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# Optimal content development and provision strategies for an integrated firm with divisional conflicts

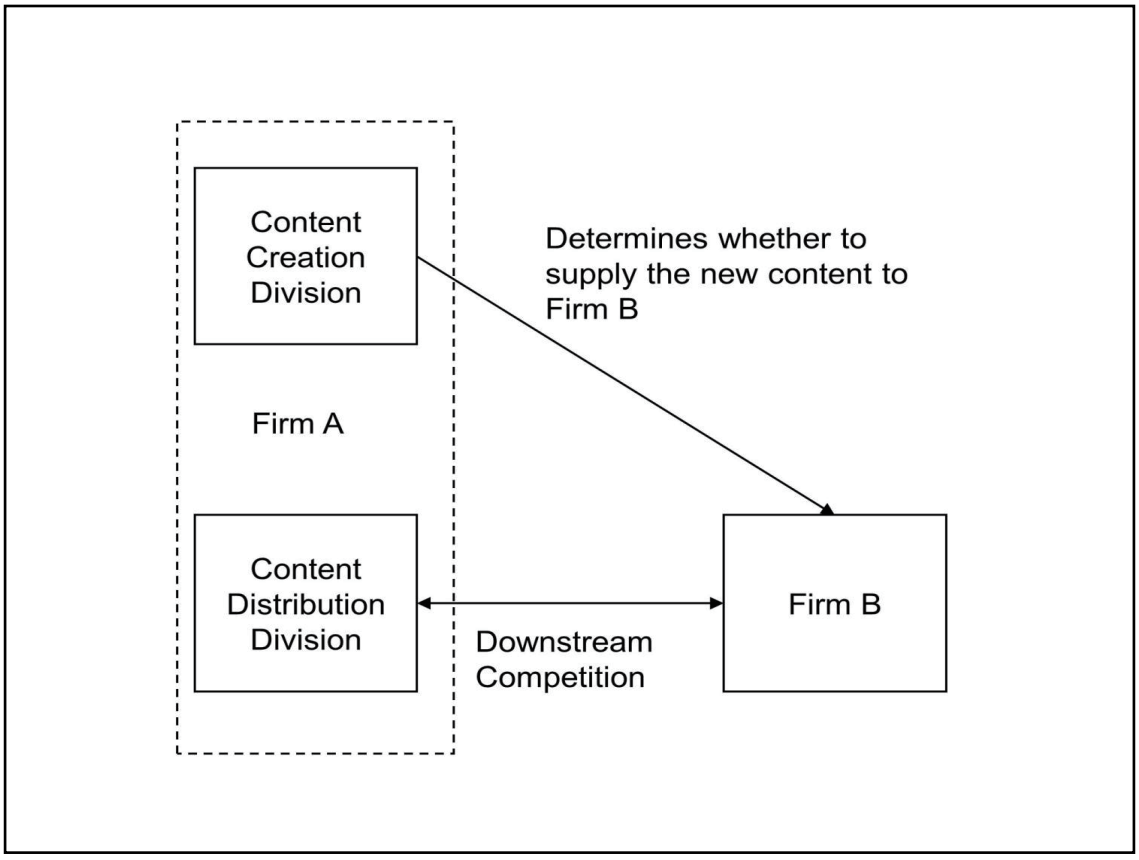
Shengming Zheng ✉

*Anhui Province Key Laboratory of Digital Intelligence Supply Chain, International Institute of Finance, School of Management, University of Science and Technology of China, Hefei 230026, China*

✉Correspondence: Shengming Zheng, E-mail: zhengsm@ustc.edu.cn



## Graphical abstract




*The research framework of our study.*

## Public summary

- This study considers divisional conflicts while examining the optimal content development and provision strategies of a vertically integrated firm that faces downstream competition.
- Our results provide plausible explanation for the phenomenon of no content provision regulation for vertical integration in media industry.
- The policymakers should exercise caution when regulating vertical integration in media industry.

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**Abstract:** This study analyzes the optimal content development and delivery strategies for an integrated firm facing downstream competition while considering inter-departmental conflicts. The integrated firm developing the new content consists of content creation and distribution divisions and determines whether to supply its newly developed content to the downstream competitor. Two organizational structures are considered: centralized and decentralized. Under the centralized structure, decisions are made to maximize the overall profit. Under the decentralized structure, the content creation and distribution divisions make decisions independently to maximize their own profits. Our results show that the centralized integrated firm always withholds its new content from its competitor, whereas the content is supplied to the competitor when it is costly to invest in the new content. Owing to the nonexclusive provision induced by divisional conflicts, the decentralized structure may result in higher-quality new content. Moreover, the decentralized structure always hurts the integrated firm, but it also hurts the downstream competitor when the content creation cost coefficient is high. As the sum of the profits of the integrated firm and downstream competitors, the industry profits are worse off under the decentralized structure. Additionally, divisional conflicts may improve consumer surplus and social welfare.

**Keywords:** integrated firm; divisional conflicts; organizational structure; content development; exclusive provision

**CLC number:** F272 **Document code:** A

## 1 Introduction

### 1.1 Background and motivation

Content plays a vital role in the media industry. Consumers make purchasing or subscription decisions largely on the basis of the available content[1–4]. Providing consumers access to attractive content such as successful TV series, popular sports programs, and recent blockbuster movies can significantly enhance firms' competitiveness in the media market. To control more premium content, firms seek vertical integration between the processes of content creation and distribution, and many vertical mergers between content creators and distributors have occurred recently. For example, Discovery merged with WarnerMedia in 2022, the Activision Blizzard merged with Microsoft in 2023, and Paramount Global merged with Skydance Media in 2024.

In media markets, integrated firms always face downstream competition from rival distributors. For example, the integrated firm of Discovery and WarnerMedia, Warner Bros. Discovery, competes with the distributors Netflix and Hulu. When facing downstream competition, whether to distribute the newly developed content exclusively or share it with its downstream competitor is an important decision for the integrated firm. In practice, some integrated firms do provide their newly developed content to a downstream rival, such as Warner Bros. Discovery provides its best-in-class streaming offering (HBO Max) to its rival distributor, Hulu. The content provision of the vertically integrated firm also raises government regulators' concerns about competition. The major concern is the input foreclosure possibility: the integrated firm may withhold its content from its distribution rivals. For example, in the vertical merger of leading multichannel video programming distributor Comcast and NBC Universal, a major content producer controlling several important movie studios, the Federal Communications Commission (FCC) of the USA was concerned that the integrated firm of Comcast and NBC Universal may "block Comcast's video distribution rivals from access to the video programming content the joint venture would come to control"[5], and some conditions were imposed to prevent the vertically integrated firm from withholding the content from other downstream distributors[6]. However, the content distribution regulation was not always imposed in the vertical integration of media industry. For example, in the recent merger of Discovery and WarnerMedia that occurred in 2022, FCC imposed no regulation on the content provision.

The vertical integration of a content producer and distributor in the media industry results in a large corporation, which usually operates through functionally different divisions. For example, Warner Bros. Discovery has a content creation division, Warner Brothers (abbreviated "WarnerBros"), which produces TV series, including Gotham and the The Big Bang



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Theory, and films such as the Harry Potter and DC movies. Meanwhile, Warner Bros. Discovery's content distribution division, HBO, provides consumers access to premium pay television and video streaming. In any vertically integrated firm, conflicts often arise naturally between departments (e.g., the content creation and distribution divisions) because of inconsistent objectives. The content creation division aims to maximize its profit from selling the newly developed content by controlling the content quality, whereas the content distribution division has the incentive to maximize its profit via its control over prices. Intrafirm conflicts among different departments in a firm are common in practice[7–14], especially for vertically integrated firms[15].

When division conflicts exist in the integrated firm, the conflicting objectives of the content creation and distribution divisions may affect the firm's optimal content development and provision strategy. It is interesting to investigate the integrated firm's strategic decisions on content development and provision in a competitive setting considering division conflicts. Moreover, consumer surplus and social welfare can also be affected by division conflicts because intrafirm conflicts impact the content development and provision strategies. Although content development and distribution have become increasingly popular due to the rapid growth of digital content platforms, few studies have considered the interaction between content development and distribution and division conflicts. It is worthwhile to fill this research gap in the content development and distribution literature by considering division conflicts.

### 1.2 Research questions and key findings

The content development and provision of the integrated firm with division conflicts motivated by industry practices raise the following questions: (ⅰ) What is the integrated firm's optimal content provision strategy for its downstream competitor when divisional conflicts are considered? (ⅱ) How do divisional conflicts affect the integrated firm's newly developed content quality decision? (ⅲ) What is the impact of divisional conflicts on the integrated firm, downstream competitor, entire industry, consumers, and social welfare?

To address these questions, we build a game-theoretic model in which a vertically integrated firm, consisting of a content creation division and a content distribution division, competes with a downstream distributor that cannot develop new content. To investigate the impact of the integrated firm's intrafirm conflicts, two organizational structures for the integrated firm are considered: centralized and decentralized. Under the centralized structure, the decisions are made to maximize the overall profit of the integrated firm. In this case, the integrated firm, which can create new content, first determines the quality of newly developed content and whether to distribute the new content exclusively or to supply its new content to the downstream competitor. Then, the integrated firm and the downstream competitor compete on price. Under the decentralized structure, the integrated firm's content creation division and distribution division make decisions independently to maximize their own profit. That is, the integrated firm's content creation division determines the new content quality and whether to supply the new content to the downstream competitor, and then the integrated firm's content distribution division competes with the downstream competitor in terms of price. The answers to the research questions and main findings are summarized as follows.

For the first question, divisional conflicts in the integrated firm can motivate nonexclusive provision of the newly developed content. In the absence of the intrafirm conflicts (i.e., centralized structure), the integrated firm never supplies the new content to its downstream competitor because the loss from market share shrinkage outweighs the wholesale revenue gain from supplying that content. In the presence of intrafirm conflicts (i.e., decentralized structure), the integrated firm's content creation division provides new content to the rival distributor when the content creation cost coefficient is relatively high. The content creation division makes content quality and provision decisions to maximize wholesale profit from the new content. If investing in the new content is costly, this division should set a low content quality. In this case, the new content cannot bring a significant competitive advantage improvement, and the creation division cannot set a high price under an exclusive provision of the new content. Therefore, it is optimal for the content creation division to supply the new content to the rival distributor when the content creation cost coefficient is high.

For the second question, the new content quality increases due to intrafirm conflicts when the content creation cost coefficient exceeds a certain threshold. This is because if investing in the new content is costly, the divisional conflicts motivate the nonexclusive provision of the integrated firm's newly developed content, so the decentralized integrated firm has the incentive to set a higher quality for the new content than in the centralized case. Moreover, divisional conflicts lead to a lower quality of newly developed content when the content creation cost coefficient is medium.

