Journal of Southeast University (English Edition) Vol. 39, No. 4, pp. 426 – 434 Dec. 2023 ISSN 1003—7985

Effects of online advertising and consumer engagement on a social media platform

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Abstract: To investigate the impact of online advertising and consumer engagement on profits, an exponential demand function is proposed to capture user behavior on a social media platform with a two-echelon supply chain model. According to the different subjects of advertising cost, three sales models are proposed: manufacturers bearing advertising cost, retailers bearing advertising cost, and manufactures and retailers sharing advertising cost. Meanwhile, three corresponding mathematical models are constructed for analysis. The equilibrium results demonstrate that improving consumer engagement can help the players earn more profits; however, typical online retailers are often reluctant to bear costs under any circumstances. When community diffusion is low, social media platforms are willing to incur a proportion of advertising costs to attract more user engagement. More meaningful management insights indicate that community diffusion has a more significant effect on manufacturers' profit. In the context of social media, supply chain players should leverage advertising to improve social community diffusion rather than focusing on the cost-sharing ratio.

Key words: advertising; online platform; social media retailer; equilibrium; cost-sharing

DOI: 10.3969/j. issn. 1003 – 7985. 2023. 04. 012

Contemporary online platforms are increasingly dominating the retail and capital markets in e-commerce. Successful startups operating as online platforms have become the engines of economic growth in many countries. The rise of online platforms has thoroughly changed the landscape of traditional retail and promoted venture capital prosperity as a new driving force for global economic growth[1]. Online platforms create value for users by reducing information asymmetries or addressing their evolving needs. However, because of low switching costs, modern consumers switch between offline and online channels[2]. As intermediaries, online platforms must not only enhance consumer experience and surplus but also increase customers' loyalty (such as eBay. com in the United States and Taobao. com in China). Advertising is used as a tool to expand the market and propagate brands that reach and connect more consumers. Social media companies often assume a proportion of advertising costs in the online channel that is shared with online retailers.

The effect of social media advertising on consumer engagement has been illustrated in previous research. For example, Levi's released promotional videos for jeans on Facebook to attract consumers to like and participate in discussions[3]. Superior advertising generates more user engagement and purchases. Advertisers have been enthusiastically integrating social media into advertising programs to drive digital engagement[4]. The role of social media advertising has been assessed in the fields of hospitality, tourism, and travel, with unprecedented opportunities for advertisers to engage and interact with their customers [5-6]. Some researchers have examined the effect of social media advertising content, referring to user-generated content or electronic word-of-mouth, on customer engagement by using social media data, such as Facebook and Twitter[7-9], determining that advertising attributes, brand personality, brand customer service, and brand intimacy positively influence consumer engagement and help firms to improve social media marketing strategies, while consumers also increasingly rely on social media influencers, which gives brands some control over the content. Examining whether consumer engagement produces a significant return on investment is one of many touchpoints. A growing interest is how to portray the effect of consumer engagement on social media advertising in a supply chain model, which this study examines by digging deeper.

A robust body of literature has contributed work from the supply chain perspective to systematically investigate the impact of advertising. Advertising is considered to be an effective demand generator that amplifies the payoffs of marketing actors (manufacturers and retailers). Advertising-dependent demand models have been proposed to characterize the effects of advertising[10]. Consumer demand depends on prices and advertising and is generally described using linear functions. Such models have included simple marketing channels that involve only one supplier and one retailer. Later, more complex structures that included two suppliers or two retailers were explored in the supply chain literature. In recent years, cooperative

Received 2023-02-27, **Revised** 2023-07-09.

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Citation: Wang Yan, Mei Shu'e, Xu Ruize, et al. Effects of online advertising and consumer engagement on a social media platform[J]. Journal of Southeast University (English Edition), 2023, 39(4): 426 – 434. DOI: 10.3969/j. issn. 1003 – 7985. 2023. 04. 012.

advertising, in reference to national and local advertising expenditure, has emerged as the dominant research direction, assuming linear functions for the advertising investments of manufacturers and retailers[11-12]. At the same time, nonlinear functions (power and exponential forms) and three-level supply chains have also been examined in previous research[13].

Social media is increasingly employed as a more pervasive platform with which to conduct marketing and advertising activities[14-15]. Its most salient feature is the exponential diffusion of information among network vertices, requiring a specific model to capture the spread and influence of such advertising. Social media marketing managers must adapt to effectively leverage social media platforms to reach consumers. When retailers want to explore the social media market, advertising investment decisions should be made based on existing online channel investments. It is insightful to compare product prices and profits across different online channels (direct online and social media channels) to make optimal decisions.

The remainder of this study is organized as follows. First, a two-echelon supply chain model is developed with considering the social media advertising. Then, equilibrium analysis in three scenarios are operated to figure out optimal results. Consequently, numerical studies give useful findings of optimal advertising investment for the social media platform and profits of three players.

