User-Generated Content, Social Media Bias and Slant Regulation (Working Paper, please do not cite !)

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Contents

Abstract

This paper applies a spatial model in a newspaper market where traditional print newspapers and online newspapers coexist. When readers are biased, and the newspaper firm slants news in a duopolistic market, more competition, for instance, by the introduction of a public-interest media firm will not decrease the media bias. However, it can reduce the price of the print newspaper, but will increase the subscription fee for an online newspaper. The slanting from the media outlets, and the "confirmatory bias" from the consumers' side, along with the user-generated content online, make this kind of government regulation much less effective. The results of the model also show that other regulatory policies, such as public pricing and tax, can decrease the level of media bias, especially the tax policy, which will also increase the social welfare.

Keywords: Social Media, Media Bias, User-Generated Content, Media Industry, Government Regulation.

JEL Codes: C1, D4, D8, L1

1 Introduction

Media industry, especially the newspaper industry, plays a vital role in our daily life. The "fourth estate", as a marketplace of ideas, helps facilitate the different points of views in the society to be heard by the citizens. Moreover, in terms of democratic society, a more diverse source of information is often recognized to help people to make better social and political decisions, and thus to push the democratic process forward(Anderson, Waldfogel, and Stromberg 2016).

The new technology has changed the "gate-keeping" function of the media. The rise of social media extends the traditional media where information is transferred only in one way to a marketplace where the exchange of ideas can be more prompt and effective.

However, more dissemination of fake information is also observed at the same time. According to Pew Research Center's investigation in 2000, about 64% of Americans think that social media can be harmful by misinformation, made-up news, hate speeches, extremism... [1]

We can also see the dark side of the social media by the increasing of discrimination and hating speeches, and the conspiracy theories online, which has catastrophic consequences: Facebook was used to provoke a surge in hate for a Muslim minority in Myanmar in 2018; last year in France, Samuel Paty, a middle-school teacher, was murdered by a teenager who even tweeted the victim's head afterwards; Facebook and Twitter banned Donald Trump's accounts after the riot on the U.S. Capitol of his supporters in 2021; the vast conspiracy theories about the vaccine during the COVID-19 crisis; the racist speech about the English football players during the UEFA Euro 2021 final ...[2]

[1] See Pew Research Center's report by Brooke Auxier in 2020: https://pewrsr.ch/3dsV7uR.

[2] https://www.economist.com/leaders/2020/10/22/how-to-deal-with-free-\

The dissemination of fake information, or misinformation, or fake news, is called "media bias" in economics. Media bias occurs when media can filter and bias information by deciding how much and which information to transmit to their consumers.(Mullainathan and Shleifer 2002)

Media bias can be classified into two categories according to the generated factors (Sutter 2000, Duggan and Martinelli 2011, Behringer and Filistrucchi 2015, Gentzkow, Shapiro, and Stone 2015, Lichter 2017):

One is the supply-side bias, also called "media slanting" (or "spin"), which refers to the bias from the side of the media firm. For example, the political or ideological bias of the journalists can impact the "tones" of the news report or the endorsement during the elections (Baron 2006, Puglisi, Snyder, et al. 2008, Kaplan and Mazurek 2018); the ownership is also proved to have an influence on the "filtering" content of a newspaper (Besley and Prat 2006, Prat and Strömberg 2013, Prat 2015, Prat 2018); others agents such as the politicians, the lobbing groups (Sobbrio 2011, Petrova 2012), or the advertisers (Gabszewicz, Laussel, and Sonnac 2002, Ellman and Germano 2009, Castañeda and C. Martinelli 2018) may also play a role in the selection of information favoring their own interests.

The other one is the demand-side bias, which arise from the demand side of the media market. Consumers' beliefs and psychology affect also their consuming behaviors and habits. Studies show that people prefer to information that confirms their prior beliefs and attitudes ("Confirmatory bias", see Rabin and Schrag 1999, Mullainathan and Shleifer 2005, Xiang and Sarvary 2007, Burke 2008, Garz et al. 2018). Besides, consumers tend to search for groups of people who share the same or similar opinions with them in the real life or on the internet (Sunstein 2006, Gentzkow and Shapiro 2010, Gentzkow and Shapiro 2011). The "filter bubbles" or "echo chamber" effects (Strömberg 2004, Chan and Suen 2008, Napoli 2018)

`speech-on-social-media`.

also enhance the confirmatory bias and thus ultimately promote the forming of extreme groups (Chan and Suen 2009, Luo 2017), especially on the social media.

Apparently, media bias is one kind of market failures in the media market. What's worse, the increasing social media platforms have obviously amplified the negative effects of media bias. Enormous studies have shown that the fake news on the social media has negative social and political effects in our daily life (Chiang and Knight 2011, Perego and Yuksel 2018, Allcott et al. 2020).

Government regulation such as public pricing on the media industry is not new[3], but most of the regulatory policies focus on the broadcasting in different countries.

The existing regulatory actions of social media concentrate on two branches:

One is economic regulation, such as the antitrust policies, the policies on mergers and competition. This branch of regulation is based on the theory that competition in the media market enables the diversity of information(Gentzkow and Shapiro 2006, Chan and Suen 2008, Anderson and McLaren 2012, Blasco and Sobrio 2012, Gentzkow, Shapiro, and Sinkinson 2014). More sources of information are proved, theoretically and empirically, to be beneficial for a more independent of media firms, a lower risk of suppression of information or censorship, a higher possibility of better-informed citizens.

This branch of regulation can be effective when the incumbent firm occupies a dominant position and there is only bias from the supply side. When the demand-side bias is taken into consideration, competition in the media market may lead to more biased news as the media firms are prone to cater to the consumers' extreme tastes of opinions (Gentzkow and Shapiro 2006, Gentzkow and Shapiro

[3] See, for example, Feldstein and Auerbach 1985's *Handbook of public economics* in Volume 1 Chapter 3.

2008), Becker et al. 2009, Germano and Meier 2013, Behringer and Filistrucchi 2015).

The other kind is the government regulation of media content. The self-regulation of social media firms, such as fact-checking and content moderating, are not sufficient when facing an enormous amount of information generated online every day. Therefore, the implement of legislation about content moderation online is reckoned necessary to restrict the dissemination of false information or dangerous speeches online such as racist, cyberbully, obscene, or terrorist content (Lo and Wei 2002, Stutzman and Hartzog 2012, Niklewicz 2017, Wardle and Derakhshan 2017, Yablon 2020). Many new social media laws have been adopted or under consideration worldwide in recent years. For example, German's Network Enforcement Act (or the "Facebook Law") in 2017, Australia's Criminal Code Amendment (Sharing of Abhorrent Violent Material) Act of 2019, the EU's Digital Services Act, the Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules 2021 in India, the Online Safety Bill 2021 in UK... [4]

Nevertheless, some argue that the regulation of online content violates the fundamental rights of of freedom of speech (Sander 2019, Svantesson 2019, Barrett 2020). It's also difficult to well define the frontier between censorship and some regulatory measures of online content (Germano and Meier 2013, Zankova and Dimitrov 2020, Samples 2019). The classification of "dangerous information" online is also ambiguous and without universal clear-out standards (Duarte, Llanso, and Loup 2018). Besides, the online content regulation can also increase the barriers of entry for media firms and impede competition in a counterproductive way (Evans and Schmalensee 2017, Langvardt 2017).

Therefore, this paper proposes three alternative economic regulatory policies of social media slant in the market of news. The model analyzes three kinds of

[4] see Beppu and Sampaio at http://www.latinlawyer.comforasummaryofthelaw

regulatory policies in a Duopolistic media market by competition (introducing a third public-interest firm), public pricing and tax. It shows that among the three regulatory policies, tax is the most effective one because it can both increase the social welfare and decrease the media slant level.

The paper is organized as follows: Section 2 presents the basic set-up of a model with relevant definitions and hypotheses; Section 3 analyzes the impact of introducing a public-interest media outlet; Section 4 explores the social welfare analysis as well as the effects of other two regulatory policies, i.e. public pricing and tax; Section 5 concludes.

2 The Model

2.1 The Newspaper Market

The payoff function of a newspaper firm depends on its revenues and costs. The profits of a media outlet come from the subscription fees of its readers, the advertising revenues, or the political rents. Here to simplify, suppose that the newspaper firm is a profit-maximizer and its only source of revenue is the subscription fees from its readers. In terms of the costs, generally, we consider the returns to scale in the traditional print newspaper industry is increasing, that is, as the production costs (collecting data and writing the news reporting) are fixed, the variable cost equals the reprinting and delivering an additional copy (Reddaway 1963, Rosse 1967).

Consider a market with two private newspaper firms, each has a print version and a digital version (a web version or an application, for example). Suppose that the cost of the production (and operation) of a print version is higher than a digital one, i.e. c for the print version and δc for the digital version, with $0 \leq \delta \leq 1$ as a discount variable. Consequently, the subscription fees of a digital version of a newspaper are also lower than the print one.

A mass of consumers can subscribe to either a print version or the digital version of a newspaper or both.[5] The difference (besides the subscription price and the cost) between the two choices is that the consumers can interact with each other on the web or through the applications by their comments or the discussions with each other, i.e. the user-generated content (UGC hereafter). Therefore, the online users' opinions are not only influenced by the newspapers' news reporting but also by the UGC online.

[5]That depends on whether the reader is single homing or multi-homing.

2.2 Model Set-up

The model's set-up is borrowed from the model of Esther Gal-or *et al.*'s model in 2013 (Yildirim, Gal-Or, and Geylani 2013) (hereinafter PET 2013) :

The role of a private newspaper firm i is to collect some data d about the state of the world t, and then to redact a piece of news n based on the data that it collects. The variable t is supposed to be normally distributed with mean as 0 and deviation as v_t, i.e. $t \sim N(0, v_t)$, where $1/v_t$ is the precision. The data received by a newspaper firm i is then $di = t + \varepsilon_i$, where ε_i is a random variable of a noise term, with $\varepsilon_i \sim N(0, v_\varepsilon))$. Therefore, the data d_i also follows normal distribution, i.e. $d_i \sim N(t, v_d)$, with $v_d = v_t + v_\varepsilon$.

The news reports n by a private newspaper firm i is a piece of processed information about the data received, that is, $n_i = d_i + s_i$, where s_i is a slant of the newspaper i's news reports. To simplify, suppose there are just two private newspaper firms in the market, i.e. i= {1, 2}. To distinguish the digital version and the print versions of a newspaper, suppose that n_i^o and n_i^p are the digital and print news respectively, and s_i^o and s_i^p their slants online and offline. Hence, $n_i^p = d_i + s_i^p$, and $n_i^o = d_i + s_i^o$.

The consumers, i.e. readers of the newspapers, are uniformly distributed between $[-b_o, b_o]$. The total number of readers is normalized to unity. A reader of type b has prior beliefs about the state of the world, and these beliefs follow normal distribution $N(b, v_t)$, that is, readers may have biased beliefs about the expected value of t. For instance, b can be the political opinions of a reader, with $b \in [-bo, 0)$ is the belief of a left-wing-party supporter, $b \in (0, bo]$ the belief of a right-wing-party supporter, and b=0 a neutralist's.

As in PET 2013, we suppose that:

For a rational and unbiased reader, his/her utility from reading a private newspaper i, i= {1, 2}, is:

$$U^r = \begin{cases} \overline{u} - \chi(s_i)^2 - P_i & \text{for the print version of a newspaper;} \\ \overline{u} - \chi({s_i}^o)^2 - K_i & \text{for the online version.}^{6} \end{cases} \tag{1}$$

For a biased reader, the bias comes from two sides:

- One called “media slant”, comes from the media’s side;

- The other is “confirmatory bias”, referring to the cognitive bias of readers who prefer the news that is more consistent with their prior beliefs. Suppose that both kinds of bias will decrease the readers’ utility.