For the third question, division conflicts always hurt the integrated firm and the industry but sometimes improve the downstream competitor's profit, consumer surplus, and social welfare. The decentralized structure harms the rival distributor if the content creation cost coefficient exceeds a certain threshold. Although nonexclusive content provision is induced by the intrafirm conflicts in the integrated firm under a high content creation cost coefficient, the price charged by the content creation division also reduces the downstream competitor's profit compared with the case without intrafirm conflicts. Additionally, the negative effect of decentralization on the integrated firm plays a dominant role, so the industry profits are also reduced regardless of whether the intrafirm conflicts benefit the downstream competitor. When the content creation cost coefficient is high, consumer surplus is increased due to decentralization. This occurs because intrafirm conflicts in the integrated firm increase the new content quality when the content creation cost coefficient exceeds a certain threshold, and lead to nonexclusive provision of the new content. Although decentralization reduces the industry profits, the positive effect of intrafirm conflicts on consumers can lead to greater social welfare.

### 1.3 Contribution statements and paper's structure

Our work makes the following specific contributions:


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This research focuses on an integrated firm's new content development and provision strategy in a setting where the firm faces downstream competition from a nonintegrated distributor. This study reveals new results with different driving forces. In contrast to the literature showing the optimality of developing exclusive content for the integrated firm from the perspectives of switching cost[6], vertical integration[16], consumers' multihoming behavior[17], and two-sided markets[18], our results indicate that a nonexclusive content provision equilibrium can emerge when divisional conflicts exist in the integrated firm. This study complements the previous literature by indicating that intrafirm conflicts in the integrated firm can induce nonexclusive content distribution. Our results can help explain the phenomenon of nonexclusive content provision in practice from the perspective of the firm's organizational structure.

Our work provides interesting managerial and policy insights. For the integrated firm, in the absence of divisional conflicts, developing exclusive new content is always optimal, but in the presence of divisional conflicts, the integrated firm's content creation division may be incentivized to supply the newly developed content to the rival distributor. Vertical integration does not always lead to exclusive provision of the integrated firm's newly developed content, which provides regulation guidance for public policymakers. Divisional conflicts in the integrated firm do not necessarily yield a higher profit for the competing downstream distributor. Moreover, consumer surplus and social welfare may both be improved when intrafirm conflicts exist in the integrated firm.

The rest of this paper is organized as follows. Section 2 reviews the related literature. The model setting is introduced in Section 3. Sections 4 and 5 analyze the game equilibrium under the centralized and decentralized structures, respectively. Section 6 investigates the impact of the integrated firm's divisional conflicts. The paper concludes in Section 7. All the proofs are given in the Appendix.

## 2 Literature review

This study draws upon two streams of prior research: content distribution and competition in media markets, and organizational structure. In this section, we provide an overview of these research streams and highlight our contributions.

Our work relates to the stream of literature on content competition and distribution in media markets. One stream of the content competition and distribution literature focused on content development. Ref. [19] studied how exclusive distribution affects the quality of programs in the TV market and showed that exclusive distribution can motivate content providers to invest in higher-quality programs that benefit TV viewers. Ref. [16] analyzed the impact of vertical integration on content quality investments in the TV market and showed that an independent content provider has more incentives to invest in content quality than a vertically integrated provider does. Ref. [20] investigated the impact of consumers' multipurchase behavior on content development strategy of the content creator selling its new content to two competing distributors; they found that consumers' multipurchase behavior reduces the qualify of new content when the two distributors are not very differentiated. Ref. [17] considered a similar setting and studied the platform's content development strategy for its rival competitor when consumers have "multihoming" behavior (i.e., subscribe to both platforms at the same time). They concluded that developing exclusive content is beneficial to consumers, platforms, and society when consumers multihome. Ref. [3] investigated the impact of a platform's recommendation system on creator's content development strategy, finding that recommending content may not induce the creator to create high-quality content.

The other stream of the literature on content competition and distribution considered the interaction between advertising and content competition. Ref. [21] investigated the impact of exclusive advertising in a setting where two competing broadcasters sell advertising space to two competing advertisers, showing that exclusive advertising contracts can benefit both advertisers and broadcasters because exclusive advertising results in fewer informed consumers and then mitigates price competition between two advertisers. Ref. [22] examined the setting in which media firms compete on both advertising markets and content markets, showing that media firms in a monopoly may charge lower prices for the content than those in a duopoly. Ref. [6] examined whether an integrated firm should supply its new content to its nonintegrated downstream competitor or distribute the content exclusively, considering the advertising revenue from the new content in the pay TV industry. They found that exclusive content distribution is optimal for the integrated firm in a dynamic setting with switching costs. Ref. [23] investigated the interaction between advertising and content development on content platforms and showed that the low level of advertising may be beneficial to the platforms.

In contrast to these works, our work considers the organizational structure of a vertically integrated firm and examines how intrafirm conflicts affect its strategy for providing newly developed content provision to a downstream rival. Incorporating organizational structure into a firm's content development and distribution strategy yields new results: the decentralized structure in the integrated firm can induce nonexclusive content distribution and may increase the quality of new content.

This work also belongs to the growing literature on the internal organizational structure of firms. Previous works have studied the impact of division conflicts from different angles. Ref. [24] examined a duopoly setting in which each firm has distinct manufacturing and marketing departments, and the firms compete on price and quality under different organizational structures. They showed that manufacturing-marketing conflict under a decentralized structure can be a strategic tool to increase a firm's profitability. Ref. [25] studied a case where the firm consists of decentralized operations and marketing divisions and decisions are made independently by two divisions, finding that the intrafirm conflicts between marketing and operations divisions can be quantitatively significant. They introduced a dynamic transfer pricing scheme as a coordination device for mitigating the negative effect of decentralization on the firm. Ref. [26] considered an electronic retail setting in which two firms compete against each other with both firms having marketing and IT departments; they


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showed that coordination between the firms' internal departments leads to a prisoner's dilemma equilibrium for the two firms. Ref. [27] considered a firm with manufacturing and remanufacturing divisions and studied how the firm's organizational structure affects its decisions on distribution channels, finding that it is optimal for the centralized firm to sell the new and remanufactured products directly to the consumer. Ref. [28] analyzed the interaction between the retailer's strategic inventory and supplier encroachment while considering the supplier's organizational structure. They found that decentralized encroachment benefits both the supplier and retailer compared with centralized encroachment if the retailer uses strategic inventory techniques. Ref. [29] studied manufacturer encroachment considering the organizational structure of the manufacturer, which deploys an e-commerce division to launch a direct selling business, showing that centralization benefits the manufacturer, retailer, and e-commerce division when the direct selling cost is sufficiently low. In contrast to these works, our focus is to investigate the integrated firm's newly developed content provision strategy facing downstream competition, and we consider the integrated firm's organizational structure when it has content creation and distribution divisions. Table 1 outlines the key distinctions between our research and the related studies about division conflicts mentioned above.

## 3 Model setup

We consider a market consisting of two competing firms, denoted A and B. The two firms are located at opposite ends of a unit-length linear city represented by the line segment $[0,1]$. Firm A is a vertically integrated firm consisting of a content creation division, denoted C, and a distribution division, denoted D. For example, Warner Bros. Discovery has a content creation division (i.e., movie studio, WarnerBros) and a content distribution division (i.e., streaming platform, HBO Max). Firm B, which is a downstream competitor of firm A, is a content distributor such as Hulu and YouTube. Distributor A is located at 0 and distributor B is located at 1. Firm $i(i \in \{A,B\})$ has existing content of value $v_i$. For ease of exposition, we assume that each firm's basic content value is symmetric, i.e., $v_A = v_B = v$ [①]. The creation division of firm A creates new content. Firm A's newly developed content value is denoted as $q$, which also reflects the quality of the new content. The content creation cost is $c(q) = kq^2$, where $k$ is the content creation cost coefficient. A quadratic cost function is commonly used in the literature (e.g., Refs. [16, 20]). However, firm B is only a content distributor and cannot develop new content. Firm A has two possible provision choices regarding its newly developed content: distributing the new content exclusively or supplying the newly developed content to firm B.

To analyze how firm A's divisional conflicts impact content development and provision strategies, two organizational structures of firm A are considered: (ⅰ) a centralized structure, in which divisional conflicts do not exist and decision making is centralized so that decisions maximize firm A's overall profit; and (ⅱ) a decentralized structure, in which divisional conflicts exist and the content creation and distribution divisions make independent decisions to maximize their own profits.

The price or subscription fee of firm $i$ is denoted as $p_i$. Note that, in the media markets, consumers pay distributor fees to gain access to content rather than the content itself. The prices that consumers pay are also called subscription fees. For convenience, in the reminder of this paper, we use the verbs "subscribe" and "purchase", and the nouns "subscription fee" and "price", interchangeably.

We adopt the Hotelling model to characterize downstream competition between two firms[30]. Consumers are uniformly distributed on the unit interval between the two firms. They purchase or subscribe to the content from only one firm. Following[16,20,31], a consumer's net utility from purchasing or subscribing to firm $i$ is given by

$$u_i = v_i + q_i - t|x - l_i| - p_i, \tag{1}$$

where $q_i$ refers to the value (also reflecting quality) of the new content; $q_i = 0$ if firm $i$ does not have the new content, and $q_i = q$ if firm $i$ has the new content. The location of firm $i$ is denoted as $l_i$ (i.e., $l_A = 0$, $l_B = 1$), and $x$ is the consumer's location on the Hotelling line, which captures their ideal horizontal preference. The transportation cost parameter $t$ reflects the intensity of the consumers' preference for a firm or the level of horizontal differentiation between the two firms. Therefore, $t|x - l_i|$ reflects the disutility that consumers located at $x$ suffer from purchasing or subscribing to firm $i$'s content, reflecting how it differs from the consumer's ideal content.

Let $\pi_i$, $i \in \{A,B\}$, denote the profit of firm $i$. Let $\pi_C$ and $\pi_D$ denote the profits of firm $A$'s content creation division and content distribution division, respectively. In addition, we use $\Pi$, $CS$, and $SW$ to denote industry profit (i.e., $\Pi = \pi_A + \pi_B$), consumer surplus, and social welfare, respectively. Table 2 summarizes the notation used in this paper.

## 4 Benchmark: centralized structure

To investigate the impact of divisional conflicts, we first consider the centralized structure scenario as the benchmark. In this case, the decisions are made to maximize firm A's overall profit.

The game sequence is as follows. First, firm A determines the quality $q$ for the newly developed content and chooses whether to supply its new content to firm B; it also sets a price $w$ for the newly developed content if the new content is provided. Second, firm B decides whether to accept the offer. Third, the two firms simultaneously determine price $p_i$. Finally, consumers make purchases, and profits are realized.

When firm A supplies its new content to firm B at price $w$ and firm B accepts the offer, both firms have content value $v+q$. Given the prices $(p_A, p_B)$, there exists a marginal consumer, located at $\bar{x}$, who is indifferent between purchasing from either firm. Solving $u_A(x) = u_B(x)$, we obtain

① Although not presented in this paper, we also carried out the analysis with asymmetric basic values and find that our main results hold qualitatively when the two firms have asymmetric basic values, and these results are available upon request.