1 Model

Social media sales have ushered in a new technological paradigm, attracting significant advertising investment. In this study, we examine the differences between the two channels of advertising investment. The optimal investments between a normal online channel (A_1) and a social media channel (A_2) are deduced using the model. Typically, a two-echelon supply chain with one manufacturer and two retailers, as shown in Fig. 1, is proposed to examine equilibrium leveraging backward induction. The decision order moves from the manufacturer that determines the whole sale price. Retailers resolve the sale price

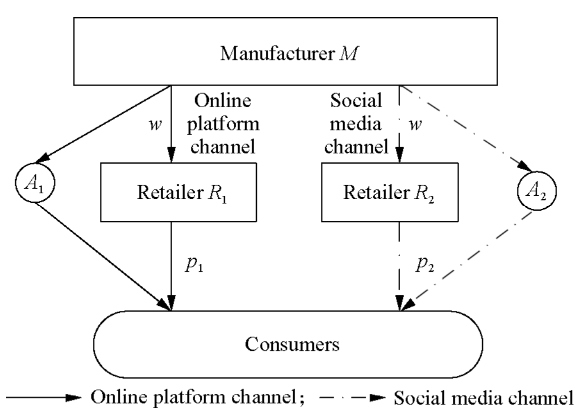

Fig. 1 The supply chain structure considering advertising

based on the advertising undertaker deciding to make an investment. This process is reversed when using backward induction to deduce the optimal results.

Based on different promotional power, social media marketing differs from normal online platforms in determining product sale prices ($p_1 \neq p_2$). For the demand function, the online platform follows the traditional linear function of market demand, while the social media channel is proposed as an exponential form. The specific function of increased demand in social media advertising investment is exponentially expressed. The sale saturation level is set to M. Parameter E represents consumer engagement and measures the advertising reach and content engagement among online users, including normal and social media channels. In this context, consumers who "like" or "thumbup" the advertisement represent positively engaged consumers, which measure the active level of consumer preferences as an exogenous variable. Moreover, this measure motivates social media platforms to devote more effort toward innovation by altering advertising content and formats, which renders advertising investment an endogenous variable. Given the differentiated pricing across channels and types of engagement, channel competition is beyond the scope of this study. Better engagement is expected to lead to increased consumer demand. The positive impact of consumer engagement represents the demand function as follows:

$$\left.\begin{aligned} d(p_1) &= \alpha_1 - \beta p_1 + \lambda E_1 \\ d(p_2) &= \alpha_2 - \beta p_2 + \lambda E_2 \end{aligned}\right\} \tag{1}$$

where $\alpha_i(i=1,2)$ is consumer potential for market i, β represents sale price, p_i indicates the sale price for channel i, E_i denotes consumer engagement investment for channel i, and λ is the level of consumer engagement.

Referencing previous literature[13, 16-19], this study models the demand function in the following multiplicative form:

$$\left.\begin{aligned} D_0 &= k\sqrt{A_1}\,d(p_1) \\ D_s &= M(1 - e^{-\eta A_2})\,d(p_2) \end{aligned}\right\} \tag{2}$$

where A_1 is the advertising investment for the normal online platform, A_2 is the advertising investment for the social media channel, k is the parameter of the advertising investment for the normal online platform, η denotes the advertising investment for the social media channel, and M is the social media channel's sale saturation level.

We consider three scenarios in which i) the manufacturer independently undertakes the cost of advertising (such as Apple company advertising), ii) two retailers assume the cost of advertising on normal and social media online platforms, advertising on eBay and Facebook, and iii) the manufacturer separately shares the cost with the two retailers; for example, Apple (manufacturer) shares the advertising costs for the iPhone with JD. com and Tmall. com. Without a loss of generality, the cost of production is normalized to zero. The manufacturer and two retailer profits are expressed in the following equations.

Scenario 1 The manufacturer independently undertakes the cost of advertising.

The manufacturer pays the fee for advertising, displaying advertisements on online and social media platforms. The advertising study explores increased market demand and consumer engagement; thus, the profits of the two retailers (π_o, π_s) and the manufacturer (π_m) are obtained as follows.

$$\pi_0 = (p_1 - w) k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) \tag{3}$$

$$\pi_s = (p_2 - w) M (1 - e^{-\eta A_2}) (\alpha_2 - \beta p_2 + \lambda E_2) \tag{4}$$

$$\pi_m = w[k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) + M(1 - e^{-\eta A_2})(\alpha_2 - \beta p_2 + \lambda E_2)] - (A_1 + A_2) \tag{5}$$

Scenario 2 Normal and social media platforms assume the costs of advertising.

In this scenario, the online and social media platforms are motivated to advertise to earn more profits, and the manufacturer benefits considerably without any expenditure. The profit functions are presented in the following equations:

$$\pi_0 = (p_1 - w) k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) - A_1 \tag{6}$$

$$\pi_s = (p_2 - w) M (1 - e^{-\eta A_2}) (\alpha_2 - \beta p_2 + \lambda E_2) - A_2 \tag{7}$$

$$\pi_m = w[k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) + M(1 - e^{-\eta A_2})(\alpha_2 - \beta p_2 + \lambda E_2)] \tag{8}$$

Scenario 3 Advertising cost-sharing between two retailers and the manufacturer.

