference}$ with respect to the cross-price sensitivity θ, which yields:

$$\frac{d\pi_{Difference}}{d\theta} = \frac{A^2\theta}{2(\theta-2)^3} < 0. \tag{G2}$$

Similarly, we take the difference of the consumer surplus between the agency model and the wholesale model, which leads to

$$CS_{Difference} = \frac{A^2}{4} - \frac{A^2}{4(\theta-2)^2} = \frac{A^2}{4}\left(\frac{(\theta-2)^2-1}{(\theta-2)^2}\right) > 0, \tag{G3}$$

$$\frac{d\,CS_{Difference}}{d\theta} = \frac{A^2}{2(\theta-2)^3} < 0. \tag{G4}$$

APPENDIX H

PROOF FOR THEOREM 2

First we subtract the retailer's profit under wholesale model from the one under the agency model and find:

$$\pi_{Retailer\_Diff} = \frac{A^2}{4}\left(\frac{\alpha(2-\theta)^2-1+\theta}{(1-\theta)(2-\theta)^2}\right). \tag{H1}$$

Notice the denominator is always positive, so the sign of this expression depends on the sign of numerator. By arranging the numerator, we obtain $\alpha\theta^2 + (1-4\alpha)\theta + 4\alpha - 1$. It can be shown that if $\alpha > \frac{1-\theta}{(2-\theta)^2}$, the numerator is positive under $\theta \in (0, 1)$, is negative when $\alpha < \frac{1-\theta}{(2-\theta)^2}$ under $\theta \in (0, 1)$ and equals to zero when $\alpha = \frac{1-\theta}{(2-\theta)^2}$.

Next we compare the publisher's profit under the two pricing schemes. Following a similar procedure, we find $\pi_{Publisher\_Diff} = \frac{1}{2}A^2(\frac{1-\alpha-\alpha(2-\theta)}{(2-\theta)(1-\alpha)})$. The sign of this expression only depends on the sign of the numerator of this expression. So if $\alpha > \frac{1-\theta}{2-\theta}$, the difference of the profits under two pricing schemes will be positive and negative when $\alpha < \frac{1-\theta}{2-\theta}$.

APPENDIX I

PROOF FOR THEOREM 3

We first characterize the revenue sharing proportions α_{r1} and α_{r2} where asymmetric retailers are indifferent between the agency model and wholesale model, respectively. We obtain:

$$\alpha_{r1} = \frac{(\theta_{1,2}+\theta_{2,1}-2)^2\left((\theta_{2,1}-6)\,\theta_{2,1}-8-\theta_{1,2}{}^2\theta_{2,1}+\theta_{1,2}\,(6+\theta_{2,1}\,(5+3\theta_{2,1}))\right)^2}{4\,(1-\theta_{1,2})\,(4-\theta_{1,2}\,\theta_{2,1})^2\Delta^2}, \tag{I1}$$

$$\alpha_{r2} = \frac{\left(\theta_{1,2} + \theta_{2,1} - 2\right)^2 \left(\left(\theta_{1,2} - 6\right)\theta_{1,2} - 8 - {\theta_{2,1}}^2 \theta_{1,2} + \theta_{2,1}\left(6 + \theta_{1,2}\left(5 + 3\theta_{1,2}\right)\right)\right)^2}{4\left(1 - \theta_{2,1}\right)\left(4 - \theta_{1,2}\theta_{2,1}\right)^2 \Delta^2}. \quad \text{(I2)}$$

One can show that the relative magnitude of α_{r1} and α_{r2} depends on the sign of δ, where

$$\begin{aligned}\delta = {} & \theta_{1,2}\left(\theta_{1,2}\left(112 + \theta_{1,2}\left(32 + \left(\theta_{1,2} - 13\right)\theta_{1,2}\right)\right) - 128\right) \\ & + 2\left(64 + 3{\theta_{1,2}}^2\left(\theta_{1,2}\left(-41 + 3\theta_{1,2}\left(3\theta_{1,2} - 16\right)\right) - 8\right)\right)\theta_{2,1} \\ & + (3\theta_{1,2}\left(16 + {\theta_{1,2}}^2\left(47 + 3\theta_{1,2}\left(20 + 9\theta_{1,2}\right)\right)\right) - 112){\theta_{2,1}}^2 \\ & - \left(32 + \theta_{1,2}\left(47\theta_{1,2} + 73{\theta_{1,2}}^3 - 82\right)\right){\theta_{2,1}}^3 \\ & + \left(13 + \theta_{1,2}\left(32 + \theta_{1,2}\left(7\theta_{1,2} - 20\right)\right)\right){\theta_{2,1}}^4. \\ & - \left(1 + 3\theta_{1,2}\right)^2 {\theta_{2,1}}^5\end{aligned}$$

If $\delta > 0$, then $\alpha_{r1} > \alpha_{r2}$ and if $\delta < 0$, then we have $\alpha_{r1} < \alpha_{r2}$.

