Economics of Content Aggregation: Pricing and Advertising Competition in a Multi-Channel Structure

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Motivated by the emergence of online content aggregators such as Google News, etc., as a prominent source of web traffic for content publishers, this paper examines the impact of introducing a content aggregator on market equilibrium and welfare under two different content publishers' business models: i) free-content with advertisements and ii) subscription-based content with advertisements. A crucial feature of our framework is competition between content publishers and aggregator platform in the advertising market. Using a game-theoretic model, our analysis yields novel results. First, we find that platform introduction is *Pareto optimal* when publishers also charge a price to the users, however, their profits strictly reduce when content is free, whereas both users and advertisers benefit. This finding contrasts with the general regulatory presumption that aggregators will make publishers worse off. Next, keeping the market structure fixed, we find that publishers will display fewer advertisements under the subscription-based model for weak content differentiation and sufficiently large platform quality or strong content differentiation. Finally, welfare analysis is conducted.

Key words: Content Aggregators, Business Models, Digital Advertising, Regulation

1. Introduction

Digital platforms (e.g., Google) have grown substantially over the past ten years, with 4.03 billion users active on Google. With a massive user base for effective monetization, in 2021, Google generated 209.5 billion dollars through digital advertising channels, occupying a dominant position in digital advertising.[1] In addition, these platforms have evolved into the role of content aggregators (e.g., Google News, Google Search) and have become an important channel for users to access third-party content. For instance, UK competition authority has reported that "*37% of online adults in Britain*

[1] Source: https://www.statista.com/statistics/205352/digital-advertising-revenue-of-leading-online-companies/, accessed December 2022.

used Facebook to access news content and 36% said they used Google".[2] This transformation of digital platforms through hosting third-party content has enabled online content publishers to reach users through two channels: the platform (indirect) channel in which users read about the content on the platform and then go to publishers' websites, and the direct channel in which users directly search for publishers' content. As a result, this has changed the nature of competition in the digital markets. Since a major source of revenue for online content publishers is advertisements, their presence on platforms such as Google News, Google Search, etc., has put them in direct competition with the platforms for advertising revenue. The users who access online content through these aggregator platforms can be reached by advertisers either through placing advertisements in the aggregator platform or in the content publishers' websites, resulting in competition between the platform and publishers to attract advertisers. In addition to online advertising, content publishers have also relied on subscription pricing for monetizing the users. For instance, by 2019, around 70% of newspapers in the US and Europe have imposed a digital paywall.[3]

A few papers have theoretically studied how the presence of an aggregator affects the market outcome and focus on the impact of platform introduction on content quality (e.g., de Cornière and Sarvary 2023, Dellarocas et al. 2013), data sharing (e.g., Krämer et al. 2019), and content-sharing strategies (e.g., Amaldoss and Du 2023). However, to the best of our knowledge, none of the existing work focuses on investigating the competitive effects of introducing aggregator platform under different publishers' business models. In particular, the role of different business models under a *two-sided* market structure (with advertisers on one side and users on the other side) in mediating the impact of content aggregators remains under-studied. We intend to fill this gap by examining the following research questions: What is the impact of introducing an aggregator platform on the payoffs of market participants under different publishers' business models? In a market with an

[2] Source: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1073411/Platforms_publishers_advice._A.pdf, accessed January 2023.

[3] Source: https://reutersinstitute.politics.ox.ac.uk/our-research/pay-models-online-news-us-and-europe-2019-update, accessed December 2022.

aggregator platform, what is the impact of introducing digital paywalls on publishers' advertising levels, and which business model of the content publishers is efficient from a social point of view?

To answer these questions, we develop a game-theoretic model with three firms (an aggregator platform and two content publishers), a set of users, and a set of advertisers. A crucial feature of our model is that all three firms compete in the advertising market, choosing the quantity of advertisements. In addition, publishers can also choose the prices under the subscription-based model. Given these choices, a user can decide to consume the content directly at a search cost, or it can use the aggregator platform (if present) to either consume the partial content available as a snippet on it or reach one of the content publishers indirectly through it. Advertisers decide on the level of advertisements to place in the platform and publishers. We examine market competition under two publishers' business models: i) free-content model with advertisements (or simply free-content model), and ii) subscription-based model with advertisements (or simply subscription-based model), and under two channel structures: i) direct channel with no aggregator platform, and ii) multi-channel with both aggregator platform and publishers. By solving the model, we investigate the competitive effects of a multi-channel structure and the implications of publishers' business models for advertising and social welfare.

Our main results are as follows. First, introducing an aggregator platform to distribute online content can be *Pareto optimal* under the subscription-based model. Intuitively, in the two-sided market structure, the publishers' pricing is guided by two forces: one-sided logic, reduce prices to attract more users, and two-sided logic, reduce prices to attract more users for the advertisers. As a result, the publishers end up passing through advertising revenue to the users in the form of lower prices, and in equilibrium, there is a complete pass-through of advertising revenue. This two-sided market property protects publishers from becoming worse off in the presence of an aggregator platform. Moreover, users benefit because of the reduction in their search costs and advertisers' profit increase as the platform channel generates additional advertising revenue. However, interestingly, publishers' profits will decrease under the free-content model. Since the two-sided property cannot be exploited in the absence of a digital paywall, publishers end up facing intense advertising competition, reducing their profits.

Next, keeping the market structure fixed, i.e., the multi-channel structure with an aggregator platform, publishers' advertising levels are determined by the extent of market power over the users as well as the competition from the aggregator platform in the advertising market. This, inter alia, depends on the extent of content differentiation and platform quality (interpreted as the value obtained from consuming the platform's content comprising of snippets available on it). We find that publishers will show lower advertisements under the subscription-based model for strong content differentiation and large platform quality. Intuitively, in this case, publishers face intense advertising competition from the platform. Given the two-sided nature of publishers' business model, under the subscription-based model, the marginal benefit of placing an advertisement reduces relative to free-content model, which in turn, leads to lower advertising under the former model.

Regarding welfare implications of publishers' business models, both platform and publishers prefer the socially optimal business model for strong content differentiation. However, for a weak to intermediate content differentiation, the efficiency of publishers' business models may not be aligned with the interests of the publishers and platform. For instance, for intermediate content differentiation, social welfare will be higher with a free-content model because it leads to higher advertising, implying a higher advertising surplus. However, publishers' market power over users is sufficiently large, making them prefer a subscription-based model. Moreover, the platform's profit is also higher under the subscription-based model because it faces weaker advertising competition under it relative to the free-content model.

Finally, we consider two variants of our baseline model with only a proportion of users present in the market without the aggregator and endogenous choice of publishers' business models. Most of our results still hold under these two settings. However, in the former case, interestingly, we find that the impact of the aggregator platform on publishers' profits is non-monotonic under the free-content model, whereas it strictly increases under the subscription-based model. This result is driven by the change in publishers' advertising revenues under the two business models, with platform introduction.

Our findings provide actionable prescriptions for managers and policymakers and enhance our understanding of the provision of online content in a multi-channel setting, where users can access content publishers either directly through an internet search or indirectly through an aggregator platform. First, contrary to the popular view,[4] platform introduction can be Pareto optimal. Importantly, regulating content aggregation cannot take the form of a blanket regulation and need to consider the underlying nuances of publishers' business models. Second, in a multi-channel setting, the impact of digital paywalls on online content design crucially hinges on the underlying market parameters. In particular, bundling advertisements with the content and advertising as a strategic tool is more effective for the publishers (imposing digital paywalls) when content is weakly differentiated and platform quality is not strong. Finally, our findings show that, in a multi-channel structure, regulating digital paywalls may not be socially optimal when the content is strongly differentiated.

The rest of the paper is organized as follows. The next section discusses the relationship to the existing literature. Section 3 sets up the baseline model. Section 4 examines the market outcomes under two business models: free-content model and subscription-based model, and two channel structures: with and without the aggregator platform. Section 5 compares the market outcomes and welfare implications of introducing aggregator platform and publishers' business models. In Section 6, we consider two extensions to the baseline model. Section 7 discusses a few important managerial and policy implications of our results and concludes. The proofs of all the lemmas and propositions are provided in the various appendices.

2. Contributions to the Literature

Our paper contributes to two broad strands of literature: channel design issues in the supply of online content and platform competition and design of online content.

[4] See, for e.g., https://www.competitionpolicyinternational.com/is-competition-policy-the-right-response-to-the-crisis-of-journalism/, accessed April 2023.

2.1. Channel Design Issues in Supply Chains in Online Businesses

Broadly, our paper is linked to the literature studying channel design issues when a seller offers an identical product through two channels: a direct channel and an indirect channel with selling through a partner (e.g., Ha et al. 2022, Cattani et al. 2006, Liu et al. 2021, Abhishek et al. 2016). We focus on the market and welfare impact of introducing an indirect channel of aggregator platform for the content publishers to offer their content to the users.

A growing stream of literature has studied the impact of how intermediaries affect the consumption of news as well as the quality of publishers' content. de Cornière and Sarvary (2023) shows that content bundling by a social media platform will increase dispersion in publishers' content quality. Dellarocas et al. (2013) and Jeon and Nasr (2016) theoretically evaluate the trade-offs between the market expansion and business stealing effects of introducing an aggregator platform and find that the net positive market expansion effect leads to higher quality among competing news publishers. A few empirical papers have studied the impact of introducing an aggregator platform on news consumption and found a positive impact on daily visits to the newspapers' websites, highlighting the underlying market expansion effect (e.g., Calzada and Gil 2020, Xu et al. 2014) and consumption depth effect (e.g., Chiou and Tucker 2017) of a multi-channel structure. Finally, Krämer et al. (2019) study the competitive effects of social login adoption. They find that by enabling data sharing between the social network and content publishers, social login acts as an exploitative tool for the social network, and the content providers' profits may reduce with voluntary adoption of social logins, yielding a prisoner dilemma outcome for them.

Our paper differs from these studies in terms of both the focus and modelling set-up, thus generating new insights. In terms of focus, we analyze the role of publishers' business models on the competitive implications of introducing an aggregator platform. The modelling set-up is also different. First, unlike previous studies, we develop a framework focussing on the advertising side competition between the aggregator and publishers and taking into account the *two-sided* market structure of the publishers' business models. Second, we allow for a multi-channel structure, in which users can consume content directly or indirectly through the aggregator, not considered in Krämer et al. (2019), de Cornière and Sarvary (2023), Dellarocas et al. (2013) and Jeon and Nasr (2016). Third, we allow publishers to charge subscription prices. The distinct framework generates novel insights. For instance, aggregator platform introduction is *Pareto optimal* under the subscription-based model, whereas consumers and advertisers can benefit at the expense of publishers under the free-content model.

A recent paper by Amaldoss and Du (2023) identifies a new mechanism, i.e., the unbundling of a publisher's articles in the presence of an aggregator platform, and studies its effect on publishers' profit under different types of aggregators. Whereas, we identify a *distinct mechanism*, i.e., the two-sided nature of the publishers' business model with advertisers and users, to determine the impact of aggregator introduction on publishers' profits and welfare. In particular, the two-sided nature of the publishers' model will lead to the pass-on of advertising revenues to users as lower prices, and it crucially changes the impact of aggregator introduction. This mechanism is not present in Amaldoss and Du (2023).

2.2. Platform Competition and Design of Online Content

Our paper builds on the literature on competition between media outlets in which firms compete for the users and advertisers under a variety of settings such as single-homing consumers (e.g., Armstrong and Wright 2007, Anderson and Coate 2005), multi-homing consumers (e.g., Ambrus et al. 2016, Athey et al. 2018), competition in advertising quantities (e.g., Peitz and Valletti 2008), competition in advertising prices (e.g., Anderson et al. 2018), etc., by introducing the aggregator platform, which makes our modelling setup distinct from these papers.

Regarding online content design, our paper contributes to the stream of literature examining the determinants of the design of online content. Peitz and Valletti (2008) study advertising intensity and content choice, finding that the choice of advertising levels and content differentiation depends on publishers' business models. George (2007) examine the role of ownership on product variety and show that mergers may encourage firms to reposition products, leading to more variety. Seamans and Zhu (2017) study platform's repositioning strategy in response to increased competition, showing that it will increase content differentiation when user preferences are heterogeneous. Gal-or et al.

(2012) examine the role of advertising on media bias, showing that advertising can lead to polarized or moderate content depending on the strength of advertiser heterogeneity. Sun and Zhu (2013) empirically studied whether content providers will excessively supply popular content when they can monetize the users of their blogs through advertisements, finding that they have the incentive to shift their content to more popular topics and improve their content quality. We contribute to the extant literature by examining the role of publishers' business models on their advertising levels in the presence of an aggregator platform. Interestingly, we find that with increased competition from the aggregator, free-content leads to higher advertising levels.

Finally, our paper contributes to the literature examining the determinants of online publishers' business models. The focus of these studies has been on the role of consumer heterogeneity in satiation levels on paywalls (Wang et al. 2023), number of firms (e.g., DeValve and Pekeč 2022), nature of the content (e.g., Amaldoss et al. 2021, Sun and Zhu 2013), asymmetric competition (e.g., Garg et al. 2022), virtual selling of content (e.g., Meng et al. 2021), etc. Our paper sets up a different market setting with an aggregator platform and advertising competition between the aggregator and the content publishers, offering new insights into the social optimality of publishers' business models that cannot be inferred from the previous literature.

3. Model Preliminaries

In this section, we set up the baseline model, explaining the structure of the market, the preferences of different players in the market, publishers' business models, and the players' objective functions.

3.1. Market Structure

Consider a market comprised of three firms: an aggregator platform (or simply platform, indexed by 0) and two content publishers (or simply publishers, indexed by 1 and 2), a unit mass of users, and a unit mass of advertisers. Connecting with real-life practice, we can think of the platform as a news aggregator (e.g., Google News) or a search engine (e.g., Google Search), and content publishers as news publishers. Users decide whether to access the preferred content directly by accessing the publishers' websites or using the platform to access the preferred content; advertisers decide whether to advertise in firm $i = 0, 1, 2$, or not; and firms decide on the quantity of advertisements, and in addition, content publishers can also decide on the user prices.

3.2. User Market Details

3.2.1. Multiple Articles and Search Cost: We focus on a single issue covered by both news publishers. Each news publisher has a homepage with multiple articles for the same issue. Moreover, we assume that the articles are heterogeneous in quality, and each news publisher has a higher quality and a lower quality article for the issue on its homepage. Let V be the gross utility obtained from reading a high quality article, and we normalize the gross utility obtained from reading a low quality to 0. If a user goes to the news website *directly*, she first reads the homepage and then clicks on a news article to read. Since searching for the higher quality requires an effort on the part of the user and can entail an attention cost to find out the articles' quality, we denote this cost by c, i.e., the search cost she incurs for finding and reading the high quality article if she accesses the publisher's website *directly*. Users can differ in their ability to determine an article's quality, and we assume that c is heterogeneous, and for simplicity, is uniformly distributed over the interval $[0, 1]$.

3.2.2. Misfit/Transportation Cost: We use a Hotelling line to model the heterogeneous content preferences of the users. Taking the example of news publishers, we can think of it as heterogeneous ideological preferences of the users, where a point x on the Hotelling line represents user x's ideological view and x is uniformly distributed over the interval $[0, 1]$. The publishers are located on the two endpoints of the Hotelling interval and represent their ideological viewpoints, with publisher 1 located at point 0 of the interval, and publisher 2 located at point 1 of the interval. The dis-utility due to the difference between a user's location x and the publisher 1's (publisher 2's) location on the Hotelling line is measured as tx $(t(1-x))$, which represents the misfit/transportation cost arising from the mismatch between the ideological preference of the user x and a publisher's ideological stand, and t is the per-unit misfit/transportation cost.

3.2.3. Aggregator Platform and Content Consumption: The following market features of content consumption on the aggregator platform are covered. First, the content on the aggregator is displayed as a snippet: a concise description of content with a title and link to the content available on the publisher's website. For e.g., a news snippet would contain a news title and a link to the news article. As stated in Economist (2023), "*Google and Facebook...retort that they merely display links and a few lines of text, rather than articles themselves.*" Second, the aggregator platform (e.g., Google News and Google Search) provides a homepage with access to multiple snippets, i.e., links to articles from multiple sites. Third, aggregator such as Google News can use data about their users' behavior and preferences to selectively display news that are of higher value to each individual consumer. Put differently, an aggregator can do a better job than a publisher at the selection of more valuable content for the consumer.

Let $q_0 = 2\theta V$ be the platform quality (gross utility) a user obtains from visiting an aggregator's homepage and consuming only the content snippets, where θ is the snippet length, and V is the value of the higher quality article of a publisher, whose link is displayed on the aggregator's homepage.[5] If the user decides to click on an article link and go to the news website to read the article, then she will not incur any search costs. This is because the aggregator only displays the link to the higher quality articles, and it benefits a user by reducing her search costs of finding the higher quality article, and we normalize it to zero.

3.2.4. Aversion to Advertisements: Users dislike advertisements that are bundled with the content of a firm and incur nuisance costs of γm_i, $i = 0, 1, 2$, where γ is per-unit nuisance cost and m_i is the total number of advertisements in firm i. This has been empirically validated in literature, where it has been shown that advertising reduces users' utility (e.g., Wilbur 2008, Depken and Wilson 2004). Prior theoretical work has also characterized advertising as a nuisance to users (e.g., Anderson and Coate 2005). So, her total dis-utility from advertisements depends on whether she visits a publisher's website directly or indirectly through an aggregator platform or she visits the aggregator platform and does not proceed to the news website. A user has to pay a price p_i to access the content (article) on a publisher's website.

[5] Note that, in our model, we think of an aggregator as a platform providing only links to the high articles (snippets), which eliminates search costs for the users. We assume that the consumption of these snippets will not reveal information regarding the ideological stance of the article. Hence, no misfit cost is incurred if a user consumes only the snippets. However, our results are robust if we allow for a partial misfit cost incurred from snippets consumption. The details are available from the authors upon request.

3.3. Publishers' Business Models

The two most dominant sources of revenue for news publishers are subscription and advertising revenue (e.g., Simon and Graves 2019). Based on this fact, we can distinguish between two different business models:

i) *Free-content with advertisements*: The content is provided for free to users. However, advertisements are bundled with content and feature alongside the content. The publisher i, $i = 1, 2$, earns all its profit from advertisers. The subscription price p_i, $i = 1, 2$, is set equal to 0.

ii) *Subscription-based content with advertisements*: The users are charged an access fee p_i to consume the publisher content. Moreover, advertising space is sold to advertisers, and advertisements are also placed alongside the content. The publisher i, $i = 1, 2$, earns its profit both from the users and the advertisers.