In this scenario, the online and social media platforms assume a portion of the advertising cost (θ) to share with the manufacturer. The profits of three participants in the supply chain are obtained as follows:

$$\pi_0 = (p_1 - w) k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) - \theta A_1 \tag{9}$$

$$\pi_s = (p_2 - w) M (1 - e^{-\eta A_2}) (\alpha_2 - \beta p_2 + \lambda E_2) - \theta A_2 \tag{10}$$

$$\pi_m = w[k \sqrt{A_1} (\alpha_1 - \beta p_1 + \lambda E_1) + M(1 - e^{-\eta A_2}) \cdot (\alpha_2 - \beta p_2 + \lambda E_2)] - (1 - \theta)(A_1 + A_2) \tag{11}$$

We next examine the optimal results of the game to determine the most reasonable scenario for the three players in the supply chain. Revealing the relationships between advertising investment, consumer engagement, and the three players' profits could help professionals to make optimal advertising decisions. The equilibrium analyses below identify the best solutions in the different scenarios.

2 Equilibrium Analysis

2.1 Equilibrium analysis in Scenario 1

Although an exponential function may correspond well with social media advertising in a social context, it is challenging to calculate optimal solutions for prices and profits, which is why researchers often employ linear expressions to portray the effects of advertising[13]. To overcome this problem on social media platforms, we reference Taylor's formula to break the stalemate[20], rewriting the function as follows:

$$1 - e^{-\eta A_2} = 1 - \left(1 - \eta A_2 + \frac{\eta^2 A_2^2}{2!} - \frac{\eta^3 A_2^3}{3!} + \frac{\eta^4 A_2^4}{4!} - \dots\right)$$

Since the value of advertising investment is located in [0, 1], we retain the first two items to obtain the new result as follows:

$$1 - e^{-\eta A_2} \approx \eta A_2 - \frac{\eta^2 A_2^2}{2}$$

In most instances, consumers encounter the same market, and there are no differences in online advertising engagement, regardless of whether ads are presented on social media or online shopping platforms. To achieve actionable results, the potential market and consumer engagement are set to $\alpha_1 = \alpha_2 = \alpha$, $E_1 = E_2 = E$. Consequently, the equilibrium results of the three scenarios can be calculated in further expressions. For Scenario 1, the equilibrium strategies are illustrated in Lemma 1.

Lemma 1 When the manufacturer independently undertakes the cost of advertising, the equilibrium wholesale price, sale prices, advertising investment, and players' profits are as follows:

$$w^{M*} = \frac{\alpha + \lambda E}{2\beta}, \quad p_1^{M*} = p_2^{M*} = \frac{3(\alpha + \lambda E)}{4\beta}$$

$$A_1^{M*} = \frac{k^2}{256\beta^2}(\alpha + \lambda E)^4, \quad A_2^{M*} = \frac{1}{\eta} - \frac{8\beta}{M\eta^2(\alpha + \lambda E)^2}$$

$$\pi_o^{M*} = \frac{k^2}{256\beta^2}(\alpha + \lambda E)^4, \quad \pi_s^{M*} = \frac{M^2\eta^4(\alpha + \lambda E)^4 - 64\beta^2}{32M\eta^2\beta(\alpha + \lambda E)^2}$$

$$\pi_m^{M*} = \frac{k^2}{128\beta^2}(\alpha + \lambda E)^4 + \frac{M^2\eta^4(\alpha + \lambda E)^4 + 64\beta^2}{16M\eta^2\beta(\alpha + \lambda E)^2} - \frac{1}{\eta}$$

Proposition 1 Consumer engagement deviations are obtained as follows:

$$\frac{\partial w^{M*}}{\partial E} = \frac{\lambda}{2\beta} \geqslant 0, \quad \frac{\partial p_1^{M*}}{\partial E} = \frac{\partial p_2^{M*}}{\partial E} = \frac{3\lambda}{4\beta} \geqslant 0$$

$$\frac{\partial A_1^{M*}}{\partial E} = \frac{k^2\lambda}{64\beta^2}(\alpha + \lambda E)^3 \geqslant 0$$

$$\frac{\partial A_2^{M*}}{\partial E} = \frac{16\beta}{M\eta^2(\alpha + \lambda E)^3} \geqslant 0, \quad \frac{\partial \pi_o^{M*}}{\partial E} = \frac{k^2\lambda}{64\beta^2}(\alpha + \lambda E)^3 \geqslant 0$$

$$\frac{\partial \pi_s^{M*}}{\partial E} = \frac{M\eta^2\lambda}{16\beta}(\alpha + \lambda E) + \frac{4\beta\lambda}{M\eta^2(\alpha + \lambda E)^3} \geqslant 0$$

$$\frac{\partial \pi_{\mathrm{m}}^{M*}}{\partial E}=\frac{k^2\lambda}{32\beta^2}(\alpha+\lambda E)^3+\frac{M\eta^2\lambda}{8\beta}(\alpha+\lambda E)-\frac{8\beta\lambda}{M\eta^2(\alpha+\lambda E)^3}$$