Therefore, the net utility function of a biased reader of belief b from reading a private newspaper i, i= {1, 2}, is:

$$U_i^b = \begin{cases} U_i^p = \overline{u} - \chi(s_i)^2 - \varphi({n_i}^p - b)^2 - P_i & \text{for a print newspaper;} \\ U_i^o = \overline{u} - \chi({s_i}^o)^2 - \varphi({n_i}^o - b)^2 - K_i & \text{for an online one.} \end{cases} \tag{2}$$

Where $\overline{u}$ is the reservation price for the reader, $\chi > 0$ represents the preference of readers for reduced slanting news reports, $\varphi > 0$ calibrates readers’ preference for hearing confirming news, K_i and P_i are the subscription fees for a digital and print version of a newspaper i.

B_i is denoted as the reporting location of a newspaper i’s print version,for example, for a political newspaper, it represents its political stance during the elections.

And it satisfies the following conditions: $s_i(d_i) = \frac{\varphi}{(\chi+\varphi)}(B_i - d_i)$ and $s_i^o(d_i) = \frac{\varphi}{(\chi+\varphi)}(B_i^o - d_i)$, with $s_i(d_i)$ the slanting strategy of a print newspaper and $s_i^o(d_i)$ of a digital one, which implies that $n_i = \gamma_i B_i + (1-\gamma_i)d_i$, $n_i^o = \gamma_i B_i^o + (1-\gamma_i)d_i$, and $\gamma = \frac{\varphi}{(\chi+\varphi)}$.[7]

[7] This transformation is to simplify mathematical analysis and decision problems.

Assume also that newspaper 1 is located at the left of newspaper 2, i.e. $B_1 < B_2$.

For the position of the digital version of a private newspaper i $B_i^o = B_i + U[b_i^o]$, with $U[b_i^o]$ the "User-generated Content" by its online subscribers.

More precisely, assume that:

$$B_1^o = B_1 + \frac{(-b_o + \hat{b}_1)}{2} \quad \text{and} \quad B_2^o = B_2 + \frac{(b_o + \hat{b}_2)}{2} \tag{3}$$

That means the online position of a newspaper(e.g "the political opinions" of a digital newspaper) is a by-product, i.e. the average value, of the position of its print version (e.g "the political opinions" of a print newspaper) and UGC (e.g "political opinions of its online subscribers.)[8]

Accordingly, we suppose that because of the UGC, online readers' opinions are more extreme than the subscribers to the print ones.

As $E[d_i] = 0$, $var[d_i] = v_d$, by simple calculation, we have the expected prior utility of a reader of type b reading a newspaper i, $i = \{1, 2\}$:

$$E[U_i] = \begin{cases} E[U_i^p] = \overline{u} - \frac{\varphi^2}{(\chi+\varphi)}(B_i - b)^2 - \frac{\chi\varphi}{(\chi+\varphi)}(b^2 + v_d) - P_i \\ E[U_i^o] = \overline{u} - \frac{\varphi^2}{(\chi+\varphi)}(B_i^o - b)^2 - \frac{\chi\varphi}{(\chi+\varphi)}(b^2 + v_d) - K_i \end{cases} \quad {}^{9} \tag{4}$$

Where $E[U_i^p]$ stands for the expected utility of a reader b from reading the print version of newspaper i and $E[U_i^o]$ for the online one.

[8] It equals the case when $\alpha = 1$ in the paper of PET 2013. However, PET 2013 supposes that $0 < \alpha < 1$, here suppose that online readers have higher power than the newspaper itself in deciding the online variant of its position.

[9] This expected utility function is taken from the work of Mullainathan and Shleifer (2005), LEMMA A1 in Appendix, P1043-1044. The market for news. American Economic Review, 2005, vol. 95, no 4, p. 1031-1053.

2.3 A Public-interest Newspaper Firm as an Instrument for Regulation

Firstly, we will see the government regulation of the media market by introducing a third public media outlet without slant. What distinguishes a public media outlet from a private one is that the former has no slant from the media side. To simplify, suppose that the public media outlet has no digital version. The intuition behind is also simple: the UGC will generate more bias as the online sources of news are only hard to be verified its truth.

The idea of introducing a public firm as an instrument for government regulation is not new (see Cremer, Marchand, and Thisse 1989, Cremer, Marchand, and Thisse 1991), De Fraja and Delbono 1989, Grilo 1994, Guo and Lai 2015). This idea has been applied to many markets, but mostly to mixed oligopoly markets recently, such as the health and education market where both public and private services exist. This may also be the case of the media market as the ownership of the news media firms can be either public or private.

LEMMA 1. Suppose that there exists a public newspaper company, who always reports the "truth" with clarity and objectivity without any slanting news reports.[10] In the following part, the net utility function of a reader of belief b from reading a third public newspaper is noted as:

$$E[U_3] = \overline{u} - E[\varphi(d-b)^2] - P_3 = \overline{u} - \varphi(v_d + b^2) - P_3 \tag{5}$$

Proof. See appendices A.1.

[10] This is a strong hypothesis as this kind of newspaper is not realistic at all in real life. Not only because of the difficulty of being "objective" and "neutral" in reporting news, but also due to the impact of the public ownership on the news, especially in the elections in a democracy, or the existence of censorship in anarchy or a dictatorship.

3 The Equilibrium Analysis of a Location-price Game

3.1 Timing of the game:

- Stage 1: The newspapers announce their positions of the print version and then their slanting strategy. The third public newspaper without slant is introduced;
- Stage 2: The prices of the print and digital versions of three newspapers are then decided;
- Stage 3: The consumers will make their subscription decisions, the newspapers publish their news, and online readers can interact online with each other via UGC (if they choose the digital versions).

This location-price game will be solved by backward induction: firstly, we find the indifferent readers in stage 3, then we analyze the newspapers' price strategies in stage 2, and at last, we can see the newspapers' slanting strategies and reporting location choices.(See Figure 1)

3.2 The Market Shares

Denote their Market Shares as $(MS)_1^o, (MS)_1^p, (MS)_3, (MS)_2^p, (MS)_2^o$ respectively. As shown in Figure 2, we have:

- $(MS)_1^o = [-b_0, \hat{b}_1]$, is the market share for the online version of newspaper 1;
- $(MS)_1^p = [\hat{b}_1, \hat{b}_{ind}^1]$, is the market share for the print version of newspaper 1;

- $(MS)_3 = [\hat{b}^1_{ind}, \hat{b}^2_{ind}]$, is the market share for the (print) newspaper 3;
- $(MS)^p_2 = [\hat{b}^2_{ind}, \hat{b}_2]$, is the market share for the print version of newspaper 2;
- $(MS)^o_2 = [\hat{b}_2, b_0]$, is the market share for the online version of newspaper 2. [11]

First, we need to identify readers that are indifferent between the digital version and the print versions of the two private newspapers, noted $\hat{b}_i$: By $E[U^o_i] = E[U^p_i]$, $i = \{1, 2\}$, we have:

$$\hat{b}^*_i = \frac{((B^o_i)^* + B^*_i)}{2} + \frac{(\varphi + \chi)}{2\varphi^2}\frac{(P^*_i - K^*_i)}{(B^*_i - (B^o_i)^*)} \tag{6}$$

Substituting the B^o_i in equation (3) and into equation (6), we can get:[12]

$$\begin{cases} \hat{b}^*_1 = \frac{2B^*_1 + b_0 - 2\sqrt{\Delta_1}}{3}, \Delta_1 = (b_0 - B^*_1)^2 - 3(P^*_1 - K^*_1)\frac{(\varphi+\chi)}{\varphi^2}; \\ \hat{b}^*_2 = \frac{2B^*_2 - b_0 + 2\sqrt{\Delta_2}}{3}, \Delta_2 = (b_0 + B^*_2)^2 - 3(P^*_2 - K^*_2)\frac{(\varphi+\chi)}{\varphi^2}. \end{cases} \tag{7}$$

Then the entry of the third public firm will “steal” one part of the news market.

Denote b^i_{ind} as readers who are indifferent between the print versions of the two private newspapers and the public newspaper.

Using $E[U_3] = E[U^p_i]$, we have:

$$\begin{cases} (\hat{b}^1_{ind})^* = \frac{((B^*_1)^2 - v_d)}{2B^*_1} + \frac{(P^*_1 - P^*_3)}{2B^*_1}\frac{(\varphi+\chi)}{\varphi^2}; \\ (\hat{b}^2_{ind})^* = \frac{((B^*_2)^2 - v_d)}{2B^*_2} + \frac{(P^*_2 - P^*_3)}{2B^*_2}\frac{(\varphi+\chi)}{\varphi^2}. \end{cases} \tag{8}$$

[11] As mentioned before, the online readers are supposed to be more extreme, that’s why the online market shares approach more to the two ends of the distribution line.

[12] As B^o_i is also a function of $\hat{b}_i$.

3.3 The Equilibrium Price Choices

Given the locations of the indifferent readers in (7) and (8), newspapers make their price choices P_i and K_i to maximize their following profits functions:

$$\begin{cases} \Pi_1 = \frac{(\hat{b}_1+b_0)}{2b_0}(K_1 - c\delta) + \frac{(\hat{b}^1_{ind}-\hat{b}_1)}{2b_0}(P_1 - c); \\ \Pi_2 = \frac{(b_0-\hat{b}_2)}{2b_0}(K_2 - c\delta) + \frac{(\hat{b}_2-\hat{b}^2_{ind})}{2b_0}(P_2 - c); \\ \Pi_3 = \frac{(\hat{b}^2_{ind}-\hat{b}^1_{ind})}{2b_0}(P_3 - c). \end{cases} \tag{9}$$

The equilibrium print prices of the three newspapers are given by optimizing the profit functions (9) concerning P_i, and using the relationship between $\frac{\partial \hat{b}_i}{\partial P_i}$ and $\frac{\partial \hat{b}_i}{\partial K_i}$ derived from (6), and $\frac{\partial \hat{b}^i_{ind}}{\partial P_i}$ derived from (8), we get:

$$\begin{cases} {P_1}^* = c - \frac{\varphi^2}{(\varphi+\chi)}\left(\frac{(B_1^*)^2}{2} + b_0 B_1^* + \frac{B_1^* B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*}-\frac{1}{B_2^*})}\right); \\ {P_2}^* = c - \frac{\varphi^2}{(\varphi+\chi)}\left(\frac{(B_2^*)^2}{2} - b_0 B_2^* + \frac{B_1^* B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*}-\frac{1}{B_2^*})}\right); \\ {P_3}^* = c - \frac{\varphi^2}{(\varphi+\chi)}\left(\frac{B_1^* B_2^*}{3} + \frac{v_d}{3} + \frac{4b_0}{3}\frac{1}{(\frac{1}{B_1^*}-\frac{1}{B_2^*})}\right). \end{cases} \tag{10}$$

As for the equilibrium online prices, by optimizing again the profit functions (9) with respect to K_i and by using $\frac{\partial \hat{b}_i}{\partial K_i}$ derived from (7), we have:

$$\begin{cases} {K_1}^* - {P_1}^* = c(\delta - 1) - \frac{\varphi^2}{(\varphi+\chi)}\left((\hat{b}_1^*)^2 - (b_0)^2\right); \\ {K_2}^* - {P_2}^* = c(\delta - 1) - \frac{\varphi^2}{(\varphi+\chi)}\left((\hat{b}_2^*)^2 - (b_0)^2\right). \end{cases} \tag{11}$$