3.4. Advertising Market Details

There is a continuum of identical advertisers whose mass is normalized to 1. We focus on the online display advertising market features (e.g., Choi et al. 2020) to model the advertising side. Advertisers intend to purchase ad impressions on publishers' websites and the platform to reach potential consumers, whereas the publishers and platforms have potential consumers who can purchase the advertisers' products. So, they sell advertising slots to the advertisers to access these consumers. The main objective of online display advertising is to generate attention and create awareness for the brands. There are three main factors that would determine the success of an advertising campaign. First, it depends on the advertising effectiveness or, in other words, the probability that a user would see the advertisement and click on it. Let α denote the advertising effectiveness of a single advertisement. Second, the greater the number of advertising slots in a firm, the greater the chance that a user would click on the advertisement. Let m_i denote the number of advertising slots in firm i, $i = 0, 1, 2$. The third important factor is the number of users joining firm i, $i = 0, 1, 2$. The larger the number of users, the higher the chance that an advertiser can find the right group of users who would click on advertisements and purchase the product. On the cost side, for each advertisement in firm i, an advertiser pays a price r_i.

3.5. Objective Functions

In this section, we formulate the objective functions of users (Section 3.5.1), and advertisers (Section 3.5.2).

3.5.1. Users: Let $u(x,c)$ denote the utility of a user defined by a pair (x,c) (refer Section 3.2) consuming publisher i's content, where $i = 1, 2$. The final utility depends on i) whether she consumes the high quality article by directly visiting the publisher's website or indirectly visiting the publisher's website using the platform or only consume the content snippets available on the platform, and ii) the revenue model used by the content publishers. Therefore, if a user visits a news publisher *directly*, her net utility is

$$U_i(x) = \begin{cases} V - \gamma m_1 - p_1 - tx - c, & \text{if she accesses publisher 1's content directly } (i=1), \\ V - \gamma m_2 - p_2 - t(1-x) - c, & \text{if she accesses publisher 2's content directly } (i=2), \end{cases} \tag{1}$$

whereas if she visits the aggregator platform, her net utility is

$$U_{0i}(x) = \begin{cases} q_0, & \text{if she only consumes the content snippets } (i=0), \\ q_0 + V - \gamma m_0 - \gamma m_1 - p_1 - tx, & \text{if she accesses publisher 1's content indirectly through platform } (i=1), \text{ and} \\ q_0 + V - \gamma m_0 - \gamma m_2 - p_2 - t(1-x), & \text{if she accesses publisher 2's content indirectly through platform } (i=2). \end{cases} \tag{2}$$

Moreover, if publisher i adopts the free-content model, then the content price is $p_i = 0$. The reservation utility of the users is normalized to zero. Thus, a user (x,c) will compare her utility under five different options: i) consume publisher 1's content directly, ii) consume publisher 2's content directly, iii) join platform and consume only snippets, iv) join platform and consume publisher 1's content indirectly, or v) join platform and consume publisher 2's content indirectly. Therefore, depending on the user adoption decision, we can obtain demand functions. As shown in Appendix B.2, there will be four sets of users - i) who have joined publisher 1 directly (denoted by N_1), ii) who have joined publisher 2 directly (denoted by N_2), iii) who have joined both platform and publisher 1 (denoted by N_{01}), and iv) who have joined both platform and publisher 2 (denoted by N_{02}).

3.5.2. Advertisers: We assume that the return from informing a user is normalized to 1, and the entire surplus is appropriated by the advertiser (e.g., Anderson and Coate 2005, Crampes et al. 2009). Next, we obtain the probability of informing a user. From Section 3.5.1, we know that we can have different sets of users depending on whether or not they join the platform. So, the probability of informing a user who has joined publisher i, $i = 1,2$, directly is $\alpha^{1/2}m_i^{1/2}$. The functional form assumes that there are positive but diminishing returns to advertising. Whereas, the probability of informing a user who has joined both platform and publisher i, $i = 1,2$, is $1-(1-\alpha^{1/2}m_0^{1/2})(1-\alpha^{1/2}m_i^{1/2})$. This captures an essential feature of the online advertising market, i.e., placing advertisements in two different firms are imperfect substitutes. This implies that the marginal value of an advertisement in firm i, $i = 0,1,2$, decreases with an increase in the number of advertisements in other firm $j \neq i$. This assumption is in line with earlier research work in platform markets literature (e.g., Hahn and Singer 2008).

Now, using these probability functions, we can find the revenue that the advertisers receive from purchasing advertising slots m_0, m_1, and m_2. The expected revenue from users who join publishers 1 and 2 directly is $\alpha^{1/2}m_1^{1/2}N_1 + \alpha^{1/2}m_2^{1/2}N_2$. Whereas, expected revenue from users who have joined both platform and either publisher 1 or 2 is $\alpha^{1/2}m_0^{1/2}[N_{01} + N_{02}] + [1-\alpha^{1/2}m_0^{1/2}]\alpha^{1/2}m_1^{1/2}N_{01} + [1-\alpha^{1/2}m_0^{1/2}]\alpha^{1/2}m_2^{1/2}N_{02}$. Thus, it equals the expected revenue from a set of users $N_{01} + N_{02}$, from joining the platform, $\alpha^{1/2}m_0^{1/2}[N_{01} + N_{02}]$, plus the additional revenue from the same set of users in publisher i, $i = 1,2$, i.e., $[1-\alpha^{1/2}m_0^{1/2}]\alpha^{1/2}m_i^{1/2}N_{0i}$. Let r_i denote the advertising price paid for a unit of an advertisement in firm i, $i = 0,1,2$. The expected profit of advertisers (AP) is as follows:

$$AP = \alpha^{1/2}m_1^{1/2}N_1 + \alpha^{1/2}m_2^{1/2}N_2 + \alpha^{1/2}m_0^{1/2}[N_{01} + N_{02}] + [1-\alpha^{1/2}m_0^{1/2}][\alpha^{1/2}m_1^{1/2}N_{01} + \alpha^{1/2}m_2^{1/2}N_{02}] - r_0m_0 - r_1m_1 - r_2m_2. \quad (3)$$

Note that, following prior work (e.g., Anderson and Coate 2005, Cornière and Taylor 2014), we have assumed that the advertisers are price takers in the model, and the advertising prices are determined to equate the demand for advertising slots by advertisers and the supply of advertising slots by firms, i.e., the choice of m_i's.

3.6. Firms: Platform and Publishers

The profit of the platform from placing m_0 advertisements in it is given by:

$$\pi_0 = r_0m_0. \quad (4)$$

The profit of content publisher i, $i=1,2$, is given by:

$$\pi_i = r_i m_i + p_i(N_i + N_{0i}), \tag{5}$$

where the first term is the profit from placing m_i advertisements, and the second term is the subscription revenue from the users accessing its content. Note that, under the free-content model, $p_i = 0$. Note that advertising revenues in firms' profit functions are affected by the number of users, i.e., N_i and N_{0i}, because advertising prices r_0 and r_i will be dependent on the number of users (see Appendix C for details).

3.7. Timeline of the Game

The timing of the game in our model is as follows:

Stage 1: Platform and publishers 1 and 2, choose the quantity of advertising slots, m_0, m_1 and m_2 respectively. Moreover, under the subscription-based model, publishers 1 and 2, choose user prices p_1 and p_2, respectively.

Stage 2: Given m_0, m_1 and m_2, the advertising prices r_0, r_1 and r_2 adjust so that the advertising market clears.

Stage 3: Users decide whether to join i) only publisher 1, ii) only publisher 2, iii) platform and consume only the content snippets, iv) both platform and publisher 1, or v) both platform and publisher 2.

We look for a sub-game perfect Nash equilibrium (henceforth equilibrium) of the game.

4. Equilibrium Analysis

In this section, we analyze the market equilibrium under two different publishers' business models: free-content and subscription-based models. We first analyze the market equilibrium under the two business models without the aggregator platform in Section 4.1, followed by the analysis with the aggregator platform in Section 4.2.

4.1. Benchmark Model: No Aggregator Platform

In this sub-section, we solve for the market equilibrium in the absence of the aggregator platform. We examine equilibrium under two different publishers' business models: i) free-content model and ii) subscription-based model.

4.1.1. Free-Content Model: We consider competition between content publishers when users can freely access the content. The following lemma characterizes the equilibrium:

LEMMA 1. *In the absence of the platform, there is a unique equilibrium, which is symmetric. The equilibrium advertising levels are* $\widetilde{m}_1^f = \widetilde{m}_2^f = \frac{t}{2\gamma}$, *and the equilibrium profits of the firms are* $\widetilde{\pi}_1^f = \widetilde{\pi}_2^f = \frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}$. *Moreover, the social welfare is* $\widetilde{SW}^f = V - \frac{3t}{4} - 1 + \frac{\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}$.

The proof of Lemma 1 is in Appendix C. The preceding lemma shows that the equilibrium advertising level is determined by the per-unit nuisance cost of advertisements γ and the per-unit transportation cost t. To gain further insight, note that as the per-unit nuisance cost parameter γ increases, users react negatively to advertisements, and the equilibrium advertising levels decrease. Moreover, as content differentiation (measured by t) increases, competition intensity reduces, implying that the equilibrium advertisements in content publishers increase. Intuitively, for large t and strong content differentiation, users would not easily switch between the two publishers, incentivizing publishers to monetize the users through higher advertising levels.

Next, we study the impact of model parameters on firms' profits and social welfare. First, consider equilibrium profits. From Lemma 1, it depends on advertising effectiveness α, per-unit transportation cost t, and per-unit nuisance cost γ. As argued in the previous paragraph, an increase in per-unit transportation cost t, or a decrease in per-unit nuisance cost γ, increases equilibrium advertisements placed in publisher i, $i = 1, 2$, increasing profits, i.e., $\partial\widetilde{\pi}_i^f/\partial t > 0$ and $\partial\widetilde{\pi}_i^f/\partial\gamma < 0$. Moreover, a higher advertising effectiveness, i.e., a higher α, would lead to better monetization of advertisements because of higher advertising prices charged to the advertisers, thus, increasing profits, i.e., $\partial\widetilde{\pi}_i^f/\partial\alpha > 0$.

Next, consider social welfare. Since prices are just transfers, it is defined as the sum of user surplus and advertising surplus. From the expression given in Lemma 1, it can be seen that an increase in advertising effectiveness α or a decrease in per-unit nuisance cost γ leads to higher advertising surplus, increasing social welfare, i.e., $\partial\widetilde{SW}^f/\partial\alpha > 0$ and $\partial\widetilde{SW}^f/\partial\gamma < 0$. However, an increase in per-unit transportation cost t has two opposing effects on social welfare. First, it increases equilibrium advertisements, leading to a larger advertising surplus. Moreover, it also leads to higher nuisance costs of advertisements and increased mismatch costs between a user's location and the publisher's location, increasing the total transportation costs for the users. The overall impact depends on the strength of the model parameters. We find that social welfare would increase, i.e., $\partial \widetilde{SW}^f / \partial t > 0$, for sufficiently small t and decrease otherwise.

4.1.2. Subscription-Based Model We consider competition between content publishers when users have to pay to access the content, i.e., publishers choose both advertising levels and prices. The following lemma characterizes the equilibrium:

LEMMA 2. *In the absence of the platform, there is a unique equilibrium, which is symmetric. The equilibrium advertising levels and prices are* $\widetilde{m}_1^s = \widetilde{m}_2^s = \frac{\alpha}{16\gamma^2}$ *and* $\widetilde{p}_1^s = \widetilde{p}_2^s = t - \frac{\alpha}{8\gamma}$*; and the equilibrium profits of the firms are* $\widetilde{\pi}_1^s = \widetilde{\pi}_2^s = \frac{t}{2}$*. Moreover, the social welfare is* $\widetilde{SW}^s = V - \frac{t}{4} - 1 + \frac{3\alpha}{4\gamma}$.

The proof of Lemma 2 is in Appendix C. To gain further insight, note that as per-unit nuisance cost parameter γ decreases, equilibrium advertising levels increase. If γ is equal to zero, then $\widetilde{m}_i^s \to \infty$, whereas if $\gamma \to \infty$, then $\widetilde{m}_i^s \to 0$. The equilibrium prices increase as per-unit transportation cost t increases. Intuitively, a higher t makes the two publishers sufficiently differentiated, raising their market power and, thus, the equilibrium prices, i.e., $\partial \widetilde{p}_i^s / \partial t > 0$. The second term shows that prices are lowered by the total amount of advertising profits generated. Thus, in equilibrium, advertising profits are competed away for the two publishers and there is a full pass-through of advertising profits to the users in the form of lower prices. This implies that a higher α or a lower γ would intensify competition between the publishers to attract users for the advertisers, leading to lower prices, i.e., $\partial \widetilde{p}_i^s / \partial \alpha < 0$ and $\partial \widetilde{p}_i^s / \partial \gamma > 0$.

Next, we study the impact of model parameters t, α, and γ on firms' profits and social welfare. Note that the profits only depend on the intensity of competition (measured by the per-unit transportation cost parameter t). Intuitively, firms pass on the advertising profits to the users in the form of lower prices, and, thus, profits are not affected by advertising effectiveness α and per-unit nuisance cost γ. They increase monotonically with an increase in t, i.e., $\partial \widetilde{\pi}_i^s / \partial t > 0$.

Next, consider social welfare. From the expression given in Lemma 2, it can be seen that an increase in per-unit transportation cost t decreases social welfare unambiguously, i.e., $\partial \widetilde{SW}^s / \partial t < 0$, because it increases the mismatch costs arising from a difference between a user's location and publisher's location. An increase in the advertising effectiveness parameter α has two opposing effects on social welfare. On the hand, it raises advertising surplus. On the other hand, users are exposed to more advertisements, leading to higher total nuisance costs. We find that the former effect dominates the latter, increasing social welfare, i.e., $\partial \widetilde{SW}^s / \partial \alpha > 0$. Similarly, we find that an increase in per-unit nuisance cost γ decreases social welfare, i.e., $\partial \widetilde{SW}^s / \partial \gamma < 0$, because of higher total nuisance costs of advertisements.

4.2. Main Model: Introducing the Aggregator Platform

Now we extend the market structure to include the aggregator platform. We characterize the equilibrium under i) free-content model and ii) subscription-based model.

4.2.1. Free-Content Model: We consider competition between platform and content publishers when users can freely access the content, i.e., both platform and content publishers choose only advertising levels. The following lemma characterizes the equilibrium:

Lemma 3. *In the presence of the platform, under the free-content model, there exists a unique equilibrium such that the equilibrium advertising levels are* $m_0^f = \frac{1+q_0}{3\gamma}$ *and* $m_1^f = m_2^f = \frac{t}{2\gamma}$*, and the equilibrium profits of the firms are* $\pi_0^f = \left[\frac{\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[1 - \frac{\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right]$ *and* $\pi_1^f = \pi_2^f = \left[\frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}\right]\left[1 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]$*. Moreover, the social welfare is* $SW^f = V - \frac{3t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0) + \frac{2\alpha^{1/2}}{3^{3/2}\gamma^{1/2}}(1+q_0)^{3/2}\left[1 - \frac{\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right] + \frac{\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}$.

The proof of Lemma 3 is in Appendix C. We find some interesting insights. First, the equilibrium advertising level in the platform depends on its quality (standalone value) q_0 it provides to users and per-unit nuisance cost γ. It is independent of the per-unit transportation cost t, as the extent of competition between the publishers doesn't affect the platform's advertising choice. Intuitively, the platform operates as a monopolist over the users who access it while deciding the optimal advertising level. As shown in Appendix B.2, the equilibrium distribution of users accessing content directly or indirectly through the platform is independent of the intensity of competition between publishers (measured by t), implying that the platform's equilibrium advertising is independent of t. Regarding content publishers, note that the publishers' equilibrium advertising levels remain unchanged with platform introduction and are the same as defined in Lemma 1. They are determined by the per-unit nuisance cost of advertisements γ, and the per-unit transportation cost t.

To gain further insight, note that as q_0 increases or γ decreases, more users join the platform to access the publishers' content, raising platform's market power and, thus, the advertisements shown to users, i.e., $\partial m_0^f/\partial q_0 > 0$ and $\partial m_0^f/\partial \gamma < 0$. The impact of model parameters on publishers' advertising levels remains the same as discussed in Section 4.1.1.

Next, we consider the impact of model parameters on firms' profits and social welfare. First, consider the effect of q_0. From Lemma 3, it can be seen that platform's profit increases with an increase in the quality q_0 provided to users, i.e., $\partial \pi_0^f/\partial q_0 > 0$. Intuitively, a higher q_0 attracts more users to access content indirectly through the platform, raising its market power and, thus, the equilibrium advertisements, increasing its profit. Since $\partial m_0^f/\partial q_0 > 0$, publishers' profits decrease because of more intense advertising competition. Next, consider social welfare. An increase in q_0 will lead to an increase in the number of users joining the platform, reducing total search costs, and also, increases the advertising surplus generated on the platform because of higher advertisements in it. These two effects together dominate the increase in the nuisance costs due to higher advertisements in the platform, and reduced advertising surplus on the publishers' websites, increasing social welfare, i.e., $\partial SW^f/\partial q_0 > 0$. The impact of per-unit transportation cost t on firms' profits is intuitive as well. On the publishers' websites, an increase in per-unit transportation cost raises the equilibrium advertising levels, increasing their profits, i.e., $\partial \pi_i^f/\partial t > 0$. On the platform, however, an increase in content differentiation and the resultant higher publishers' advertising levels increases competition in the advertising market and decreases the price per advertisement charged by the platform, decreasing its profit, i.e., $\partial \pi_0^f/\partial t < 0$.

Next, we study the impact of parameters γ and α on firms' profits and social welfare. The following proposition summarizes our main result on the comparative statics:

Proposition 1. *In the presence of the platform:*

(i) An increase in per-unit nuisance cost γ decreases platform's profit, publishers' profits, and social welfare, i.e., $\partial\pi_0^f/\partial\gamma < 0$, $\partial\pi_i^f/\partial\gamma < 0$, and $\partial SW^f/\partial\gamma < 0$.

(ii) An increase in advertising effectiveness α increases platform's profit, publishers' profits, and social welfare, i.e., $\partial\pi_0^f/\partial\alpha > 0$, $\partial\pi_i^f/\partial\alpha > 0$, and $\partial SW^f/\partial\alpha > 0$.

