

Pricing and Quality Decisions in the Distribution System of Physical Books and Electronic Books

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Abstract—Since the increasing popularity of electronic book cannibalizes the sales of physical book, publishers try to enhance the competitiveness of physical book by improving its quality in recent years. Inspired by this phenomenon, we establish analytical models to investigate the optimal quality and pricing decisions in book supply chain by game theory. We also analyze the effects of physical book quality and customer acceptance of electronic book on the publisher's and bookstore's pricing strategies. We find that both the physical book quality and customer acceptance of electronic book have a great impact on the publisher's and bookstore's pricing policies and profits. An interesting result shows that the improvement in the quality of physical book always leads to the increase of physical book's optimal price, but its influence on electronic book's optimal price depends on whether the market is price oriented or quality oriented.

Keywords—pricing decision; electronic book; product quality; supply chain management

I. INTRODUCTION

As electronic technology develops rapidly, people's way of reading has been greatly changed. Electronic books (e-books), as an alternative to physical books (p-books), gain increasing attention from readers. According to the 2018 Stat Shot Annual issued by the Association of American Publishers, in 2017, American publishers' book sales in online retail channels approximate to \$7.5 billion, 27% of which are e-books. Consequently, with the increasing popularity of e-books, traditional publication industry is facing a growing threat, since the sales of p-books show a decreasing trend in recent years [1].

In practice, publishers are paying more attention on physical books' quality: well-designed cover, intricate end papers, high-quality paper and beautiful illustrations. For instance, Bloomsbury Publishing who released the Harry Potter series in Britain has been adopting a strategy to increase the premium design flourishes on its physical books. All of these efforts make p-books significantly different from e-books, as Bosman [2] put it, "For publishers, the strategy has a clear payoff: to increase the value of print books and build a healthy, diverse marketplace that includes brick-and-mortar bookstores and is not dominated by Amazon and e-books". There are signs that exquisite design of physical books can make print sales reach new heights and cut into e-book sales. For instance, Bonnie and Eang [3] compare the best-seller lists of p-books

and e-books on Amazon and find that books which contain various colors and graphics are on the top sellers list of p-books, but not on the best-seller list of e-books. To summarize, significant quality improvement of p-books can contribute to the sale of p-books. However, it also brings the increase of production costs and cannibalizes e-book sales simultaneously. Consequently, it is critical for the publisher and the retailer to adopt appropriate strategies which combine quality decision and pricing policy.

Former studies related to e-books mainly concentrated on e-book conception, e-book's impact of users, comparison with p-book, e-book technologies and its application and trends [4][5][6][7]. In recent years, an increasing number of papers focus on topics about the supply chain, pricing strategies, and business models of e-books. Vasileiou, Hartley, and Rowley [8] pay attention to the potential of the e-book marketplace and give insight into e-book vendors and their services. Jiang and Katsamakas [9] analyze how the introduction of an e-book seller affects traditional sellers and consumers in the book markets. Li and Lin [1] discuss the publisher's and the retailer's launch and pricing strategies, and also analyze influence of market structure parameters on the publisher's launch and pricing decisions in different copyright and launch modes. Chen and King [10] investigate how a retailer can benefit from introducing e-book lending service, its impact on pricing strategy and cannibalization of retailer's printed books. Lu, Shi and Huang [11] identify a Pareto zone in the centralized channels where both the publisher and the bookstore benefit from agency model in particular situations.

At present, no literature concentrates on how the quality of p-books influences the pricing policy of e-books. Inspired and motivated by above context, this paper attempts to answer the following questions. Firstly, how do factors, like customer acceptance of e-book and price elasticity, affect the publishing stakeholders' marketing strategies? Secondly, how to adopt proper pricing policy after deciding the quality level of p-books?

II. MODEL DESCRIPTION AND ASSUMPTIONS

We establish a book supply chain structure consisting of a publisher and an independent bookstore. The publisher sells p-books at a wholesale price w_p and e-books at a wholesale price w_e simultaneously to the bookstore who, in turn, sells p-books and e-books to readers at retail prices p_p and p_e , respectively.

In addition, the publisher adds value v to p-books by quality upgrading in order to make p-books significantly different from e-books and maintain the profit gained from publishing p-books.

Due to the fact that digital distribution reduces the marginal cost of e-books to essentially zero, we assume the marginal cost of publishing e-books is zero. We take the cost of p-books' added value v by quality into consideration in our model and assume that the added value v is independent. Furthermore, we adopt a common form of the cost for added value, that is $c(v) = cv^2 (c > 0)$.