3.4 The Equilibrium Reporting Positions and Slanting Strategies

By plugging the equilibrium prices P^* and K^* into the profit functions Π_i and then by optimizing the new profit functions to the locations B_i, we get the following:

$$\begin{cases} \frac{\partial \Pi_1}{B_1^*} = \frac{1}{2b_0}\left(((K_1^* - c\delta) - (P_1^* - c)) \frac{\partial \hat{b}_1}{\partial B_1^*} + (P_1^* - c)(\frac{\partial \hat{b}_{ind}^1}{\partial B_1^*} + \frac{\partial \hat{b}_{ind}^1}{\partial P_3^*}\frac{\partial P_3^*}{\partial B_1^*}) \right); \\ \frac{\partial \Pi_2}{B_2^*} = \frac{1}{2b_0}\left((-(K_2^* - c\delta) + (P_2^* - c)) \frac{\partial \hat{b}_2}{\partial B_2^*} + (P_2^* - c)(\frac{\partial \hat{b}_{ind}^2}{\partial B_2^*} + \frac{\partial \hat{b}_{ind}^2}{\partial P_3^*}\frac{\partial P_3^*}{\partial B_2^*}) \right). \end{cases} \tag{12}$$

Taking B_2 for example, finally, we get:

$$\frac{\left((\hat{b}_2^*)^2 - (b_0)^2\right)((\hat{b}_2^*)^2 + b_0)}{(b_0 + 3\hat{b}_2^* - 2B_2^*)} + \left(\frac{(B_2^*)^2}{2} - b_0 B_2^* + \frac{B_1^* B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*} - \frac{1}{B_2^*})} \right) \left(\frac{1}{4} + \frac{v_d}{6(B_2^*)^2} - \frac{b_0 B_1^*}{3(B_2^* - B_1^*)^2} - \frac{2b_0 (B_1^*)^2}{3B_2^*(B_2^* - B_1^*)^2} + \frac{B_1^*}{6B_2^*} \right) = 0 \tag{13}$$

To compare the equilibrium results with those in the model of PET 2013, we need to simplify the above formulas by only considering the symmetric solutions hereinafter,[13] that is, suppose that $(-B_1)^* = B_2{}^* = B^*, (-B_1^o)^* = (B_2^o)^* = (B^o)^*, (-\hat{b}_1)^* = (\hat{b}_2)^* = \hat{b}^*, (-\hat{b}_{ind}^1)^* = (\hat{b}_{ind}^2)^* = \hat{b}_{ind}^*$, and suppose also that the costs of running a print and a digital newspaper equal to 0, which leads to the following results at equilibrium:

1) The equilibrium positions of indifferent readers and the equilibrium prices

[13] The asymmetric solutions are either too complicated or may not exist at all.

are:

$$\begin{cases} -(\hat{b}^1_{ind})^* = (\hat{b}^2_{ind})^* = \hat{b}^*_{ind} = \frac{(B^*+2b_0-v_d)}{6}; \\ -\hat{b}^*_1 = \hat{b}^*_2 = \hat{b}^* = \frac{2B^*-b_0+2\sqrt{\Delta}}{3}, \Delta = (b_0+B^*)^2 - 3\left((\hat{b}^*)^2 - (b_0)^2\right); \\ P^*_1 = P^*_2 = P^* = \frac{-\varphi^2}{3(\varphi+\chi)}\left((B^*)^2 - 4b_0 B^* - v_d\right); \\ P^*_3 = \frac{\varphi^2}{3(\varphi+\chi)}\left((B^*)^2 + 2b_0 B^* - v_d\right); \\ P^*_1 - K^*_1 = P^*_2 - K^*_2 = \frac{\varphi^2}{(\varphi+\chi)}\left((\hat{b}^*)^2 - (b_0)^2\right). \end{cases} \tag{14}$$

2) And the equilibrium reporting position B^* satisfies:

$$\begin{aligned} &\frac{2((\hat{b}^*)^2-(b_0)^2)((\hat{b}^*)^2+b_0)}{(b_0+3(\hat{b}^*)^2-2B^*)} + \\ &\frac{1}{36}\left((B^*)^2 - 5b_0 B^* + 4(b_0)^2 + v_d - \frac{7b_0 v_d}{B^*} - \frac{2(v_d)^2}{(B^*)^2}\right) = 0 \end{aligned} \tag{15}$$

LEMMA 2. To support the market segmentation in Figure 2 at the symmetric equilibrium, and to guarantee a non-negative price, the following conditions need to be satisfied:[14]

$$B^* \in [-b_0 + \sqrt{(b_0)^2 + v_d}, 2b_0 + \sqrt{4(b_0)^2 + v_d}] \quad \text{and} \quad B^* > \frac{(\hat{b}^*)^2}{2b_0} \tag{16}$$

Recall that the equilibrium prices without slant regulation in the model of PET 2013 are:[15]

$$\begin{cases} P^E_1 = P^E_2 = \frac{2\varphi^2}{(\varphi+\chi)} b_0 B^E; \\ K^E_1 - P^E_1 = K^E_2 - P^E_2 = \frac{\varphi^2}{2(\varphi+\chi)}(b_0 - \hat{b}^E)(b_0 + 3\hat{b}^E - 2B^E) \end{cases} \tag{17}$$

Proof. See appendices A.2.

[14]These are necessary but not sufficient conditions.

[15]To better compare the two equilibrium results, we only consider the symmetric scenario, with zero costs of production, and $\alpha = 1$ based on the model of PET 2013.

3.5 The Effects of Slant Regulation on Equilibrium Prices

Now we can observe the following results:

Proposition 1.

i). $P_i^E > P_i^*$, $i=\{1, 2\}$, and $P_i^E > P_3^*$. Regulation by introducing a third public newspaper firm without slant will reduce the equilibrium prices of the print versions of the two private newspapers.

ii). $P_3^* < P^*$ when $({B_*}^2 - v_d - b_0 B^*) < 0$. As for the price of the public no-slanting newspaper, it's not necessarily lower than the two private ones.

Proof. See appendices A.5.1.

Apparently, the new entry of the public newspaper in the media market decreases the price of the newspaper. As the three newspapers are all profit-maximizers, the effects of competition on equilibrium prices in a media market are similar to other markets.

However, a public newspaper may be more expensive than a private one under some conditions. The institution behind this scenario is quite simple:

i). The lack of (economic) profits from online versions to finance the public newspaper forces it to increase the price to make ends meets;

ii). The high "quality" of the news of the public firm, i.e. news without slanting, increases its "product differentiation", and therefore can release some pressure from the fierce price competition.

Proposition 2.

i). $K_i^* > P_i^*$, that is, after slant regulation, a digital version of a newspaper is more expensive than its print version.

ii). $K_i^* > K_i^E$, i.e. the subscription fees for digital newspapers become higher under slant regulation.

Proof. See appendices A.5.2.

The slant regulation by introducing a public newspaper firm without bias has changed the composition of the price, especially that of a digital version. After the entry of a third newspaper firm, the digital subscription fee is much less affected by the position of the print version, as there is no more "B^*" in the $(P_i - K_i)$ of (14) compared with that in (17).

This result corresponds to the assumption that the Internet (UGC) has higher power than the newspaper itself in deciding the online variant of its position at the beginning of this paper.[16] Once the UGC has a higher discretion in deciding the position of a digital newspaper, it's no longer a by-product of its print version, but more like a new differentiated product.

It may be due to a "Daily-me" effect (See Sunstein 2001, Perego and Yuksel 2018), where UGC helps every user online find information that is more consistent with his/her prior beliefs or even news reports that cater to his/her beliefs, especially for the extremists who can hardly get approved in their "offline" life. Therefore, for this segmentation of consumers, they are willing to pay higher prices to digital newspapers.

This also corresponds to the characteristics of UGC : for an online newspaper and its online readers, they try to get higher profits not only by competing on prices but also by drawing the "attention" of consumers (the "competition for

[16]See footnote 4 in section 3.

attention" effet) (See Bordalo, Gennaioli, and Shleifer 2016, Chen and Suen 2018, Galperti and Trevino 2018, Chen and Suen 2019). For example, the more an article is transferred online and is clicked by online readers, the more it becomes popular and gets more readers, no matter how credible it is. [17]

3.6 The Effects of Slant Regulation on Newspapers' Reporting Positions and Slanting Strategies

In terms of the reporting positions and the slanting strategies at equilibrium. We can see that it's hard to find a simple and direct solution. However, we can at least rule out some hypotheses and still draw some interesting conclusions.

Rewrite the (15) as two parts:

$$\begin{aligned} (A) &= \frac{2((\hat{b}^*)^2 - (b_0)^2)((\hat{b}^*)^2 + b_0)}{(b_0 + 3(\hat{b}^*)^2 - 2B^*)} \\ (B) &= \frac{1}{36}\left((B^*)^2 - 5b_0B^* + 4(b_0)^2 + v_d - \frac{7b_0v_d}{B^*} - \frac{2(v_d)^2}{(B^*)^2}\right) \end{aligned} \tag{18}$$

LEMMA 3.

i) As for the former part (A):

$$\begin{cases} (A) > 0 & \text{when} \quad B^* > \frac{3((\hat{b}_2^*)^2+b_0)}{2}; \\ (A) \leq 0 & \text{otherwise.} \end{cases}$$

ii) Solutions for the second part of (B) = 0 are (see Figure 3):

$$\begin{cases} B_1 = \frac{b_0 - \sqrt{(b_0)^2 - 8v_d}}{2}, B_2 = \frac{b_0 + \sqrt{(b_0)^2 - 8v_d}}{2}, \\ B_3 = 2b_0 - \sqrt{4(b_0)^2 + v_d}, B_4 = 2b_0 + \sqrt{4(b_0)^2 + v_d}. \end{cases} \tag{19}$$

[17] Sometimes fake news can get much more attention than the true news, as the former always has a more "eye-catching" title and more astonishing contents.

iii) The conditions satisfying the symmetric assumptions, i.e. $(-B_1)^* = {B_2}^* = B^*, B_1 < B_2, v_d = {\delta_d}^2 > 0$, are:

$$(2b_0 - \sqrt{4(b_0)^2 + v_d}) < 0 < (-b_0 + \sqrt{(b_0)^2 + v_d}) < (2b_0 + \sqrt{4(b_0)^2 + v_d}) \quad (20)$$

Proof. See appendices A.3.

Combined with the conditions in LEMMA 2, we can draw the following conclusions:

Proposition 3.

i) When $(b_2^*)^2 \geq \frac{2}{3}b_0 \geq \frac{1}{3}$, there exists an equilibrium reporting position for the private newspapers denoted as B^*, taking the newspaper 2 for example, satisfying the conditions in equation (15) and the conditions in LEMMA 2.

ii) And this equilibrium reporting position is more extreme than when there are only print newspapers in the news market in the model of MS 2005, i.e. $B^* > \frac{3}{2}b_0$. Hence, it's also more extreme than the equilibrium level without slant regulation (B^E) in the model of PET 2013.

Proof. See appendices A.6.

Under slanting regulation, the equilibrium slanting level of the (private) newspapers may be higher than the one without slanting regulation. The two private newspapers may offer more extreme news when a public unbiased newspaper is introduced compared to the scenario when there is no slant regulation in the newspaper market (PET 2013) or the case when there are only print versions of newspapers in the news market (MS 2005).

As we can see from Figure 3, the equilibrium slanting level increases with the value of Vd and bo, i.e. the variance of the date and the extremist opinions of its readers. The more variant data the newspapers collect, the more exogenous readers are, the government regulation by introducing a public newspaper without bias has less effect on reducing the slanting level of the private newspapers.

4 Implementation of other Regulatory Policies

We have shown that the government regulation of a Duopolistic newspaper market by introducing a third public newspaper without slant is not as effective as we thought. Now we turn to other alternative regulatory policies such as price regulation and tax policy, to examine their effects on reducing the media bias.

We will return to the original model of PET 2013 in the following analyses (see Figure 4), but to simplify, we still assume that the costs are zero.