Lemma 1 and Proposition 1 demonstrate that consumer engagement leads to increased wholesale price, sales price, and advertising investment. It is reasonable that the cost bearer should invest more to attract more consumer engagement in advertising. Since the sponsor in this scenario is the manufacturer, wholesale and retail prices will rise with consumer engagement; however, retail and manufacturer profits rise with high consumer engagement, which indicates that more expenditure on advertising to promote consumer engagement is beneficial for the whole supply chain. In this scenario, even if only the manufacturer invests in the ad, all players benefit from advertising and increased consumer interaction.

As shown in Proposition 1, the rates of change for consumer engagement are all positive except for the manufacturer's profit. When social media advertising investment is low, the manufacturer's profit will decrease to a certain extent. To assure the value $\frac{\partial \pi_{\mathrm{m}}^{M*}}{\partial E}\geqslant 0$, a higher advertising investment (η) will elicit better consumer engagement and profit, which is also the measurement of the social community diffusion index. Therefore, for the manufacturer, it is wise to advertise in a community with a high clustering coefficient to increase profit.

2.2 Equilibrium analysis in Scenario 2

Lemma 2 When the retailers assume the cost of advertising, the equilibrium wholesale price, sale price, advertising investment, and players' profits are as follows:

$$w^{R*}=\frac{\alpha+\lambda E}{2\beta},\ p_1^{R*}=p_2^{R*}=\frac{3(\alpha+\lambda E)}{4\beta},\ A_2^{R*}=\frac{1}{\eta}$$

wherein A_1^{R*} has no optimal value which needs to satisfy $A_1^{-\frac{1}{2}}=0$. $\pi_{\mathrm{o}}^{R*}=\frac{k(\alpha+\lambda E)^2\sqrt{A_1}}{16\beta}-A_1$, $\pi_{\mathrm{s}}^{M*}=\frac{M(\alpha+\lambda E)^2}{32\beta}-\frac{1}{\eta}$, $\pi_{\mathrm{m}}^{R*}=\frac{(M+2k\sqrt{A_1})(\alpha+\lambda E)^2}{16\beta}$.

Proposition 2 Changes in consumer engagement are obtained as follows:

$$\frac{\partial w^{R*}}{\partial E}=\frac{\lambda}{2\beta}\geqslant 0,\ \frac{\partial p_1^{R*}}{\partial E}=\frac{\partial p_2^{R*}}{\partial E}=\frac{3\lambda}{4\beta}\geqslant 0,\ \frac{\partial A_2^{R*}}{\partial E}=0$$

$$\frac{\partial \pi_{\mathrm{s}}^{R*}}{\partial E}=\frac{M\lambda}{16\beta}(\alpha+\lambda E)\geqslant 0$$

Obviously, in Scenario 2, the online-shopping platform cannot achieve optimal profit if it must bear the advertising cost instead of the manufacturer. In addition, the manufacturer's optimal profit cannot be achieved because the value of advertising investment on a normal online platform is missing. Surprisingly, the social media platform offers a solution in which it bears the advertising cost. The motivation to assume this cost is to accelerate community dissemination and produce an exponential increase in consumer demand; therefore, higher community dissemination requires lower advertising investment.

In Proposition 2, the two retailers' wholesale and sale prices continue to rise as consumer engagement increases. At the same level of consumer engagement (λ) and sale price (β), sale prices will rise with a relatively larger ratio. When retailers assume the cost of advertising, consumer engagement has no relation with advertising investments on normal online shopping or social media platforms. The retailers' marginal profit on the social media platform is positively correlated with consumer engagement. When considering the strategy of assuming the advertising cost, the two retailers make radically different decisions. The normal online platform does not fully negate the channel cost of advertising to obtain optimal payoff, which also results in the manufacturer not obtaining optimal profit, while the social media channel is willing to independently invest in advertising according to reciprocal community diffusion(η). It is more beneficial for the retailer to draw additional consumer engagement in a highly diffused social media community.

2.3 Equilibrium analysis in Scenario 3

Since the retailer on the normal online channel is reluctant to independently shoulder the burden of advertising, a cost-sharing strategy is logically proposed to seek an equilibrium solution. In Scenario 3, each retailer shares the cost of advertising in a proportion (θ) of the whole amount with the manufacturer. The equilibrium strategies are deduced in Lemma 3.