We assume that the demand functions of e-books and p-books are linear in price, cross-price effect and added value. Next, we use D_e and D_p to denote e-books and p-books demands, respectively. Then we formulate the demand functions as follows:

$$D_e = \theta a - p_e + \alpha(p_p - v), \quad (1)$$

$$D_p = (1 - \theta)a - bp_p + \alpha(p_e + v) + \beta v, \quad (2)$$

where a represents the total market scale of books while $\theta (0 < \theta < 1)$ captures readers' preference for e-books. Parameter b is price elasticity of p-books and it is assumed that $0 < b < 1$, for the reason that p-book buyers are less sensitive about price than e-book buyers in reality. And $\beta (\beta > 0)$ indicates the marginal p-books demand per quality value added. The parameter α , described as diffusion intensity, measures the shift between e-books and p-books with regards to the price and added value.

To ensure that our model makes sense, the following constraints should also be satisfied: first, $D_e > 0$, $D_p > 0$; second, retail price should be not less than marginal cost. Then we obtain:

$$0 \leq cv^2 \leq w_p \leq p_p \leq Xv + A, \quad (3)$$

$$0 \leq w_e \leq p_e \leq Yv + B, \quad (4)$$

where

$$X = \frac{\alpha + \beta - \alpha^2}{b - \alpha^2}, \quad Y = \frac{(\alpha + \beta)\alpha - ab}{b - \alpha^2}, \quad A = \frac{\theta a \alpha + (1 - \theta)a}{b - \alpha^2},$$

$$B = \frac{\theta ab + (1 - \theta)a \alpha}{b - \alpha^2}.$$

Noticing that the total demand should decrease with the increase of the prices, so we have $0 < \alpha < b \leq 1$, and $0 < \theta < 1$ before, so $X > 0$, $A > 0$, and $B > 0$. Additionally, we derive $cv^2 - Xv - A \leq 0$ from (3). Considering that $c > 0$, $X > 0$, and $A > 0$, we get that added value v is confined to an interval, denoted as $[\underline{v}, \bar{v}]$.

Then, the profit of publisher can be formulated as follows:

$$\pi_{pub} = w_e D_e + (w_p - c \cdot v^2) D_p, \quad (5)$$

and the bookstore's the profit function is:

$$\pi_{bs} = (p_e - w_e) D_e + (p_p - w_p) D_p. \quad (6)$$

III. ANALYSIS OF THE STACKELBERG EQUILIBRIUM

In this section, we analyze the equilibrium prices and added value v under Stackelberg competition model and assume that publisher is the Stackelberg leader. The publisher determines the added value v , the wholesale price of p-book w_p , and the wholesale price of e-book w_e first, then the bookstore as the Stackelberg follower determines her best response strategy based on the publisher's decisions. We can adopt the two-stage optimization technique. To be specific, we first maximize profits when v is given, then we solve the optimal v . The solving sequence is organized as follows.

A. Bookstore's Best Response

Firstly, substituting (1) and (2) into (6), we get $\pi_{bs} = (p_e - w_e) (\theta a - p_e + \alpha(p_p - v)) + (p_p - w_p) ((1 - \theta)a - bp_p + \alpha(p_e + v) + \beta v)$

. Secondly, we get the Hessian matrix of π_{bs} by taking the second-order partial derivative with respect to p_p and p_e :

$$H(p_e, p_p) = \begin{pmatrix} -2 & 2\alpha \\ 2\alpha & -2b \end{pmatrix}. \quad \text{Since } \frac{\partial^2 \pi_{bs}}{\partial p_e^2} = -2 < 0, \text{ and } \begin{vmatrix} -2 & 2\alpha \\ 2\alpha & -2b \end{vmatrix} = 4b - 4\alpha^2 > 0, \pi_{bs} \text{ is strictly jointly concave in } p_e \text{ and } p_p.$$

Then, we take the first-order partial derivative of π_{bs} with respect to p_e and p_p , then we assign zero to these derivatives and solve the optimal retail prices as follows:

$$p_e^* = \frac{Y}{2}v + \frac{B}{2} + \frac{w_e}{2}, \quad (7)$$

$$p_p^* = \frac{X}{2}v + \frac{A}{2} + \frac{w_p}{2}, \quad (8)$$

which satisfy (3) and (4); then we have the optimal profit of bookstore $\pi_{bs}(w_e, w_p, v)$.