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**Table 1.** Major differences between this paper and the relevant papers about divisional conflicts.

| Paper | Research setting | Type of division conflicts | Main findings |
|---|---|---|---|
| [24] | Two firms with distinct manufacturing and marketing departments compete on price and quality | Manufacturing-marketing conflict | Manufacturing-marketing conflict can increase firm profits |
| [25] | Monopoly firm with independent operations and marketing divisions | Marketing-operations conflict | Dynamic transfer pricing scheme can serve as a coordination device for mitigating the negative effect of division conflcts |
| [26] | Two firms with distinct marketing and IT departments | Marketing-IT conflict | Coordination between the firms' internal departments leads to a prisoners' dilemma equilibrium for two firms |
| [27] | Monopoly firm with independent manufacturing and remanufacturing divisions | Manufacturing-remanufacturing conflict | It is optimal for the firm to sell the new and remanufactured products directly without division conflicts |
| [28] | The manufacturer selling through one retailer has an independent subsidiary | Conflicts between the manufacturer and the subsidiary | Decentralized encroachment benefits both the supplier and retailer compared with centralized encroachment if the retailer uses strategic inventory techniques |
| [29] | The manufacturer selling through one retailer has an independent e-commerce division | Conflicts between the manufacturer and e-commerce division | Centralization benefits the manufacturer, retailer, and e-commerce division when the direct selling cost is sufficiently low |
| Our work | A vertically integrated firm consisting of content creation and distribution divisions competes with one downstream competitor | Content creation-distribution conflict | Divisional conflicts lead to non-exclusive content provision and higher quality of newly developed content |

**Table 2.** Summary of notation.

| Notation | Interpretation |
|---|---|
| $u_i$ | Consumer's net utility from subscribing to firm $i$, $i \in \{A, B\}$ |
| $v$ | Basic content value of firm $i$ |
| $q$ | Value (also reflecting quality) of new content developed by firm $A$ |
| $l_i$ | Location of firm $i$ |
| $x$ | Location of the consumer |
| $t$ | Transportation cost parameter |
| $p_i$ | Price or subscription fee of firm $i$ |
| $p_D$ | Price set by division D of firm $A$ |
| $c$ | Content creation cost |
| $k$ | Content creation cost coefficient |
| $w$ | Newly developed content price |
| $d_i$ | Demand for firm $i$ |
| $d_D$ | Demand for division D of firm $A$ |
| $\pi_i$ | Profit of firm $i$ |
| $\pi_C$ | Profit of firm $A$'s content creation division |
| $\pi_D$ | Profit of firm $A$'s content distribution division |
| $\Pi$ | Profit of the industry |
| $CS$ | Consumer surplus |
| $SW$ | Social welfare |

$$\bar{x} = \frac{1}{2} + \frac{p_B - p_A}{2t}.$$

Therefore, the demand for firm A is $d_A = \bar{x} = \frac{1}{2} + \frac{p_B - p_A}{2t}$ and for firm B is $d_B = 1 - \bar{x} = \frac{1}{2} + \frac{p_A - p_B}{2t}$. Firm A's maximization problem is

$$\max_{p_A} \pi_A = p_A d_A + w - kq^2 = p_A\left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right) + w - kq^2. \quad (2)$$

Firm B's maximization problem is

$$\max_{p_B} \pi_B = p_B d_B - w = p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) - w. \quad (3)$$

If firm A supplies its new content to firm B and firm B does not accept the offer, then only firm A has content value $v+q$ while firm B has content value $v$. Similarly, we obtain the demand functions for two firms:

$$d_A = \frac{1}{2} + \frac{p_B - p_A + q}{2t}, \quad d_B = \frac{1}{2} + \frac{p_A - p_B - q}{2t}.$$

Solving firm A's maximization problem

$$\max_{p_A} \pi_A = p_A d_A - kq^2 = p_A\left(\frac{1}{2} + \frac{p_B - p_A + q}{2t}\right) - kq^2, \quad (4)$$

and firm B's maximization problem

$$\max_{p_B} \pi_B = p_B d_B = p_B\left(\frac{1}{2} + \frac{p_A - p_B - q}{2t}\right), \quad (5)$$

we obtain the subgame equilibrium stated in the following lemma.

**Lemma 1.** Given firm A's offer, when firm B does not accept the offer to access firm A's new content, the optimal decisions, demand, and profits for the two firms are as follows.

- If $q \le 3t$, then $p_A^* = t + \frac{q}{3}$, $p_B^* = t - \frac{q}{3}$, $d_A^* = \frac{1}{2} + \frac{q}{6t}$, $d_B^* = \frac{1}{2} - \frac{q}{6t}$, $\pi_A^* = \frac{(t+q/3)^2}{2t}$, $\pi_B^* = \frac{(t-q/3)^2}{2t}$;
- if $q > 3t$, then $p_A^* = q - t$, $p_B^* = 0$, $d_A^* = 1, d_B^* = 0$, $\pi_A^* = q - t$, $\pi_B^* = 0$.

The results of Lemma 1 can be explained as follows. If the


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value of the newly developed content is not very high (i.e., $q \le 3t$), firm A is not much more competitive than firm B. Hence, firms A and B engage in price competition, and both obtain a positive market share. If the new content value is very high (i.e., $q > 3t$), then firm A is extremely competitive; firm B will not obtain any market share (i.e., $d_B^* = 0$), so it will make zero profit. Without loss of generality, we assume that if firm B is indifferent between accepting and not accepting firm A's offer, it will accept the offer. We obtain the following corollary, which shows firm B's optimal content acquisition strategy given firm A's offer.

**Corollary 1.** Given firm A's offer of new content, firm B will accept the offer only if $w \le \frac{q}{3t} - \frac{q^2}{18t}$ when $q \le 3t$, or $w \le \frac{t}{2}$ when $q > 3t$.

If firm A provides new content for firm B at price $w$, firm B will have the incentive to acquire the content only when buying firm A's new content does not reduce its profit. If the wholesale price $w$ for new content exceeds firm B's profit gain from market expansion because of firm A's new content, firm B will not purchase the new content. Therefore, firm B accepts firm A's offer only when $w$ is below a certain threshold. If firm A does not supply its new content to firm B, then only firm A has content value $v+q$ and firm B has content value $v$. Therefore, the equilibrium results are equivalent to those in the case where firm A offers its new content to firm B and firm B does not accept the offer.

If firm A supplies its new content to firm B, its profit will be

$$\pi_A^s = \begin{cases} \frac{t}{2} + \frac{q}{3t} - \frac{q^2}{18t} - kq^2, \text{ if } q \le 3t; \\ t - kq^2, \text{ if } q > 3t. \end{cases} \tag{6}$$

If firm A does not supply its new content to firm B, its profit will be

$$\pi_A^n = \begin{cases} \frac{t}{2} + \frac{q}{3t} + \frac{q^2}{18t} - kq^2, \text{ if } q \le 3t; \\ q - t - kq^2, \text{ if } q > 3t. \end{cases} \tag{7}$$

The following proposition shows firm A's optimal content development and provision strategy.

**Proposition 1.** Under a centralized structure, firm A will not supply its newly developed content to firm B. The equilibrium solutions are as follows.

- If $k \le \frac{\sqrt{13}+11}{108t}$, then $q^* = \frac{1}{2k} > 3t$, and $p_A^* = \frac{1}{2k} - t$, $p_B^* = 0$, $\pi_A^* = \frac{1}{4k} - t$, $\pi_B^* = 0$.
- If $k > \frac{\sqrt{13}+11}{108t}$, then $q^* = \frac{3t}{18kt-1} < 3t$, and $p_A^* = t + \frac{t}{18kt-1}$, $p_B^* = t - \frac{t}{18kt-1}$, $\pi_A^* = \frac{9kt^2}{18kt-1}$, $\pi_B^* = \frac{2t(1-9kt)^2}{(1-18kt)^2}$.

Under centralization, decisions are made to maximize the overall profit of the firm A. Supplying new content to firm B makes firm B more competitive, resulting in more intense downstream competition. Firm A should consider the gain in wholesale revenue from content provision and the loss in market share. Note that the maximum wholesale price of new content charged by firm A cannot exceed firm B's profit gain from new content since a higher price is functionally equivalent to not offering the content. Although the content provision brings a new stream of revenue for firm A, the wholesale revenue from providing new content for firm B is always less than the profit loss due to stronger downstream competition. In this case, firm A has no incentive to supply its new content to firm B, and the new content is exclusively distributed by firm A. When the content creation cost coefficient $k$ is relatively low (i.e., $k \le \frac{\sqrt{13}+11}{108t}$), firm A has an incentive to produce extremely high-quality new content (i.e., $q^* = \frac{1}{2k} > 3t$), which drives the downstream competitor (i.e., firm B) out of the market. When $k$ is high (i.e., $k > \frac{\sqrt{13}+11}{108t}$), it is costly to create new content, and then it is optimal for firm A to produce relatively low-quality new content (i.e., $q^* = \frac{3t}{18kt-1} < 3t$); in this case, firms A and B both have positive demand.

## 5 Decentralized structure

We now proceed to the analysis of the decentralized structure. In this case, firm A's content creation and distribution divisions make decisions independently. The game sequence is as follows. First, firm A's content creation division C determines the quality $q$ for the newly developed content, chooses whether to offer its new content to firm B, and sets the price $w$ for the new content[①]. Second, firm B's and firm A's content distribution division D decide whether to accept the offer of division C's new content. Third, firm B and division D simultaneously determines price $p_B$ and $p_D$. Finally, consumers make purchases, and profits are realized.

When division C offers its new content to firm B, there are four possible subgame equilibria: (i) neither division D nor firm B accepts the offer; (ii) division D accepts the offer, and firm B does not; (iii) division D does not accept the offer, and firm B does; (iv) both division D and firm B accept the offer. Without loss of generality, we assume that if firm B or division D is indifferent between accepting or refusing division C's offer, it will accept it.

If neither division D nor firm B accepts the offer, then division D and firm B both have content value $v$. Given the prices $(p_D, p_B)$, there exists a marginal consumer, located at $\bar{x}$, who is indifferent between purchasing from firm B and division D. Similarly, we obtain

$$\bar{x} = \frac{1}{2} + \frac{p_B - p_D}{2t}.$$

Therefore, the demand for division D is $d_D = \bar{x} = \frac{1}{2} + \frac{p_B - p_D}{2t}$ and for firm B is $d_B = 1 - \bar{x} = \frac{1}{2} + \frac{p_D - p_B}{2t}$. Division D's maximization problem is

① Note that we assume that division C always supplies its newly developed content to division D because division C and division D are different departments of one firm, i.e., firm A. Moreover, we assume that division C charges the same price for the new content on both division D and firm B.