Lemma 3 When two retailers and the manufacturer share the cost of advertising, the equilibrium wholesale price, sale prices, advertising investments, and players' profits are as follows:

$$w^{\mathrm{CS}*}=\frac{\alpha+\lambda E}{2\beta},\ p_1^{\mathrm{CS}*}=p_2^{\mathrm{CS}*}=\frac{3(\alpha+\lambda E)}{4\beta}$$

$$A_1^{\mathrm{CS}*}=\frac{k^2(\alpha+\lambda E)^4}{256\beta^2(1-\theta)^2},\ A_2^{\mathrm{CS}*}=\frac{1}{\eta}-\frac{8\beta(1-\theta)}{M\eta^2(\alpha+\lambda E)^2}$$

$$\pi_{\mathrm{o}}^{\mathrm{CS}*}=\frac{k^2(\alpha+\lambda E)^4(1-2\theta)}{256\beta^2(1-\theta)}$$

$$\pi_{\mathrm{s}}^{\mathrm{CS}*}=\frac{M^2\eta^4(\alpha+\lambda E)^4-8M\eta\beta\theta(\alpha+\lambda E)^3+64\beta^2\theta(1-\theta)(\alpha+\lambda E)-64\beta^2(1-\theta)^2}{8M\eta^2\beta(\alpha+\lambda E)^3}$$

$$\pi_{\mathrm{m}}^{\mathrm{CS}*}=\frac{k^2(\alpha+\lambda E)^4}{256\beta^2(1-\theta)^2}+\frac{M^2\eta^4(\alpha+\lambda E)^4-32\beta^2(2-\alpha+\lambda E)(1-\theta)^2}{4M\eta^2\beta(\alpha+\lambda E)^3}-\frac{1-\theta}{\eta}$$

Proposition 3 Changes in consumer engagement are obtained as follows:

$$\frac{\partial w^{\mathrm{CS}*}}{\partial E}=\frac{\lambda}{2\beta}\geqslant 0,\ \frac{\partial p_1^{\mathrm{CS}*}}{\partial E}=\frac{\partial p_2^{\mathrm{CS}*}}{\partial E}=\frac{3\lambda}{4\beta}\geqslant 0$$

$$\frac{\partial A_1^{\mathrm{CS}*}}{\partial E}=\frac{k^2\lambda}{64\beta^2(1-\theta)^2}(\alpha+\lambda E)^3\geqslant 0$$

$$\frac{\partial \pi_{\mathrm{o}}^{\mathrm{CS}*}}{\partial E}=\frac{k^2\lambda(1-2\theta)}{64\beta^2(1-\theta)}(\alpha+\lambda E)^3$$

$$\frac{\partial \pi_{\mathrm{s}}^{\mathrm{CS}*}}{\partial E}=\frac{M\lambda}{8\beta}-\frac{16\beta\lambda\theta(1-\theta)}{M\eta^2(\alpha+\lambda E)^3}+\frac{24\beta\lambda(1-\theta)^2}{M\eta^2(\alpha+\lambda E)^4}$$

$$\frac{\partial \pi_{\mathrm{m}}^{\mathrm{CS}*}}{\partial E}=\frac{k^2\lambda(\alpha+\lambda E)^3}{32\beta^2(1-\theta)^2}+\frac{M\eta^2\lambda}{4\beta}+\frac{16\beta\lambda(1-\theta)^2(3-2\alpha+\lambda E)}{M\eta^2(\alpha+\lambda E)^4}$$

Lemma 3 indicates that the two retailers' optimum wholesale price and sale prices do not change when compared with the first two scenarios. As the range of θ is (0, 1), in the same setting of other parameters, the optimal advertising investments on normal and social media platforms should be committed more than that in Scenario 1, while the social media platform assumes less investment than when it independently bears the cost of advertising. The results are realistic in accordance with common sense. Carrying the cost of advertising alone incurs more expenditure. Since the manufacturer is the item producer that seeks to sell the product and establish its brand through advertising, the normal online retailer may not have a strong willingness to invest in advertising. In contrast, the social media retailer can increase demand among social communities with the help of advertising due to the effect of exponential diffusion. In addition, to guarantee the optimal profit for the normal online retailer ($\partial\pi_{\mathrm{o}}^{\mathrm{CS}*}$), the proportion assumed cannot exceed 50% ($1-2\theta\geqslant 0$). Determining the optimal profits for the social media channel retailer and the manufacturer requires numerical study after setting the values of parameters in their expressions.

Proposition 3 illustrates the effects of consumer engagement on prices and profits. Unsurprisingly, continuous investment in consumer engagement leads to higher wholesale and retail prices. To attract increased consumer engagement, advertising investments continuously rise, even when the manufacturer shares the cost with two retailers across different channels. In addition, the manufacturer's profit margin is greater than zero, meaning that the producer will prefer interaction with customers, whereas only when the cost-sharing ratio is lower than 0.5 will sustainably increasing customer interaction contribute to profit growth for a normal online retailer. In the social media channel, the saturation level of sales and advertising investment has a more important role in determining profit margins. For advertising cost-sharing in the social media channel, the social media retailer's profit margin is further examined using simulation.