B. Publisher's Best Response

Next we focus on the publisher's pricing strategy. Substituting (7) and (8) into (5), we have

$$\pi_{pub} = \frac{1}{2} \left(-w_e^2 - w_e(v + cv^2 - 2w_p)\alpha - (cv^2 - w_p) \right. \\ \left. - (bw_p + v(\alpha + \beta)) + a(w_p + cv^2(-1 + \theta) + w_e\theta - w_p\theta) \right) \quad (9)$$

Then we get the Hessian matrix of π_{pub} by taking the second-order partial derivative with respect to w_e and w_p : $H(w_e, w_p) = \begin{pmatrix} -1 & \alpha \\ \alpha & -b \end{pmatrix}$. Since $\frac{\partial^2 \pi_{pub}}{\partial w_e^2} = -1 < 0$, and $\begin{vmatrix} -1 & \alpha \\ \alpha & -b \end{vmatrix} = b - \alpha^2 > 0$, π_{pub} is strictly jointly concave in w_e and w_p . Next, we derive the optimal wholesale prices for any given added value and get the following proposition.

Proposition 1. For any given added value v , the publisher's optimal wholesale prices can be determined as follows:

$$w_e^*(v) = \frac{Y}{2}v + \frac{B}{2}, \quad (10)$$

$$w_p^*(v) = \frac{c}{2}v^2 + \frac{X}{2}v + \frac{A}{2}, \quad (11)$$

From Proposition 1, we have $\frac{dw_e(v)}{d\theta} = \frac{a(b-\alpha)}{2(b-\alpha^2)} > 0$, $\frac{dw_p(v)}{d\theta} = \frac{a(\alpha-1)}{2(b-\alpha^2)} < 0$. It indicates that for any given added value, the optimal wholesale price of e-books will increase and the optimal wholesale price of p-books will decrease with increasing parameter θ , which is reasonable and easy to understand. Since in real world, if the reader's acceptance of e-book is high, then the wholesale price of e-books should be set high and the p-books' price should be reduced.

Substituting (10) and (11) into (7) and (8), we get the following proposition, which shows the bookstore's optimal pricing strategies.

Proposition 2. For any given added value v , the integrated bookstore's optimal retail prices are:

$$p_e^*(v) = \frac{3Y}{4}v + \frac{3B}{4}, \quad (12)$$

$$p_p^*(v) = \frac{c}{4}v^2 + \frac{3X}{4}v + \frac{3A}{4}, \quad (13)$$

To analyze the impact of added value v and readers' acceptance of e-books θ on the publisher's and bookstore's optimal pricing strategies, we differentiate optimal prices with respect to v and θ , respectively, and get the following proposition.

Proposition 3. For any given added value v :

$$\bullet \frac{dp_e(v)}{dv} \begin{cases} > \frac{dw_e(v)}{dv} > 0, \text{ if } \alpha + \beta - b > 0, \\ = \frac{dw_e(v)}{dv} = 0, \text{ if } \alpha + \beta - b = 0, \\ < \frac{dw_e(v)}{dv} < 0, \text{ if } \alpha + \beta - b < 0. \end{cases} \quad (14)$$

$$\bullet \frac{dp_p(v)}{dv} = \frac{cv}{2} + \frac{3X}{4} > 0; \text{ when } v \geq \frac{X}{2c}, \frac{dp_p(v)}{dv} > \frac{dc(v)}{dv}; \text{ and when } v < \frac{X}{2c}, \frac{dp_p(v)}{dv} > \frac{dc(v)}{dv} \quad (15)$$

$$\bullet \frac{dp_e(v)}{d\theta} > 0, \frac{dp_p(v)}{d\theta} < 0. \quad (16)$$

Proposition 3(1) shows an interesting finding that the value of $\alpha + \beta - b$ determines the publisher's pricing strategy of e-books. Notice that the sum of α and β ($\beta > 0$) measures marginal value-added p-books' demand and b represents marginal price-based p-books' demand, we can get the following implications. When $\alpha + \beta - b > 0$, the optimal price of e-books increases with the increasing added value. It means the demand of p-books is more quality oriented than price oriented, then significant quality upgrade of p-books not only potentially attract increased p-books' demand, but also afford a higher optimal retail price of e-books, meaning a decreased e-books' demand. Correspondingly, the optimal price of e-books decreases with the increasing added value when $\alpha + \beta - b < 0$. It shows readers are more sensitive about p-book's price than its quality differentiation, then a lower optimal price of e-books should be adopted, which leads to an increased demand for e-books.