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$$\max_{p_D} \pi_D = p_D d_D = p_D\left(\frac{1}{2} + \frac{p_B - p_D}{2t}\right), \tag{8}$$

and firm B's maximization problem is

$$\max_{p_B} \pi_B = p_B d_B = p_B\left(\frac{1}{2} + \frac{p_D - p_B}{2t}\right). \tag{9}$$

If only division D accepts the offer, then division D has content value $v+q$ and firm B has content value $v$. As above, we obtain the demand functions for division D and firm B: $d_D = \frac{1}{2} + \frac{p_B - p_D + q}{2t}$, $d_B = \frac{1}{2} + \frac{p_D - p_B - q}{2t}$. Solving division D's maximization problem

$$\max_{p_D} \pi_D = p_D d_D - w = p_D\left(\frac{1}{2} + \frac{p_B - p_D + q}{2t}\right) - w, \tag{10}$$

and firm B's maximization problem

$$\max_{p_B} \pi_B = p_B d_B = p_B\left(\frac{1}{2} + \frac{p_D - p_B - q}{2t}\right), \tag{11}$$

we obtain this subgame equilibrium expressed in the following lemma.

**Lemma 2.** When division C supplies its new content to firm B and only division D accepts the offer, the optimal decisions, demand, and profits are as follows:

- If $q \le 3t$, then $p_D^* = t + \frac{q}{3}$, $p_B^* = t - \frac{q}{3}$, $d_D^* = \frac{1}{2} + \frac{q}{6t}$, $d_B^* = \frac{1}{2} - \frac{q}{6t}$, $\pi_D^* = \frac{(t+q/3)^2}{2t} - w$, $\pi_B^* = \frac{(t-q/3)^2}{2t}$;
- if $q > 3t$, then $p_D^* = q - t$, $p_B^* = 0$, $d_D^* = 1$, $d_B^* = 0$, $\pi_D^* = q - t - w$, $\pi_B^* = 0$.

Similarly, if only firm B accepts the offer, we obtain the following equilibrium results:

$$p_B^* = t + \frac{q}{3},\ p_D^* = t - \frac{q}{3},\ d_B^* = \frac{1}{2} + \frac{q}{6t},\ d_D^* = \frac{1}{2} - \frac{q}{6t},$$
$$\pi_B^* = \frac{(t+q/3)^2}{2t} - w,\ \pi_D^* = \frac{(t-q/3)^2}{2t}$$

when $q \le 3t$, and

$$p_B^* = q - t,\ p_D^* = 0,\ d_B^* = 1, d_D^* = 0,\ \pi_B^* = q - t - w,\ \pi_D^* = 0$$

when $q > 3t$.

If division D and firm B both accept the offer, then both of them have content value $v+q$. Then, the demands are $d_D = \frac{1}{2} + \frac{p_B - p_D}{2t}, d_B = \frac{1}{2} + \frac{p_D - p_B}{2t}$, and division D's maximization problem is

$$\max_{p_D} \pi_D = p_D d_D - w = p_D\left(\frac{1}{2} + \frac{p_B - p_D}{2t}\right) - w. \tag{12}$$

Firm B's maximization problem is

$$\max_{p_B} \pi_B = p_B d_B - w = p_B\left(\frac{1}{2} + \frac{p_D - p_B}{2t}\right) - w. \tag{13}$$

The following lemma shows the optimal content acquisition strategies of firm B and division D when division C offers its new content to firm B.

**Lemma 3.** Assume that division C offers its new content to firm B.

- When $q \le 3t$, if $w \le \frac{q}{3} - \frac{q^2}{18t}$, then both division D and firm B will purchase the new content; if $\frac{q}{3} - \frac{q^2}{18t} < w \le \frac{q}{3} + \frac{q^2}{18t}$, then only one of division D or firm B will purchase the new content; if $w > \frac{q}{3} + \frac{q^2}{18t}$, neither division D nor firm B will purchase the new content.
- When $q > 3t$, if $w \le \frac{t}{2}$, then both division D and firm B will purchase the new content; if $\frac{t}{2} < w \le q - \frac{3t}{2}$, then only one of division D or firm B will purchase the new content; if $w > q - \frac{3t}{2}$, then neither division D nor firm B will purchase the new content.

Lemma 3 indicates that both firm B and division D have an incentive to acquire the new content when the content price $w$ is low (i.e., $w \le \frac{q}{3} - \frac{q^2}{18t}$ if $q \le 3t$ or $w \le \frac{t}{2}$ if $q > 3t$). Only one of division D or firm B purchases the new content when the content price is medium (i.e., $\frac{q}{3} - \frac{q^2}{18t} < w \le \frac{q}{3} + \frac{q^2}{18t}$ if $q \le 3t$ or $\frac{t}{2} < w \le q - \frac{3t}{2}$ if $q > 3t$). In this case, it is optimal for a division or a firm to purchase the content only when its downstream competitor does not acquire it. Neither division D nor firm B have an incentive to purchase the content if $w$ is relatively high (i.e., $w > \frac{q}{3} + \frac{q^2}{18t}$ if $q \le 3t$ or $w > q - \frac{3t}{2}$ if $q > 3t$). When firm B or division D decides whether to purchase the new content, the strategic effect of its content acquisition decision on both firm B's and division D's competitive pricing decisions should be considered. Firm B and division D need to compare two profits to determine whether to acquire the new content at price $w$. The first is firm B's or division D's profit conditional on purchasing the new content in anticipation of its competitor's best response regarding the content acquisition decision and consequent optimal pricing decisions. The second is firm B's or division D's profit conditional on not purchasing the new content considering its competitor's optimal choice of content acquisition and consequent optimal pricing decisions. When the former profit is higher than the latter, firm B or division D will purchase the new content; otherwise, firm B or division D will not acquire the new content.

On the basis of Lemma 3, we obtain division C's optimal price when division C offers the new content to firm B, as expressed in the following lemma.

**Lemma 4.** When division C offers its new content to firm B, the following results hold: If $q \le 2t$, division C's optimal price is $w^* = \frac{q}{3} - \frac{q^2}{18t}$ and both firm B and division D purchase the content. If $2t < q \le 3t$, division C's optimal price is $w^* = \frac{q}{3} + \frac{q^2}{18t}$ and only one of firm B or division D purchases the content. If $q > 3t$, division C's optimal price is $w^* = q - \frac{3t}{2}$ and only firm B or division D purchases the content.

When the new content quality is low (i.e., $q \le 2t$), the new content cannot significantly increase firm B's or division D's competitive advantage. In this case, both firm B and division



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D have no incentive to pay a high price for the new content even if its competitor does not purchase the content. Therefore, it is optimal for division C to set a relatively low price $w$ (i.e., $\frac{q}{3}-\frac{q^2}{18t}$), which induces both firm B and division D to purchase the content. When the new content quality is in the intermediate range (i.e., $2t<q\le 3t$), the new content can help increase the competitive advantage of firm B or division D only if the purchaser obtains the new content exclusively. In this case, both firm B and division D can gain positive market share when only one of the firms purchases the new content. Hence, it is optimal for division C to set a high price $w$ (i.e., $\frac{q}{3}+\frac{q^2}{18t}$) for the content, which induces only one of firm B or division D to purchase the content. When the new content quality is very high (i.e., $q>3t$), the new content can make firm B or division D extremely competitive, and the firm or division without the new content cannot obtain any market share. In this case, division C should set $w^*=q-\frac{3t}{2}$, which induces either firm B or division D to purchase the content, and the firm or division that does not acquire the content will be driven out of the market by competition.

When division C does not supply its new content to firm B, if division D does not accept the offer of division C, it is easy to obtain the equilibrium outcomes $p_D^*=p_B^*=t$, $d_D^*=d_B^*=\frac{1}{2}$, $\pi_D^*=\pi_B^*=\frac{t}{2}$, and if division D accepts the offer, then the equilibrium outcomes are

$$p_D^*=\begin{cases} t+\frac{q}{3}, \text{ if } q\le 3t;\\ q-t, \text{ if } q>3t+q; \end{cases} \quad p_B^*=\begin{cases} t-\frac{q}{3}, \text{ if } q\le 3t;\\ 0, \text{ if } q>3t; \end{cases}$$

$$d_D^*=\begin{cases} \frac{1}{2}+\frac{q}{6t}, \text{ if } q\le 3t;\\ 1, \text{ if } q>3t; \end{cases} \quad d_B^*=\begin{cases} \frac{1}{2}-\frac{q}{6t}, \text{if } q\le 3t;\\ 0, \text{ if } q>3t; \end{cases}$$

$$\pi_D^*=\begin{cases} \frac{(t+q/3)^2}{2t}-w, \text{ if } q\le 3t;\\ q-t-w, \text{ if } q>3t; \end{cases}, \quad \pi_B^*=\begin{cases} \frac{(t-q/3)^2}{2t}, \text{ if } q\le 3t;\\ 0, \text{ if } q>3t. \end{cases}$$

Therefore, when division C does not supply its new content to firm B, division C's optimal price is

$$w^*=\begin{cases} \frac{q}{3}+\frac{q^2}{18t}, \text{ if } q\le 3t;\\ q-\frac{3t}{2}, \text{ if } q>3t. \end{cases}$$

We assume that if division C's profit is the same for supplying or not supplying its new content to firm B, it will make the content provision decision based on the overall profit of firm A: when not supplying its new content to firm B can result in a higher overall profit of firm A, division C will withhold its newly developed content from firm B. The following lemma gives division C's optimal content provision strategy.

**Lemma 5.** Given the newly developed content quality $q$, division C supplies its new content to firm B only when $q\le 2t$.

Lemma 5 shows that division C provides the new content for firm B only if the new content quality is relatively low (i.e., $q\le 2t$). This result can be explained as follows. When the new content quality is low (i.e., $q\le 2t$), neither firm B nor division D has an incentive to pay a high price for the content even if its competitor does not purchase the content. Therefore, division C cannot set a high price $w$ regardless of whether the new content is supplied to firm B. Note that, under the decentralized structure, decisions are made independently to maximize the divisions' own profits rather than the overall profit of firm A, so Division C considers only its wholesale revenue from the new content. Hence, to obtain more wholesale revenue, division C supplies the new content to firm B and sets a relatively low price $w$, which induces both firm B and division D to purchase the content. When the new content quality is relatively high (i.e., $q>2t$), the new content significantly increases firm B's or division D's competitive advantage if the content is obtained exclusively. In this case, division C sets a price $w$ sufficiently high to induce only one of firm B or division D to purchase the content. In equilibrium, only firm B or division D will purchase content when content quality is high ($q>2t$). Division C gains the same profit when either firm B or division D purchases the content exclusively. However, the overall profit of firm A when only division D purchases the content is greater than that when only firm B acquires the content. Therefore, division C does not provide new content for firm B when the content quality is high. The results of Lemma 5 suggest that the content creation division of the integrated firm will withhold the new content with high quality from its rival distributor. These results can potentially explain the phenomenon of the exclusive distribution of high-quality new content via the distribution division of the integrated firm in practice. For example, the high quality TV series Westworld, produced by Warner Brothers (i.e., the content creation division of Warner Bros. Discovery) are exclusively distributed by HBO (i.e., the content distribution division of Warner Bros. Discovery).