The proof of Proposition 1 is in Appendix C. First, consider part (i) of Proposition 1. An increase in per-unit nuisance cost γ has two opposing effects on the platform's profit. On the one hand, as user aversion to advertisements increases, the platform's advertisements decrease, reducing its advertising revenue. Whereas it also decreases the advertisements in the publishers' websites, increasing the price per advertisement charged by the platform. As shown in Appendix C, the effect of increased nuisance costs dominates higher advertising price, reducing the platform's profit, i.e., $\partial\pi_0^f/\partial\gamma < 0$. Moreover, in the presence of the platform, an increase in γ has two opposing effects on the publishers' profits. On the one hand, it reduces the publishers' advertising levels, whereas on the other hand, with lower advertisements in the platform, the price per advertisement charged by the publishers also increases. So, the net effect depends on which of the two effects dominates. As shown in Appendix C, an increase in γ reduces publishers' advertising levels, decreasing their profits, i.e., $\partial\pi_i^f/\partial\gamma < 0$. The parameter γ will affect social welfare through a re-distribution of advertising surplus generated from the platform and the publishers and also the change in nuisance costs. We find that an increase in per-unit nuisance cost γ increases total nuisance costs sufficiently, reducing social welfare, i.e., $\partial SW^f/\partial\gamma < 0$ (see Appendix C for details).

Consider part (ii). As shown in Appendix C, an increase in advertising effectiveness α increases the platform's profit, i.e., $\partial\pi_0^f/\partial\alpha > 0$, because it can charge a higher advertising price. Similarly, advertising effectiveness α affects the publishers' profits through a change in equilibrium advertising price. We find that an increase in α sufficiently raises the price per advertisement charged by publisher i, raising its profit, i.e., $\partial\pi_i^f/\partial\alpha > 0$. Moreover, social welfare increases with an increase in advertising effectiveness, i.e., $\partial SW^f/\partial\alpha > 0$. Intuitively, the advertising surplus generated increases sufficiently to offset higher nuisance costs, increasing social welfare.

4.2.2. Subscription-Based Model: We now consider competition between platform and content publishers when users have to pay to access the content, i.e., the platform chooses only advertising levels, whereas content publishers choose both advertising levels and prices. The following lemma characterizes the equilibrium:

LEMMA 4. *In the presence of the platform, under subscription-based model, there exists a unique equilibrium such that the equilibrium advertising levels are* $m_0^s = \frac{1+q_0}{3\gamma}$ *and* $m_i^s = \frac{\alpha}{16\gamma^2}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2$, $i=1,2$, *the equilibrium prices are* $p_i^s = t - \frac{\alpha}{8\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2$, *and the equilibrium profits of the firms are* $\pi_0^s = \frac{\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\left[1-\frac{\alpha}{4\gamma}+\frac{\alpha^{3/2}(1+q_0)^{3/2})}{2.3^{3/2}\gamma^{3/2}}\right]$ *and* $\pi_1^s = \pi_2^s = \frac{t}{2}$. *Moreover, the social welfare is* $SW^s = V - \frac{t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0) + \frac{3\alpha}{16\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2 + \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}$.

The proof of Lemma 4 is in Appendix C. The preceding lemma shows some interesting insights. First, consider the equilibrium advertising levels. On the platform, it remains unchanged. Since the platform still acts as a monopolist over the users joining it to access the publishers' content, its optimal choice remains the same as under the free-content model (defined in Lemma 3). On the publishers, since users are single-homing and advertisers are multi-homing (present in both content publishers), they act as "bottlenecks" or "gatekeepers" providing exclusive access to the single-homing users. In this *two-sided* market structure, they will compete intensively for users and, in return, will extract high rents from the advertisers who want to reach these users and generate attention for their products. As a result, publishers compete aggressively for the users, and they will pass on the profits extracted from the advertising side to the users in the form of lower prices. In this structure, profit maximization can be looked at as a two-step process. First, they maximize profits with respect to advertisements. They do so by maximizing the joint advertising surplus between the publisher and the user. Note that the advertising surplus is affected by the gross expected advertising revenue, which depends on the advertising effectiveness α, the cost to users, which depends on the per-unit nuisance cost of advertisements γ, and the number of users accessing the publisher i's content through the platform. This implies that the advertising levels are chosen such that the marginal advertising benefit $\frac{\alpha^{1/2}}{4m_i^{1/2}}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]$ equals its marginal cost γ and explains the equilibrium advertising quantities stated in Lemma 4. In the second step, the publishers pass on the advertising profit to the users, determining the equilibrium prices as shown in Lemma 4. It has two components: the first component shows the effect of competition intensity on the pricing level (measured by t), and the second component measures the advertising profit that is passed on to the users in the form of lower prices. Importantly, in this *two-sided* market structure, there is a complete pass-through of advertising revenue to users in the form of lower prices, and the publishers' profits remain independent of the advertising revenue at $t/2$.

Next, we examine the effect of platform introduction on publishers' advertising levels. Comparing Lemmas 2 and 4 shows that it reduces the equilibrium advertisements. Intuitively, the marginal benefit of an advertisement reduces for each publisher because of competition from the platform in the advertising market, however, the marginal cost remains the same, reducing the advertising levels.

Furthermore, we examine the change in the equilibrium decisions with changes in model parameters. First, consider equilibrium advertising levels and the effect of q_0, γ, and α on them. An increase in q_0 increases the advertisements shown to users on the platform, i.e., $\partial m_0^s/\partial q_0 > 0$, however, it reduces the publishers' advertising levels, i.e., $\partial m_i^s/\partial q_0 < 0$, because it decreases the marginal benefit of an advertisement for them. Next, consider the per-unit nuisance cost of advertisements γ. On the platform, it always reduces advertising level, i.e., $\partial m_0^s/\partial \gamma < 0$, because user aversion to advertisements increases, raising the marginal cost of advertisements. Whereas, on the publishers' websites, it depends on the value of model parameters. It increases both the marginal benefit and cost of an advertisement for them. The former increases because of lower platform advertisements, raising the price per advertisement that they can charge, whereas the latter increases because of increased user aversion to advertisements. For a sufficiently small q_0, we find that publishers' advertising levels decrease with an increase in γ, i.e., $\partial m_i^s/\partial \gamma < 0$, and increases otherwise. Similarly, the impact of an increase in advertising effectiveness α on publishers' advertising levels also depends on the value of model parameters. It increases the effectiveness of an advertisement, both in the publishers' websites and the platform. We find that for a sufficiently small q_0, publishers' advertising levels increase, i.e.,

$\partial m_i^s/\partial\alpha > 0$, and decrease otherwise. Note that the non-monotonic effect of γ and α is different from their effect on publishers' advertising levels under the benchmark model (refer Lemma 2).

Next, consider the equilibrium prices. From Lemma 4, it can be seen that strong content differentiation (higher t) reduces the prices charged to the users. Moreover, platform quality q_0, advertising effectiveness α, and the per-unit nuisance cost of advertisements γ, will affect the prices through their effect on equilibrium advertisements on the platform and publishers. An increase in q_0 always reduces publishers' advertising levels, which, in turn, reduces the advertising profits made by them and, thus, increases prices because lower advertising profits are passed on to the users. Moreover, we find that for a sufficiently large q_0, an increase in advertising effectiveness will increase price, i.e., $\partial p_i^s/\partial\alpha > 0$, and decreases it otherwise. Likewise, for a sufficiently small q_0, an increase in per-unit nuisance cost will increase equilibrium price, i.e., $\partial p_i^s/\partial\gamma > 0$, and decreases it otherwise.

Finally, we draw some insights on comparative statics of equilibrium profits and social welfare. From Lemma 4, we can see that publishers' profits are independent of the advertising profits and remain at the same level as defined in Lemma 2. As explained above, this is because prices are lowered by the total amount of advertising profits generated. Thus, in equilibrium, there is a full pass-through of advertising profits to the users in the form of lower prices. So, publishers' profits are independent of changes in advertising effectiveness α and the per-unit nuisance cost of advertisements γ. However, as content differentiation increases, i.e., t increases, equilibrium prices increase, raising publishers' profits, i.e., $\partial\pi_i^s/\partial t > 0$.

The following proposition summarizes our main results on the impact of parameters q_0, γ, and α on the platform's profit and social welfare:

PROPOSITION 2. *In the presence of the platform:*

(i) An increase in q_0 increases both platform's profit, i.e., $\partial\pi_0^s/\partial q_0 > 0$, and social welfare, i.e., $\partial SW^s/\partial q_0 > 0$.

(ii) An increase in per-unit nuisance cost γ increases platform's profit, i.e., $\partial\pi_0^s/\partial\gamma > 0$, if and only if q_0 is below a threshold, i.e., $q_0 < q_0^p$, and decreases it otherwise. Moreover, social welfare decreases with an increase in per-unit nuisance cost, i.e., $\partial SW^s/\partial\gamma < 0$.

(iii) An increase in advertising effectiveness α increases platform's profit, i.e., $\partial\pi_0^s/\partial\alpha > 0$, if and only if q_0 is above a threshold, i.e., $q_0 > q_0^p$, and decreases it otherwise. Moreover, social welfare increases with an increase in advertising effectiveness, i.e., $\partial SW^s/\partial\alpha > 0$.

Please note that the threshold q_0^p is defined in Appendix C along with the proof of Proposition 2. Part (i) can be explained as follows. An increase in q_0 increases the platform's advertising level, increasing its profit, i.e., $\partial\pi_0^s/\partial q_0 > 0$. On social welfare, an increase in q_0 has two main effects. First, it will lead to an increase in the number of users joining the platform, reducing total search costs. Second, it leads to a redistribution of advertising surplus across the platform and publishers and also changes total nuisance costs because advertising levels on the former increase and decrease on the latter. As shown in Appendix C, we find that the reduction in the search costs dominates any change in advertising surplus, increasing social welfare, i.e., $\partial SW^s/\partial q_0 > 0$. Consider parts (ii) and (iii). An increase in γ will affect the platform's profit through two channels. First, it will lead to lower platform advertisements because of increased user aversion to advertisements. Second, for small q_0, it will reduce publishers' advertising levels, raising the price per advertisement charged by the platform. We find that for a sufficiently small q_0, i.e., $q_0 < q_0^p$, advertising price increases sufficiently, increasing the platform's profit, i.e., $\partial\pi_0^s/\partial\gamma > 0$, and profit decreases otherwise. An increase in α will affect the platform's profit through its impact on the price per advertisement charged by it. On the one hand, it will increase because of the higher targeting rate. On the other hand, for small q_0, it will decrease because of higher publishers' advertising levels, leading to intensified advertising competition. We find that for a sufficiently large q_0, i.e., $q_0 > q_0^p$, the publishers' advertising levels decrease sufficiently, leading to higher advertising price and, thus, increasing the platform's profit, i.e., $\partial\pi_0^s/\partial\alpha > 0$, and profit decreases otherwise. Therefore, interestingly, the comparative statics on the platform's profit is different, relative to the free-content model case (discussed in Section 4.2.1), implying that the underlying business model of the content publishers crucially determines how the platform responds to changes in the market conditions. On social welfare, an increase in advertising effectiveness α or per-unit nuisance cost γ will have an impact through a re-distribution of advertising surplus that can be generated from the platform and the publishers and a change in nuisance costs. We find that social welfare increases with an increase in α, i.e., $\partial SW^s/\partial\alpha > 0$, and decreases with an increase in γ, i.e., $\partial SW^s/\partial\gamma < 0$ (see Appendix C for details).

5. Model Implications

In this section, we first examine the impact of introducing an aggregator platform on publishers' profits and welfare in Section 5.1, followed by the comparison of the market outcomes under the main model in Section 5.2. Note that, in the following subsections, the comparison is based on both publishers adopting free-content and subscription-based models. In Section 6.2, we endogenize the business model choice and show that these are the two equilibrium business model choices with or without the aggregator platform. We observe a shift in the business model with platform introduction for a small range of parameter values (refer Section 6.2). Nevertheless, the main results will hold for a large range of parameter values of t and q_0.

5.1. What is the Effect of Introducing an Aggregator Platform on the Payoffs of Market Participants?

We first examine the effect of introducing an aggregator platform on the publishers' profits and welfare. Formally, we compare Lemmas 1 and 3 when content is offered for free to users and Lemmas 2 and 4 when publishers impose a digital paywall. Interestingly, the effect crucially hinges on the underlying publishers' business model summarized in Proposition 3.

Proposition 3. *In the presence of an aggregator platform, under the free-content model, the profits of the publishers decrease, however, they remain unchanged under the subscription-based model.*

The proof of Proposition 3 is in Appendix C. The intuition is as follows. Under the free-content model, comparing Lemmas 1 and 3, we can see that the publishers' profits decrease with platform introduction because the presence of the platform intensifies the advertising competition, reducing the advertising prices that publishers can charge. However, the subscription-based model changes the nature of the publishers' profits. Comparing Lemmas 2 and 4 shows that the equilibrium profits of the publishers remain unchanged. This is a result of the *two-sided* pricing structure, as discussed in previous subsections (see discussion of Lemma 4). With or without the platform, the advertisers multi-home and users single-home, leading to a competitive bottleneck situation and full pass-through of advertising revenues to the users in the form of lower prices. Formally, with platform introduction, the advertising revenue earned by a publisher equals $\frac{\alpha}{16\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2$, which equals the total pass-through to the users in the form of lower prices, resulting in profits remaining independent of the advertising revenues at $t/2$.

Proposition 3 identifies a *new mechansim*, i.e., the competitive bottleneck effect resulting from the two-sided market structure to explain the effect of aggregator introduction on the publishers' profits. This mechanism is distinct from the previous literature. Amaldoss et al. (2021) identifies unbundling of news articles as the mechanism to explain the profit implications of joining an aggregator. Whereas, Dellarocas et al. (2013) and Jeon and Nasr (2016) focus on market expansion and business stealing effects to determine the impact of introducing an aggregator platform on equilibrium outcomes and profits. In contrast to these studies, we do not rely on the unbundling of articles or the market expansion effect. The price competition under the two-sided market structure will lead to user-side subsidization, which will protect publishers' profits from decreasing with platform introduction.

Next, we examine the effect of introducing an aggregator platform on consumer surplus and advertisers' profit. The welfare effects of platform introduction are driven by various trade-offs involved. First, advertisers benefit because of an additional channel (platform channel) to reach users, however, they might pay a higher total price to place advertisements. Second, the change in consumer surplus depends on the strength of reduced search costs for a subset of users, as they rely on the aggregator for accessing the content and the change in nuisance costs of advertisements and prices.[6] The following proposition characterizes the welfare effects.

Proposition 4. *In the presence of an aggregator platform, both consumer surplus and advertisers' profit increase, irrespective of the publishers' business models.*

The proof of Proposition 4 is in Appendix C. First, consider consumer surplus. Under the free-content model, as shown in Appendix C, the change in consumer surplus has two components. First, platform

[6] Note that since all users go to the publishers website either directly or indirectly through the platform, there is no reduction in value obtain from consuming publishers' content.

introduction leads to reduced search costs for a subset of users, as they rely on it for accessing the content, which eliminates search costs for these users. The second effect comes from the change in nuisance costs of advertisements. From Lemmas 1 and 3, we know that $m_i^f = \widetilde{m}_i^f$, implying that the nuisance costs of advertisements remain unchanged on the publishers. However, a subset of users are exposed to advertisements in the platform, and nuisance costs increase for these users. We find that the reduction in search costs is sufficient to offset increased nuisance costs, improving consumer surplus with the introduction of the platform.

Next, consider the subscription-based model. The change in consumer surplus has three components: the change in search costs, the change in nuisance costs of advertisements, and the change in surplus due to the change in equilibrium prices. First, like in the previous case, joining the aggregator platform eliminates search costs for a subset of users. Second, note that, from Lemmas 2 and 4, we have $m_i^s < \widetilde{m}_i^s$. Thus, nuisance costs on the publishers would go down, however, it increases for the users who access the publishers' content indirectly through the platform because they will be exposed to platform advertisements. Third, comparing Lemmas 2 and 4, we can see that $p_i^s > \widetilde{p}_i^s$. So, users pay a higher price in the presence of the platform. The net effect depends on the magnitude of these three effects. We find that the reduced search costs and reduced nuisance costs (because of lower publishers' advertisements) together dominate the reduction in surplus because of higher prices and higher nuisance costs (because of platform advertisements), leading to increased consumer surplus with platform introduction.

Next, consider advertisers' profit. As shown in Appendix C, with the platform introduction, advertisers can use one additional channel, i.e., the platform, to reach a subset of users. This would improve the probability that advertisers can reach users, raising their surplus, offsetting any increase in total advertising price, and increasing advertisers' profit under both business models.

It is worth emphasizing that platform introduction can be *Pareto optimal* under the subscription-based model. This result is novel as it does not depend on the unbundling of articles (Amaldoss et al. (2021)) or demand expansion effect considered in previous work (e.g., Jeon and Nasr 2016). It results from the *two-sided* market structure of publishers' business, which protects them against increased advertising competition from the platform. Moreover, the new platform channel for advertising and content consumption benefits both advertisers and consumers. However, platform introduction is not *Pareto optimal* under the free-content model. This is because the publishers do not have the paywall, and they face stronger advertising competition, reducing their advertising prices, and thus, profits. Whereas, as explained above, both consumers and advertisers benefit.

5.2. In the Presence of an Aggregator, How do Digital Paywalls Affect the Provision of Advertisements, Firms' Profits, and Welfare?

We first examine publishers' advertising levels in the presence of an aggregator platform. The following proposition compares the equilibrium decisions under the free-content and subscription-based models.

PROPOSITION 5. *There exists thresholds t_1 and q_0^1 such that:*

(i) If the extent of content differentiation is sufficiently strong, i.e., $t > t^1$, then free-content always leads to higher publishers' advertising levels, i.e., $m_i^f > m_i^s$,

(ii) however, if $t \leq t^1$, publishers' advertising levels under free-content are higher than under the subscription-based model, i.e., $m_i^f > m_i^s$ if and only if platform quality q_0 is large, i.e., $q_0 > q_0^1$, and lower otherwise, and

(iii) advertising in the platform remains unchanged, i.e., $m_0^f = m_0^s$.