Also, we can get from Proposition 3(2) that the optimal retail price of p-books $p_p(v)$ increases with increasing added

value. It is intuitive because an increasing v leads to more demand of p-books and larger costs, and bookstore should raise the price of p-books to achieve the optimal profit. We also find that when v is less than a threshold, the rate of change of $p_p(v)$ with respect to v is larger than that of the cost for added value.

Additionally, Proposition 3(3) indicates that for any given v , the retail price of e-books increases with increasing θ , while the retail price of p-book decreases with increasing θ .

C. Stackelberg Equilibrium

Now we want to find the Stackelberg equilibrium in the book supply chain. We first substitute (10) and (11) into (9) and get the optimal profit π_{pub} of the publisher, then differentiate π_{pub} with respect to v , and let its result be zero. We find there are no more than three real roots in $[\bar{v}, \underline{v}]$. The equilibrium v can be found among these real roots, \bar{v} , and \underline{v} . Then we substitute the equilibrium v into (10), (11), (12) and (13) and get the equilibrium prices for publisher and bookstore. Moreover, we can also get the optimal profit π_{bs} .

IV. NUMERICAL STUDIES

In this section, we carry out numerical experiments to illustrate how the main parameters effect equilibrium decisions and benefits in our model. The results of our numerical studies are summarized in Fig. 1-2, where the parameters are set as follows: $a = 40$, $\alpha = 0.2$, $b = \{0.3, 0.7\}$, $\beta = \{0.3, 0.5\}$ and $c = 0.02$. All these parameters satisfy the requirements we discussed before and are chosen to make our experiments credible and meaningful. The rest of the experiments show similar results so we omit reporting them.

We first analyze the impact of customer acceptance of e-books θ and customers' preferences when the supply chain is centralized. From Fig. 1-2, if other parameters are fixed, the retail price of e-books increases with increasing θ , while the retail price of p-books decreases with increasing θ . From Fig. 1(a), when $\alpha + \beta - b < 0$, the optimal added value v decreases with increasing θ ; from Fig. 2(a), when $\alpha + \beta - b > 0$, the optimal v increases with increasing θ . Conversely, from Fig. 1-2 we can find that if customer acceptance of e-books θ is fixed, the optimal v and the retail price of p-books increase with increasing the value of $\alpha + \beta - b$.

Additionally, Fig. 1(b) shows that when customer acceptance of e-books θ is extremely high and the value of $\alpha + \beta - b$ is extremely low (means the p-books' market is price oriented), e-books can be more expensive than p-books.

V. CONCLUSIONS

In this paper, we investigated the price and quality decisions in distribution system of p-books and e-books by adopting the method of two-stage optimization and Stackelberg game.

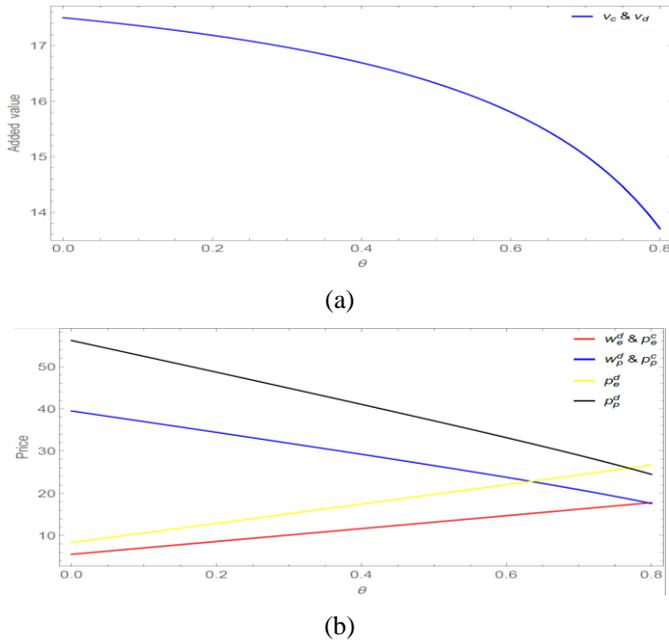


Fig. 1. The impact of customer acceptance of e-books θ on the p-book quality decision and the optimal prices when the market is price oriented ($\alpha + \beta - b < 0$).