4.1 Social Welfare

LEMMA 4. Define the social welfare of the Duopolistic market in PET 2013 as the total surplus of the newspaper firms and their readers:

$$SW = \int_{-b_0}^{\hat{b}_1} \frac{U_1^0}{2b_0} db + \int_{\hat{b}_1}^{b_{ind}} \frac{U_1^p}{2b_0} db + \int_{b_{ind}}^{\hat{b}_2} \frac{U_2^p}{2b_0} db + \int_{\hat{b}_2}^{b_0} \frac{U_2^0}{2b_0} db + \Pi_1 + \Pi_2$$

$$= \overline{u} - \frac{1}{2b_0} \frac{\varphi^2}{(\varphi+\chi)} \begin{pmatrix} \int_{-b_0}^{\hat{b}_1} (B_1^o - b)^2 db + \int_{\hat{b}_1}^{b_{ind}} (B_1 - b)^2 db + \\ \int_{b_{ind}}^{\hat{b}_2} (B_2 - b)^2 db + \int_{\hat{b}_2}^{b_0} (B_2^o - b)^2 db \end{pmatrix} - \frac{2\chi\varphi}{(\varphi+\chi)} \left(\frac{(b_0)^3}{3} + v_d b_0 \right) \quad (21)$$

Optimizing the above equation with respect to the (print and digital) reporting locations of newspaper i separately, we get:

$$\begin{cases} B_1^0 = \frac{(\hat{b}_1 - b_0)}{2}; B_1 = \frac{(b_{ind} + \hat{b}_1)}{2}; \\ B_2 = \frac{(b_{ind} + \hat{b}_2)}{2}; B_2^0 = \frac{(b_0 + \hat{b}_2)}{2} \end{cases} \tag{22}$$

Proof. See appendices A.4.

As shown in Figure 5a and Figure 5b, The socially optimal slanting is the mean value of the opinions of readers in the print or digital market.

However, the optimal (first-best) reporting locations can be different according the value of α.[18]

1) **Scenario 1.**

When $0 < \alpha < 1$, i.e. the online variant of the online news reports are not totally decided by UGC, we get:

Proposition 4. As shown in Figure 5a and Figure 5b, in the original model of PET 2013:

i) The symmetric solutions for optimal (first-best) reporting locations are : $(B_1^0, B_1, B_2, B_2^0) = \left(\frac{(-\hat{b}-b_0)}{2}, \frac{-\hat{b}}{2}, \frac{\hat{b}}{2}, \frac{(\hat{b}+b_0)}{2}\right)$, with $(-\hat{b}_1) = \hat{b}_2 = \hat{b}$.

ii) And the optimal level of slants is:

$$(s_1^0(d_1), s_1(d_1), s_2(d_2), s_2^0(d_2))^{SW} =$$

$$\left(\frac{-\varphi}{(\varphi+\chi)}(\hat{b}+b_0+d_1), \frac{-\varphi}{(\varphi+\chi)}(\frac{\hat{b}}{2}+d_1), \frac{\varphi}{(\varphi+\chi)}(\frac{\hat{b}}{2}-d_2), \frac{\varphi}{(\varphi+\chi)}(\frac{(\hat{b}+b_0)}{2}-d_2)\right).$$

Corollary 1. Furthermore, we have:

$$-B_1^{(sw)} = B_2^{(sw)} = \frac{\hat{b}}{2} = \frac{(\alpha-1)}{2\alpha}b_0, -(B_1^o)^{(sw)} = (B_2^o)^{(sw)} = \frac{\hat{b}}{2(1-\alpha)} = \frac{1}{2\alpha}b_0.$$

[18] For more discussions, please consult the part "A.4 Proof of LEMMA 4" in the appendices.

Remarks:

i)$\frac{\partial B_i}{\partial \alpha} < 0, \frac{\partial B_i^o}{\partial \alpha} < 0$. The relative weight of newspapers' reporting positions to the most extremist readers' opinions decrease with α. The more decisive the UGC plays in the role of the online content of a newspaper, the more extreme the reporting positions of a (print and digital) newspaper get.

ii) When $\alpha < \frac{1}{4}$, the (print and digital) newspapers' reporting opinions are more extreme than when there are only print newspapers in the news market, i.e. $B^{(sw)} > \frac{3}{2}b_0$;

iii) $B_i^o > B_i$. The digital version of a newspaper are always more extreme than the print ones.

Proof. See appendices A.7.1.

2) **Scenario 2:** When $\alpha = 1$, i.e. UGC's effect on the online news reports attends to its maximal level, we can observe that:

Proposition 5.

i) The symmetric solutions for the optimal (first-best) reporting locations are: $(B_1^0, B_1, B_2, B_2^0) = (\frac{-b_0}{2}, 0, 0, \frac{b_0}{2})$;

ii) And the optimal level of slants in this scenario is:

$$(s_1^0(d_1), s_1(d_1), s_2(d_2), s_2^0(d_2))^{SW} = \left(\frac{-\varphi}{(\varphi+\chi)}(\frac{b_0}{2}+d_1), \frac{-\varphi d_1}{(\varphi+\chi)}, \frac{-\varphi d_2}{(\varphi+\chi)}, \frac{\varphi}{(\varphi+\chi)}(\frac{b_0}{2}-d_2) \right).$$

iii) The socially optimal payoffs for the two private newspaper firms are: $(\Pi_1, \Pi_2)^{SW} = (\frac{K_1}{2}, \frac{K_2}{2})$.

Proof. See appendices A.7.2.

Under the assumption of $\alpha = 1$, that is, when the UGC plays a more important role than the newspaper itself in deciding the reporting position of its digital version, e.g. left or right in the election, when social welfare is maximized, the news market is occupied by the social media (the digital versions of the two newspapers). The “traditional” print newspapers are “crowded out” of the market by the social media.Moreover, as we suppose that the costs of production are zero, the socially optimal payoffs of the two newspapers depend only on the price of their digital versions.

The optimal reporting locations for the two digital versions of newspapers are the same. The socially optimal reporting strategy corresponds to the “Minimum Differentiation Principle” in Hotelling’s model (Hotelling 1929).

Moreover, the optimal slanting level for a traditional print newspaper depends on the data it collects (d_i), the degree of its readers’ preference for confirming news (φ) and their dislike for slanting news (χ).

Social welfare is maximized when social media expresses more diverse but less extreme opinions. The optimal slanting level for a digital newspaper depends not only on its data source (d_i), on its readers’ preference for ”confirmatory news” (φ) and dislike for slanting news (χ), but also on the extremist readers’ opinions (b_0).[19] The more extreme readers’ opinions are, the higher the level of the socially optimal slanting. This finding is consistent with the literature shows that the ”echo chamber” Effect, the ”filter bubble” effect, ”Dunning–Kruger” effect...

[19]That is also due to the assumption that the UGC’s effect attends to its maximal level, i.e. $\alpha = 1$.

4.2 Price Regulation

We now turn to an other regulatory policy, i.e. price regulation, and see its effects on decreasing the level of slanting in the media market.

Suppose that the government sets a unique price $\overline{P}$ for the print newspapers and $\overline{K}$ for the digital versions, and again, we only see the symmetric solutions when the costs are 0. The new payoff functions for the two private newspapers are:

$$\begin{cases} \overline{\Pi}_1 = \frac{(\hat{b}_1+b_0)}{2b_0}\overline{K} + \frac{(b_{ind}-\hat{b}_1)\overline{P}}{2b_0} = \frac{\overline{P}}{2b_0}(b_{ind} + \frac{b_0}{2} - \frac{\hat{b}_1}{2}); \\ \overline{\Pi}_2 = \frac{(b_0-\hat{b}_2)}{2b_0}\overline{K} + \frac{(\hat{b}_2-b_{ind})}{2b_0}\overline{P} = \frac{\overline{P}}{2b_0}(-b_{ind} + \frac{b_0}{2} + \frac{\hat{b}_2}{2}); \\ \overline{P} = 2\overline{K}. \end{cases}$$

By simple calculations, we observe that:

$$\frac{\partial\overline{\Pi}_1}{B_1} > 0, \frac{\partial\overline{\Pi}_2}{B_2} < 0, \frac{\partial\overline{\Pi}_1}{B_1^0} < 0, \frac{\partial\overline{\Pi}_2}{B_2^0} > 0.$$

Therefore we can get the following results:

Proposition 6. Under price regulation:

i) The equilibrium reporting positions are $(\overline{B}_1^0, \overline{B}_1, \overline{B}_2, \overline{B}_2^0) = (-b_0, 0, 0, b_0)$;

ii) The slanting strategies are:

$$(\overline{s}_1^0(d_1), \overline{s}_1(d_1), \overline{s}_2(d_2), \overline{s}_2^0(d_2)) = \left(\frac{-\varphi}{(\varphi+\chi)}(b_0+d_1), \frac{-\varphi d_1}{(\varphi+\chi)}, \frac{-\varphi d_2}{(\varphi+\chi)}, \frac{\varphi}{(\varphi+\chi)}(b_0-d_2)\right).$$

iii) When the regulated price of the print newspapers is twice that of the digital versions, i.e. when $\overline{P} = 2\overline{K}$, the two newspapers can maximize their profits, which are:

$$\begin{cases} \overline{\Pi}_1 = \frac{\overline{P}}{2b_0}\frac{(b_0-\hat{b}_1)}{2} = \frac{3}{4}\overline{P} - \frac{(\varphi+\chi)}{8(b_0{}^2)\varphi^2}(\overline{P})^2; \\ \overline{\Pi}_2 = \frac{\overline{P}}{2b_0}\frac{(b_0+\hat{b}_2)}{2} = \frac{1}{2}\overline{P} - \frac{(\varphi+\chi)}{8(b_0{}^2)\varphi^2}(\overline{P})^2. \end{cases}$$

We can see from the above functions that the only possibility to guarantee the non-negative payoffs for the two private newspapers are when $\overline{P} = 2\overline{K} = 0$.

Therefore, under price regulation, the two private newspapers get 0 profits at the equilibrium.

Proof. See appendices A.8.

Compared to the social optimal situation, the price regulation has decreased the slanting level of a print newspaper, while the slant level of the digital versions augments compared to the socially optimal slanting level.

The market share for print newspapers decreases to zero, i.e. the news market is occupied by social media, and the traditional print newspapers are "crowded out". As the regulated prices for the two kinds of newspapers are all 0, there is no longer any profits from publishing a print newspaper. However, under the assumption of zero costs, online newspapers still exist.

This may be, again, due to the "competition for attention" effect. Even when there is no longer pecuniary motivation to publish a print newspaper, a digital newspaper can still draw the attention of readers, make them interact with each other, generate online content (UGC), and may therefore gain a reputation (well, a good one or a bad one...) for the newspaper firms. In this case, the culture, social and political significations of a newspaper for its readers are much more important than its economic contributions to the society.