Next we characterize the revenue sharing proportion $\alpha_{p'}$ where the publisher is indifferent between the agency model and wholesale model. And we find

$$\alpha_{p'} = \frac{32 + {\theta_{1,2}}^3 + \theta_{2,1}\left(\theta_{2,1} - 2\right)\left(8 + \theta_{2,1}\right) + \theta_{1,2}\left(\theta_{2,1}\left(7\theta_{2,1} - 36\right) - 16\right) + {\theta_{1,2}}^2\left(6 + \theta_{2,1}\left(7 + 8\theta_{2,1}\right)\right)}{4\left(4 - \theta_{1,2}\theta_{2,1}\right)\Delta}. \quad \text{(I3)}$$

By comparing the relative magnitude of $\alpha_{p'}$, α_{r1}, and α_{r2}, we obtain the following two conditions. Condition 1 reflects the situation where there exists a region of revenue sharing proportion α such that both retailers and publisher prefer the agency model. Condition 2 reflects the region of cross-price sensitivity such that the retailers have conflicting preference over the contract schemes.

Condition 1 (Region I in Figure 2):

$$\left\{\left(\theta_{1,2}, \theta_{2,1}\right) |(\delta > 0 \cap \alpha_{p'} > .\alpha_{r1}) \overset{(\delta\langle}{\cup} 0 \overset{\alpha_{p'}}{\cap}\rangle \alpha_{r2}), \theta_{1,2}, \theta_{2,1} \in (0, 1)\right\}.$$

Condition 2 (Regions II and III in Figure 2):

$$\left\{(\theta_{1,2}, \theta_{2,1}) |(\delta > 0 \cap^{\alpha_{p'}} < \alpha_{r1} \cap^{\alpha_{p'}} > \alpha_{r2}) \cup^{(\delta\langle 0 \ \cap^{\alpha_{p'}}} \rangle \alpha_{r1} \cap^{\alpha_{p'}} < \alpha_{r2}),\ \theta_{1,2}, \theta_{2,1} \in (0, 1)\right\}.$$

APPENDIX J

OVERVIEW OF ANALYSIS FOR PRINTED BOOK

Now we provide an overview of the analysis when we incorporate the printed book into the model. For tractability, we normalize the production cost for printed books to be zero. In the wholesale model, the publisher first offers both retailers the e-book and printed books at the price of w. We assume that the publisher charges the uniform wholesale price for both the e-book and the printed book as based on the business practice quoted in the New York Times (Rich & Stone, 2010): "Amazon buys and resells e-books in the same way it handles printed books, by paying publishers a wholesale price that is generally equivalent to half the list price of a print edition." After observing the wholesale price, both retailers decide their preferred e-book retail price and the Retailer 1 also determines the optimal printed book sales price. As a result, the problem is formulated as follows:

$$\max_{w} \pi_P = w \sum_{i,j} \left(B - p_i + \theta p_j + r p_T\right) + w \left(B - p_T + r p_i + r p_j\right) \quad \text{(J1)}$$

$$\text{s.t.} p_i, p_j, p_T \in \text{argmax}\{(p_1 - w)\, D_1{}^E \left(p_i, p_j, p_T\right) + (p_T - w)\, D_i{}^P \left(p_i, p_j, p_T\right) - f_1\, (p_2 - w)\, D_2{}^E \left(p_i, p_j, p_T\right) - f_2\}.$$

Under the agency model, the publisher determines both retail prices for the e-book and the wholesale price for the printed books. The Retailer 1 only determines the retail price for printed books. So we can formulate the problem as,

$$\max_{w, p_i} \pi_P = (1 - \alpha) \sum_{i,j} p_i \left(B - p_i + \theta p_j + r p_T\right) + w \sum_{i,j} \left(B - p_T + r p_i + r p_j\right) \quad \text{(J2)}$$

$$\text{s.t.} \quad p_T \in \text{argmax} \left\{\alpha\ p_1\ D_1{}^E \left(p_i, p_j, p_T\right) + (p_T - w)\, D_1{}^P \left(p_i, p_j, p_T\right) - f_1\right\} .$$

We solve both of the Stackelberg games by backward induction. The solution procedure is very similar to the base model and is omitted.

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