Therefore, the optimal newly developed content quality can be analyzed by solving division C's maximization problem:

$$\max_q \pi_C(q)=\begin{cases} \frac{2q}{3}-\frac{q^2}{9t}-kq^2, \text{ if } q\le 2t;\\ \frac{q}{3}+\frac{q^2}{18t}-kq^2, \text{ if } 2t<q\le 3t;\\ q-\frac{3t}{2}-kq^2, \text{ if } q>3t. \end{cases} \tag{14}$$

We summarize the equilibrium results under the decentralized structure in the following proposition.

**Proposition 2.** Under the decentralized structure, the equilibrium outcomes are as follows:

- If $k\le\frac{\sqrt{217}-1}{108t}$, then $q^*=\frac{1}{2k}$ and division C does not supply its new content to firm B. Then, $w^*=\frac{1}{2k}-\frac{3t}{2}$, $p_D^*=\frac{1}{2k}-t, p_B^*=0$, $\pi_D^*=\frac{t}{2}$, $\pi_B^*=0$, $\pi_C^*=\frac{1}{4k}-\frac{3t}{2}$.
- If $k>\frac{\sqrt{217}-1}{108t}$, then $q^*=\frac{3t}{9kt+1}$ and division C supplies its new content to firm B. Then, $w^*=\frac{t(18kt+1)}{(9kt+1)^2}$, $p_D^*=p_B^*=t$, $\pi_D^*=\pi_B^*=\frac{81k^2t^3}{2(9kt+1)^2}$, $\pi_C^*=\frac{t}{9kt+1}$.

Recall that division C is incentivized to supply its new content to firm B only when the content quality is low (i.e.,


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$q \le 2t$). When the content creation cost coefficient $k$ is low (i.e., $k \le \frac{\sqrt{217}-1}{108t}$), division C has a higher incentive to set a high content quality (i.e., $q^* = \frac{1}{2k} > 2t$) and then not supply its new content to firm B. In this case, new content is exclusively acquired by division D, and firm B will be driven out of the market. When $k$ is high (i.e., $k > \frac{\sqrt{217}-1}{108t}$), it is optimal for division C to set a relatively low quality for new content (i.e., $q^* = \frac{3t}{9kt+1} \le 2t$) and then provide its new content to firm B, so both firm B and division D will make positive profits in the market. Proposition 2 indicates that division C supplies the new content to firm B only when the content creation cost coefficient $k$ is low. Note that, under the centralized structure, the new content is not supplied to firm B, i.e., the content is distributed exclusively by the integrated firm. However, under the decentralized structure, the new content is supplied to firm B when the content creation cost coefficient is relatively high. These results provide an intriguing message: the organizational structure can alter the vertically integrated firm's content provision strategy for its downstream competitor, and decentralization can result in nonexclusive provision of newly developed content.

Ref. [6] showed that the exclusive provision of newly developed content is optimal for the integrated firm. Complementing their finding, Proposition 2 shows that nonexclusive content provision can also be optimal when considering division conflicts. The results of Proposition 2 provide interesting and useful managerial implications for the regulation of vertical integration in the media industry: It is not necessary to always regulate the exclusive provision of the vertically integrated firm. This is because, in practice, division conflicts usually exist in the vertically integrated firms. Owing to the division conflicts, the newly developed content of the integrated firm will be supplied to the distribution rivals even without content provision regulation policy. The above results can also potentially explain the recent lack of content provision regulation for vertical integration in the media industry recently. In the vertical merger example of Comcast and NBC Universal occurred in 2011, the government policymaker (FCC of the USA) has imposed some conditions to prevent the integrated firm from withholding the content from other downstream distributors. However, in the merger example of Discovery and WarnerMedia occurred in 2022, FCC imposed no regulation on the content provision.

## 6 Impact of divisional conflicts

This section compares the centralized structure with the decentralized structure to investigate how the integrated firm's divisional conflicts impact different parties. We first consider the impact of divisional conflicts on the newly developed content quality.

**Proposition 3.** When $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts have no impact on the quality of new content. When $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$, divisional conflicts reduce the quality of new content. When $k > \frac{2}{9t}$, divisional conflicts increase the quality of new content.

Recall that compared with centralization, decentralization does not change the optimal new content provision strategy when $k$ is relatively low (i.e., $k \le \frac{\sqrt{217}-1}{108t}$). Thus, divisional conflicts have no impact on the new content quality if $k \le \frac{\sqrt{217}-1}{108t}$. When $k$ is relatively high (i.e., $k > \frac{\sqrt{217}-1}{108t}$), the newly developed content is (not) supplied to firm B under the decentralized (centralized) structure. That is, the decentralized structure induces nonexclusive provision of the new content. Therefore, when $k > \frac{\sqrt{217}-1}{108t}$, under centralization, the new content is exclusively distributed by firm A, and the quality of new content is determined to maximize the overall profit. In contrast, under decentralization, the new content is distributed by both division D and firm B, and the quality of new content is set by division C to maximize the wholesale revenue from the content. When the creation cost coefficient is medium (i.e., $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$), investing in the new content is not very costly for firm A. Hence, compared with the decentralized case, firm A has more incentive to produce higher-quality new content to considerably increase its competitive advantage. Moreover, the quality enhancement due to the centralized structure decreases as the content creation cost coefficient $k$ increases. When that coefficient is high (i.e., $k > \frac{2}{9t}$), it is costly to invest in the new content for firm A or division C, but division C gains wholesale revenue for the new content from both division D and firm B. Therefore, in this case, the quality of new content set to maximize division C's profit under decentralization is higher than the quality determined to maximize the overall profit of firm A under centralization. Fig. 1a illustrates the impact of divisional conflicts on the qualify of new content. The above results and Fig. 1a indicate that vertical integration in the media industry may lead to a higher quality of newly developed content, suggesting that regulating vertical integration may be harmful to content development.

**Proposition 4.** When $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts have no impact on firm A. When $k > \frac{\sqrt{217}-1}{108t}$, divisional conflicts hurt firm A.

Recall that divisional conflicts have no effect on the new content quality if $k \le \frac{\sqrt{217}-1}{108t}$. Hence, in this case, firm A's profit is not affected by the divisional conflicts. When $k > \frac{\sqrt{217}-1}{108t}$, intuitively, divisional conflicts are harmful to the vertically integrated firm (i.e., firm A) because of the inconsistent objectives of firm A's different divisions.

**Proposition 5.** When $k \le \frac{\sqrt{217}-1}{108t}$, firm A's divisional conflicts have no impact on firm B. When $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$, firm A's divisional conflicts benefit firm B. When $k > \frac{2}{9t}$, firm A's divisional conflicts hurt firm B.



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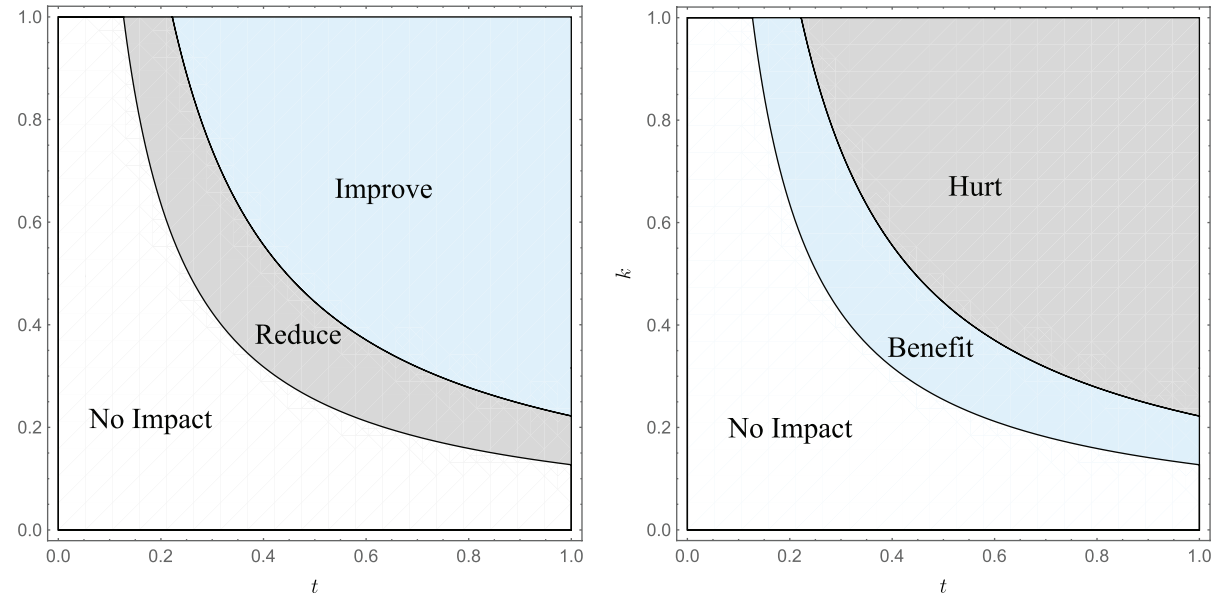


(a) New Content Quality (b) Firm B

**Fig. 1.** Impact of division conflicts on new content quality and Firm B.

When $k$ is relatively low (i.e., $k \le \frac{\sqrt{217}-1}{108t}$), divisional conflicts do not change firm A's new content provision strategy, so divisional conflicts do not affect firm B's profit when $k \le \frac{\sqrt{217}-1}{108t}$. When $k$ is high (i.e., $k > \frac{\sqrt{217}-1}{108t}$), the decentralized structure induces the new content provision for firm B. Note that when $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$, the new content quality under the centralized structure is higher than that under the decentralized structure. The new content increases firm A's competitive advantage under centralization, and the new content with higher quality results in a more competitive position for firm A. However, firm B does not have a competitive disadvantage under firm A's decentralized structure due to the nonexclusive provision of new content. Therefore, in this case, although firm B must pay the new content fee $w$, firm B's profit is higher in the decentralized case. When $k > \frac{2}{9t}$, the new content quality under centralization is lower than that under decentralization. Firm B's competitive disadvantage under centralization is not very strong. However, under decentralization, the new content price paid by firm B is relatively high because of its high quality. Hence, although firm B and division D are equally competitive under the decentralized structure, the price charged by division C makes firm B worse off than in the centralized case. Fig. 1b depicts the impact of divisional conflicts on firm B. Proposition 5 and Fig. 1b imply that nonexclusive newly developed content provision by the vertically integrated firm (i.e., firm A) does not always benefit the downstream competitor (i.e., firm B). Distributing the newly developed content does not always increase firm B's profit.

We have so far discussed the impact of divisional conflicts from the perspective of firm A and firm B. How do divisional conflicts affect the entire industry? The following proposition specifies how divisional conflicts impact the industry.

**Proposition 6.** When $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts have no impact on industry profits. When $k > \frac{\sqrt{217}-1}{108t}$, divisional conflicts reduce industry profits.

Divisional conflicts have no impact on both firms A and B when $k \le \frac{\sqrt{217}-1}{108t}$. Therefore, in this case, decentralization does not affect industry profits when $k$ is low. Divisional conflicts hurt firm A only when $k > \frac{\sqrt{217}-1}{108t}$ and benefit firm B when the content creation coefficient is medium (i.e., $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$). Consequently, decentralization hurts the industry when $k$ is high. When the content creation coefficient is medium (i.e., $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$), although divisional conflicts benefit firm B, the profit loss for firm A because decentralized structure dominates the profit gain for firm B; thus divisional conflicts still reduce industry profits.