4.3 Tax for fake news

Consider the government will impose a tax for fake news, named $\boldsymbol{T}$. The payoffs of the two private newspapers then turn to:

$$\Pi_1^T = \frac{(\hat{b}_1 + b_0)\overline{K}}{2b_0} + \frac{(b_{ind} - \hat{b}_1)\overline{P}}{2b_0} - \frac{T\varphi^2}{(\varphi + \chi)^2}\left((B_1)^2 + (B_1^0)^2\right);$$

$$\Pi_2^T = \frac{(b_0 - \hat{b}_2)\overline{K}}{2b_0} + \frac{(\hat{b}_2 - b_{ind})\overline{P}}{2b_0} - \frac{T\varphi^2}{(\varphi + \chi)^2}\left((B_2)^2 + (B_2^0)^2\right).$$

Optimizing the payoff functions with respect to P_i, we can get the same results as in the model of PET 2013.[20] Then replace the equilibrium prices into the payoff function, and optimize the news payoff functions with respect to B_i, we can draw the following conclusions:

Proposition 7. Under tax regulation:

i) The equilibrium reporting positions are:

$$-(B_1)^T = (B_2)^T = B^T = \frac{\left((\hat{b}_2)^2 + (b_0)^2\right)}{b_0} \frac{1}{(\frac{4T}{(\varphi+\chi)} + \frac{1}{3})}$$

$$-(B_1^0)^T = (B_2^0)^T = (B^0)^T = \frac{\left((\hat{b}_2)^2 + (b_0)^2\right)}{b_0} \frac{1}{(\frac{4T}{(\varphi+\chi)} + \frac{1}{3})} + \frac{(b_0 + \hat{b})}{2}.$$

The equilibrium reporting positions of the newspapers (print and digital versions) get extreme when the tax level for slanting increases.

ii) The prices at equilibrium are:

$$P_1{}^T = P_2^T = P^T = 2b_0 B \frac{\varphi^2}{(\varphi+\chi)} = \frac{\varphi^2}{(\varphi+\chi)} \frac{\left((\hat{b})^2 + (b_0)^2\right)}{(2T + \frac{1}{6})};$$

$$K_1{}^T = K_2^T = K^T = \frac{\varphi^2}{(\varphi+\chi)} \left(\frac{(b_0 + 3\hat{b})(b_0 - \hat{b})}{2} + \frac{3\left((\hat{b})^2 + (b_0)^2\right)(\hat{b} + b_0)}{b_0(12T+1)} \right).$$

The equilibrium (print and digital) prices of the newspapers increase with the level of slanting but decrease with tax level (that is so wired).

Proof. See appendices A.9.

[20] See the equation (11) in the model of PET 2013, Yildirim, Gal-Or, and Geylani: User-Generated Content and Bias in News Media, Management Science 59(12), pp.2660.

4.4 The Average Bias level

Define the average bias level (**ARB**) for the heterogeneous readers as:[21]

$$ARB = \int_b E_d[(n_i - d_i)^2] = \frac{\varphi^2}{2b_0(\varphi+\chi)^2}\Big((\hat{b}_1 + b_0)(B_1^0)^2 + (b_{ind} - \hat{b}_1)(B_1)^2 + (\hat{b}_2 - b_{ind})(B_2)^2 + (b_0 - \hat{b}_2)(B_2^0)^2\Big)$$

We can then compare the average bias level under the above three different regulation policies:[22]

1) Social optimally, $(-B_1^0, B_1, B_2, B_2^0) = (-\frac{b_0}{2}, 0, 0, \frac{b_0}{2})$, so:

$$(ARB)^{(SW)} = \frac{\varphi^2}{(\varphi+\chi)^2}\frac{b_0(b_0 - \hat{b})}{4}$$

2) Under price regulation, $(-B_1^0, B_1, B_2, B_2^0) = (-b_0, 0, 0, b_0)$, so:

$$(ARB)^{(PR)} = \frac{\varphi^2}{(\varphi+\chi)^2} b_0(b_0 - \hat{b})$$

3) Under tax regulation:

$$(ARB)^T = \frac{\varphi^2}{(\varphi+\chi)^2}\left((B^T)^2 + \frac{((b_0)^2 - (\hat{b})^2)}{b_0}B^T + \frac{(b_0 - \hat{b})(b_0 + \hat{b})^2}{4b_0}\right)$$

Further, under extremest conditions where there are only digital newspapers, i.e. $-\hat{b}_1 = \hat{b}_2 = \hat{b} = 0$, we finally have:

$$(ARB)^{(SW)} = \frac{\varphi^2}{(\varphi+\chi)^2}\frac{(b_0)^2}{4},$$
$$(ARB)^{(PR)} = \frac{\varphi^2}{(\varphi+\chi)^2}(b_0)^2,$$
$$(ARB)^T = \frac{\varphi^2}{(\varphi+\chi)^2}(B^T + \frac{b_0}{2})^2, \text{with} B^T = \frac{b_0}{(\frac{4T}{(\varphi+\chi)} + \frac{1}{3})}$$

[21] As in MS 2015, the average bias is defined as "the average amount by which the news read deviates from the data for the average reader".

[22] Again, we only see the symmetric solutions for analytic and mathematical reasons.

So as long as the tax level $T \geq \frac{5(\varphi+\chi)}{12}$, the average bias level under tax regulation is the lowest.

Proposition 8. $(ARB)^{PR} > (ARB)^{SW} > (ARB)^{T}$. when $T \geq \frac{5(\varphi+\chi)}{12}$.

When the tax is high enough, the average bias under tax regulation is even smaller than the socially optimal average bias. The average bias level under the price regulation is the highest.

Proof. See appendices A.10.

5 Conclusion

Social media bias has become a concern for all countries. The exiting regulatory actions either focus on antitrust policies or content moderation, while the effects of the former are still unclear, and the latter encounters the critics such as the violation of the right of free speech. Therefore, this paper propose three alternative policies: public-interest firms, price caps, and tax in the news market.

In a Duopolistic newspaper market, two newspapers offer two different products: a print version and an online version. The online version is different from the print one as online readers can generate content by interacting with others. The user-generated content has a non-negligible effect on deciding the positions of a newspaper's online version. Sometimes, user-generated content is one of the most important reasons for people spreading fake news and dangerous speeches on social media.

The introduction of a third public firm without slanting seems to be a feasible solution to reduce the social media bias. However, this paper shows that when media bias comes from both supply and demand side, more competition fails to reduce the social media bias. The only positive effect of competition is the drop of the subscription fee of a print newspaper. On the contrary, the price of an online newspaper increases, and the slanting level may get higher under some conditions.

In terms of social welfare:

- The price regulation can reduce the bias of a print newspaper, but the online media bias increases;
- Under tax regulation, the media bias level (both print and digital ones) decreases with the tax level;
- What's more, the average bias under tax is smaller than the socially optimal

average bias, and the average bias under the price regulation is the highest.

These results shed light on the policy implementation on how to regulate social media market. When consumers have confirmatory bias and media firms tend to cater the preferences of the groups of like-minded people, more competition will lead to more media bias. The possible policy is taxing the slanting of the newspapers. Similar to the fact-checking mechanism, the government can use human-coding or algorithms to capture the slanting of the newspapers on their website, and once the slanting level reaches the threshold, the newspapers will be charged a tax. However, the criteria of measuring the level of social media bias remain a challenge for the executives. Besides, this model does not consider the costs of slanting for media outlets, the costs of searching for information for consumers, or the costs of detecting fake news for the government. The model is concerned with only two media outlets in the market, there are no third agents such as advertisers, politicians, or lobbing groups. Further research can explore these areas.

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A Appendices

A.1 Proof of LEMMA 1

According "Appendix A: LEMMAS" in the model of MS 2005[23], the slant strategy of a newspaper which biases around point B is defined as $s_B(d) = \frac{\varphi}{\chi+\varphi}(B-d)$.

The expected utility of a reader from reading an unbiased newspaper is:

$$E_d[U\left(s_B(d)\right)] = \overline{u} - \chi \int_d \frac{\varphi}{\chi+\varphi}(B-d)^2 - \varphi \int_d \left(d + \frac{\varphi}{\chi+\varphi}(B-d) - b\right)^2 - p.$$

When a newspaper is unbiased, i.e. the slant is zero ($(B-d)=0$) and the vector χ does not exist any more, the expected utility of a reader from reading an unbiased newspaper then changes to:

$$E_d[U\left(s_B(d)\right)] = \overline{u} - \varphi \int_d (d-b)^2 - p = \overline{u} - \varphi(v_d + b^2)$$

A.2 Proof of LEMMA 2:

To explain the rang of the value of B^*, we need to see how to get the locations of the indifferent readers and the prices choice of newspapers at the equilibrium.

A.2.1 The indifferent readers at equilibrium

1) First, the readers who are indifferent between the print newspapers and digital ones ($\hat{b}$):

[23] From (A1) to (A11), pp. 1043–1044, Sendhil Mullainathan and Andrei Shleifer. "The market for news". In:American Economic Review95.4 (2005), pp. 1031–1053.

When $E[U_i^o] = E[U_i^p]$, $i = \{1,\ 2\}$:

$$\begin{aligned} E[U_i^p] &= E[U_i^o] \\ \overline{u} - \frac{\varphi^2}{(\chi+\varphi)}(B_i - \hat{b}_i)^2 - \frac{\chi\varphi}{(\chi+\varphi)}(\hat{b}^2 + v_d) - P_i & \\ = \overline{u} - \frac{\varphi^2}{(\chi+\varphi)}(B_i^o - \hat{b})^2 - \frac{\chi\varphi}{(\chi+\varphi)}(\hat{b}^2 + v_d) - K_i & \\ \Rightarrow \frac{\varphi^2}{(\chi+\varphi)}(B_i - \hat{b})^2 + P_i = \frac{\varphi^2}{(\chi+\varphi)}(B_i^o - \hat{b})^2 + K_i & \\ \Rightarrow \frac{\varphi^2}{(\chi+\varphi)}\Big((B_i - \hat{b})^2 - (B_i^o - \hat{b})^2\Big)^2 = K_i - P_i & \\ \Rightarrow \hat{b} = \frac{(B_i^o + B_i)}{2} + \frac{(\varphi+\chi)}{2\varphi^2}\frac{(P_i - K_i)}{(B_i - B_i^o)}(= \hat{b}_i) & \end{aligned} \tag{Eq.(A.1)}$$

As there are two different newspapers, we note the readers who are indifferent between the print version and digital one of newspaper i as $\hat{b}_i$, with $i = \{1,\ 2\}$. Recall that:

$$B_1^o = B_1 + \frac{(-b_o + \hat{b}_1)}{2} \quad \text{and} \quad B_2^o = B_2 + \frac{(b_o + \hat{b}_2)}{2}$$

Then replace them into (Eq.(A.1)), taking $i = 1$ for example, we get:

$$\begin{aligned} \hat{b}_1 = \frac{2B_1 + \frac{1}{2}(-b_0 + \hat{b}_1)}{2} + \frac{(\varphi+\chi)}{2\varphi^2}\frac{(P_1 - K_1)}{\frac{-1}{2}(-b_0 + \hat{b}_1)} = & \\ B_1 + \frac{1}{4}(\hat{b}_1 - b_0) - \frac{(\varphi+\chi)}{\varphi^2}\frac{(P_1 - K_1)}{(\hat{b}_1 - b_0)} & \\ \Rightarrow \frac{3}{4}(\hat{b}_1 - b_0)^2 + (b_0 - B_1)(\hat{b}_1 - b_0) + \frac{(\varphi+\chi)}{\varphi^2}(P_1 - K_1) = 0 & \end{aligned} \tag{Eq.(A.2)}$$

$$\Rightarrow \hat{b}_1^* = \frac{2B_1^* + b_0 - 2\sqrt{\Delta_1}}{3}, \Delta_1 = (b_0 - B_1^*)^2 - \frac{3(\varphi+\chi)}{\varphi^2}(P_1^* - K_1^*),$$

and similarly:

$$\hat{b}_2^* = \frac{2B_2^* - b_0 + 2\sqrt{\Delta_2}}{3}, \Delta_2 = (b_0 + B_2^*)^2 - \frac{3(\varphi+\chi)}{\varphi^2}(P_2^* - K_2^*).$$ [24]

2). Then the readers who are indifferent between the print versions of the two private newspapers and the public one, i.e. b_{ind}^i :

When $E[U_3] = E[U_i^p]$,i= {1, 2}:

$$
\begin{aligned}
E[U_i^p] &= E[U_3] \\
\Rightarrow \overline{u} - \frac{\varphi^2}{(\chi+\varphi)}(B_i - b)^2 - \frac{\chi\varphi}{(\chi+\varphi)}(b^2 + v_d) - P_i &= \overline{u} - \varphi(v_d + b^2) - P_3 \\
\Rightarrow \frac{\varphi^2}{(\chi+\varphi)}(v_d - {B_i}^2 + 2B_i b) &= P_i - P_3 \\
\Rightarrow b = \frac{{B_i}^2 - v_d}{2B_i} + \frac{(P_i - P_3)}{2B_i}\frac{(\varphi+\chi)}{\varphi^2} &(= \hat{b}_{ind}^i).
\end{aligned}
$$

So we can get:

$$
\begin{aligned}
(\hat{b}_{ind}^1)^* &= \frac{((B_1^*)^2 - v_d)}{2B_1^*} + \frac{(P_1^* - P_3^*)}{2B_1^*}\frac{(\varphi+\chi)}{\varphi^2}; \\
(\hat{b}_{ind}^2)^* &= \frac{((B_2^*)^2 - v_d)}{2B_2^*} + \frac{(P_2^* - P_3^*)}{2B_2^*}\frac{(\varphi+\chi)}{\varphi^2}.
\end{aligned}
\qquad \text{(Eq.(A.3))}
$$

A.2.2 The prices choices at equilibrium

1) The prices of the print newspapers.