Please note that we provide expressions for thresholds t^1 and q_0^1 in Appendix C along with the proof of Proposition 5. First, consider part (i) of Proposition 5. Under the free-content model, advertising levels are given by Lemma 3, while under the subscription-based model, it is given by Lemma 4. If $\frac{t}{2\gamma} > \frac{\alpha}{16\gamma^2}\left[1 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2$, then advertising under free-content is greater than advertising under the subscription-based model. The comparison depends on the extent of content differentiation (measured by t), the quality level of the platform q_0, advertising effectiveness α, and the per-unit nuisance cost of advertisements γ. Suppose content is strongly differentiated, i.e., $t > t^1$, then free-content always provides higher advertising levels. Intuitively, since advertisements are indirect prices charged to the users, weak competition on the user side implies publishers have large market power over their users and, thus, can set large advertising levels under free-content. Next, consider part

(ii). When $t \leq t^1$, then the comparison also depends on the value of q_0. From Lemma 4, we can see that q_0 affects the publishers' advertising levels under the subscription-based model. Intuitively, it determines the extent of competition that the publishers face in the advertising market while deciding on the advertising levels. For q_0 sufficiently small, i.e., $q_0 \leq q_0^1$, the platform advertising level is small, implying that the marginal benefit from placing advertisements in publishers is higher, leading to higher advertisements under subscription-based content. Whereas, for $q_0 > q_0^1$, platform advertising is sufficiently large, implying intense advertising competition for the publishers, and, thus, leading to lower advertising levels in the publishers under subscription-based model.

Part (iii) shows that the platform's advertising level remains unchanged. This can be explained as follows. Since the distribution of users who access content directly and indirectly through the platform remains unaffected by the strength of competition in the advertising market, the platform's profit maximization yields the same advertising levels, independent of publishers' business models.

Having understood the comparison of advertising level decisions, next, in Proposition 6, we compare the profits of publishers, platform, and social welfare under the two business models: free-content and subscription-based content.

Proposition 6. *There exists thresholds t^1, t^2, q_0^1, and q_0^2 such that:*

(i) If content is strongly differentiated, i.e., $t > t^1$, then free-content always leads to lower profits for the platform and publishers, i.e., $\pi_0^f < \pi_0^s$ and $\pi_i^f < \pi_i^s$. However, if $t \leq t^1$, the profits of the platform and publishers are higher under free-content, i.e., $\pi_0^f \geq \pi_0^s$, and $\pi_i^f \geq \pi_i^s$, if and only if platform quality is sufficiently small, i.e., $q_0 \leq q_0^1$, and lower otherwise.

(ii) If content is strongly differentiated, i.e., $t > t^2$, then free-content always leads to lower social welfare, i.e., $SW^f < SW^s$. However, for $t \leq t^2$, social welfare under free-content is higher than under the subscription-based model, i.e., $SW^f \geq SW^s$, if and only if platform quality is intermediate, i.e., $q_0^1 < q_0 \leq q_0^2$, and lower otherwise.

Please note that expressions for thresholds t^1, t^2, q_0^1, and q_0^2 are defined in Appendix C along with the proof of Proposition 6. Consider part (i) of Proposition 6. As shown in the appendix, the platform's profit comparison monotonically depends on the extent of advertising competition it faces, which, in turn, depends on the publishers' advertising levels. Since the profit comparison depends on the publishers' advertising levels comparison, the boundary condition for the platform's profit to change with a change in the business model coincides with those defined in Proposition 5, i.e., thresholds t^1 and q_0^1. A strong content differentiation, i.e., $t > t^1$, or a weak content differentiation, i.e., $t \leq t^1$, with large platform quality, i.e., $q_0 > q_0^1$, implies free-content model has higher publishers' advertising levels (refer to Proposition 5). This, in turn, means stronger advertising competition under free-content model, generating lower profit for the platform relative to the subscription-based model. In a similar way, we can argue that free-content leads to higher platform profit for $t \leq t^1$ and $q_0 \leq q_0^1$.

Next, consider publishers' profits. From Lemma 3, it can be seen that under the free-content model, publishers' profits depend on the platform's quality q_0, whereas they are independent of the same under the subscription-based model (as shown in Lemma 4). Intuitively, under the latter, there is a full pass-through of advertising revenue to users in the form of lower prices. Comparing the two lemmas, if $\left[\frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}\right]\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right] > t/2$, then free-content model leads to higher profits for the publishers, and lower otherwise. Thus, we need to understand how different model parameters affect the comparison. The comparison depends, inter alia, on the values of t and q_0. As shown in the proof of Proposition 6, the boundary conditions coincide with t^1 and q_0^1. If t is sufficiently large, i.e., $t > t^1$, then under the subscription-based model, the equilibrium prices charged to the users are sufficiently large, leading to higher profits. If t is sufficiently small, i.e., $t \leq t^1$, then the comparison is more intricate. It depends on the value of platform quality q_0. If q_0 is small, i.e., $q_0 \leq q_0^1$, then despite lower t, the price charged per advertisement is high enough to obtain more profits under the free-content model, whereas for higher q_0, i.e., $q_0 > q_0^1$, the advertising prices are sufficiently small, leading to lower publishers' profits under the free-content model relative to the subscription-based model.

Part (*ii*) compares the social welfare under the two business models. From Lemmas 3 and 4, we can see that the platform advertising level remains unchanged, implying that the welfare comparison depends on the comparison of total advertising revenue from content publishers and total nuisance costs of publishers' advertisements. For sufficiently strong content differentiation, i.e., $t > t^2$, free-content leads to higher nuisance costs because of higher publishers' advertisements. This dominates any increase in advertising surplus, leading to lower social welfare relative to the subscription-based business model. However, if content is weakly differentiated, i.e., $t \leq t^2$, then the analysis is more complex. We need to compare the change in nuisance costs and advertising surplus. Note that q_0 affects the publishers' advertising levels under the subscription-based model (refer Lemma 4) but not under the free-content model (refer Lemma 3). If q_0 is large, i.e., $q_0 > q_0^2$, then subscription-based content leads to sufficiently lower publishers' advertising levels relative to the free-content model, leading to lower nuisance costs, and increasing social welfare. Likewise, for very weak content differentiation, i.e., $t \leq t^1$, and small q_0, i.e., $q_0 \leq q_0^1$, subscription-based content leads to sufficiently high publishers' advertising levels relative to the free-content model, leading to higher advertising surplus, offsetting increased nuisance costs, thus, increasing social welfare. Otherwise, free-content advertising levels are high enough to increase social welfare because of the higher advertising surplus generated.

Based on the profits of the platform, publishers, and social welfare, we define three regions (illustrated in Figure 1) in which different participants have different preferences between free-content and subscription-based models. To compare the preferences, we define the efficient model as the one with higher social welfare. Each player's preference depends on the extent of content differentiation (measured by t) and the quality of the aggregator platform q_0. In Region I, both platform and publishers are better off with free-content model. In Regions II and III, content differentiation is sufficiently strong and the preference of the platform aligns with publishers, and both prefer the subscription-based model. Social planner prefers the free-content model in Region II, but the subscription-based model in Regions I and III. Thus, imposing digital paywalls is socially optimal in Region III; otherwise not.

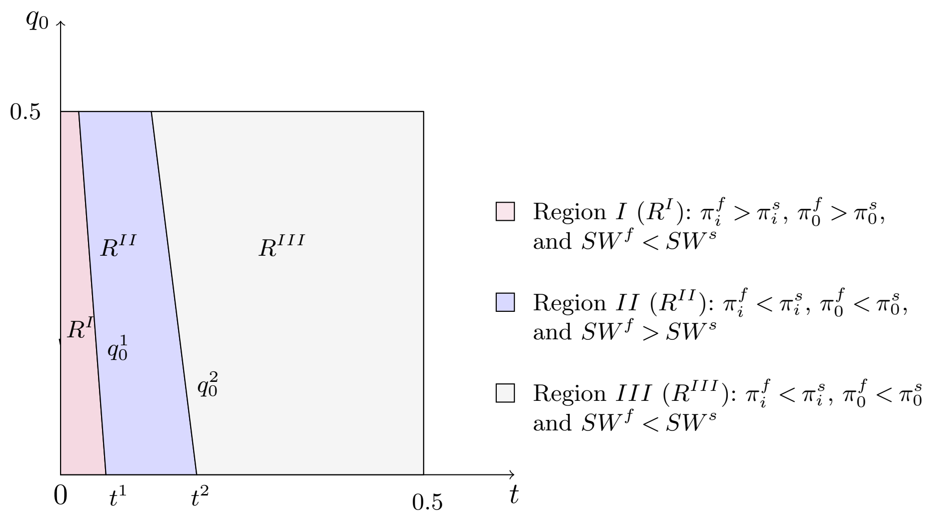

Figure 1 **Comparison of profits, and social welfare under the two business models ($\alpha = 0.4$ and $\gamma = 0.8$). Thresholds t^1, t^2, q_0^1 and q_0^2 are the boundary conditions as defined in Propositions 5 and 6.**

6. Extensions

In this section, we discuss a few extensions to the baseline model.

6.1. Demand Expansion Effect

In the baseline model, we assumed that all users are present in the content consumption market in the absence of the aggregator. We now relax this assumption and consider a setting with only $\beta \in (0, 1]$ users present in the market without the aggregator. This modelling captures the idea that a proportion $1 - \beta$ of users have significantly high search costs to search directly for the content and would always rely on the aggregator for finding the content, whereas β users can still consume preferred content in the absence of an aggregator. As a result, when we introduce the aggregator platform, then i) β users would decide whether to consume the publishers' content by directly searching for the publishers' websites or indirectly reach the websites through the aggregator or consume only the content snippets available on the platform and ii) $1 - \beta$ users would rely on the aggregator to choose between their preferred content. Relegating the details to Appendix D, the proposition summarizes the important findings based on our analysis.[7]

[7] Note that the comparison of profits and social welfare under the two business models is qualitatively the same as under the baseline model. The details are readily available from authors upon request.

Proposition 7. *In the presence of an aggregator platform:*

(i) Under the free-content model, publishers' profit decrease for β sufficiently small or large. Whereas, for intermediate β, there exists a threshold q_0^f, such that for $q_0 > q_0^f$, publishers' profits decrease; otherwise, increase.

(ii) Under the subscription-based model, publishers' profits increase.

(iii) Both consumers and advertisers are better off, irrespective of the publishers' business model.

Please note that we provide the expression for threshold q_0^f in Appendix D along with the proof of Proposition 7. First, consider part (i). Under the free-content model, as shown in the appendix, the advertising levels remain unchanged with or without platform and are as defined in Lemma 1. The impact of platform introduction is driven by two forces: a positive effect, as additional $1-\beta$ users enter the market and increases demand for publishers' content, and a negative effect, because of increased advertising competition from the aggregator. If β is sufficiently small or large, then the increased advertising competition is sufficiently strong, offsetting demand expansion and reducing publishers' profit. However, for intermediate β, and large platform quality, i.e., $q_0 > q_0^f$, the platform advertising level is sufficiently large to reduce advertising prices charged by the publishers, making them worse off; otherwise, increased demand leads to higher profits. Next, consider part (ii). Similar to the baseline model, introducing paywalls lead to a two-sided pricing structure, and there is a complete pass-through of advertising revenue with or without the platform. Thus, the increased demand will lead to higher profits with the platform introduction.

Regarding welfare effects, the intuition follows from our discussion in Section 5.1. The change in consumer surplus has four components: the increased surplus of $1-\beta$ users, and for β users, the surplus change is driven by the change in search costs, the change in nuisance costs of advertisements, and the change in surplus due to the change in equilibrium prices (if there are paywalls). Under free-content model, for β users, nuisance costs remain unchanged over the publishers (because advertising levels are the same), and increase (because of platform advertisements), and the search costs decrease. The latter effect offsets any decrease in surplus, increasing aggregate consumer surplus. Under the subscription-based model, as shown in Appendix D, for β users, the reduced search costs and reduced nuisance costs of publishers' advertisements together dominate the reduction in surplus because of higher prices and nuisance costs associated with platform's advertisements, and together with the surplus of $1-\beta$ users, overall consumer surplus increase. Finally, advertisers' profits increase because, for β users, they find an additional channel to show advertisements driving up their profit from them, and they also show advertisements to additional $1-\beta$ users.

6.2. Equilibrium Business Models

Our main results rest on the comparison of two symmetric publishers' business models with either free-content or subscription-based models. In this section, we endogenize the publishers' business model choice with or without the aggregate platform, and examine the equilibrium business models. Formally, we introduce stage 0, at which, publishers simultaneously and non-cooperatively decide whether to choose free-content model or subscription-based model. Thus, based on stage 0 equilibrium choices, three distinct business model regimes are possible: i) both publishers choose free-content model, ii) both publishers choose subscription-based model and iii) asymmetric business model regime with one publisher choosing free-content model, and the other publisher choosing subscription-based model. Relegating the details to Appendix E, the following proposition summarizes our insights on publishers' business model choices.

PROPOSITION 8. *Allowing for publishers to endogenously choose their business models:*

(i) In any equilibrium, both publishers will either choose a free-content model or a subscription-based model with or without the aggregator platform.

(ii) For the intermediate level of per-unit transportation cost, the equilibrium business model of the publishers can shift from free-content to subscription-based with platform introduction, and publishers' profits can decrease or increase.

Consider part (i). If publisher i believes that publisher j, $j \neq i$, will not charge a positive price, then it is also not optimal for publisher i to charge a positive price to the users. Intuitively, adopting a subscription-based model will generate a two-sided market effect in which profits are lowered by the amount of advertising revenues passed on to the user (in the form of lower prices) and the strength of this effect depends on the level of per-unit transportation cost t. For small per-unit transportation costs, the reduction in profits because of charging a positive price and pass-on of advertising revenues to users as lower prices are sufficiently strong, implying not charging a positive price is a dominant strategy for each publisher, Thus, both adopt the free-content model and rely solely on advertising revenue. Whereas, for sufficiently large per-unit transportation cost, market power over users is sufficiently strong, and charging a positive price offsets any reduction in advertising revenue, and it is a dominant strategy for each publisher, implying both adopt subscription-based model. Thus, asymmetric business models will never arise in equilibrium with or without the aggregator platform. Moreover, as shown in Appendix E, the boundary condition for the profitability of publishers' business models with platform introduction remains the same as described in Section 5.2.

Next, consider part (*ii*). By endogenizing the business model choice, as shown in Appendix E, our main analysis on the impact of platform introduction is consistent for a large range of parameter values. The new insight is that we observe a shift from the case of free-content model (in the absence of the platform) to the case of subscription-based model (in the presence of the platform). Intuitively, since publishers face advertising competition from the platform and advertising revenues are reduced, there is a smaller pass-through of advertising revenues to the users in the form of lower prices. This implies that publishers will find it profitable to rely subscription-based model for a greater range of per-unit transportation cost, relative to the case when there is no aggregator platform. Thus, as shown in Appendix E, for intermediate values of per-unit transportation cost, the equilibrium business models of the publishers shift from free-content to subscription-based model. Consequently, for this range, publishers' profit can decrease for small per-unit transportation costs because of intensified price competition, and increase otherwise.

7. Discussion and Conclusion

In digital markets, content aggregators such as Google News, Google Search, etc., have become a prominent source of traffic for online content publishers (e.g., news publishers). In this multi-channel market structure, a user can access online content (e.g., news) by directly accessing their websites or indirectly reaching their websites through aggregator platforms or consuming only the snippets available on the platform. Another crucial feature is that both aggregators and content publishers compete in the advertising market. With the increasing dominance of aggregators, it is crucial to understand the implications of introducing an aggregator platform for competition and welfare. In particular, the impact on payoffs of market participants and the effective monetization strategy of users and advertisers will determine the success of content publishers in future.

Our paper sets up a theoretical model with one aggregator platform, two publishers, a set of users, and a set of advertisers. Using this model, we examine the effects of introducing an aggregator platform under different publishers' business models and the effect on competition and welfare when advertising-financed content publishers consider charging prices to the users. An important feature of the setting is the advertising competition between the platform and publishers.

The theoretical framework developed offers several interesting insights. First, platform introduction can be *Pareto optimal* under the subscription-based model, however, publishers can suffer, and both users and advertisers benefit under the free-content model (refer Propositions 3, 4 and 7). Second, from the content design point of view, publishers' advertising levels can be higher under the free-content model for sufficiently strong advertising competition from the aggregator platform (refer Proposition 5). Third, contrary to the conventional view in the literature, we show that even with non-unique content, publishers can profitably charge subscription prices to the users (refer Proposition 6 and 8). Next, we evaluate the payoffs of publishers, platforms, advertisers, and social planner as free-content publishers opt for charging subscription prices. Interestingly, our results show that, under strong content differentiation, imposing a digital paywall can benefit the publishers and platform and improve social welfare (refer Proposition 6).

7.1. Managerial Implications

The results in our paper can help inform platform owners about optimal monetization and design policies.

7.1.1. What Should be the Platform Policy for Improving its Profit? Our results offer insight on the platform's optimal design policy. First, consider the platform quality decision. In our model, a higher platform quality (value) can be interpreted as a measure to increase the snippet length of content displayed on a platform, which will improve its quality (value) to the users. Importantly, we show that the platform's choice of quality level would depend on the publishers' business models. Comparing Lemmas 3 and 4 shows that the marginal benefit of improving quality, i.e., longer snippet length, is greater under the subscription-based model relative to the free-content model. Intuitively, quality improves a user's willingness to pay to join a platform under both models. Moreover, under the subscription-based model, it also reduces the attractiveness of placing advertisements in the publishers' websites, implying weak advertising competition for the platform. This additional effect improves its incentive even further to opt for a higher quality (longer snippet policy) under the subscription-based model. Thus, our result complements the findings in the previous literature (e.g., Liu et al. 2022).

7.1.2. Implications for Online Content Design We examined an important design decision, i.e., bundling of advertisements with online content. This is intricately linked to the intensity of advertising competition in a multi-channel structure and publishers' business models. Interestingly, we find that managers should strategize to display more advertisements when content is offered for free if the platform quality is large. Another aspect of our content design is that offering unique content along with a paywall can help publishers protect and improve their profits. This is intuitive and in line with the empirical evidence that newspapers with proportionately more unique content have experienced a smaller decline in profits relative to newspapers with less unique content (Kim et al. 2020).

7.1.3. When Should Content Publishers Opt for Digital Paywalls? Our model explains why news publishers are opting for digital paywalls. Based on our results, it helps them protect against strong advertising competition. Consider the large news publishers such as The New York Times, The Guardian, etc. A part of their business models relies on placing advertisements. Moreover, users can access these newspapers through aggregator platforms such as Google News, etc. Since the quality of these platforms has improved over time, users' value for these platforms has increased. As a result, our model predicts that advertising competition for news publishers has increased, and to protect themselves against it, they will adopt the digital paywall, i.e., rely on the subscription-based model. This is in line with the change in the business models of these news publishers and reinforces the popular view that solely relying on maximizing advertising revenue is no longer a viable business model.

7.2. Policy Implications

Our result proposes important implications for the regulation of online content provision through aggregator platforms.