3 Numerical Studies

To clearly investigate changes in the advertising investments and profits of players in the supply chain, a numerical example is presented in this subsection to provide management insights into the proposed models. As we focus on changes in advertising investment and consumer engagement, the market potential and price parameters are set to reasonable fixed values ($\alpha=0.5$, $\beta=0.5$). The level of consumer engagement and advertising investment on a normal online platform are given values of 0.3, 0.5, and 0.7. The parameter of advertising investment on the social media channel captures the capacity for advertising diffusion among social communities. The powers of exponential value are usually located at (−2, −3), according to power-law distribution in the real world[21]. Therefore, the parameter of advertising investment on social media channels is set as $\eta=1, 2, 3$ based on the small-world effect and sale saturation is set at 10 in this example.

In Scenario 1, from the horizontal view, the optimal advertising investment for the normal online platform increases with consumer engagement investment regardless of the level of consumer engagement (λ). For optimal advertising investment on the social media platform, as shown in Fig. 2(a)-(c), the curves increase slowly with gradual changes in consumer engagement based on a horizontal comparison. When the diffusion indices of a social community are 2 and 3, the changes in optimal advertising investment are slight overall. If the diffusion capacity in a social community is low ($\eta=1$), the social media platform could invest a little when consumer engagement is also low; however, in the higher interval, the social media platform must invest more in advertising. Sometimes the value of advertising investment is larger than that of high diffusion levels among social communities, especially in circumstances with low consumer engagement ($\lambda=0.3$), and the advertising investment remains high but stable when the community diffusion capacity is 3. Normally, the social media platform maintains relatively stable advertising investment to attract consumer engagement within a given social community. A higher level of consumer engagement helps decrease advertising investment.

To compare the changes in the three players' profits, we fix the level of consumer engagement ($\lambda=0.7$) to obtain the same patterns of change with other values. For the same reason, when comparing the manufacturer's results, the parameter of advertising investment on the normal online platform is set to 0.3. The scales of the three players' profits indicate that the manufacturer can gain

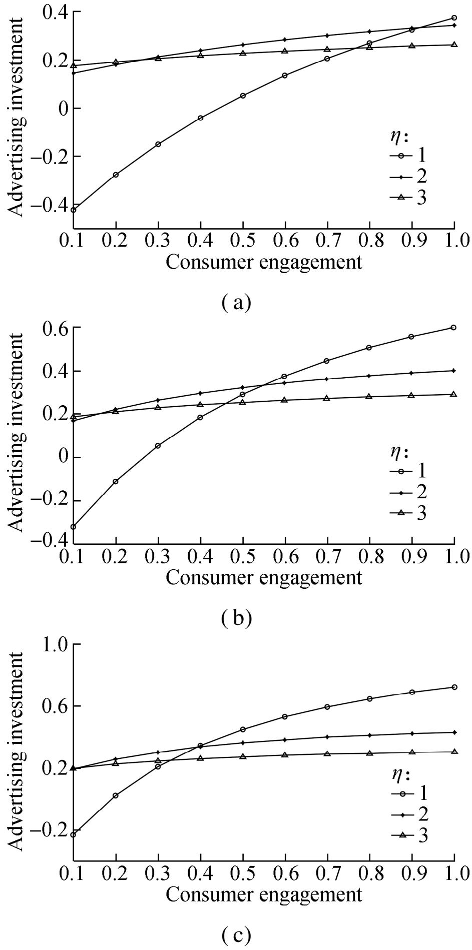

Fig. 2 Changes in advertising investment on the social media platform. (a) Ad investment change ($\lambda = 0.3$); (b) Ad investment change($\lambda = 0.5$); (c) Ad investment change($\lambda = 0.7$)

relatively higher values than the two retailers. In the three simulated cases, the manufacturer's profits are 10 times that of the social media retailer. Nevertheless, the social media platform is superior to the normal online platform for generating profit. Notably, social media platforms are being shaped into a major thriving market for the future. Manufacturers that want to gain more profit will also invest more in social media platform advertising.

Horizontally, for the normal online platform, increasing advertising investment can double profits from 0.3 to 0.5 and from 0.5 to 0.7, respectively. As shown in Table 1, advertising is confirmed to be a critical factor in obtaining higher profit. Attracting higher consumer engagement has the same effect; however, promoting consumer engagement with the social media platform can result in gradual profit increases. The growth of diffusion power (η) in the social community has a more notable effect on profit enhancement than the improvement of consumer engagement. Similarly, with added diffusion power, the manufacturer's payoff jumps in the same circumstances of consumer engagement. Unfortunately, compared to the advertising investment parameter on the social media platform, the advertising investment parameter on the normal online platform makes a negligible contribution to profit growth. Therefore, it is wise for manufacturers to devote more expenditure to advertising on the social media platform.