The payoff functions for newspapers are:

$$
\begin{aligned}
\Pi_1 &= \frac{(\hat{b}_1 + b_0)}{2b_0}(K_1 - c\delta) + \frac{(\hat{b}_{ind}^1 - \hat{b}_1)}{2b_0}(P_1 - c); \\
\Pi_2 &= \frac{(b_0 - \hat{b}_2)}{2b_0}(K_2 - c\delta) + \frac{(\hat{b}_2 - \hat{b}_{ind}^2)}{2b_0}(P_2 - c); \\
\Pi_3 &= \frac{(\hat{b}_{ind}^2 - \hat{b}_{ind}^1)}{2b_0}(P_3 - c).
\end{aligned}
$$

Taking newspaper 1 for example, optimize the above payoff function of newspaper 1 (Π_1) as to P_1 and K_1, we get:

$$
\begin{aligned}
\frac{\partial \Pi_1}{\partial P_1^*} &= \frac{1}{2b_0}\left(\frac{\partial \hat{b}_1^*}{\partial P_1^*}(K_1^* - c\delta) + (\frac{\partial (\hat{b}_{ind}^1)^*}{\partial P_1^*} - \frac{\partial \hat{b}_1^*}{\partial P_1^*})(P_1^* - c) + ((\hat{b}_{ind}^1)^* - \hat{b}_1^*)\right) = 0 \\
\frac{\partial \Pi_1}{\partial K_1^*} &= \frac{1}{2b_0}\left(\frac{\partial \hat{b}_1^*}{\partial K_1^*}(K_1^* - c\delta) + (\hat{b}_1^* + b_0) - \frac{\partial \hat{b}_1^*}{\partial K_1^*}(P_1^* - c)\right) = 0
\end{aligned}
$$

We notice from (Eq.(A.2)) that $\frac{\partial \hat{b}_i^*}{\partial P_i^*} = -\frac{\partial \hat{b}_i^*}{\partial K_i^*}$, so if we add $\frac{\partial \Pi_1}{\partial P_1^*}$ and $\frac{\partial \Pi_1}{\partial K_1^*}$ in the above equations together, we have :

$$\frac{\partial \Pi_1}{\partial P_1^*} + \frac{\partial \Pi_1}{\partial K_1^*} = \frac{1}{2b_0}\left(\frac{\partial \hat{b}_{ind}^1}{\partial P_1^*}(P_1^* - c) + (\hat{b}_{ind}^1)^* + b_0\right) = 0$$

Replace $\frac{\partial \hat{b}_{ind}^1}{\partial P_1^*} = \frac{(\chi+\varphi)}{2B_1^*\varphi^2}$ [25]:

$$\frac{(\chi+\varphi)}{2B_1^*\varphi^2}(P_1^* - c) + (\hat{b}_{ind}^1)^* + b_0 = 0$$

i.e.

$$P_1^* = c - (\hat{b}_{ind}^1 + b_0)\frac{2B_1\varphi^2}{(\chi+\varphi)}$$

Replace the value $(\hat{b}_{ind}^1)^*$ in (Eq.(A.3)):

$$\begin{aligned} P_1^* &= c - \left(\frac{((B_1^*)^2 - v_d)}{2B_1^*} + \frac{(P_1^* - P_3^*)}{2B_1^*}\frac{(\varphi+\chi)}{\varphi^2} + b_0\right)\frac{2B_1^*\varphi^2}{(\chi+\varphi)} \\ &= c - \frac{\varphi^2}{(\chi+\varphi)}((B_1^*)^2 - v_d) - (P_1^* - P_3^*) - \frac{\varphi^2}{(\chi+\varphi)}2b_0B_1^* \\ &\Rightarrow P_1^* = \frac{c+P_3^*}{2} - \frac{\varphi^2}{2(\chi+\varphi)}((B_1^*)^2 + 2b_0B_1^* - v_d) \qquad \text{(Eq.(A.4))} \end{aligned}$$

Similarly, we get:

$$\Rightarrow P_2^* = \frac{c+P_3^*}{2} - \frac{\varphi^2}{2(\chi+\varphi)}((B_2^*)^2 - 2b_0B_2^* - v_d)$$

As for P_3^*, maximize the payoff function of newspaper 3, i.e.Π_3 as to P_3:

$$\begin{aligned} \frac{\partial \Pi_3}{\partial P_3^*} &= \frac{1}{2b_0}\left(\left(\frac{\partial(\hat{b}_{ind}^2)^*}{\partial P_3^*} - \frac{\partial(\hat{b}_{ind}^1)^*}{\partial P_3^*}\right)(P_3^* - c) + (\hat{b}_{ind}^2)^* - (\hat{b}_{ind}^1)^*\right) = 0 \\ &\Rightarrow P_3^* = \frac{c}{2} + \frac{1}{2}\frac{(P_1^*B_2^* - P_2^*B_1^*)}{(B_2^* - B_1^*)} - \frac{\varphi^2}{2(\chi+\varphi)}(B_1^*B_2^* + v_d) \end{aligned}$$

Then replace the value of P_1^* and P_2^* in (Eq.(A.4)) into P_3^*:

$$\begin{aligned} P_3^* &= \frac{c}{2} + \frac{1}{2}\left(\frac{c}{2} + \frac{P_3^*}{2} + \frac{\varphi^2}{2(\chi+\varphi)}(B_1^*B_2^* + v_d) - \frac{2\varphi^2}{(\chi+\varphi)}\frac{b_0B_1^*B_2^*}{(B_2^* - B_1^*)}\right) \\ -\frac{\varphi^2}{2(\chi+\varphi)}(B_1^*B_2^* + v_d) &= \frac{3c}{4} + \frac{P_3^*}{4} - \frac{\varphi^2}{4(\chi+\varphi)}(B_1^*B_2^* + v_d) - \frac{\varphi^2}{(\chi+\varphi)}\frac{b_0B_1^*B_2^*}{(B_2^* - B_1^*)} \\ &\Rightarrow P_3^* = c - \frac{\varphi^2}{(\chi+\varphi)}\left(\frac{(B_1^*B_2^* + v_d)}{3} + \frac{4}{3}\frac{b_0B_1^*B_2^*}{(B_2^* - B_1^*)}\right) \qquad \text{(Eq.(A.5))} \end{aligned}$$

[25] It's calculated from (Eq.(A.3))

Then we replace the value of P_3^* above in (Eq.(A.5)) into (Eq.(A.4)), finally we get the prices at equilibrium:

$$\begin{aligned} P_1^* &= c - \frac{\varphi^2}{(\chi+\varphi)}\left(\frac{(B_1^*)^2}{2} + b_0 B_1^* + \frac{B_1^* B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*} - \frac{1}{B_2^*})}\right) \\ P_2^* &= c - \frac{\varphi^2}{(\chi+\varphi)}\left(\frac{(B_2^*)^2}{2} - b_0 B_2^* + \frac{B_1^* B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*} - \frac{1}{B_2^*})}\right) \end{aligned} \quad \text{(Eq.(A.6))}$$

2) The prices of the digital newspapers.

Maximizing the payoff function of newspaper i (Π_i) as to K_i, $i = \{1, 2\}$, we get:

$$\begin{aligned} \frac{\partial \Pi_1}{\partial K_1^*} &= \frac{1}{2b_0}\left(\frac{\partial \hat{b}_1^*}{\partial K_1^*}(K_1^* - c\delta) + (\hat{b}_1^* + b_0) - \frac{\partial \hat{b}_1^*}{\partial K_1^*}(P_1^* - c)\right) = 0 \\ \frac{\partial \Pi_2}{\partial K_2^*} &= \frac{1}{2b_0}\left(-\frac{\partial \hat{b}_2^*}{\partial K_2^*}(K_2^* - c\delta) + (b_0 - \hat{b}_2^*) + \frac{\partial \hat{b}_2^*}{\partial K_2^*}(P_2^* - c)\right) = 0 \end{aligned}$$

Taking K_1 for example:

$$\begin{aligned} &\frac{\partial \Pi_1}{\partial K_1^*} = \frac{1}{2b_0}\left(\frac{\partial \hat{b}_1^*}{\partial K_1^*}(K_1^* - c\delta) + (\hat{b}_1^* + b_0) - \frac{\partial \hat{b}_1^*}{\partial K_1^*}(P_1^* - c)\right) = 0 \\ &\Rightarrow K_1^* - P_1^* = c\delta - c - \frac{(\hat{b}_1^* + b_0)}{\frac{\partial \hat{b}_1^*}{\partial K_1^*}} \end{aligned}$$

And from (Eq.(A.1)):

$$\frac{\partial \hat{b}_1^*}{\partial K_1^*} = \frac{(\chi+\varphi)}{2\varphi^2}\frac{1}{(B_1^0 - B_1^*)} = \frac{(\chi+\varphi)}{\varphi^2}\frac{1}{(\hat{b}_1^* - b_0)}$$ [26]

Then replace the value of $\frac{\partial \hat{b}_1}{\partial K_1}$, we finally get:

$$K_1^* - P_1^* = c(\delta - 1) - \frac{\varphi^2}{(\chi+\varphi)}\left((\hat{b}_1^*)^2 - (b_0)^2\right)$$

Similarly, we can have:

$$K_2^* - P_2^* = c(\delta - 1) - \frac{\varphi^2}{(\chi+\varphi)}\left((\hat{b}_2^*)^2 - (b_0)^2\right) \quad \text{(Eq.(A.7))}$$

[26] As $B_1^o = B_1 + \frac{(-b_o + \hat{b}_1)}{2}$.