7.2.1. Should there be a Regulation for Online Content Aggregation? Propositions 3 and 7 show that, with platform introduction, content publishers' profits can decrease only under the free-content model. This lends support to the view that publishers would be more willing to join a platform under the subscription-based model and regulation restricting access of content through aggregators may be not be required. This is in line with the anecdotal evidence. For instance, in December 2014, the Spanish government imposed a strict regulation on Google to pay Spanish news providers every time their content appears on Google News. In response, Google shut down its operations in Spain. However, Spanish Newspaper Publishers Association later compelled the Spanish government to stop the shutdown (Biggs 2014). This can be explained partly because the digital paywall is an important source of revenue for these publishers. Moreover, our analysis indicates that, from a social welfare point of view, regulating the provision of third-party content through aggregators can be welfare-reducing. Thus, the call for regulations such as taxing aggregators for hosting content can be counter-productive (Bacon 2012).

7.2.2. What Should be the Nature of Regulation in the Presence of Digital Paywalls in a Multi-Channel Structure? Digital paywalls provide publishers with an additional source of revenue. However, its welfare implications are not clear-cut, given the two-sided nature of the market with users and advertisers. Our paper contributes to the debate on regulating digital paywalls by isolating the effect arising from nuances of advertisements. In markets with strong content differentiation, publishers impose digital paywalls, and a lower advertising surplus is offset by lower total nuisance costs of advertisements, increasing social welfare. Thus, a regulator needs to balance the interests of publishers against advertisers. One policy suggestion, based on our findings, is that in markets with strong content differentiation, the regulator should focus efforts on protecting the health of the advertising ecosystem by improving their ability to generate higher profits.

As aggregator platforms have become increasingly more popular for the diffusion of online content, our framework would be useful to study policy issues such as the regulation of digital platforms, their design, and the potential welfare implications of publishers' business models in this broader context.

References

Abhishek V, Jerath K, Zhang ZJ (2016) Agency selling or reselling? Channel structures in electronic retailing. *Management Science* 62(8):2259–2280.

Amaldoss W, Du J (2023) Express: How can publishers collaborate and compete with news aggregators? *Journal of Marketing Research* (published online January 13, 2023), https://journals.sagepub.com/doi/10.1177/00222437231153607.

Amaldoss W, Du J, Shin W (2021) Media platforms' content provision strategies and sources of profits. *Marketing Science* 40(3):527–547.

Ambrus A, Calvano E, Reisinger M (2016) Either or both competition: A two-sided theory of advertising with overlapping viewerships. *American Economic Journal: Microeconomics* 8(3):189–222.

Anderson SP, Coate S (2005) Market provision of broadcasting: A welfare analysis. *The Review of Economic Studies* 72(4):947–972.

Anderson SP, Foros Kind HJ (2018) Competition for advertisers and for viewers in media markets. *The Economic Journal* 128(608):34–54.

Armstrong M, Wright J (2007) Two-sided markets, competitive bottlenecks and exclusive contracts. *Economic Theory* 32(2):353–380.

Athey S, Calvano E, Gans JS (2018) The impact of consumer multi-homing on advertising markets and media competition. *Management Science* 64(4):1574–1590.

Bacon D (2012) Taxing times. *The Economist* https://www.economist.com/finance-and-economics/2012/11/03/taxing-times (accessed on 18-12-2022).

Biggs J (2014) Spanish newspapers want google news back. *TechCrunch* https://techcrunch.com/2014/12/14/spanish-newspapers-want-google-news-back/ (accessed on 18-12-2022).

Calzada J, Gil R (2020) What do news aggregators do? Evidence from google news in spain and germany. *Marketing Science* 39(1):134–167.

Cattani K, Gilland W, Heese HS, Swaminathan J (2006) Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production and Operations Management* 15(1):40–56.

Chiou L, Tucker C (2017) Content aggregation by platforms: The case of the news media. *Journal of Economics & Management Strategy* 26(4):782–805.

Choi H, Mela CF, Balseiro SR, Leary A (2020) Online display advertising markets: A literature review and future directions. *Information Systems Research* 31(2):556–575.

Cornière AD, Taylor G (2014) Integration and search engine bias. *The RAND Journal of Economics* 45(3):576–597.

Crampes C, Haritchabalet C, Julien B (2009) Advertising, competition and entry in media industries. *The Journal of Industrial Economics* 57(1):7–31.

de Cornière A, Sarvary M (2023) Social media and news: Content bundling and news quality. *Management Science* 69(1):162–178.

Dellarocas C, Katona Z, Rand W (2013) Media, aggregators, and the link economy: Strategic hyperlink formation in content networks. *Management Science* 59(10):2360–2379.

Depken C, Wilson D (2004) Is advertising a good or a bad? Evidence from U.S. magazine subscriptions. *Journal of Business* 77(S2):S60–S80.

DeValve L, Pekeč S (2022) Optimal price/advertising menus for two-sided media platforms. *Operations Research* 70(3):1629–1645.

Economist (2023) Artificial intelligence is reaching behind newspaper paywalls. *The Economist* https://www.economist.com/business/2023/03/02/artificial-intelligence-is-reaching-behind-newspaper-paywalls (accessed on 20-06-2023).

Gal-or E, Geylani T, Yildirim TP (2012) The impact of advertising on media bias. *Journal of Marketing Research* 49(1):92–99.

Garg A, Ghosh V, Cho S, Banerjee A, Bandyopadhyay S (2022) The streaming games: Analyzing the revenue models of online media firms, SSRN: https://ssrn.com/abstract=4064875.

George L (2007) What's fit to print: The effect of ownership concentration on product variety in daily newspaper markets. *Information Economics and Policy* 19(3):285–303.

Ha AY, Tong S, Wang Y (2022) Channel structures of online retail platforms. *Manufacturing & Service Operations Management* 24(3):1547–1561.

Hahn HW, Singer RJ (2008) An antitrust analysis of google's proposed acquisition of doubleclick. Technical report, AEI-Brookings Joint Center for Regulatory Studies No. 07-24, https://dx.doi.org/10.2139/ssrn.1016189.

Jeon DS, Nasr N (2016) News aggregators and competition among newspapers on the internet. *American Economic Journal: Microeconomics* 8(4):91–114.

Kim H, Song R, Kim Y (2020) Newspapers' content policy and the effect of paywalls on pageviews. *Journal of Interactive Marketing* 49:54–69.

Krämer J, Schnurr D, Wohlfarth M (2019) Winners, losers, and facebook: The role of social logins in the online advertising ecosystem. *Management Science* 65(4):1678–1699.

Liu M, Brynjolfsson E, Dowlatabadi J (2021) Do digital platforms reduce moral hazard? The case of uber and taxis. *Management Science* 67(8):4665–4685.

Liu Y, Yildirim P, Zhang ZJ (2022) Implications of revenue models and technology for content moderation strategies. *Marketing Science* 41(4):831–847.

Meng Z, Hao L, Tan Y (2021) Freemium pricing in digital games with virtual currency. *Information Systems Research* 32(2):481–496.

Peitz M, Valletti TM (2008) Content and advertising in the media: Pay-TV versus free-to-air. *International Journal of Industrial Organization* 26(4):949–965.

Seamans R, Zhu F (2017) Repositioning and cost-cutting: The impact of competition on platform strategies. *Strategy Science* 2(2):83–99.

Simon F, Graves L (2019) Factsheet-Pay models for online news in the US and Europe: 2019 update. Technical report, Reuters Institute for the Study of Journalism, https://www.digitalnewsreport.org/publications/2019/pay-models-2019-update/.

Sun M, Zhu F (2013) Ad revenue and content commercialization: Evidence from blogs. *Management Science* 59(10):2314–2331.

Wang C, Zhou B, Joshi YV (2023) Endogenous consumption and metered paywalls. *Marketing Science* (published online May 9, 2023), https://doi.org/10.1287/mksc.2023.1444.

Wilbur KC (2008) A two-sided, empirical model of television advertising and viewing markets. *Marketing Science* 27(3):356–378.

Xu J, Forman C, Kim JB, Ittersum KV (2014) News media channels: Complements or substitutes? evidence from mobile phone usage. *Journal of Marketing* 78(4):97–112.

Appendices for "Economics of Content Aggregation: Pricing and Advertising Competition in a Multi-Channel Structure"

Appendix A: Model Assumptions

Assumption 1 *Advertising technology is imperfect, i.e.,*

$$\alpha < \min\left\{\frac{\gamma}{2t}, \frac{\gamma^3}{2t}, \frac{2\gamma}{(1+q_0)^3}\right\}.$$

This assumption imposes parametric restrictions such that the probability of a match on all three firms remains between [0,1]. It is also in line with the empirical observation that advertising targeting rates on platforms are not perfect.

Assumption 2 *Platform quality is sufficiently small, i.e.,*

$$0 < q_0 < 0.5.$$

This assumption ensures that, in equilibrium, users will consume publishers' content, both directly and indirectly (through the platform). This is also the interesting case in line with the anecdotal evidence.

Appendix B: Demand Estimation

B.1. Demand Estimation under Benchmark Model

Since there is no platform, a user will incur search cost c while deciding which publisher to join. Let $\hat{x} \in [0,1]$ be the location of the user indifferent between joining publisher 1 or 2, such that *a)* $U(\hat{x}, c; 1) = U(\hat{x}, c; 2)$, *b)* $U(x, c; 1) \geq U(\hat{x}, c; 1)$ for all $x \leq \hat{x}$ and *c)* $U(\hat{x}, c; 1) \leq U(x, c; 2)$ for all $x \geq \hat{x}$. Using (1), we obtain the utility from joining publisher $i, i = 1, 2$, as

$$U(x, c; i) = V - \gamma m_i - p_i - c - t[\mathbb{L} + 2x(1-\mathbb{L}) - x], \tag{6}$$

where $\mathbb{L}$ is the indicator function, such that $\mathbb{L} = 0$ (1) if she accesses publisher 1's content directly (if she accesses publisher 2's content directly) Using (6), we get the value of $\hat{x}$ as

$$\hat{x} = \frac{1}{2} + \frac{\gamma(\widetilde{m}_2 - \widetilde{m}_1)}{2t} + \frac{(\widetilde{p}_2 - \widetilde{p}_1)}{2t}. \tag{7}$$

A user with location $x \leq \hat{x}$ joins publisher 1, and a user with location $x \geq \hat{x}$ joins publisher 2. Thus, publishers' market shares are

$$\widetilde{N}_1 = \hat{x} = \frac{1}{2} + \frac{\gamma(\widetilde{m}_2 - \widetilde{m}_1)}{2t} + \frac{(\widetilde{p}_2 - \widetilde{p}_1)}{2t}, \text{ and } \widetilde{N}_2 = (1-\hat{x}) = \frac{1}{2} + \frac{\gamma(\widetilde{m}_1 - \widetilde{m}_2)}{2t} + \frac{(\widetilde{p}_1 - \widetilde{p}_2)}{2t}, \tag{8}$$

where $\widetilde{N}_i$ is the total number of users who join publisher i, $i = 1, 2$.

B.2. Demand Estimation under Main Model

A user defined by a pair (x, c) can choose among the five options as defined in Section 3.5.1. Let $U(x, c; Y)$ be the user (x, c) utility from opting for option Y, where $Y \in \{00, 01, 02, 1, 2\}$. Using (1) and (2), we can write

$$\begin{aligned}
U(x, c; 00) &= q_0, && (9)\\
U(x, c; 01) &= V + q_0 - \gamma(m_0 + m_1) - p_1 - tx, && (10)\\
U(x, c; 02) &= V + q_0 - \gamma(m_0 + m_2) - p_2 - t(1-x), && (11)\\
U(x, c; 1) &= V - \gamma m_1 - p_1 - tx - c, \text{ and} && (12)\\
U(x, c; 2) &= V - \gamma m_2 - p_2 - t(1-x) - c. && (13)
\end{aligned}$$

Note that since a user obtains a non-negative utility from consuming a publisher's content, she can always improve her utility by joining one of the two publishers either directly or indirectly through the platform. Thus, option 00 will never arise in equilibrium. Since x and c are independently and identically distributed over the line [0,1], we can find out the separate cut-off values for the user who is indifferent between joining the platform or not and joining publisher 1 or 2. Let $\hat{c} \in [0,1]$ be the location of the user indifferent between joining platform or not. Then, we have *a)* $U(x, \hat{c}; 0i) = U(x, \hat{c}; i)$, *b)* $U(x, \hat{c}; 0i) \leq U(x, c; i)$ for all $c \leq \hat{c}$ and *c)* $U(x, \hat{c}; 0i) \geq U(x, c; i)$ for all $c \geq \hat{c}$, where $i = 1, 2$. Using utility functions defined in (10)-(13), we get the value of $\hat{c}$ as

$$\hat{c} = \gamma m_0 - q_0. \tag{14}$$

A user with a search cost greater than $\hat{c}$, i.e., $c \geq \hat{c}$, joins the platform. Similarly, let $\hat{x} \in [0,1]$ be the location of the user indifferent between joining publisher 1 or 2, such that *a)* $U(\hat{x},c;01) = U(\hat{x},c;02)$ and $U(\hat{x},c;1) = U(\hat{x},c;2)$, *b)* $U(x,c;01) \geq U(\hat{x},c;02)$ and $U(x,c;1) \geq U(\hat{x},c;2)$ for all $x \leq \hat{x}$, and *c)* $U(\hat{x},c;01) \leq U(x,c;02)$ and $U(\hat{x},c;1) \leq U(x,c;2)$ for all $x \geq \hat{x}$. Using utility functions defined in (10)-(13), we get the value of $\hat{x}$ as

$$\hat{x} = \frac{1}{2} + \frac{\gamma(m_2 - m_1)}{2t} + \frac{(p_2 - p_1)}{2t}. \tag{15}$$

A user with location $x \leq \hat{x}$ joins publisher 1, and a user with location $x \geq \hat{x}$ joins publisher 2, independent of their decision to join the platform. Thus, based on cut-offs defined in (14) and (15), four different demand functions can be defined as $N_1 = \hat{c} * \hat{x}$, $N_2 = \hat{c} * (1-\hat{x})$, $N_{01} = (1-\hat{c}) * \hat{x}$, and $N_{02} = (1-\hat{c}) * (1-\hat{x})$. They are

$$N_1 = [\gamma m_0 - q_0] * \left[\frac{1}{2} + \frac{\gamma(m_2 - m_1)}{2t} + \frac{(p_2 - p_1)}{2t}\right], N_2 = [\gamma m_0 - q_0] * \left[\frac{1}{2} + \frac{\gamma(m_1 - m_2)}{2t} + \frac{(p_1 - p_2)}{2t}\right], \tag{16}$$

$$N_{01} = [1 - \gamma m_0 + q_0] * \left[\frac{1}{2} + \frac{\gamma(m_2 - m_1)}{2t} + \frac{(p_2 - p_1)}{2t}\right], \text{ and } N_{02} = [1 - \gamma m_0 + q_0] * \left[\frac{1}{2} + \frac{\gamma(m_1 - m_2)}{2t} + \frac{(p_1 - p_2)}{2t}\right], \tag{17}$$

where N_i is the total number of users who join publisher $i, i = 1,2$, directly, and N_{0i} is the total number of users who join both platform and publisher i, $i = 1,2$. Therefore, the market share of the platform is $N_{01} + N_{02}$.

Appendix C: Proofs of the Technical Results

Proof of Lemma 1

At stage 3, users decide whether to join publisher 1 or 2. We get user demand functions user defined by putting $\widetilde{p}_1 = \widetilde{p}_2 = 0$ in (8). At stage 2, advertisers decide to advertise in publisher i, $i = 1,2$, as long as the marginal benefit of a unit of an advertisement is equal to its marginal cost. The advertiser's profit can be written as $\widetilde{AP} = \alpha^{1/2}\widetilde{m}_1^{1/2}\widetilde{N}_1 + \alpha^{1/2}\widetilde{m}_2^{1/2}\widetilde{N}_2 - \widetilde{r}_1\widetilde{m}_1 - \widetilde{r}_2\widetilde{m}_2$. Using the preceding equation, we get the inverse advertising demand functions as

$$\widetilde{r}_1 = \frac{1}{2}\alpha^{1/2}\widetilde{m}_1^{-1/2}\widetilde{N}_1, \text{ and } \widetilde{r}_2 = \frac{1}{2}\alpha^{1/2}\widetilde{m}_2^{-1/2}\widetilde{N}_2. \tag{18}$$

The profit of publisher i, $i = 1,2$, is $\widetilde{\pi}_i = \widetilde{r}_i\widetilde{m}_i$, where the profit is only from placing $\widetilde{m}_i$ advertisements. At stage 1, using the user demand functions, and the inverse advertising demand functions given in (18), putting the values for them in the profit functions, publisher i, $i = 1,2$, chooses advertising quantity $\widetilde{m}_i$ to maximize its profits. Any optimal pair of advertising quantities must satisfy the first-order necessary conditions of firms' optimization problem, given by

$$\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{m}_i} = \frac{1}{4}\alpha\widetilde{m}_i^{-1/2}\widetilde{N}_i + \frac{1}{2}\alpha\widetilde{m}_i^{1/2}\frac{\partial \widetilde{N}_i}{\partial \widetilde{m}_i} \leq 0,\ i = 1,2. \tag{19}$$

First, we argue that the advertising levels in both publishers are positive, which would imply that the first-order conditions defined by (19) bind. This follows since, in any equilibrium with both publishers having a positive market share, i.e., $0 < \widetilde{N}_1; \widetilde{N}_2 < 1$, and zero advertising levels, i.e., $\widetilde{m}_1^f = \widetilde{m}_2^f = 0$ would violate (19). Thus, first-order necessary conditions defined by (19) would bind, and at symmetric equilibrium, i.e., $\widetilde{m}_1^f = \widetilde{m}_2^f > 0$ would give us the advertising levels as defined in Lemma 1. They are $\widetilde{m}_1^f = \widetilde{m}_2^f = \frac{t}{2\gamma}$.[8] By substituting the equilibrium decisions into the demand functions defined by putting $\widetilde{p}_1 = \widetilde{p}_2 = 0$ in (8), we have $\widetilde{N}_1^f = \widetilde{N}_2^f = 1/2$. Then, using these values, we obtain equilibrium profits as defined in Lemma 1. Social welfare is defined as the sum of user surplus and advertising surplus. At the market equilibrium, it is

$$\widetilde{SW} = \underbrace{\int_0^{1/2} (V - \gamma \widetilde{m}_1^f - tx)dx + \int_{1/2}^{1} (V - \gamma \widetilde{m}_2^f - t(1-x))dx}_{\text{user surplus}} + \underbrace{\alpha^{1/2}(\widetilde{m}_1^f)^{1/2}\widetilde{N}_1^f + \alpha^{1/2}(\widetilde{m}_2^f)^{1/2}\widetilde{N}_2^f}_{\text{advertising surplus}}.$$