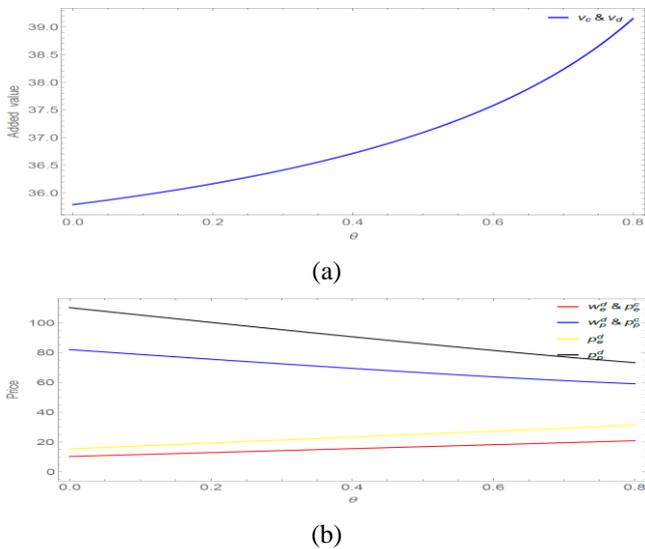


Fig. 2. The impact of customer acceptance of e-books θ on the p-book quality decision and the optimal prices when the market is quality oriented ($\alpha + \beta - b > 0$).

The contributions of our work can be summarized as follows. We considered quality when studying the competition between p-books and e-books. In this paper, we afforded the book industry appropriate strategies which combine quality decision and pricing policy. The results showed that the added value of p-books by quality can greatly influence the publisher's and the bookstore's pricing decisions and profits. For example, if readers are more quality oriented than price oriented, then providing the significant quality of p-books afford a higher optimal retail price of e-books. On the other

hand, if readers are more sensitive about book's price than its quality, then a lower optimal price of e-books should be adopted if the added value of p-books is set to be high. These results provide the publishers and the bookstores a practical and feasible decision making support.

We also got the following results from numerical studies. Firstly, both the customers' preferences (i.e., whether the readers are quality oriented or price oriented) and their acceptance of e-books have a significant impact on publisher's quality and pricing decisions. Generally speaking, in a centralized channel, the publisher should increase the price of e-books and decrease the price of p-books when customer acceptance of e-books arises. The pricing decisions for the publisher and the bookstore in a decentralized channel is also following above trend.

Secondly, if customers are more sensitive about book's price than its quality, the publisher should decrease the added value of p-books with increasing customer acceptance of e-books. Correspondingly, when customers are more sensitive about quality than price, the publisher should increase the added value of p-books with increasing customer acceptance of e-books.

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REFERENCES

- [1] Y. Li, Z. Lin, L. Xu, and A. Swain, "Do the electronic books reinforce the dynamics of book supply chain market? A theoretical analysis." *European Journal of Operational Research*, 2015, vol. 245(2), pp. 591-601.
- [2] J. Bosman, Selling books by their gilded covers. <http://www.nytimes.com/2011/12/04/books/publishers-gild-books-with-special-effects-to-compete-with-e-books>. Accessed on August 20, 2018.
- [3] D. Bounie, B. Eang, M. Sirbu, and P. Waelbroeck, "Superstars and outsiders in online markets, An empirical analysis of electronic books." *Electronic Commerce Research and Applications*, 12, 1 (2011), 52-59.
- [4] C.K. Ramaiah, "An overview of electronic books: A bibliography." *Electronic Library*, 2005, vol. 23(1), 17-44.
- [5] S.S. Rao, "Electronic books: a review and evaluation," *Library Hi Tech*, 2003, vol. 21(1), 85-93.
- [6] J. Shah and R.M.B. Jr, "Towards electronic paper displays made from microbial cellulose," *Applied Microbiology and Biotechnology*, 2005, vol. 66(4), pp. 352-355.
- [7] W.D. Woody, D.B. Daniel, and C.A. Baker, "E-books or textbooks: Students prefer textbooks," *Computers and Education*, 2010, vol. 55(3), pp. 945-948.
- [8] M. Vasileiou, R. Hartley, and J. Rowley, "An overview of the e-book marketplace," *Online Information Review*, 2009, Vol. 33(1), pp. 173-192.
- [9] Y. Jiang and E. Katsamakas, "Impact of e-book technology: Ownership and market asymmetries in digital transformation," *Electronic Commerce Research and Applications*, 2010, vol. 9(5), pp. 386-399.
- [10] C. Li and R.C. King, "To lend is to own: A game theoretic analysis of the e-book lending market," *International Journal of Electronic Commerce*, 2017, vol. 21(3), pp. 334-362.
- [11] Q. Lu, V. Shi, and J. Huang, "Who benefit from agency model: A strategic analysis of pricing models in distribution channels of physical books and e-books," *European Journal of Operational Research*, vol. 264(3), pp. 1074-1091.