To simplify the mathematical analyses, we only consider the symmetric solutions hereinafter.[27]

Suppose that $(-B_1)^* = B_2{}^* = B^*, (-B_1^o)^* = (B_2^o)^* = (B^o)^*, (-\hat{b}_1)^* = (\hat{b}_2)^* = \hat{b}^*, \left(-\hat{b}_{ind}^1\right)^* = \left(\hat{b}_{ind}^2\right)^* = \hat{b}_{ind}^*$, which turns the above equilibrium results into:

$$-(\hat{b}_{ind}^1)^* = (\hat{b}_{ind}^2)^* = \hat{b}_{ind}^* = \frac{B^* + 2b_0 - v_d}{6};$$

$$-\hat{b}_1^* = \hat{b}_2^* = \hat{b}^* = \frac{2B^* - b_0 + 2\sqrt{\Delta}}{3}, \Delta = (b_0 + B^*)^2 - 3\left((\hat{b}^*)^2 - (b_0)^2\right);$$

$$P_1^* = P_2^* = P^* = c - \frac{\varphi^2}{3(\varphi + \chi)}\left((B^*)^2 - 4b_0 B^* - v_d\right);$$

$$P_3^* = c + \frac{\varphi^2}{3(\varphi + \chi)}\left((B^*)^2 + 2b_0 B^* - v_d\right);$$

$$P_1^* - K_1^* = P_2^* - K_2^* = c + \frac{\varphi^2}{(\varphi + \chi)}\left((\hat{b}^*)^2 - (b_0)^2\right).$$

To support the market segmentation at the symmetric equilibrium, and to guarantee a non-negative price, the following conditions need to be satisfied:[28]

$$-b_0 < \hat{b}_1^* < (\hat{b}_{ind}^1)^* < (\hat{b}_{ind}^2)^* < \hat{b}_2^* < b_0$$

$$\Rightarrow -b_0 < -\hat{b}^* < -\hat{b}_{ind}^* < 0 < \hat{b}_{ind}^* < \hat{b}^* < b_0$$

$$\Rightarrow 0 < \frac{B^* + 2b_0 - v_d}{6} < \frac{2B^* - b_0 + 2\sqrt{\Delta}}{3} < b_0$$

Note also that: $\Delta = (b_0 + B^*)^2 - 3\left((\hat{b}^*)^2 - (b_0)^2\right) \geq 0$ and $P^* \geq c$

$$\Rightarrow B^* \in [-b_0 + \sqrt{(b_0)^2 + v_d}, 2b_0 + \sqrt{4(b_0)^2 + v_d}] \quad \text{and} \quad B^* > \frac{(\hat{b}^*)^2}{2b_0}$$

[27] The asymmetric solutions are either too complicated or may not exist at all.

[28] These are necessary but not sufficient conditions.

A.3 Proof of LEMMA 3

A.3.1 The reporting position choices at equilibrium

Taking B_2^* for example, we have :

$$\frac{\partial \Pi_2}{\partial B_2^*} = \frac{1}{2b_0}\left(((P_2^* - c) - (K_2^* - c\delta))\frac{\partial \hat{b}_2^*}{\partial B_2^*} - (P_2^* - c)(\frac{\partial (\hat{b}_{ind}^2)^*}{\partial B_2^*} + \frac{\partial (\hat{b}_{ind}^2)^*}{\partial P_3^*}\frac{\partial P_3^*}{\partial B_2^*}) \right) = 0 \quad \text{(Eq.(A.8))}$$

From (Eq.(A.2)):

$$\frac{\partial \hat{b}_2^*}{\partial B_2^*} = \frac{2}{3}(1 + \frac{1}{2\sqrt{\Delta_2}}\frac{\partial \Delta_2}{\partial B_2^*}) = \frac{2}{3}\left(1 + \frac{(B_2^* + b_0)}{\sqrt{\Delta_2}}\right)$$

And also note that: $\sqrt{\Delta_2} = \frac{2}{3}(b_2)^2 - B_2^* + \frac{1}{2}b_0$, so replace it in the above function:

$$\begin{aligned}\frac{\partial \hat{b}_2^*}{\partial B_2^*} &= \frac{2}{3}(1 + \frac{1}{2\sqrt{\Delta_2}}\frac{\partial \Delta_2}{\partial B_2^*}) = \frac{2}{3}\left(1 + \frac{(B_2^* + b_0)}{\sqrt{\Delta_2}}\right) \\ &= \frac{2}{3}\left(1 + \frac{2(B_2^* + b_0)}{3(b_2^*)^2 - 2B_2^* + b_0}\right) = \frac{2\left((b_2^*)^2 + b_0\right)}{3(b_2^*)^2 - 2B_2^* + b_0}\end{aligned}$$

As for $\frac{\partial \hat{b}_{ind}^2}{\partial B_2}$, replace P_2^* and P_2^* in (Eq.(A.5)) and (Eq.(A.6)) into $(\hat{b}_{ind}^2)^*$ in (Eq.(A.3)), we get:

$$\begin{aligned}(\hat{b}_{ind}^2)^* &= \frac{B_2^*}{4} - \frac{V_d}{6B_2^*} + \frac{B_1^*}{12} + \frac{b_0}{2} + \frac{b_0 B_1^*}{3(B_2^* - B_1^*)} \\ \Rightarrow \frac{\partial (\hat{b}_{ind}^2)^*}{\partial B_2^*} &= \frac{1}{4} + \frac{V_d}{6(B_2^*)^2} - \frac{b_0 B_1^*}{3(B_2^* - B_1^*)^2}\end{aligned}$$

We can also get from (Eq.(A.3)) and (Eq.(A.5)) that:

$$\frac{\partial (\hat{b}_{ind}^2)^*}{\partial P_3^*} \cdot \frac{\partial P_3^*}{\partial B_2^*} = \frac{(\chi + \varphi)}{2\varphi^2 B_2^*}\frac{\varphi^2}{(\chi + \varphi)}\left(\frac{B_1^*}{3} - \frac{4b_0}{3}\frac{(B_1^*)^2}{(B_2^* - B_1^*)^2}\right) = \frac{B_1^*}{6B_2^*}\left(1 - \frac{4b_0 B_1^*}{(B_2^* - B_1^*)^2}\right)$$

So finally, integrate the above values of $\frac{\partial \hat{b}_2^*}{\partial B_2^*}$, $\frac{\partial(\hat{b}_{ind}^2)^*}{\partial B_2^*}$, and $\frac{\partial(\hat{b}_{ind}^2)^*}{\partial P_3^*}\cdot\frac{\partial P_3^*}{\partial B_2^*}$ into (Eq.(A.7)), we have:

$$\frac{\partial \Pi_2}{\partial B_2^*} = \frac{1}{2b_0}\left(((P_2^*-c)-(K_2^*-c\delta))\frac{\partial \hat{b}_2^*}{\partial B_2^*} - (P_2^*-c)(\frac{\partial(\hat{b}_{ind}^2)^*}{\partial B_2^*} + \frac{\partial(\hat{b}_{ind}^2)^*}{\partial P_3^*}\frac{\partial P_3^*}{\partial B_2^*})\right) = 0$$
$$\Rightarrow (P_2^* - K_2^* + c\delta - c)\frac{2\left((b_2^*)^2+b_0\right)}{3(b_2^*)^2 - 2B_2^* + b_0}$$
$$-(P_2^*-c)\left(\frac{1}{4} + \frac{V_d}{6(B_2^*)^2} - \frac{b_0B_1^*}{3(B_2^*-B_1^*)^2} + \frac{B_1^*}{6B_2^*}\left(1 - \frac{4b_0B_1^*}{(B_2^*-B_1^*)^2}\right)\right) = 0$$

Then replace the $K_2^* - P_2^*$ in (Eq.(A.7)) and the P_2^* in (Eq.(A.6)), we finally have:

$$\left((b_2^*)^2 - (b_0)^2\right)\frac{2\left((b_2^*)^2+b_0\right)}{3(b_2^*)^2 - 2B_2^* + b_0} + \left(\frac{(B_2^*)^2}{2} - b_0B_2^* + \frac{B_1^*B_2^*}{6} - \frac{v_d}{3} + \frac{2b_0}{3}\frac{1}{(\frac{1}{B_1^*} - \frac{1}{B_2^*})}\right)$$
$$\left(\frac{1}{4} + \frac{V_d}{6(B_2^*)^2} - \frac{b_0B_1^*}{3(B_2^*-B_1^*)^2} + \frac{B_1^*}{6B_2^*} - \frac{2b_0B_1^*}{3B_2^*(B_2^*-B_1^*)^2}\right) = 0$$

To compare the equilibrium results with those in the model of PET 2013, we need to simplify the above formulas by only considering the symmetric solutions hereinafter.[29]

So suppose that $(-B_1)^* = B_2{}^* = B^*, (-B_1^o)^* = (B_2^o)^* = (B^o)^*, (-\hat{b}_1)^* = (\hat{b}_2)^* = \hat{b}^*, (-\hat{b}_{ind}^1)^* = (\hat{b}_{ind}^2)^* = (\hat{b}_{ind})^*$, which leads to the following results:

$$\frac{2((\hat{b}^*)^2 - (b_0)^2)((\hat{b}^*)^2 + b_0)}{3(\hat{b}^*)^2 - 2B^* + b_0} + \frac{1}{36}\left((B^*)^2 - 5b_0B^* + 4b_0{}^2 + v_d - \frac{7b_0v_d}{B^*} - \frac{2(v_d)^2}{(B^*)^2}\right) = 0$$

Rewrite the above formula as two parts:

$$(A) = \frac{2((\hat{b}^*)^2 - (b_0)^2)((\hat{b}^*)^2 + b_0)}{(b_0 + 3(\hat{b}^*)^2 - 2B^*)}$$
$$(B) = \frac{1}{36}\left((B^*)^2 - 5b_0B^* + 4(b_0)^2 + v_d - \frac{7b_0v_d}{B^*} - \frac{2(v_d)^2}{(B^*)^2}\right) \qquad \text{(Eq.(A.9))}$$

[29]The asymmetric solutions are either too complicated or may not exist at all.

A.3.2 The Range of the reporting strategy at equilibrium

At last, according to the market segmentation in Figure 2 and the symmetric assumptions [30]:

$$-b_0 < \hat{b}_1 < \hat{b}_{ind}^1 < \hat{b}_{ind}^2 < \hat{b}_2 < b_0$$

$$-b_0 < \frac{-2B^* + b_0 - 2\sqrt{\Delta}}{3} < \frac{-B^* + v_d - 2b_0}{3} < \frac{B^* - v_d + 2b_0}{6} < \frac{2B^* - b_0 + 2\sqrt{\Delta}}{3} < b_0$$

$$\Delta \geq 0 \Longrightarrow B^* > \frac{(\hat{b}^*)^2}{2b_0}$$

So we can get:

i) $(A) > 0$ when $B^* > \frac{3((\hat{b}_2^*)^2 + b_0)}{2}$ and $(A) \leq 0$ otherwise.

ii) The solutions for $(B) = 0$ are:

$$B_1 = \frac{b_0 - \sqrt{(b_0)^2 - 8v_d}}{2}, B_2 = \frac{b_0 + \sqrt{(b_0)^2 - 8v_d}}{2},$$
$$B_3 = 2b_0 - \sqrt{4(b_0)^2 + v_d}, B_4 = 2b_0 + \sqrt{4(b_0)^2 + v_d}.$$

iii) The conditions satisfying the symmetric assumptions, i.e. $(-B_1)^* = {B_2}^* = B^*, B_1 < B_2, v_d = {\delta_d}^2 > 0$, are:

$$(2b_0 - \sqrt{4(b_0)^2 + v_d}) < 0 < (-b_0 + \sqrt{(b_0)^2 + v_d}) < (2b_0 + \sqrt{4(b_0)^2 + v_d}).$$

[30] Suppose that $(-B_1)^* = {B_2}^* = B^*, (-B_1^o)^* = (B_2^o)^* = (B^o)^*, (-\hat{b}_1)^* = (\hat{b}_2)^* = \hat{b}^*, {(-\hat{b}_{ind}^1)}^* = {(\hat{b}_{ind}^2)}^* = {(\hat{b}_{ind})}^*$