**Proposition 7.** When $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts have no impact on consumer surplus. When $\frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}$, divisional conflicts reduce consumer surplus. When $k > \frac{\sqrt{13}+11}{108t}$, divisional conflicts improve consumer surplus.

Note that when $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts do not impact the optimal new content quality and provision decisions. Hence, consumer surplus does not change when the organizational structure shifts from a centralized to decentralized structure. When $k > \frac{\sqrt{217}-1}{108t}$, divisional conflicts have two effects on consumers: (i) the positive nonexclusive provision effect, that is, decentralization induces nonexclusive distribution of the vertically integrated firm's newly de-


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veloped content; (ii) the content quality effect, that is, decentralization results in strategic changes in the creation of the new content. The effect is negative (positive) if $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$ ($k > \frac{2}{9t}$) because the new content quality is reduced (enhanced). Note that the negative content quality effect becomes weak as content creation coefficient $k$ increases when $\frac{\sqrt{217}-1}{108t} < k \le \frac{2}{9t}$. In this case, if $k$ is not high (i.e., $k \le \frac{\sqrt{13}+11}{108t} < \frac{2}{9t}$), the negative content quality effect is strong and plays the dominant role. Therefore, divisional conflicts hurt consumers when $\frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}$. Conversely, if $k$ is relatively high (i.e., $\frac{\sqrt{13}+11}{108t} < k \le \frac{2}{9t}$), the negative content quality effect is weak and the positive nonexclusive provision effect is dominant, so divisional conflicts are beneficial to consumers. When $k$ is quite high (i.e., $k > \frac{2}{9t}$), the two effects are both positive and thus divisional conflicts benefit consumers. Fig. 2a illustrates the impact of divisional conflicts on consumer surplus. Proposition 7 and Fig. 2a show that intrafirm conflicts in the vertically integrated firm do not always increase consumer surplus; they may reduce it. These results imply that regulating vertical integration may hurt consumers.

**Proposition 8.** When $k \le \frac{\sqrt{217}-1}{108t}$, divisional conflicts have no impact on social welfare. When $\frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}$, divisional conflicts reduce social welfare. When $k > \frac{\sqrt{13}+11}{108t}$, divisional conflicts improve social welfare.

When $k \le \frac{\sqrt{217}-1}{108t}$, industry profits and consumer surplus do not change when the organizational structure has shifted from a centralized to decentralized structure. Consequently, in this case, divisional conflicts do not affect social welfare. Recall that the decentralized structure reduces industry profits and improves consumer surplus when $k > \frac{\sqrt{13}+11}{108t}$. Therefore, from the perspective of social welfare consisting of industry profits and consumer surplus, divisional conflicts have a positive impact on social welfare only when $k > \frac{\sqrt{13}+11}{108t}$. The results of Proposition 8 are illustrated in Fig. 2b. Proposition 8 and Fig. 2b show that divisional conflicts in the vertically integrated firm may also harm social welfare, implying that regulating vertical integration in the media industry may lead to unintended consequences. Policymakers should be cautions when restricting vertical integration.

# 7 Conclusions

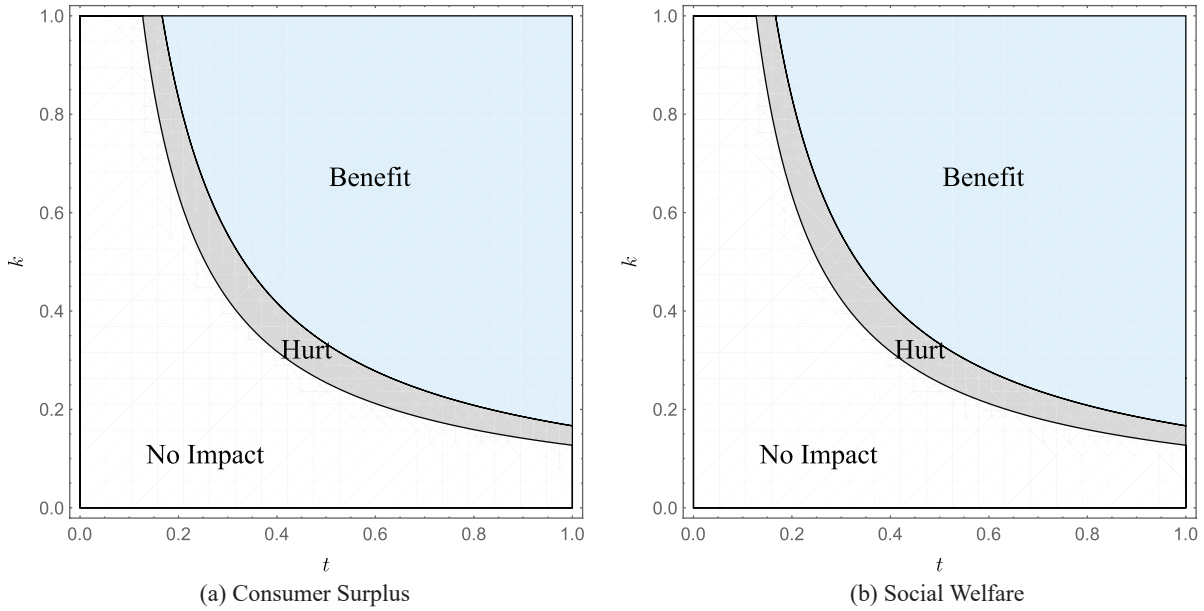
## 7.1 Summary

This paper studies how divisional conflicts within a vertically integrated firm developing new content impact the content provision strategy applied to its downstream competitor. We compare the centralized structure and decentralized structure cases (i.e., without and with intrafirm conflict) and then study how intrafirm conflict affects the content quality and provision decisions. Additionally, we analyze the impact of divisional conflicts on firms, the industry, consumers, and social welfare. There are several major findings from this research.

## 7.2 Main findings and managerial insights

The answers to the research questions raised in Introduction as well as the associated managerial insights are summarized as follows.

(I) Content provision strategy (Research Question 1): The integrated firm developing the new content never supplies the newly developed content to its downstream competitor under the centralized structure (i.e., when divisional conflicts do not




(a) Consumer Surplus (b) Social Welfare

**Fig. 2.** Impact of division conflicts on consumer surplus and social welfare.



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exist). This is because providing the new content for the downstream competitor weakens the integrated firm's competitive advantage, and we have shown that the wholesale revenue from the newly developed content cannot adequately compensate for this effect. However, if the new content creation coefficient is relatively high and the content quality is low, the new content will be supplied to the downstream competitor under the decentralized structure (where divisional conflicts exist and decisions are made independently by different divisions of the integrated firm). Maximizing its wholesale revenue from the new content incentivizes the content creation division of the integrated firm to supply the content to the downstream competitor when the content quality is low. The above results provide a plausible explanation for the phenomenon of no content provision regulation for vertical integration in media industry.

(Ⅱ) Newly developed content quality (Research Question 2): Although a decentralized structure can lead to nonexclusive new content provisions, content quality is reduced due to decentralization under a moderate content creation coefficient. This result is driven by the fact that the vertically integrated firm has an incentive to set a higher quality for the new content to significantly increase its competitive advantage under the centralized structure when investing in the new content is not very costly. In addition, divisional conflicts reduce the quality of the newly developed content when the content creation cost coefficient is medium. These results suggest that regulating vertical integration does not always benefit new content development.

(Ⅲ) Impact on different parties (Research Question 3): Although the decentralized structure induces provision of the newly developed content provision to the downstream competitor, the competitor is also worse off under decentralization because the new content price charged by the content creation division when the content creation coefficient is considerably high. Consequently, industry profit, which is the sum of the profits of the integrated firm and downstream competitor, is lower under the decentralized structure. From the perspective of consumers, although divisional conflicts result in nonexclusive provision of the integrated firm's newly developed content, the reduced content quality caused by divisional conflicts hurts consumer surplus when the content creation coefficient is moderate. Owing to the negative effect on consumer surplus when the content creation coefficient is in a medium range and the negative effect on the industry profits, the decentralized structure also hurts social welfare if that coefficient is relatively low. Our findings imply that restricting vertical integration may lead to unintended consequences. Policymakers should exercise caution when regulating vertical integration in media industry.

### 7.3 Future research

We suggest several potential directions for future research. First, our work focuses on the competition between one vertically integrated firm (consisting of content creation and distribution divisions) and one downstream competitor, with the latter being a pure distributor. It would be interesting to study the content development and provision problems under competition between two vertically integrated firms when either or both could have intrafirm conflicts. Second, we only consider the case in which consumers purchase the product or service from one of the competing firms at most. In practice, consumers may purchase multiple competing products or purchase services from different firms[20, 32], which is especially common for information goods or services (e.g., digital music, video streaming). Incorporating consumers' multipurchase behavior into our model may be an interesting direction for future research. Finally, an important direction for future research is to investigate the integrated firm's content development and provision problems under asymmetric information because, in reality, firms may have different information about demand.

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## Conflict of interest

The author declares that hehas no conflict of interest.

## Biography

**Shengming Zheng** is currently an Special Associate Professor at the Department of Management Science, University of Science and Technology of China (USTC). He received his B.S. degree in Mathematics and Applied Mathematics from Anhui University in 2014 and his Ph.D. degree in Management Science and Engineering from USTC in 2021. His research mainly focuses on supply chain management and consumer behavior.

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## Appendix

**Proof of Lemma 1.** Solving Eqs. (2) and (3), we obtain the optimal decisions, demand, and profits $p_A^* = p_B^* = t$, $d_A^* = d_B^* = \frac{1}{2}$, $\pi_A^* = \frac{t}{2} + w$, $\pi_B^* = \frac{t}{2} - w$.

Solving Eqs. (4) and (5), we have $p_A(p_B) = \begin{cases} \frac{t + p_B + q}{2}, \text{ if } p_B \le 3t - q; \\ p_B + q - t, \text{ if } p_B > 3t - q \end{cases}$ and $p_B(p_A) = \begin{cases} \frac{t + p_A - q}{2}, \text{ if } p_A \le 3t + q; \\ p_A - q - t, \text{ if } p_A > 3t + q. \end{cases}$ Therefore, we obtain the subgame equilibrium as follows.

$$p_A^* = \begin{cases} t + \frac{q}{3}, \text{ if } q \le 3t; \\ q - t, \text{ if } q > 3t; \end{cases} \quad p_B^* = \begin{cases} t - \frac{q}{3}, \text{ if } q \le 3t; \\ 0, \text{ if } q > 3t; \end{cases} \quad d_A^* = \begin{cases} \frac{1}{2} + \frac{q}{6t}, \text{ if } q \le 3t; \\ 1, \text{ if } q > 3t; \end{cases} \quad d_B^* = \begin{cases} \frac{1}{2} - \frac{q}{6t}, \text{ if } q \le 3t; \\ 0, \text{ if } q > 3t; \end{cases}$$

$$\pi_A^* = \begin{cases} \frac{(t + q/3)^2}{2t}, \text{ if } q \le 3t; \\ q - t, \text{ if } q > 3t; \end{cases} \quad \pi_B^* = \begin{cases} \frac{(t - q/3)^2}{2t}, \text{ if } q \le 3t; \\ 0, \text{ if } q > 3t. \end{cases}$$

**Proof of Corollary 1.** Given firm A's offer, if firm B accepts the offer, its profit will be $\frac{t}{2} - w$; if firm B does not accept the offer, its profit will be $\frac{(t - q/3)^2}{2t}$ when $q \le 3t$ and 0 when $q > 3t$. Therefore, we obtain that firm B will accept firm A's offer only if $w \le \frac{q}{3t} - \frac{q^2}{18t}$ when $q \le 3t$, or $w \le \frac{t}{2}$ when $q > 3t$.