Using the equilibrium advertising levels (defined in Lemma 1) and simplifying the preceding expression gives us the social welfare as defined in Lemma 1. This completes the proof. ■

Proof of Lemma 2

At stage 3, users decide whether to join publisher 1 or 2. We get user demand functions as defined in (8). At stage 2, we get the inverse advertising demand functions as defined in (18). The profit of publisher i, $i = 1, 2$, is $\widetilde{\pi}_i = \widetilde{r}_i \widetilde{m}_i + \widetilde{p}_i \widetilde{N}_i$, where the first term is the profit from placing $\widetilde{m}_i$ advertisements and the second term is the profit from subscriptions. At stage 1, using the user demand functions defined in (8), and the inverse advertising demand functions given in (18), putting the values for them in the profit functions, publisher i, $i = 1, 2$, chooses price $\widetilde{p}_i$ and advertising quantity $\widetilde{m}_i$ to maximize its profits. Any optimal pair of prices and advertising quantities must satisfy the first-order necessary conditions of firms' optimization problem.[9] They are:

$$\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{p}_i} = \widetilde{N}_i + \left[\widetilde{p}_i + \frac{1}{2}\alpha^{1/2}\widetilde{m}_i^{1/2}\right]\frac{\partial \widetilde{N}_i}{\partial \widetilde{p}_i} = 0, \text{ and } \frac{\partial \widetilde{\pi}_i}{\partial \widetilde{m}_i} = \frac{1}{4}\alpha^{1/2}\widetilde{m}_i^{-1/2}\widetilde{N}_i + \left[\widetilde{p}_i + \frac{1}{2}\alpha^{1/2}\widetilde{m}_i^{1/2}\right]\frac{\partial \widetilde{N}_i}{\partial \widetilde{m}_i} \leq 0, \; i = 1, 2. \quad (20)$$

First, we argue that the advertising levels in both publishers are positive, which would imply that the first-order conditions $\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{m}_i}, i = 1, 2$, defined by (20) bind. This follows since, in any equilibrium with both firms having a positive market share, i.e., $0 < \widetilde{N}_1; \widetilde{N}_2 < 1$, and zero advertising levels, i.e., $\widetilde{m}_1^s = \widetilde{m}_2^s = 0$ would violate (20). Thus, $\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{m}_i}, i = 1, 2$, would bind. Using $\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{p}_i}$ together with $\frac{\partial \widetilde{\pi}_i}{\partial \widetilde{m}_i}$ defined in (20), we get $\frac{1}{4}\alpha \widetilde{m}_i^{-1/2} = \gamma$, $i = 1, 2$. This gives $\widetilde{m}_i^s = \frac{\alpha}{16\gamma^2}$, as defined in Lemma 2. Next, using this advertising value and user demand functions (defined in (8)) in (20), we can solve for the symmetric equilibrium price as defined in Lemma 2. It is $\widetilde{p}_i^s = \frac{t}{2} - \frac{\alpha}{8\gamma}$. By

[8] It can be easily seen that the profit functions are strictly concave in advertising levels, implying that the solution constitutes a global maximum.

[9] Note that second-order conditions at the solutions to the first-order conditions are satisfied. The details are readily available upon request.

substituting the equilibrium decisions into the demand functions given in (8), we have $\widetilde{N}_1^s = \widetilde{N}_2^s = 1/2$. Then, putting these values into the profit functions, we have equilibrium profits, as defined in Lemma 1.

Social welfare is defined as the sum of user surplus and advertising surplus. At the market equilibrium, it is

$$\widetilde{SW} = \underbrace{\int_0^{1/2} (V - \gamma \widetilde{m}_1^s - tx)dx + \int_{1/2}^1 (V - \gamma \widetilde{m}_2^s - t(1-x))dx}_{\text{user surplus}} + \underbrace{\alpha^{1/2}(\widetilde{m}_1^s)^{1/2}\widetilde{N}_1^s + \alpha^{1/2}(\widetilde{m}_2^s)^{1/2}\widetilde{N}_2^s}_{\text{advertising surplus}}.$$

Using the equilibrium advertising levels (defined in Lemma 2) in the preceding expression for social welfare and simplifying it gives us the social welfare, as defined in Lemma 2. This completes the proof. ■

Proof of Lemma 3

At stage 2, advertisers decide to advertise in the platform and publisher i, $i = 1, 2$, as long as the marginal benefit of a unit of an advertisement is equal to its marginal cost. The advertiser's profit is as defined in (3). Using it, the inverse advertising demand functions are

$$r_0 = \frac{1}{2}\alpha^{1/2} m_0^{-1/2} \sum_{i=1}^{2} [N_{0i} - \alpha^{1/2} m_i^{1/2} N_{0i}], \text{ and } r_i = \frac{1}{2}\alpha^{1/2} m_i^{-1/2}[(1 - \alpha^{1/2} m_0^{1/2})N_{0i} + N_i], \; i = 1, 2. \tag{21}$$

At stage 1, using the user demand functions defined in (16)-(17), and the inverse advertising demand functions defined in (21), and putting the values for them in the profit functions defined by (4) and (5), setting $p_i = 0$, platform and publisher i, $i = 1, 2$, choose advertising levels m_0 and $m_i, i = 1, 2$, to maximize their profits. The first-order conditions are:

$$\frac{\partial \pi_0}{\partial m_0} = \frac{1}{4}\alpha^{1/2} m_0^{-1/2} \sum_{i=1}^{2} [N_{0i} - \alpha^{1/2} m_i^{1/2} N_{0i}] + \frac{1}{2}\alpha m_0^{1/2}[-\gamma + m_1^{1/2}(\gamma \hat{x}) + m_2^{1/2}(\gamma(1-\hat{x}))] \leq 0, \tag{22}$$

$$\frac{\partial \pi_i}{\partial m_i} = [(1 - \alpha^{1/2} m_0^{1/2})] \left[N_{0i}\frac{1}{4}\alpha^{1/2} m_i^{-1/2} - \frac{1}{2}\alpha^{1/2} m_i^{1/2}(1-\hat{c})\frac{\gamma}{2t} \right] - \frac{1}{2}\alpha^{1/2} \left[m_i^{1/2}\hat{c}\frac{\gamma}{2t} - \frac{1}{2} m_i^{-1/2} N_i \right] \leq 0. \tag{23}$$

where $\hat{c}$ and $\hat{x}$ are as defined in (14) and (15). Similar to the arguments given in the proofs of Lemmas 1 and 2, we can argue that (22)-(23) will bind. At symmetric equilibrium, we have $\hat{x} = 1/2$ and $m_1^f = m_2^f$. Using this in (22)-(23), we get the equilibrium advertising decisions, as defined in Lemma 3.[10] Next, using the equilibrium advertising values in (14), we get $\hat{c} = (1 - 2q_0)/3$. Finally, using the equilibrium advertising values and the values for $\hat{x}$ and $\hat{c}$, we obtain the equilibrium profits, as defined in Lemma 3.

Social welfare is defined as the sum of user surplus and advertising surplus. At the market equilibrium, it is

$$\begin{aligned} SW = & \int_0^{\hat{c}} \int_0^{\hat{x}} (V - \gamma m_1 - tx - c)dxdc + \int_0^{\hat{c}} \int_{\hat{x}}^1 (V - \gamma m_2 - t(1-x) - c)dxdc \\ & + \int_{\hat{c}}^1 \int_0^{\hat{x}} (V + q_0 - \gamma m_1 - tx)dxdc + \int_{\hat{c}}^1 \int_{\hat{x}}^1 (V + q_0 - \gamma m_2 - t(1-x))dxdc \\ & + \alpha^{1/2} m_1^{1/2} N_1 + \alpha^{1/2} m_2^{1/2} N_2 + \alpha^{1/2} m_0^{1/2}[N_{01} + N_{02}] + [1 - \alpha^{1/2} m_0^{1/2}]\alpha^{1/2} m_1^{1/2} N_{01} + [1 - \alpha^{1/2} m_0^{1/2}]\alpha^{1/2} m_2^{1/2} N_{02}. \end{aligned}$$

[10] Moreover, straightforward calculations will show that the profit functions are concave in advertising levels. Hence, the solution constitutes a global maximum.

Using the values for $N_1 = \hat{c}\hat{x}$, $N_2 = \hat{c}(1-\hat{x})$, $N_{01} = (1-\hat{c})\hat{x}$, and $N_{02} = (1-\hat{c})(1-\hat{x})$, and simplifying the preceding expression, we get

$$SW = \underbrace{V - \gamma m_1.\hat{x} - \gamma m_2.(1-\hat{x}) + (q_0 - \gamma m_0)(1-\hat{c}) - \frac{t}{2} - t(\hat{x})^2 + t\hat{x} - \frac{(\hat{c})^2}{2}}_{\text{user surplus}}$$
$$+ \underbrace{\alpha^{1/2}m_0^{1/2}[1-\alpha^{1/2}m_1^{1/2}\hat{x} - \alpha^{1/2}m_2^{1/2}(1-\hat{x})](1-\hat{c}) + \alpha^{1/2}m_1^{1/2}\hat{x} + \alpha^{1/2}m_2^{1/2}(1-\hat{x})}_{\text{advertising surplus}}. \quad (24)$$

Now, putting the equilibrium values for advertisements, $\hat{x}$ and $\hat{c}$, in the preceding expression, we obtain the value for the social welfare, as defined in Lemma 3, completing the proof. ■

Proof of Proposition 1

First, consider the platform's profit. Using the expression for equilibrium profits, given in Lemma 3, and differentiating platform's profit w.r.t. α and γ, we have

$$\frac{\partial \pi_0^f}{\partial \alpha} = \frac{(1+q_0)^{3/2}}{2\alpha^{1/2}3^{3/2}\gamma^{1/2}}\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right], \text{ and } \frac{\partial \pi_0^f}{\partial \gamma} = -\frac{\alpha^{1/2}(1+q_0)^{3/2}}{23^{3/2}\gamma^{3/2}}\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right].$$

Under Assumption 1, we have $\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right] > 0$, implying $\frac{\partial \pi_0^f}{\partial \alpha} > 0$, and $\frac{\partial \pi_0^f}{\partial \gamma} < 0$. Next, differentiating publisher i's profit w.r.t. α and γ, we have

$$\frac{\partial \pi_i^f}{\partial \alpha} = \frac{t^{1/2}}{2^{7/2}\alpha^{1/2}3^{3/2}\gamma^{1/2}}\left[1 - \frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right], \text{ and } \frac{\partial \pi_i^f}{\partial \gamma} = -\frac{t^{1/2}}{2^{7/2}\alpha^{1/2}3^{3/2}\gamma^{3/2}}\left[1 - \frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right].$$

Given Assumption 1, we have $\left[1 - \frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right] > 0$, implying $\frac{\partial \pi_i^f}{\partial \alpha} > 0$ and $\frac{\partial \pi_i^f}{\partial \gamma} < 0$.

Next, consider social welfare. Differentiating the expression given in Lemma 3, w.r.t. α and γ, we get

$$\frac{\partial SW^f}{\partial \alpha} = \frac{\alpha^{-1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right] + \frac{\alpha^{-1/2}t^{1/2}}{2^{3/2}\gamma^{1/2}}, \text{ and } \frac{\partial SW^f}{\partial \gamma} = -\frac{\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right] - \frac{\alpha^{1/2}t^{1/2}}{2^{3/2}\gamma^{3/2}}.$$

Under Assumption 1, $\left[1 - \frac{2\alpha^{1/2}t^{1/2}}{2^{1/2}\gamma^{1/2}}\right] > 0$, implying $\frac{\partial SW^f}{\partial \alpha} > 0$ and $\frac{\partial SW^f}{\partial \gamma} < 0$. This completes the proof. ■

Proof of Lemma 4

At stage 1, using the user demand functions defined in (16)-(17), and the inverse advertising demand functions defined in (21), and putting the values for them in the profit functions defined by (4) and (5), the platform chooses advertising quantity m_0 and publisher i, $i = 1, 2$, chooses price p_i, and advertising quantity m_i to maximize their profits. The first-order conditions are:

$$\frac{\partial \pi_0}{\partial m_0} = \frac{1}{4}\alpha^{1/2}m_0^{-1/2}[N_{01} + N_{02} - \alpha^{1/2}m_1^{1/2}N_{01} - \alpha^{1/2}m_2^{1/2}N_{02}]$$
$$+ \frac{1}{2}\alpha^{1/2}m_0^{1/2}[-\gamma\hat{x} - \gamma(1-\hat{x}) + \alpha^{1/2}m_1^{1/2}(\gamma\hat{x}) + \alpha^{1/2}m_2^{1/2}(\gamma(1-\hat{x}))] \leq 0, \quad (25)$$

$$\frac{\partial \pi_i}{\partial m_i} = [(1-\alpha^{1/2}m_0^{1/2})N_{0i}]\frac{1}{4}\alpha^{1/2}m_i^{-1/2} - (1-\alpha^{1/2}m_0^{1/2})\frac{1}{2}\alpha^{1/2}m_i^{1/2}(1-\hat{c})\frac{\gamma}{2t}$$
$$- \frac{1}{2}\alpha^{1/2}m_i^{1/2}\hat{c}\frac{\gamma}{2t} + \frac{1}{4}\alpha^{1/2}m_i^{-1/2}N_i - p_i\frac{\gamma}{2t} \leq 0, \ i = 1, 2, \text{ and} \quad (26)$$

$$\frac{\partial \pi_i}{\partial p_i} = -[(1-\alpha^{1/2}m_0^{1/2})(1-\hat{c})]\frac{1}{2}\alpha^{1/2}m_i^{1/2}\frac{1}{2t} - \frac{1}{2}\alpha^{1/2}m_i^{1/2}\hat{c}\frac{1}{2t} + N_{0i} + N_i - p_i\frac{1}{2t} = 0, \ i = 1, 2, \quad (27)$$

where $\hat{c}$ and $\hat{x}$ are as defined in (14) and (15). At symmetric equilibrium, we have $\hat{x}=1/2$ and $m_1^s=m_2^s$. Using (26) and (27) together, we get equilibrium publishers advertising levels as $m_i^s=\frac{\alpha}{16\gamma^2}[(1-\alpha^{1/2}(m_0^f)^{1/2})(1-\hat{c})+\hat{c}]^2$ and using (25), we get $m_0^s=\frac{1+q_0}{3\gamma}$, as defined in Lemma 4. Using m_0^s in (14), we get $\hat{c}^s=(1-2q_0)/3$. Using $\hat{c}^s$ in (26), we get publishers' advertising levels, as defined in Lemma 4. Next, using demand functions (16)-(17) in (27) and the equilibrium advertising levels, we will obtain equilibrium prices, as defined in Lemma 4.[11] Next, using the equilibrium advertising values and prices, $\hat{c}=(1-2q_0)/3$ and $\hat{x}=1/2$ will give us $N_1^s=N_2^s=(1-2q_0)/6$ and $N_{01}=N_{02}=(1+q_0)/3$. Using these equilibrium values in profit functions defined in (4) and (5), we obtain the equilibrium profits, as defined in Lemma 4. Finally, social welfare is as defined in (24). Putting the equilibrium values for advertisements, $\hat{x}$ and $\hat{c}$ in (24), we obtain the social welfare, as defined in Lemma 3. This completes the proof. ■

Proof of Proposition 2

First, consider the platform's profits. Using the expression for equilibrium profits given in Lemma 4, and differentiating platform's profit w.r.t. q_0, α and γ, we have

$$\frac{\partial\pi_0^s}{\partial q_0}=\frac{\alpha^{1/2}(1+q_0)^{1/2}}{23^{1/2}\gamma^{1/2}}\left[1-\frac{\alpha}{4\gamma}\right]+\frac{\alpha^2(1+q_0)^2}{4.3^{1/2}\gamma^2},\ \frac{\partial\pi_0^s}{\partial\alpha}=\frac{(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\left[\frac{\alpha^{-1/2}}{2}-\frac{3\alpha^{1/2}}{8\gamma}+\frac{\alpha(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}\right], \text{ and}$$

$$\frac{\partial\pi_0^s}{\partial\gamma}=-\frac{\alpha(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}\left[\frac{\alpha^{-1/2}}{2}-\frac{3\alpha^{1/2}}{8\gamma}+\frac{\alpha(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}\right].$$

From the preceding expressions, we can see that $\frac{\partial\pi_0^s}{\partial q_0}>0$. Moreover, $\frac{\partial\pi_0^s}{\partial\alpha}>0$ and $\frac{\partial\pi_0^s}{\partial\gamma}<0$ if and only if $\left[\frac{\alpha^{-1/2}}{2}-\frac{3\alpha^{1/2}}{8\gamma}+\frac{\alpha(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}\right]>0$. This gives a threshold q^p, where $q^p=\frac{3\gamma^{1/3}}{4}\frac{(3\alpha-4\gamma)^{2/3}}{\alpha}-1$. Using numerical simulation, we confirm that $q^p\in(0,0.5)$. Therefore, for $q>q^p$, we have $\frac{\partial\pi_0^f}{\partial\alpha}>0$ and $\frac{\partial\pi_0^f}{\partial\gamma}<0$, whereas for $q\le q^p$, we have $\frac{\partial\pi_0^f}{\partial\alpha}\le 0$ and $\frac{\partial\pi_0^f}{\partial\gamma}\ge 0$.

Next, consider social welfare. Differentiating the expression given in Lemma 4 w.r.t. q_0, α and γ, we get

$$\frac{\partial SW^s}{\partial q_0}=\frac{2}{3}+\frac{\alpha^{1/2}(1+q_0)^{1/2}}{3^{1/2}\gamma^{1/2}}\left[1-\frac{3\alpha}{8\gamma}\left(1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right)\right],$$

$$\frac{\partial SW^s}{\partial\alpha}=\frac{3}{16\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[1-\frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]+\frac{\alpha^{-1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}, \text{ and}$$

$$\frac{\partial SW^s}{\partial\gamma}=-\frac{3}{16\gamma^2}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[1-\frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]-\frac{\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{3/2}}.$$

Under Assumption 1, $\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[1-\frac{4\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]>0$, implying $\frac{\partial SW^s}{\partial q_0}>0$, $\frac{\partial SW^s}{\partial\alpha}>0$ and $\frac{\partial SW^s}{\partial\gamma}<0$, completing the proof. ■

Proof of Proposition 3

[11] Note that second-order conditions for the local maximum are satisfied. The details are available on request.