In Scenario 2, where the advertising cost is assumed only by retailers, the normal online retailer will be reluctant to invest in advertising. Although the optimal profit of the social media channel can be achieved in Scenario 2, the simulated study provides some valuable insights. Fig. 3 shows that the values of optimal advertising investment on social media platforms are all negative when the level of consumer engagement is low ($\lambda = 0.3$). This implies that the social media platform would not invest in advertising when consumer engagement is low. Even when consumer engagement is at a medium stage, the social media retailer should not make advertising investments in low diffusion communities ($\eta = 1$). Normally, two retailers are unwilling to independently undertake advertising costs. The social media platform is an optimal advertising investment only with a relatively high level of consumer engagement when the consumer engagement investment is in high intervals, and the value of exponential power is large ($\eta = 2$ or 3). Therefore, the social media platform will tend to independently bear the advertising cost in social communities with high diffusion power and high consumer engagement.

Table 1 Optimal profits of three players in Scenario 1 with simulated values when $\lambda = 0.7$

E	0.1	0.3	0.5	0.7	0.9	1.0
π_o^{M*} ($k = 0.3$)	0.000 2	0.000 4	0.000 7	0.001 4	0.002 3	0.002 9
π_o^{M*} ($k = 0.5$)	0.000 4	0.000 9	0.002 0	0.003 8	0.006 4	0.008 1
π_o^{M*} ($k = 0.7$)	0.000 8	0.001 9	0.004 0	0.007 4	0.012 5	0.015 9
π_s^{M*} ($\eta = 1$)	0.126 1	0.265 5	0.417 0	0.587 1	0.778 5	0.882 6
π_s^{M*} ($\eta = 2$)	0.793 0	1.247 9	1.797 6	2.443 9	3.187 4	3.595 7
π_s^{M*} ($\eta = 3$)	1.819 0	2.830 1	4.060 2	5.510 2	7.180 4	8.098 1
π_m^{M*} ($k = 0.3, \eta = 1$)	1.800 4	2.647 3	3.863 1	5.383 4	7.181 0	8.179 4
π_m^{M*} ($k = 0.3, \eta = 2$)	7.815 2	12.227 2	17.650 5	24.069 0	31.476 0	35.549 2
π_m^{M*} ($k = 0.3, \eta = 3$)	18.028 1	28.078 1	40.347 2	54.828 3	71.518 6	80.691 8
π_m^{M*} ($k = 0.7, \eta = 1$)	1.801 7	2.650 5	3.869 6	5.395 4	7.201 4	8.205 4
π_m^{M*} ($k = 0.7, \eta = 2$)	7.816 5	12.230 4	17.657 0	24.089 0	31.496 4	35.575 2
π_m^{M*} ($k = 0.7, \eta = 3$)	18.029 4	28.081 3	40.353 7	54.840 3	71.539 0	80.717 7

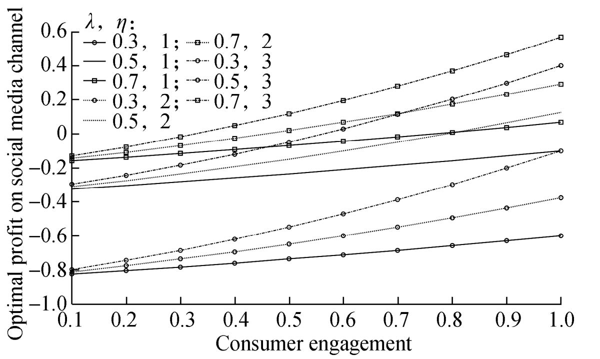

Fig. 3 Changes in the social media retailer's optimal profit in Scenario 2

In Scenario 3, the two retailers take a proportion (θ) of the advertising cost and share costs with the manufacturer in the supply chain. To determine the relationship between the sharing ratio and the three players' profits, other parameters are set as $\lambda = 0.3$, $E = 0.5$, and $k = 0.3$. To guarantee a positive profit for the normal online retailer, the sharing proportion satisfies $\theta \leqslant 0.5$ in this example. The findings clearly indicate that the normal online retailer should add advertising investment in line with the larger cost-sharing proportion in Lemma 3. After simulating other equilibrium results, Fig. 4 reveals different changes in advertising investment on the social media platform. From the horizontal perspective, as community diffusion increases, optimal advertising investment noticeably drops. When community diffusion is high, changes in the cost-sharing proportion have a minimal meaningful impact on advertising investment in the social media platform. In other words, within a relatively high range, community diffusion has a significant role in determining optimal advertising investment.