**Proof of Proposition 1.** It is easy to obtain $\pi_A^s < \pi_A^n$. Therefore, firm A will not supply its new content to firm B. Therefore, the optimal new content quality can be analyzed by solving firm A's maximization problem

$$\max_q \pi_A(q) = \begin{cases} \frac{t}{2} + \frac{q}{3} + \frac{q^2}{18t} - kq^2, \text{ if } q \le 3t; \\ q - t - kq^2, \text{ if } q > 3t. \end{cases}$$

We have



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$$\frac{\mathrm{d}\pi_A(q)}{\mathrm{d}q}=\begin{cases}\frac{1}{3}+\frac{q}{9t}-2kq, \text{ if } q\le 3t;\\ 1-2kq, \text{ if } q>3t.\end{cases}$$

Next, we analyze firm A's optimal quality decision based on the cost coefficient $k$.

If $k\le\frac{1}{9t}$, $\pi_A(q)$ increases in $q$ when $q<\frac{1}{2k}$ and decreases in $q$ when $q>\frac{1}{2k}$. Hence, the optimal content quality is $q^*=\frac{1}{2k}$.

If $\frac{1}{9t}<k\le\frac{1}{6t}$, $\pi_A(q)$ increases in $q$ when $q<\frac{3t}{18kt-1}$ and $3t<q<\frac{1}{2k}$; $\pi_A(q)$ decreases in $q$ when $\frac{3t}{18kt-1}<q<3t$ and $q>\frac{1}{2k}$. Hence, the optimal content quality is $q^*=\frac{3t}{18kt-1}$ or $q^*=\frac{1}{2k}$. If $q=\frac{3t}{18kt-1}$, then $\pi_A(q)=\frac{9kt^2}{18kt-1}$; if $q=\frac{1}{2k}$, then $\pi_A(q)=\frac{1}{4k}-t$. It is easy to obtain $\frac{1}{4k}-t>\frac{9kt^2}{18kt-1}$ when $\frac{1}{9t}<k\le\frac{\sqrt{13}+11}{108t}$. Therefore, the optimal content quality is $q^*=\frac{1}{2k}$ when $\frac{1}{9t}<k\le\frac{\sqrt{13}+11}{108t}$ and $q^*=\frac{3t}{18kt-1}$ when $\frac{\sqrt{13}+11}{108t}<k\le\frac{1}{6t}$.

If $k>\frac{1}{6t}$, $\pi_A(q)$ increases in $q$ when $q<\frac{3t}{18kt-1}$ and decreases in $q$ when $q>\frac{3t}{18kt-1}$. Hence, the optimal content quality is $q^*=\frac{3t}{18kt-1}$.

In summary, we have $q^*=\begin{cases}\frac{1}{2k}, \text{ if } k\le\frac{\sqrt{13}+11}{108t};\\ \frac{3t}{18kt-1}, \text{ if } k>\frac{\sqrt{13}+11}{108t}.\end{cases}$.

**Proof of Lemma 2.** Solving Eqs. (8) and (9), we obtain the optimal decisions, demand, and profits $p_D^*=p_B^*=t$, $d_D^*=d_B^*=\frac{1}{2}$, $\pi_D^*=\pi_B^*=\frac{t}{2}$.

Solving Eq. (10), we have $p_D(p_B)=\begin{cases}\frac{t+p_B+q}{2}, \text{ if } p_B\le 3t-q;\\ p_B+q-t, \text{ if } p_B>3t-q.\end{cases}$ Solving Eq. (11), we have $p_B(p_D)=\begin{cases}\frac{t+p_D-q}{2}, \text{ if } p_D\le 3t+q;\\ p_D-q-t, \text{ if } p_D>3t+q.\end{cases}$ Therefore, we obtain the subgame equilibrium as follows.

$$p_D^*=\begin{cases}t+\frac{q}{3}, \text{ if } q\le 3t;\\ q-t, \text{ if } q>3t;\end{cases}\quad p_B^*=\begin{cases}t-\frac{q}{3}, \text{ if } q\le 3t;\\ 0, \text{ if } q>3t;\end{cases}\quad d_D^*=\begin{cases}\frac{1}{2}+\frac{q}{6t}, \text{ if } q\le 3t;\\ 1, \text{ if } q>3t;\end{cases}\quad d_B^*=\begin{cases}\frac{1}{2}-\frac{q}{6t}, \text{ if } q\le 3t;\\ 0, \text{ if } q>3t;\end{cases}$$

$$\pi_D^*=\begin{cases}\frac{(t+q/3)^2}{2t}-w, \text{ if } q\le 3t;\\ q-t-w, \text{ if } q>3t;\end{cases}\quad \pi_B^*=\begin{cases}\frac{(t-q/3)^2}{2t}, \text{ if } q\le 3t;\\ 0, \text{ if } q>3t.\end{cases}$$

**Proof of Lemma 3.** Solving Eqs. (12) and (13), we obtain $p_D^*=p_B^*=t$, $d_D^*=d_B^*=\frac{1}{2}$, $\pi_D^*=\pi_B^*=\frac{t}{2}-w$.

Therefore, the following decision matrix for division D and firm B is obtained (see Table A1).

Define $w_D=\begin{cases}\frac{q}{3}-\frac{q^2}{18t}, \text{if } q\le 3t;\\ \frac{t}{2}, \text{if } q>3t\end{cases}$ and $w_B=\begin{cases}\frac{t}{2}, \text{if } q\le 3t;\\ q-\frac{3t}{2}, \text{if } q>3t.\end{cases}$ When $w\le w_D$, if $q\le 3t$, we have $\frac{t}{2}-w\ge\frac{(t-q/3)^2}{2}$ and $\frac{(t+q/3)^2}{2}-w>\frac{t}{2}$; if $q>3t$, we have $\frac{t}{2}-w\ge 0$ and $q-t-w>\frac{t}{2}$. This means that each decision maker will accept division C's offer regardless whether its rival accepts the offer. Therefore, in equilibrium, both division D and firm B will accept the offer. When $w_D<w\le w_B$, if $q\le 3t$, we have $\frac{t}{2}-w<\frac{(t-q/3)^2}{2}$ and $\frac{(t+q/3)^2}{2}-w\ge\frac{t}{2}$; if $q>3t$, we have $\frac{t}{2}-w>0$ and $q-t-w\ge\frac{t}{2}$.

**Table A1.** Decision matrix for Division D and Firm B.

| Division D/Firm B | | Accept | Not accept |
|---|---|---|---|
| $q\le 3t$ | Accept | $\pi_D^*=\frac{t}{2}-w$, $\pi_B^*=\frac{t}{2}-w$ | $\pi_D^*=\frac{(t+q/3)^2}{2t}-w$, $\pi_B^*=\frac{(t-q/3)^2}{2t}$ |
| | Not accept | $\pi_D^*=\frac{(t-q/3)^2}{2t}$, $\pi_B^*=\frac{(t+q/3)^2}{2t}-w$ | $\pi_D^*=\frac{t}{2}$, $\pi_B^*=\frac{t}{2}$ |
| $q>3t$ | Accept | $\pi_D^*=\frac{t}{2}-w$, $\pi_B^*=\frac{t}{2}-w$ | $\pi_D^*=q-t-w$, $\pi_B^*=0$ |
| | Not accept | $\pi_D^*=0$, $\pi_B^*=q-t-w$ | $\pi_D^*=\frac{t}{2}$, $\pi_B^*=\frac{t}{2}$ |



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Therefore, each decision maker will accept division C's offer only when its rival does not accept the offer. Therefore, in equilibrium, only one decision maker will accept the offer. When $w > w_B$, if $q \le 3t$, we have $\frac{t}{2} - w < \frac{(t-q/3)^2}{2}$ and $\frac{(t+q/3)^2}{2} - w < \frac{t}{2}$; if $q > 3t$, we have $\frac{t}{2} - w < 0$ and $q - t - w < \frac{t}{2}$. This means that each decision maker will not accept the creator's offer regardless regardless of whether its rival accepts the offer. Thus, in equilibrium, neither division D nor firm B will accept the offer.

**Proof of Lemma 4.** Based on Lemma 3, when $q \le 3t$, there are two possible optimal prices for division C, $\frac{q}{3} - \frac{q^2}{18t}$ and $\frac{q}{3} + \frac{q^2}{18t}$. When $q \le 3t$, if $w^* = \frac{q}{3} - \frac{q^2}{18t}$, then $\pi_C^* = \frac{2q}{3} - \frac{q^2}{9t}$; if $w^* = \frac{q}{3} + \frac{q^2}{18t}$, then $\pi_C^* = \frac{q}{3} + \frac{q^2}{18t}$. It is easy to know $\frac{2q}{3} - \frac{q^2}{9t} \ge \frac{q}{3} + \frac{q^2}{18t}$ if $q \le 2t$. Hence, the optimal price is $\frac{q}{3} - \frac{q^2}{18t}$ when $q \le 2t$ and $\frac{q}{3} + \frac{q^2}{18t}$ when $2t < q \le 3t$. When $q > 3t$, there are two possible optimal prices for division C, $\frac{t}{2}$ and $q - \frac{3t}{2}$. When $q > 3t$, if $w^* = \frac{t}{2}$, then $\pi_C^* = t$; if $w^* = q - \frac{3t}{2}$, then $\pi_C^* = q - \frac{3t}{2}$. It is easy to know $q - \frac{3t}{2} > t$ when $q > 3t$. In summary, division C's optimal price is

$$w^* = \begin{cases} \frac{q}{3} - \frac{q^2}{18t}, \text{ if } q \le 2t; \\ \frac{q}{3} + \frac{q^2}{18t}, \text{ if } 2t < q \le 3t; \\ q - \frac{3t}{2}, \text{ if } q > 3t. \end{cases}$$

**Proof of Lemma 5.** For reference convenience, we use superscripts $s$ and $n$ to represent the content provision and no content provision cases. We have

$$\pi_C^s = \begin{cases} \frac{2q}{3} - \frac{q^2}{9t}, \text{ if } q \le 2t; \\ \frac{q}{3} + \frac{q^2}{18t}, \text{ if } 2t < q \le 3t; \\ q - \frac{3t}{2}, \text{ if } q > 3t \end{cases} \quad \text{and} \quad \pi_C^n = \begin{cases} \frac{q}{3} + \frac{q^2}{18t}, \text{ if } q \le 3t; \\ q - \frac{3t}{2}, \text{ if } q > 3t. \end{cases}$$

It is easy to obtain $\frac{2q}{3} - \frac{q^2}{9t} > \frac{q}{3} + \frac{q^2}{18t}$ if $q \le 2t$. Therefore, division C will supply its new content to firm B when $q \le 2t$. When $q > 2t$, division C is indifferent between supplying or not supplying its new content to firm B. However, the total profit of firm A is $\pi_A^s = \begin{cases} \frac{q^2}{9t} + \frac{t}{2}, \text{ if } 2t < q \le 3t; \\ q - \frac{3t}{2}, \text{ if } q > 3t \end{cases}$ (if only firm B accepts division C's offer) and $\pi_A^n = \begin{cases} \frac{q}{3} + \frac{q^2}{18t} + \frac{t}{2}, \text{ if } 2t < q \le 3t; \\ q - t, \text{ if } q > 3t. \end{cases}$ It is easy to obtain $\pi_A^s < \pi_A^n$; hence, division C will not supply its new content to firm B if $q > 2t$.