First, consider publishers' profits under the free-content model. From Lemmas 1 and 3, we can see that the equilibrium profits of publishers are always lower in the presence of the platform. Next, under the subscription-based model, comparing Lemmas 2 and 4 shows that the equilibrium profits of the publishers remain unchanged with the introduction of the platform. This completes the proof. ■

Proof of Proposition 4

First, we consider consumer surplus. Under the free-content model, the consumer surplus with and without the platform is $CS^f = V - \frac{3t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0)$, and $\widetilde{CS}^f = V - \frac{3t}{4} - 1$. Using the preceding expression, it can be seen that the change in consumer surplus, i.e., $\Delta CS^f = CS^f - \widetilde{CS}^f$, is $\Delta CS^f = 1 - \frac{1}{18}(1-2q_0)(5+2q_0) > 0$. Under the subscription-based model, the consumer surplus with and without the platform is $CS^s = V - \frac{t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0) - \frac{\alpha}{16\gamma}\left[1 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2 - p^s$, and $\widetilde{CS}^s = V - \frac{t}{4} - 1 - \widetilde{p}^s$, where p^s ($\widetilde{p}^s$) is the equilibrium price with (without) the platform. Using Lemmas 2 and 4, and putting in the values for p^s ($\widetilde{p}^s$) in the consumer surplus with and without the platform, the change in consumer surplus, i.e., $\Delta CS^s = CS^s - \widetilde{CS}^s$, is $\Delta CS^s = 1 - \frac{1}{18}(1-2q_0)(5+2q_0) - \frac{\alpha}{16\gamma}\left[\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[2 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]$. Since $\frac{1}{18}(1-2q_0)(5+2q_0) < \frac{2}{3}(1+q_0)$, we have $\Delta CS^s > \frac{2}{3}(1+q_0) - \frac{\alpha}{16\gamma}\left[\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]\left[2 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]$. After some simple algebra, we can show that it is positive if $1 > \frac{\alpha}{16\gamma}\left[\frac{\alpha^{1/2}(1+q_0)^{1/2}}{3^{1/2}\gamma^{1/2}}\right]\left[2 - \frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]$, which holds since $\alpha < 2\gamma$ (by Assumption 1), implying that $\Delta CS^s > 0$.

Next, consider advertisers' profit. Under the publisher business model j, $j = f, s$, the advertisers' profit with and without the platform is

$$AP^j = \alpha^{1/2}(m_i^j)^{1/2}\hat{c}^j + \alpha^{1/2}m_0^{1/2}(1-\hat{c}^j) + [1-\alpha^{1/2}(m_0^j)^{1/2}]\alpha^{1/2}(m_i^j)^{1/2}(1-\hat{c}^j) - 2p_i^j m_i^j - p_0^j m_0^j. \tag{28}$$

$$\widetilde{AP}^j = \alpha^{1/2}(\widetilde{m}_i^j)^{1/2} - 2\widetilde{p}_i^j \widetilde{m}_i^j. \tag{29}$$

Under free-content model, from Lemmas 1 and 3, we know that $m_i^f = \widetilde{m}_i^f$. Using equilibrium values for advertising prices (defined by (18) and (21)), the change in advertisers' profit, i.e., $\Delta AP^f = AP^f - \widetilde{AP}^f$, is $\Delta AP^f = \frac{1}{2}(\alpha^{1/2})(m_0^f)^{1/2}(1-c^f) > 0$. Under the subscription-based model, using equilibrium values for advertising prices (defined by (18) and (21)), the change in advertisers' profit, i.e., $\Delta AP^s = AP^s - \widetilde{AP}^s$, can be written as $\Delta AP^s = \frac{\alpha^{1/2}}{2}[(m^s)^{1/2} - \widetilde{m}^s)^{1/2}] + \frac{\alpha^{1/2}}{2}(m_0^s)^{1/2}(1-c^s)$. Now, using Lemma 2 and $m_i^s = \frac{\alpha}{16\gamma^2}[(1-\alpha^{1/2}(m_0^f)^{1/2})(1-\hat{c}) + \hat{c}]^2$, we can see that $(m^s)^{1/2} = \frac{\alpha^{1/2}}{4\gamma}[(1-\alpha^{1/2}m_0^{1/2})(1-c^s) + c^s] = (\widetilde{m}^s)^{1/2}[(1-\alpha^{1/2}m_0^{1/2})(1-c^s) + c^s] = [1-\alpha^{1/2}(m_0^s)^{1/2}(1-c^s)](\widetilde{m}^s)^{1/2} > 0$. Using this equality in ΔAP^s, we get $\Delta AP^s = \frac{\alpha^{1/2}}{2}(m_0^s)^{1/2}(1-c^s)(1-\alpha^{1/2}(\widetilde{m}^s)^{1/2})$. Since $1-\alpha^{1/2}(\widetilde{m}^s)^{1/2} > 0$, implies $\Delta AP^s > 0$, completing the proof. ■

Proof of Proposition 5

Comparing Lemmas 3 and 4 shows that advertising under free-content model is greater than advertising under the subscription-based model if $\frac{t}{2\gamma} > \frac{\alpha}{16\gamma^2}\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2$. From this, we can obtain the threshold $q_0^1(t)$ defined by the equality

$$t=\frac{\alpha}{8\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0^1(t))^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2. \tag{30}$$

Moreover, as t increases, L.H.S. in (30) increases, implying $\partial q_0^1(t)/\partial t<0$. At $t=t^1$, we have $q_0^1(t^1)=0$. This gives $t^1=\frac{\alpha}{8\gamma}\left[1-\frac{2\alpha^{1/2}}{3^{3/2}\gamma^{1/2}}\right]^2$. Since $t^1>0$, for $t>t^1$, we have $m_i^f>m_i^s$. For $t\le t^1$, we need to consider $q_0^1(t)$ also. Therefore, for $q_0>q_0^1(t)$, we have $m_i^f>m_i^s$, and $m_i^f\le m_i^s$ otherwise. This completes the proof. ■

Proof of Proposition 6

Consider part (i). At symmetric equilibrium, the platform's equilibrium profit for the business model j, $j=f,s$, can be written as $\pi_0^j=\frac{1}{2}\alpha^{1/2}(m_0^j)^{1/2}(1-\hat{c}^j)\left[1-\alpha^{1/2}(m^j)^{1/2}\right]$, $j=f,s$, where $\hat{c}^j$ is as defined in (14). From Proposition 5, we know that $m_0^f=m_0^s$, implying $\hat{c}^f=\hat{c}^s$. Therefore, using $\hat{c}^f=\hat{c}^s=c$, we get $\pi_0^f-\pi_0^s=\frac{1}{2}\alpha(m_0^f)^{1/2}(1-c)\left[(m^s)^{1/2}-(m^f)^{1/2}\right]$. From the preceding expression, we can see that platform's profit comparison depends on the extent of advertising competition, which, in turn, depends on the publishers' advertising levels. Hence, we obtain the same boundary condition for the platform's profit comparison, as defined in (30) in the previous proof, i.e., $q_0^1(t)$ with $q_0^1(t^1)=0$. Thus, for $t>t^1$, we have $m_i^f>m_i^s$, implying $\pi_0^f<\pi_0^s$. If $t\le t^1$, then for $q_0\ge q_0^1(t)$, $m_i^f\ge m_i^s$, implying $\pi_0^f\le\pi_0^s$, and $\pi_0^f>\pi_0^s$ otherwise.

Now, consider publishers' profits. Comparing Lemmas 3 and 4, if $\left[\frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}\right]\left[1-\frac{2\alpha^{1/2}(1+q_0)^{3/2}}{3^{3/2}\gamma^{1/2}}\right]>t/2$, then free-content model leads to higher profits for the publishers, and lower otherwise. This gives the same threshold $q_0^1(t)$, as defined in (30), and from it, we obtain the threshold t^1. Therefore, for $t>t^1$, free-content leads to lower profits, i.e., $\pi_i^f<\pi_i^s$. For $t\le t^1$, and $q_0\ge q_0^1(t)$, free-content leads to lower profits, i.e., $\pi_i^f\le\pi_i^s$ and higher otherwise.

Finally, consider part (ii). Using (24), and $\hat{x}=1/2$, $\hat{c}^f=\hat{c}^s=c$ and $m_0^f=m_0^s=m_0$, the change in social welfare can be written as $\Delta SW=SW^f-SW^s=[(m^s)^{1/2}-(m^f)^{1/2}][\gamma((m^s)^{1/2}+(m^f)^{1/2})-\alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))]$, where $\hat{c}^f=\hat{c}^s=c$ and $m_0=m_0^f=m_0$. Using ΔSW, we can obtain two thresholds $q_0^1(t)$ and $q_0^2(t)$, where $q_0^1(t)$ is as defined in (30), and $q_0^2(t)$ is obtained by equating $[\gamma((m^s)^{1/2}+(m^f)^{1/2})-\alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))]=0$. Using Lemmas 3 and 4, we obtain $q_0^2(t)$ as

$$\frac{t}{2}=\frac{\alpha^{1/2}(t^2)1/2}{2^{1/2}\gamma^{1/2}}\left[1-\frac{2\alpha^{1/2}(1+q_0^2(t))^{3/2}}{3^{3/2}\gamma^{1/2}}\right]-\frac{3\alpha}{16\gamma}\left[1-\frac{2\alpha^{1/2}(1+q_0^2(t))^{3/2}}{3^{3/2}\gamma^{1/2}}\right]^2, \tag{31}$$

such that for $q_0>q_0^2(t)$, $[\gamma((m^s)^{1/2}+(m^f)^{1/2})-\alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))]>0$ and <0 otherwise. Next, since $m^s=\widetilde{m}^s[1-\alpha^{1/2}(m_0^s)^{1/2}(1-c^s)]^2$, and m^f is independent of q_0, we can show that $[\gamma((m^s)^{1/2}+(m^f)^{1/2})-$

$\alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2})(1-c)]$ is increasing in q_0. This implies that as t increases, which in turn, increases m^f, it must be that $q_0^2(t)$ decreases. Next, at $q_0 = q_0^1(t)$, we have $(m^s)^{1/2} = (m^f)^{1/2}$ and $[\gamma((m^s)^{1/2} + (m^f)^{1/2}) - \alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))] > 0$, and since $1-\alpha^{1/2}(m_0)^{1/2}(1-c)$ is decreasing in q_0, we have $q_0^1(t) < q_0^2(t)$. Let $t = t^2$ be defined by $q_0^2(t^2) = 0$. Using (31), it is $\frac{t^2}{2} = \frac{\alpha^{1/2}(t^2)^{1/2}}{2^{1/2}\gamma^{1/2}}\left[1 - \frac{2\alpha^{1/2}}{3^{3/2}\gamma^{1/2}}\right] - \frac{3\alpha}{16\gamma}\left[1 - \frac{2\alpha^{1/2}}{3^{3/2}\gamma^{1/2}}\right]^2$. First, note that for $t > t^2$, $m^s < m^f$ and $[\gamma((m^s)^{1/2} + (m^f)^{1/2}) - \alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))] > 0$, implying $SW^f < SW^s$. Similarly, for $t < t^1$, and $q_0 \leq q_0^1(t)$, we have $m^s > m^f$ and $[\gamma((m^s)^{1/2} + (m^f)^{1/2}) - \alpha^{1/2}(1-\alpha^{1/2}(m_0)^{1/2}(1-c))] < 0$, implying $SW^f < SW^s$. Otherwise, $SW^f > SW^s$. This completes the proof. ■

Appendix D: Demand Expansion Effect

D.1. Estimation of Demand Functions

In the absence of the aggregator, only β users will incur search cost c while deciding which publisher to join. Let $\hat{x} \in [0,1]$ be the location of the user indifferent between joining publisher 1 or 2. Using (6) and following a similar approach as in Appendix B, we get the location of the indifferent user $\hat{x}$ as defined in (15) and thus, publishers' market shares are

$$\widetilde{N}_1 = \beta\hat{x} \text{ and } \widetilde{N}_2 = \beta(1-\hat{x}). \tag{32}$$

In the presence of the aggregator platform, we have two subsets of users: i) β users who decide whether to join only the platform or join platform and publisher 1 or join platform and publisher 2, and ii) $1-\beta$ users who decide which publisher 1 or 2 to join through the platform. First, consider β users. They can choose among the five options as defined in Section 3.5.1 Using (10)-(13), we can find cut-offs $\hat{c}$ and $\hat{x}$ as defined in (14) and (15). and thus, demand functions can be defined as

$$N_1' = \beta\hat{c} * \hat{x},\ N_2' = \beta\hat{c} * (1-\hat{x}),\ N_{01}' = \beta(1-\hat{c}) * \hat{x} \text{ and } N_{02}' = \beta(1-\hat{c}) * (1-\hat{x}). \tag{33}$$

Next, consider $1-\beta$ users. Since they will join one of the publishers through the aggregator, the effective cut-off is $\hat{x}$ as defined in (15), giving demand functions as

$$N_1'' = (1-\beta)\hat{x}, \text{ and } N_2'' = (1-\beta)(1-\hat{x}). \tag{34}$$

Next, consider the advertising side. In the absence of the aggregator. the advertiser's profit is $\widetilde{AP} = \alpha^{1/2}\widetilde{m}_1^{1/2}\widetilde{N}_1 + \alpha^{1/2}\widetilde{m}_2^{1/2}\widetilde{N}_2 - \widetilde{r}_1\widetilde{m}_1 - \widetilde{r}_2\widetilde{m}_2$. Using the preceding equation, we get the inverse advertising demand functions as

$$\widetilde{r}_1 = \frac{1}{2}\alpha^{1/2}\widetilde{m}_1^{-1/2}\widetilde{N}_1, \text{ and } \widetilde{r}_2 = \frac{1}{2}\alpha^{1/2}\widetilde{m}_2^{-1/2}\widetilde{N}_2, \tag{35}$$

where $\widetilde{N}_1$ and $\widetilde{N}_2$ are as defined by (32).

In the presence of the aggregator, the advertiser's profit can be written as

$$AP = \sum_{i=1}^{2} \alpha^{1/2} m_i^{1/2} N_i' + \alpha^{1/2} m_0^{1/2} [N_{01} + N_{02}] + \sum_{i=1}^{2} [1 - \alpha^{1/2} m_0^{1/2}] \alpha^{1/2} m_i^{1/2} N_{0i} - r_0 m_0 - \sum_{i=1}^{2} r_i m_i,$$

where N_1' and N_2' are as defined in (33), and $N_{01} = N_1'' + N_{01}'$ and $N_{02} = N_2'' + N_{02}'$. Using the preceding equation, the inverse advertising demand functions are

$$r_0 = \frac{1}{2} \alpha^{1/2} m_0^{-1/2} \left[\sum_{i=1}^{2} (N_{0i} - \alpha^{1/2} m_i^{1/2} N_{0i}) \right], \text{ and } r_i = \frac{1}{2} \alpha^{1/2} m_i^{-1/2} [(1 - \alpha^{1/2} m_0^{1/2}) N_{0i} + N_i'], \; i = 1, 2. \quad (36)$$

D.2. Optimal Profits and Consumer Surplus in the Absence of the Aggregator

First, consider free-content model. At stage 1, using the user demand functions defined by putting $\widetilde{p}_1 = \widetilde{p}_2 = 0$ in (32), and the inverse advertising demand functions given in (35), putting the values for them in the profit functions $\widetilde{\pi}_i = \widetilde{r}_i \widetilde{m}_i$, publisher i, $i = 1, 2$, chooses advertising quantity $\widetilde{m}_i$ to maximize its profits. Following a similar approach as under the proof of Lemma 1, we would obtain the advertising levels as defined in Lemma 1.[12] They are $\widetilde{m}_1^f = \widetilde{m}_2^f = \widetilde{m}^f = \frac{t}{2\gamma}$. This gives optimal symmetric publishers' profits, consumer surplus and advertisers' profits as

$$\widetilde{\pi}_1^f = \widetilde{\pi}_2^f = \widetilde{\pi}^f = \frac{\beta \alpha^{1/2} t^{1/2}}{2^{5/2} \gamma^{1/2}}, \; \widetilde{CS}^f = \beta \left[V - \frac{3t}{4} - 1 \right], \text{ and } \widetilde{AP}^f = \frac{\beta}{2} \alpha^{1/2} \widetilde{m}^f. \quad (37)$$

Next, consider the subscription-based model. At stage 1, using the user demand functions defined in (32), and the inverse advertising demand functions given in (35), putting the values for them in the profit functions $\widetilde{\pi}_i = \widetilde{r}_i \widetilde{m}_i + \widetilde{p}_i \widetilde{N}_i$, publisher i, $i = 1, 2$, chooses price $\widetilde{p}_i$ and advertising quantity $\widetilde{m}_i$ to maximize its profits. Using a similar approach as in the proof of Lemma 2, we obtain symmetric advertising levels as $\widetilde{m}^s = \frac{\alpha}{16\gamma^2}$, as defined in Lemma 2 and the symmetric equilibrium price as defined in Lemma 2. It is $\widetilde{p}^s = \frac{t}{2} - \frac{\alpha}{8\gamma}$. This gives optimal symmetric publishers' profits, consumer surplus, and advertisers' profits as

$$\widetilde{\pi}_1^s = \widetilde{\pi}_2^s = \widetilde{\pi}^s = \frac{\beta t}{2}, \; \widetilde{CS}^s = \beta \left[V - \frac{t}{4} - 1 - \gamma \widetilde{m}^s - \widetilde{p}^s \right], \text{ and } \widetilde{AP}^s = \frac{\beta}{2} \alpha^{1/2} \widetilde{m}^s. \quad (38)$$

D.3. Optimal Profits and Consumer Surplus in the Presence of the Aggregator

First, consider the free-content model. At stage 1, using the user demand functions defined by (33) and (34), and the inverse advertising demand functions defined in (36), and putting the values for them in the profit functions defined by (4) and (5), setting $p_i = 0$, platform and publisher i, $i = 1, 2$, choose advertising levels m_0 and $m_i, i = 1, 2$, to maximize their profits. Similar to the approach followed in proof of Lemma 3, we can

[12] It can be easily shown that the profit functions are strictly concave in advertising levels, implying that the solution constitutes a global maximum.