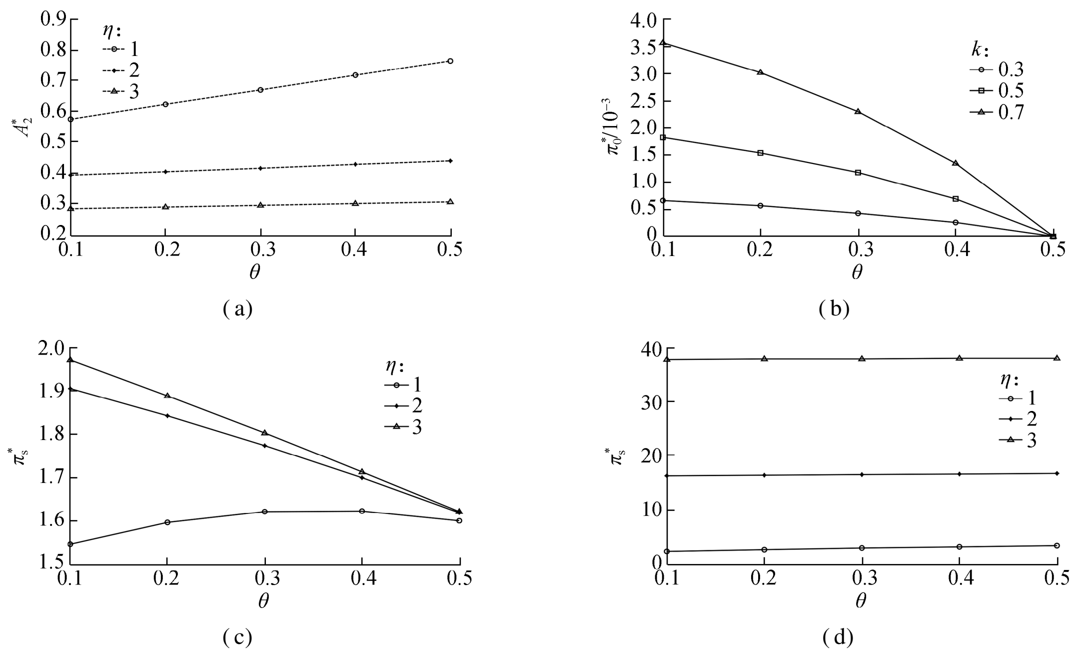

Fig. 4 Optimal advertising investment for the social media platform and profits of three players in Scenario 3. (a) Optimal advertising investment; (b) Optimal online retailer profit; (c) Optimal offline retailer profit; (d) Optimal manufacturer profit

The downward trends of the normal online retailer's profit indicate that this player would be disinclined toward assuming a high proportion of the advertising cost. If the proportion reaches 50%, the normal online retailer receives no benefit at all. As expected, a higher parameter of advertising investment in the low cost-sharing ratio can help to earn higher profits. For the social media platform, with normal community diffusion ($\eta = 2, 3$), profits exhibit signs of decline with a cost-sharing ratio increase. Although lower community diffusion leads to lower profit, it exhibits a slow upward trend followed by a downward trend. This finding implies that the social media platform can assume a certain percentage of advertising cost when its social diffusion power is low. The most important finding is that the manufacturer's profit changes are minor in all three cases of increased cost-sharing ratio, as the sharing ratio decrease of advertising cost for the manufacturer does not bring significant profit growth. Instead, increased community diffusion exerts a substantial impact on profit. This finding provides useful management insight that pursuing community diffusion empowerment on social media platforms rather than cost-sharing advertisement is more impactful for all players in the supply chain.

4 Conclusions

1) When manufacturers sponsor advertising, social media platforms outperform normal online platforms for increasing profit. Manufacturers should focus on investing resources in advertising and marketing on social media

platforms and increase the virality of advertising content to generate higher profit returns.

2) The normal online retailer is reluctant to independently assume the cost of advertising. In contrast, to pursue optimal profit, social media platforms would rather undertake the advertising cost alone in circumstances with high diffusion power and high consumer engagement in the social community. This indicates that social media platforms can be confident in gaining high returns through advertising. Manufacturers should actively cooperate with mainstream social media platforms and allow them to help with promotions and place advertisements.

3) In the advertising cost-sharing scenario, a high sharing ratio is unfavorable for the normal online retailer. Furthermore, it also cannot boost the manufacturer's profit with other parameters fixed. The social media platform is initially willing to bear a larger proportion to attract more users only when community diffusion is low. Therefore, the most crucial management insight for all players is to enhance community diffusion on the social media platform rather than advertising expenditure.

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在线广告和消费者参与对社交媒体平台的影响

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摘要:为了研究在线广告和消费者参与对利润的影响,提出了一个指数形式的公式来描述社交媒体平台在两阶段供应链模型中的实际用户需求.根据广告成本承担主体的不同,提出了3种销售模式:制造商承担广告成本、零售商承担广告成本以及制造商和零售商分摊广告成本.对应3种销售模式构造了3种不同的数学模型进行分析.均衡分析结果表明,提高消费者黏性可以帮助玩家获得更多利润.正常的网络商家在任何情况下都不愿意承担成本.当社区扩散较低时,社交媒体平台愿意承担一定比例的广告成本,以吸引更多的用户参与.另外,社区扩散对制造商的利润具有更显著的提升作用.在社交媒体的背景下,供应链中的参与者应该将重点放在利用广告来改善社区扩散能力,而不是争论成本分担比例.

关键词:广告;在线平台;社交媒体零售商;均衡;成本分摊

中图分类号:C934