**Proof of Proposition 2.** We have

$$\frac{\mathrm{d}\pi_C(q)}{\mathrm{d}q} = \begin{cases} \frac{2}{3} - 2(k + \frac{1}{9t})q, \text{ if } q \le 2t; \\ \frac{1}{3} - (2k - \frac{1}{9t})q, \text{ if } 2t < q \le 3t; \\ 1 - 2kq, \text{ if } q > 3t. \end{cases}$$

Next, we analyze division C's optimal quality decision based on the cost coefficient $k$.

If $k \le \frac{1}{18t}$, $\pi_C(q)$ increases in $q$ when $q < \frac{1}{2k}$ and decreases in $q$ when $q > \frac{1}{2k}$. Hence, the optimal content quality is $q^* = \frac{1}{2k}$.

If $\frac{1}{18t} < k \le \frac{1}{9t}$, $\pi_C(q)$ increases in $q$ when $q < \frac{3t}{9kt+1}$ and $2t < q < \frac{1}{2k}$; $\pi_C(q)$ decreases in $q$ when $\frac{3t}{9kt+1} < q < 2t$ and $q > \frac{1}{2k}$. Hence, the optimal content quality is $q^* = \frac{3t}{9kt+1}$ or $q^* = \frac{1}{2k}$. If $q = \frac{3t}{9kt+1}$, then $\pi_C(q) = \frac{t}{9kt+1}$; if $q = \frac{1}{2k}$, then $\pi_C(q) = \frac{1}{4k} - \frac{3t}{2}$. It is easy to obtain $\frac{1}{4k} - \frac{3t}{2} > \frac{t}{9kt+1}$ when $\frac{1}{18t} < k \le \frac{1}{9t}$. Therefore, the optimal content quality is $q^* = \frac{1}{2k}$.

If $\frac{1}{9t} < k \le \frac{5}{36t}$, $\pi_C(q)$ increases in $q$ when $q < \frac{3t}{9kt+1}$, $2t < q < \frac{3t}{18kt-1}$, and $3t < q < \frac{1}{2k}$; $\pi_C(q)$ decreases in $q$ when $\frac{3t}{9kt+1} < q < 2t$, $\frac{3t}{18kt-1} < q < 3t$, and $q > \frac{1}{2k}$. Hence, the optimal content quality is $q^* = \frac{3t}{9kt+1}$ or $q^* = \frac{3t}{18kt-1}$ or $q^* = \frac{1}{2k}$. If $q = \frac{3t}{9kt+1}$, then $\pi_C(q) = \frac{t}{9kt+1}$; if $q = \frac{3t}{18kt-1}$, then $\pi_C(q) = \frac{t}{2(18kt-1)} < \frac{t}{9kt+1}$; if $q = \frac{1}{2k}$, then $\pi_C(q) = \frac{1}{4k} - \frac{3t}{2}$. It is easy to obtain $\frac{1}{4k} - \frac{3t}{2} > \frac{t}{9kt+1}$ when $\frac{1}{9t} < k < \frac{\sqrt{217}-1}{108t}$ and $\frac{1}{4k} - \frac{3t}{2} < \frac{t}{9kt+1}$ when $\frac{\sqrt{217}-1}{108t} < k \le \frac{5}{36t}$. Therefore, the optimal


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content quality is $q^* = \frac{1}{2k}$ when $\frac{1}{9t} < k \le \frac{\sqrt{217}-1}{108t}$ and $q^* = \frac{3t}{9kt+1}$ when $\frac{\sqrt{217}-1}{108t} < k \le \frac{5}{36t}$.

If $\frac{5}{36t} < k \le \frac{1}{6t}$, $\pi_C(q)$ increases in $q$ when $q < \frac{3t}{9kt+1}$ and $3t < q < \frac{1}{2k}$; $\pi_C(q)$ decreases in $q$ when $\frac{3t}{9kt+1} < q < 3t$ and $q > \frac{1}{2k}$. Hence, the optimal content quality is $q^* = \frac{3t}{9kt+1}$ or $q^* = \frac{1}{2k}$. If $q = \frac{3t}{9kt+1}$, then $\pi_C(q) = \frac{t}{9kt+1}$; if $q = \frac{1}{2k}$, then $\pi_C(q) = \frac{1}{4k} - \frac{3t}{2}$. It is easy to obtain $\frac{1}{4k} - \frac{3t}{2} < \frac{t}{9kt+1}$ when $\frac{5}{36t} < k \le \frac{1}{6t}$. Therefore, the optimal content quality is $q^* = \frac{3t}{9kt+1}$.

If $k > \frac{1}{6t}$, $\pi_C(q)$ increases in $q$ when $q < \frac{3t}{9kt+1}$ and decreases in $q$ when $q > \frac{3t}{9kt+1}$. Hence, the optimal content quality is $q^* = \frac{3t}{9kt+1}$.

In summary, we have $q^* = \begin{cases} \frac{1}{2k}, \text{ if } k \le \frac{\sqrt{217}-1}{108t}; \\ \frac{3t}{9kt+1}, \text{ if } k > \frac{\sqrt{217}-1}{108t}. \end{cases}$

**Proof of Proposition 3.** For reference convenience, we use superscripts $d$ and $c$ to represent the decentralized and centralized structure cases. We have

$$q^d - q^c = \begin{cases} 0, \text{ if } k \le \frac{\sqrt{217}-1}{108t}; \\ \frac{-3kt-1}{2k(9kt+1)}, \text{ if } \frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}; \\ \frac{3t(9kt-2)}{(9kt+1)(18kt-1)}, \text{ if } k > \frac{\sqrt{13}+11}{108t}. \end{cases}$$

The proposition follows immediately.

**Proof of Proposition 4.** We have

$$\pi_A^d - \pi_A^c = \begin{cases} 0, \text{ if } k \le \frac{\sqrt{217}-1}{108t}; \\ \frac{486k^3t^3+27k^2t^2-10kt-1}{4k(9kt+1)^2}, \text{ if } \frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}; \\ -\frac{t(81k^2t^2+2)}{2(9kt+1)^2(18kt-1)}, \text{ if } k > \frac{\sqrt{13}+11}{108t}. \end{cases}$$

It is easy to obtain $486k^3t^3+27k^2t^2-10kt-1<0$ when $\frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}$. The proposition follows immediately.

**Proof of Proposition 5.** We have

$$\pi_B^d - \pi_B^c = \begin{cases} 0, \text{ if } k \le \frac{\sqrt{217}-1}{108t}; \\ \frac{81k^2t^3}{2(9kt+1)^2}, \text{ if } \frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}; \\ -\frac{t(9kt-2)(324k^2t^2-9kt-2)}{2(1-18kt)^2(9kt+1)^2}, \text{ if } k > \frac{\sqrt{13}+11}{108t}. \end{cases}$$

It is easy to obtain $-t(9kt-2)(324k^2t^2-9kt-2)>0$ only if $k < \frac{2}{9t}$ when $k > \frac{\sqrt{13}+11}{108t}$.

**Proof of Proposition 6.** We have

$$\Pi^d - \Pi^c = \begin{cases} 0, \text{ if } k \le \frac{\sqrt{217}-1}{108t}; \\ \frac{648k^3t^3+27k^2t^2-10kt-1}{4k(9kt+1)^2}, \text{ if } \frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}; \\ -\frac{t(2187k^3t^3-405k^2t^2+18kt+1)}{(1-18kt)^2(9kt+1)^2}, \text{ if } k > \frac{\sqrt{13}+11}{108t}. \end{cases}$$

It is easy to obtain $648k^3t^3+27k^2t^2-10kt-1<0$ when $\frac{\sqrt{217}-1}{108t} < k \le \frac{\sqrt{13}+11}{108t}$ and $2187k^3t^3-405k^2t^2+18kt+1>0$ when $k > \frac{\sqrt{13}+11}{108t}$. The proposition follows immediately.

**Proof of Proposition 7.** We have


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$$CS^d - CS^c = \begin{cases} 0, \text{ if } k \le \dfrac{\sqrt{217}-1}{108t}; \\ \dfrac{t(5-63kt)}{36kt+4}, \text{ if } \dfrac{\sqrt{217}-1}{108t} < k \le \dfrac{\sqrt{13}+11}{108t}; \\ \dfrac{t(2916k^2t^2-495kt+17)}{4(9kt+1)(18kt-1)^2}, \text{ if } k > \dfrac{\sqrt{13}+11}{108t}. \end{cases}$$

It is easy to obtain $5-63kt<0$ when $\dfrac{\sqrt{217}-1}{108t} < k \le \dfrac{\sqrt{13}+11}{108t}$ and $2916k^2t^2-495kt+17>0$ when $k > \dfrac{\sqrt{13}+11}{108t}$. The proposition follows immediately.

**Proof of Proposition 8.** We have

$$SW^d - SW^c = \begin{cases} 0, \text{ if } k \le \dfrac{\sqrt{217}-1}{108t}; \\ \dfrac{81k^3t^3+9k^2t^2-5kt-1}{4k(9kt+1)^2}, \text{ if } \dfrac{\sqrt{217}-1}{108t} < k \le \dfrac{\sqrt{13}+11}{108t}; \\ \dfrac{t(17496k^3t^3+81k^2t^2-414kt+13)}{4(9kt+1)^2(18kt-1)^2}, \text{ if } k > \dfrac{\sqrt{13}+11}{108t}. \end{cases}$$

It is easy to obtain $81k^3t^3+9k^2t^2-5kt-1<0$ when $\dfrac{\sqrt{217}-1}{108t} < k \le \dfrac{\sqrt{13}+11}{108t}$ and $17496k^3t^3+81k^2t^2-414kt+13>0$ if $k > \dfrac{\sqrt{13}+11}{108t}$. The proposition follows immediately.



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