obtain the equilibrium advertising levels defined as $m_0^f = \frac{1+\beta q_0}{3\beta\gamma}$, and $m_1^f = m_2^f = m^f = \frac{t}{2\gamma}$.[13] Next, using the equilibrium advertising values in (14) and (15), we get $\hat{c} = c^f = (1-2\beta q_0)/3\gamma\beta$ and $\hat{x} = 1/2$. Finally, using the equilibrium advertising values and the values for $\hat{x}$ and $\hat{c}$, we obtain the equilibrium profits, as

$$\pi_0^f = \frac{1}{2}\alpha^{1/2}(m_0^f)^{1/2}(1-\beta c^f)[1-\alpha^{1/2}(m^f)^{1/2}] \text{ and } \pi_1^f = \pi_2^f = \pi^f = \left[\frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}\right]\left[1-\frac{2\alpha^{1/2}(1+\beta q_0)^{3/2}}{3^{3/2}\gamma^{1/2}\beta^{1/2}}\right]. \quad (39)$$

The consumer surplus and advertisers' profits are

$$CS^f = (1-\beta)\left[V - \frac{3t}{4} - 1 - \gamma m_0^f\right] + \beta\left[V - \frac{3t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0)\right], \text{ and} \quad (40)$$

$$AP^f = \frac{1}{2}\alpha^{1/2}(m^f)^{1/2} + \frac{1}{2}\alpha^{1/2}(m_0^f)^{1/2}(1-\beta c^f). \quad (41)$$

Next, consider the subscription-based model. At stage 1, using the user demand functions defined in (34) and (33), and the inverse advertising demand functions defined in (36), and putting the values for them in the profit functions defined by (4) and (5), the platform chooses advertising quantity m_0 and publisher i, $i = 1, 2$, chooses price p_i, and advertising quantity m_i to maximize their profits. Following a similar approach as in the proof of Lemma 4, we obtain equilibrium advertising levels as $m_0^s = \frac{1+\beta q_0}{3\beta\gamma}$, and $m_1^s = m_2^s = m^s = \frac{\alpha}{16\gamma^2}[1-(1-\beta c^s)(\alpha^{1/2}(m_0^s)^{1/2})]$, where $c^s = (1-2\beta q_0)/3\gamma\beta$. Using the advertising levels, the symmetric equilibrium price p^s is $p_1^s = p_2^s = p^s = t - \frac{\alpha}{8\gamma}[1-(1-\beta c^s)(\alpha^{1/2}(m_0^s)^{1/2})]^2$. The equilibrium profits are

$$\pi_0^s = \frac{1}{2}\alpha^{1/2}(m_0^s)^{1/2}(1-\beta c^s)[1-\alpha^{1/2}(m^s)^{1/2}], \text{ and } \pi_1^s = \pi_2^s = \pi^s = \frac{t}{2}. \quad (42)$$

The consumer surplus and advertisers' profits are

$$CS^s = (1-\beta)\left[V - \frac{t}{4} - 1 - \gamma m_0^s - \gamma m^s - p^s\right] + \beta\left[V - \frac{t}{4} - \frac{1}{18}(1-2q_0)(5+2q_0) - \gamma m^s - p^s\right], \text{ and} \quad (43)$$

$$AP^s = \frac{1}{2}\alpha^{1/2}(m^s)^{1/2} + \frac{1}{2}\alpha^{1/2}(m_0^s)^{1/2}(1-\beta c^s). \quad (44)$$

D.4. Proof of Proposition 7

First, consider the free-content model. Using the profit functions defined in (37) and (39), we get $\widetilde{\pi}^f > \pi^f$ if and only $\beta > 1 - \frac{2\alpha^{1/2}(1+\beta q_0)^{3/2}}{\beta^{1/2}\gamma^{1/2}3^{3/2}}$. It can be seen that if $\beta \to 0$ or $\beta \to 1$, the preceding inequality always holds. Whereas, for intermediate β, $\widetilde{\pi}^f > \pi^f$ if and only if $q_0 > q_0^f$, where

$$q_0^f = \frac{1}{\beta}\left[\frac{3\beta^{1/2}\gamma^{1/3}(1-\beta)^{1/2}}{2^{3/2}\alpha^{1/2}} - 1\right].$$

Now, consider consumer surplus. Comparing (37) and (40), we can see that $CS^f > \widetilde{CS}^f$, because $\frac{1}{18}(1-2q_0)(5+2q_0) < 1$ and additional $1-\beta$ users also get a positive surplus. Comparing (37) and (41), and given that $\widetilde{m}^f = m^f$, the change in advertisers' profits is positive, i.e., $AP^f > \widetilde{AP}^f$.

[13] Moreover, It is straightforward to show that the profit functions are concave in advertising levels. Hence, the solution constitutes a global maximum.

Next, consider the subscription-based model. Using (38) and (42), we can see that $\widetilde{\pi}^s > \pi^s$. Comparing (38) and (43), and given that $\frac{1}{18}(1-2q_0)(5+2q_0) < 1$ and $\widetilde{m}^s > m^s$, we can show that $CS^s > \widetilde{CS}^s$. Using (38) and (44), and the fact that $m^s = \widetilde{m}^s[1-\alpha^{1/2}(m_0^s)^{1/2}(1-\beta c^s)]$, the change in advertisers' profits can be written as $AP^s - \widetilde{AP}^s = \frac{1}{2}(1-\beta)\alpha^{1/2}(\widetilde{m}^s)^{1/2} + \frac{1}{2}\alpha^{1/2}(m^s)^{1/2}(1-\beta c^s)[1-\alpha^{1/2}(\widetilde{m}^s)^{1/2}] > 0$. This completes the proof. ■

Appendix E: Business Model Choice

First, consider the market without an aggregator platform. The equilibrium profits when both publishers choose free-content model or subscription-based model are as defined in Lemmas 1 and 2. Under an asymmetric business model regime, without loss of generality, suppose publisher 1 has a subscription-based model and publisher 2 has a free-content model. At stage 3, users decide whether to join publisher 1 or 2. We get user demand functions by putting $p_2 = 0$ in (8). At stage 2, we get the inverse advertising demand functions as defined in (18). At stage 1, using the user demand functions and the inverse advertising demand functions, putting the values for them in the profit functions defined as $\widetilde{\pi}_1 = \widetilde{r}_1\widetilde{m}_1 + \widetilde{p}_1\widetilde{N}_1$ and $\widetilde{\pi}_2 = \widetilde{r}_2\widetilde{m}_2$, publisher 1 chooses price $\widetilde{p}_1$ and advertising quantity $\widetilde{m}_1$, and publisher 2 chooses advertising quantity $\widetilde{m}_2$ to maximize its profits. The first-order necessary conditions of firms' optimization problem.[14] They are:

$$\frac{\partial\widetilde{\pi}_1}{\partial\widetilde{p}_1} = \widetilde{N}_1 + \left[\widetilde{p}_1 + \frac{1}{2}\alpha^{1/2}\widetilde{m}_1^{1/2}\right]\frac{\partial\widetilde{N}_1}{\partial\widetilde{p}_1} = 0, \text{ and } \frac{\partial\widetilde{\pi}_i}{\partial\widetilde{m}_i} = \frac{1}{4}\alpha^{1/2}\widetilde{m}_i^{-1/2}\widetilde{N}_i + \left[\frac{1}{2}\alpha^{1/2}\widetilde{m}_i^{1/2}\right]\frac{\partial\widetilde{N}_i}{\partial\widetilde{m}_i} \leq 0,\ i = 1,2. \quad (45)$$

Similar to the proof of Lemma 2, we can argue that $\frac{\partial\widetilde{\pi}_i}{\partial\widetilde{m}_i}$ defined in (45) would bind. Using $\frac{\partial\widetilde{\pi}_1}{\partial\widetilde{p}_1}$ together with $\frac{\partial\widetilde{\pi}_i}{\partial\widetilde{m}_i}$, we get $\frac{1}{4}\alpha\widetilde{m}_1^{-1/2} = \gamma$, $i = 1,2$. This gives $\widetilde{m}_1^a = \frac{\alpha}{16\gamma^2}$. Using it in (45), we get $\widetilde{p}_1^a = \frac{4t}{5} - \frac{\alpha}{10\gamma}$ and $\widetilde{m}_2^a = \frac{3t}{5\gamma} - \frac{\alpha}{80\gamma^2}$. Using equilibrium values we obtain demands as $\widetilde{N}_1^a = \frac{2}{5} + \frac{\alpha}{80t\gamma}$ and $\widetilde{N}_2^a = \frac{3}{5} - \frac{\alpha}{80t\gamma}$, and the equilibrium profits are

$$\widetilde{\pi}_1^a = \left[\frac{4t}{5} + \frac{\alpha}{40\gamma}\right]\left[\frac{2}{5} + \frac{\alpha}{80t\gamma}\right], \text{ and } \widetilde{\pi}_2^a = \frac{1}{2}\alpha^{1/2}\left[\frac{3t}{5\gamma} - \frac{\alpha}{80\gamma^2}\right]^{1/2}\left[\frac{3}{5} - \frac{\alpha}{80t\gamma}\right]. \quad (46)$$

Now, we examine the equilibrium business models. First, note that for $t \leq \frac{\alpha}{8\gamma}$, the equilibrium price will be zero (no publisher will be able to charge a positive price), and hence the only equilibrium possible is both publishers adopting the free-content model. Next, consider $t > \frac{\alpha}{8\gamma}$, and a publisher will be able to charge a positive price. The equilibrium business model of publisher i will depend on the rival j's choice. Suppose j selects subscription-based model. Then, publisher i will compare its profit from subscription-based model (defined in Lemma 2) and free-content model (defined by (46)). We find a threshold $\bar{t}$ defined by $\bar{t}/2 = \frac{1}{2\gamma^{1/2}}\alpha^{1/2}\bar{t}^{1/2}\left[\frac{3}{5} - \frac{\alpha}{80\bar{t}\gamma}\right]^{3/2}$ such that for $t > \bar{t}$, we have $t/2 > \frac{1}{2\gamma^{1/2}}\alpha^{1/2}t^{1/2}\left[\frac{3}{5} - \frac{\alpha}{80t\gamma}\right]^{3/2}$ and publisher i will choose subscription-based model and for $t \leq \bar{t}$ publisher i will choose free-content model. If rival j chooses a free-content model, then

[14] Note that second-order conditions are satisfied at the solutions. The details are available on request.

publisher i will compare its profit from subscription-based model (defined by (46)) and free-content model (defined by (1)). We find a threshold $\bar{\bar{t}}$ such that for $t > \bar{\bar{t}}$, we have $2t\left[\frac{2}{5} + \frac{\alpha}{80t\gamma}\right]^2 > \frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}$, and publisher i will choose subscription-based model, and for $t \leq \bar{\bar{t}}$ publisher i will choose free-content model.

Next, we compare $\alpha/8\gamma$, $\bar{t}$ and $\bar{\bar{t}}$ and it can be easily shown that $\alpha/8\gamma < \bar{t} < \bar{\bar{t}}$. This implies that i) for $t \leq \bar{t}$ both publishers will choose free-content model, ii) for $\bar{t} < t \leq \bar{\bar{t}}$, we have multiple equilibria with either both publishers choosing free-content model or subscription-based model, and iii) for $t > \bar{\bar{t}}$, both publishers choose subscription-based model. To proceed, we can use Pareto-dominant equilibrium to rule Nash equilibria which gives both publishers a lower payoff, and thus, for $\bar{t} < t \leq \bar{\bar{t}}$, we have both publishers choosing subscription-based model.

Next, consider market competition with platform introduction. We can obtain the demand functions by setting $p_2 = 0$ in (16)-(17). At stage 1, using the user demand functions, and the inverse advertising demand functions defined in (21), and putting the values for them in the profit functions defined by (4), and (5) for $p_2 = 0$, platform chooses advertising quantity m_0, publisher 1 chooses price p_1, and advertising quantity m_1, and publisher 2 chooses advertising quantity m_2 to maximize their profits. The first-order conditions are:

$$\frac{\partial \pi_0}{\partial m_0} = \frac{1}{4}\alpha^{1/2}m_0^{-1/2}[N_{01} + N_{02} - \alpha^{1/2}m_1^{1/2}N_{01} - \alpha^{1/2}m_2^{1/2}N_{02}]$$
$$+ \frac{1}{2}\alpha^{1/2}m_0^{1/2}[-\gamma\hat{x} - \gamma(1-\hat{x}) + \alpha^{1/2}m_1^{1/2}(\gamma\hat{x}) + \alpha^{1/2}m_2^{1/2}(\gamma(1-\hat{x}))] \leq 0, \quad (47)$$

$$\frac{\partial \pi_1}{\partial m_1} = [(1-\alpha^{1/2}m_0^{1/2})N_{01}]\frac{1}{4}\alpha^{1/2}m_1^{-1/2} - (1-\alpha^{1/2}m_0^{1/2})\frac{1}{2}\alpha^{1/2}m_1^{1/2}(1-\hat{c})\frac{\gamma}{2t}$$
$$- \frac{1}{2}\alpha^{1/2}m_1^{1/2}\hat{c}\frac{\gamma}{2t} + \frac{1}{4}\alpha^{1/2}m_1^{-1/2}N_1 - p_1\frac{\gamma}{2t} \leq 0, \quad (48)$$

$$\frac{\partial \pi_1}{\partial p_1} = -[(1-\alpha^{1/2}m_0^{1/2})(1-\hat{c})]\frac{1}{2}\alpha^{1/2}m_1^{1/2}\frac{1}{2t} - \frac{1}{2}\alpha^{1/2}m_1^{1/2}\hat{c}\frac{1}{2t} + N_{01} + N_1 - p_1\frac{1}{2t} = 0, \text{ and} \quad (49)$$

$$\frac{\partial \pi_2}{\partial m_2} = [(1-\alpha^{1/2}m_0^{1/2})N_{02}]\frac{1}{4}\alpha^{1/2}m_2^{-1/2} - (1-\alpha^{1/2}m_0^{1/2})\frac{1}{2}\alpha^{1/2}m_2^{1/2}(1-\hat{c})\frac{\gamma}{2t}$$
$$- \frac{1}{2}\alpha^{1/2}m_2^{1/2}\hat{c}\frac{\gamma}{2t} + \frac{1}{4}\alpha^{1/2}m_2^{-1/2}N_2 \leq 0. \quad (50)$$

where $\hat{c}$ and $\hat{x}$ are defined by (14) and (15) (by setting $p_2 = 0$). Using (48) and (49) together, we get equilibrium publisher 1's advertising level as $m_1^a = \frac{\alpha}{16\gamma^2}[(1-\alpha^{1/2}(m_0^f)^{1/2})(1-\hat{c}) + \hat{c}]^2$. Using (47), we get $m_0^a = \frac{1+q_0}{3\gamma}$, as defined in Lemma 4. Using m_0^a in (14), we get $\hat{c}^a = (1-2q_0)/3$. Using $\hat{c}^a$, we get publisher 1's advertising levels, as $m_1^a = \frac{\alpha}{16\gamma^2}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]^2$. Next, using m_1^a in (49) and (50), and solving them, we obtain

$p_1^a = \frac{4t}{5} - \frac{8\gamma m_1^a}{5}$ and $m_2^a = \frac{3t}{5\gamma} - \frac{m_1^a}{5}$. Now using these equilibrium values in (15), we obtain $x^a = \frac{2}{5} + \frac{\gamma m_1^a}{5t}$. The profits of the publishers are

$$\pi_1^a = \left[\frac{4t}{5} + \frac{\alpha}{40\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]\right]\left[\frac{2}{5} + \frac{\alpha}{80t\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]\right], \text{ and} \tag{51}$$

$$\pi_2^a = \frac{1}{2}\alpha^{1/2}\left[\frac{3t}{5\gamma} - \frac{\alpha}{80\gamma^2}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]\right]^{1/2}\left[\frac{3}{5} - \frac{\alpha}{80t\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]\right] * \left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]. \tag{52}$$

Now, we examine the equilibrium business models. First, note that for $t \leq \frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$, the equilibrium price will be zero (no publisher will be able to charge a positive price), and hence the only equilibrium possible is both publishers adopting the free-content model. Next, consider $t > \frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$, and a publisher will be able to charge a positive price. The equilibrium business of publisher i will depend on the rival j's choice. Suppose j selects subscription-based model. Then, publisher i will compare its profit from subscription-based mode (defined in Lemma 4) and free-content model (defined by (52)). Comparing Lemma 4 and (52), we find that if $t > \frac{\alpha}{\gamma}\left[\frac{3}{5} - \frac{\alpha}{80t\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]\right]^3 * \left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]^2$, publisher i will choose subscription-based model. We show that this inequality always hold for $t > \frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$. Let $f(q_0) = \left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$. Then at $t = \frac{\alpha}{8\gamma}f(q_0)^2$, the inequality becomes $\frac{\alpha}{8\gamma}f(q_0)^2 > \frac{\alpha}{\gamma}\left[\frac{3}{5} - \frac{\alpha}{80t\gamma}f(q_0)\right]^3 f(q_0)^2$. Further simplifying it, we get $\frac{1}{8} > \left[\frac{3}{5} - \frac{\alpha}{80t\gamma}f(q_0)\right]^3$, which always hold because $f(q_0) < 1/2$ given Assumptions 1 and 2. Therefore, publisher i will choose subscription-based model. If rival j chooses a free-content model, then publisher i will compare its profit from subscription-based model (defined by (51)) and free-content model (defined by Lemma 1). Comparing (51) and Lemma 1, we find that publisher i will choose subscription-based model if $2t\left[\frac{2}{5} + \frac{\alpha}{80t\gamma}f(q_0)\right]^2 > \frac{\alpha^{1/2}t^{1/2}}{2^{5/2}\gamma^{1/2}}f(q_0)$, where $f(q_0) = \left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$. Since $f(q_0) < 1/2$, the inequality will always hold and publisher i chooses subscription-based model. Therefore, for $t > \frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$, it is a dominant strategy for each publisher to choose subscription-based model. Moreover, note that the equality $t = \frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right]$ gives the same threshold q_0^1 as defined in (30).

Next, we compare business models with and without aggregator platform. First, it can be argued that $\frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right] < \bar{t}$. Therefore, for $\frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right] < t \leq \bar{t}$, there will be a shift in the business model of the publishers from both choosing free-content model without platform to both choosing subscription-based model with platform introduction. Since $\frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right] < \frac{\alpha}{8\gamma} < \bar{t}$, we have both publishers' profit reducing with platform introduction for $\frac{\alpha}{8\gamma}\left[1 - \frac{2\alpha^{1/2}}{\gamma^{1/2}}\left(\frac{1+q_0}{3}\right)^{1.5}\right] < t \leq \frac{\alpha}{8\gamma}$ and increasing otherwise. For $t < \frac{\alpha}{8\gamma}f(q_0)$, both publishers choose free-content model and for $t > \bar{t}$, both publishers choose subscription-based model with or without aggregator platform. For these cases, the comparison remains the same as discussed in the proof of Proposition 3. This completes the proof. ■