A.4 Proof of LEMMA 4

The social welfare are the total surplus of the newspaper firms and their readers, i.e:

$$
\begin{aligned}
SW &= \int_{-b_0}^{\hat{b}_1} \frac{U_1^0}{2b_0} db + \int_{\hat{b}_1}^{b_{ind}} \frac{U_1^p}{2b_0} db + \int_{b_{ind}}^{\hat{b}_2} \frac{U_2^p}{2b_0} db + \int_{\hat{b}_2}^{b_0} \frac{U_2^0}{2b_0} db + \Pi_1 + \Pi_2 \\
&= \frac{1}{2b_0} \int_{-b_0}^{\hat{b}_1} \left(\overline{u} - \frac{(\varphi)^2}{(\varphi+\chi)} (B_1^0 - b)^2 - \frac{\chi\varphi}{(\varphi+\chi)} (b^2 + v_d) - K_1 \right) db \\
&+ \frac{1}{2b_0} \int_{\hat{b}_1}^{b_{ind}} \left(\overline{u} - \frac{(\varphi)^2}{(\varphi+\chi)} (B_1 - b)^2 - \frac{\chi\varphi}{(\varphi+\chi)} (b^2 + v_d) - P_1 \right) db \\
&+ \frac{1}{2b_0} \int_{b_{ind}}^{\hat{b}_2} \left(\overline{u} - \frac{(\varphi)^2}{(\varphi+\chi)} (B_2 - b)^2 - \frac{\chi\varphi}{(\varphi+\chi)} (b^2 + v_d) - P_2 \right) db \\
&+ \frac{1}{2b_0} \int_{\hat{b}_2}^{b_0} \left(\overline{u} - \frac{(\varphi)^2}{(\varphi+\chi)} (B_2^0 - b)^2 - \frac{\chi\varphi}{(\varphi+\chi)} (b^2 + v_d) - K_2 \right) db \\
&+ \Pi_1 + \Pi_2 \\
&= \frac{1}{2b_0} \Bigg(2b_0 \overline{u} - \frac{(\varphi)^2}{(\varphi+\chi)} \Big(\int_{-b_0}^{\hat{b}_1} (B_1^0 - b)^2 db + \int_{\hat{b}_1}^{b_{ind}} (B_1 - b)^2 db \\
&+ \int_{b_{ind}}^{\hat{b}_2} (B_2 - b)^2 db + \int_{\hat{b}_2}^{b_0} (B_2^0 - b)^2 db \Big) - \frac{\chi\varphi}{(\varphi+\chi)} \int_{-b_0}^{b_0} (b^2 + v_d) db \\
&- \int_{-b_0}^{\hat{b}_1} K_1 db - \int_{\hat{b}_1}^{b_{ind}} P_1 db - \int_{b_{ind}}^{\hat{b}_2} P_2 db - \int_{\hat{b}_2}^{b_0} K_2 db \Bigg) \\
&+ \frac{(\hat{b}_1 + b_0)K_1 + (b_{ind} - \hat{b}_1)P_1}{2b_0} + \frac{(b_0 - \hat{b}_2)K_2 + (\hat{b}_2 - b_{ind})P_2}{2b_0} \\
&= \overline{u} - \frac{1}{2b_0} \frac{\varphi^2}{(\varphi+\chi)} \Bigg(\int_{-b_0}^{\hat{b}_1} (B_1^o - b)^2 db + \int_{\hat{b}_1}^{b_{ind}} (B_1 - b)^2 db + \\
&\int_{b_{ind}}^{\hat{b}_2} (B_2 - b)^2 db + \int_{\hat{b}_2}^{b_0} (B_2^o - b)^2 db \Bigg) - \frac{\chi\varphi}{(\varphi+\chi)} \int_{-b_0}^{b_0} (b^2 + v_d) db
\end{aligned}
\tag{Eq.(A.10)}
$$

Note (Eq.(A.10)) as:

$$
SW = \overline{u} - \frac{1}{2b_0} \frac{\varphi^2}{(\varphi+\chi)} F(B_i, B_i^0) - \frac{\chi\varphi}{(\varphi+\chi)} \int_{-b_0}^{b_0} (b^2 + v_d) db, \text{ with}
$$

$$
F(B_i, B_i^0) = \int_{-b_0}^{\hat{b}_1} (B_1^o - b)^2 db + \int_{\hat{b}_1}^{b_{ind}} (B_1 - b)^2 db + \int_{b_{ind}}^{\hat{b}_2} (B_2 - b)^2 db + \int_{\hat{b}_2}^{b_0} (B_2^o - b)^2 db
$$

Then optimize SW as respect to B_i and B_i^0, and as $\frac{\partial SW}{\partial B_i} = \frac{\partial SW}{\partial B_i}, \frac{\partial SW}{\partial B_i^0} = \frac{\partial SW}{\partial B_i^0}$, we finally get:

$$\begin{aligned}
\frac{\partial SW}{\partial(B_1^0)} &= \frac{\partial F(B_i, B_i^0)}{\partial B_1^0} = 2B_1^0(\hat{b}_1 + b_0) - \left((\hat{b}_1)^2 - (b_0)^2\right) = 0 \\
\frac{\partial SW}{\partial B_1} &= \frac{\partial F(B_i, B_i^0)}{\partial B_1} = 2B_1(b_{ind} - \hat{b}_1) - \left((b_{ind})^2 - (\hat{b}_1)^2\right) = 0 \\
\frac{\partial SW}{\partial B_2} &= \frac{\partial F(B_i, B_i^0)}{\partial B_2} = 2B_2(\hat{b}_2 - b_{ind}) - \left((\hat{b}_2)^2 - (b_{ind})^2\right) = 0 \\
\frac{\partial SW}{\partial(B_2^0)} &= \frac{\partial F(B_i, B_i^0)}{\partial B_2^0} = 2B_2^0(b_0 - \hat{b}_2) - \left((b_0)^2 - (\hat{b}_2)^2\right) = 0
\end{aligned}$$

And the first order conditions are:

$$(B_1^0)^{(sw)} = \frac{(\hat{b}_1 - b_0)}{2}, B_1^{(sw)} = \frac{(b_{ind} + \hat{b}_1)}{2}, B_2^{(sw)} = \frac{(b_{ind} + \hat{b}_2)}{2}, (B_2^0)^{(sw)} = \frac{(b_0 + \hat{b}_2)}{2}.$$

A.5 Proof of Proposition 1 and Proposition 2

To compare the effects of slant regulation by introduction a third public newspaper, we need to unify the hypothesis about the value of α. So suppose that $\alpha = 1$, and we only consider the symmetric scenario.

Recall that the equilibrium prices without slant regulation in the model of PET 2013 are:

$$\begin{aligned}
P_1^E = P_2^E &= c + \frac{2\varphi^2}{(\varphi + \chi)} b_0 B^E \\
K_1^E - P_1^E = K_2^E - P_2^E &= -c + \frac{\varphi^2}{2(\varphi + \chi)}(b_0 - \hat{b}^E)(b_0 + 3\hat{b}^E - 2B^E)
\end{aligned}$$

And the symmetric equilibrium prices in this model are:

$$\begin{aligned}
P_1^* = P_2^* = P^* &= c - \frac{\varphi^2}{3(\varphi + \chi)} \left((B^*)^2 - 4b_0 B^* - v_d\right); \\
P_3^* &= c + \frac{\varphi^2}{3(\varphi + \chi)} \left((B^*)^2 + 2b_0 B^* - v_d\right); \\
P_1^* - K_1^* = P_2^* - K_2^* &= c + \frac{\varphi^2}{(\varphi + \chi)} \left((\hat{b}^*)^2 - (b_0)^2\right).
\end{aligned}$$

A.5.1 Proposition 1: Comparison of print newspapers' prices.

So we have:

i) $P_i^E - P_i^* = \frac{\varphi^2}{3(\varphi+\chi)}\left((B^*)^2 + 8b_0B^* - v_d\right)$. And $(B^*)^2 + 8b_0B^* - v_d \geq 0$ according to LEMMA 2, so $P_i^E \geq P_i^*$.

ii) $P_3^* - P_i^* = \frac{2\varphi^2}{3(\varphi+\chi)}\left((B^*)^2 - b_0B^* - v_d\right)$. $P_3^* \leq P_i^*$ only when $(B^*)^2 - b_0B^* - v_d \leq 0$.

iii) $P_3^* - P_i^E = \frac{\varphi^2}{3(\varphi+\chi)}\left((B^*)^2 - 10b_0B^* - v_d\right)$. As $(B^*)^2 - 10b_0B^* - v_d \leq 0$ according to LEMMA 2, so $P_3^* \leq P_i^E$.

A.5.2 Proposition 2: Comparison of digital newspapers' prices.

$$
\begin{aligned}
K_i^* - K_i^E = (K_i^* - P_i^*) - (K_i^E - P_i^E) - (P_i^E = P_i^*) = -c - \frac{\varphi^2}{(\varphi+\chi)}\left((\hat{b})^2 - (b_0)^2\right) \\
- \left(-c + \frac{\varphi^2}{2(\varphi+\chi)}(b_0 - \hat{b})(b_0 + 3\hat{b} - 2B)\right) - \frac{\varphi^2}{(\varphi+\chi)}\left(\frac{(B^*)^2 + 8b_0B^* - v_d}{3}\right) \\
= \frac{\varphi^2}{(\varphi+\chi)}\left(\frac{(b_0 - \hat{b}_2)(b_0 - \hat{b}_2 + 2B)}{2} - \frac{(B^*)^2 + 8b_0B^* - v_d}{3}\right)
\end{aligned}
$$

Again, according to LEMMA 2, we have $\frac{(b_0-\hat{b}_2)(b_0-\hat{b}_2+2B)}{2} - > -2b_0B > \frac{(B^*)^2+8b_0B^*-v_d}{3}$. So finally we get $K_i^* > K_i^E$.

A.6 Proof of Proposition 3

We first see the conditions when there exists $B^* > \frac{3}{2}b_0$. Combine LEMMA 2 and LEMMA 3, if $B^* > \frac{3}{2}b_0$, the part $(B) > 0$ in (Eq.(A.10)), which leads to the part $(A) < 0$ in (Eq.(A.10)).

We further get $B < \frac{3(\hat{b})^2+b_0}{2}$, so as long as $\frac{3(\hat{b})^2+b_0}{2} \geq \frac{(\hat{b})^2}{2b_0}$ and $\frac{3(\hat{b})^2+b_0}{2} \geq \frac{3}{2}b_0$, i.e. $(b_2^*)^2 \geq \frac{2}{3}b_0 \geq \frac{1}{3}$, there exists at least one equilibrium reporting position for the print newspapers, which is more extreme than when there are only print newspapers in the news market (when $B^* = \frac{3}{2}b_0$), hence, also more extreme than the newspapers' reporting position without slanting regulation in the model of PET 2013.[31]

Therefore, the slanting regulation by introduction a third newspaper firm without slant can backfire when $(b_2^*)^2 \geq \frac{2}{3}b_0 \geq \frac{1}{3}$.

A.7 Proof of Proposition 4 and Proposition 5

We need to discuss different scenarios of these results:

A.7.1 Scenario 1: The impact of UGC on online variant of a digital newspaper is not dominant.

If we follows the assumption in the model of PET 2013, i.e.:

$B_1^o = B_1 + \frac{\alpha(-b_o+\hat{b}_1)}{2}, B_2^o = B_2 + \frac{\alpha(b_o+\hat{b}_2)}{2}$ with $0 < \alpha < 1$. That does not change too much the above FOC, except for $b_0 = \frac{\alpha}{2(1-\alpha)}(\hat{b}_2 - \hat{b}_1)$.

So we will explore the results of symmetric equilibrium, where $-B_1^{(sw)} = B_2^{(sw)} = B^{(sw)}$:

$$-B_1^{(sw)} = B_2^{(sw)} = \frac{\hat{b}}{2} = \frac{(\alpha-1)}{2\alpha}b_0,$$
$$-(B_1^o)^{(sw)} = (B_2^o)^{(sw)} = \frac{\hat{b}}{2(1-\alpha)} = \frac{1}{2\alpha}b_0.$$

Remarks:

i) $\frac{\partial B_i}{\partial \alpha} < 0, \frac{\partial B_i^o}{\partial \alpha} < 0$. The relative weight of newspapers' reporting positions

[31] As shown in the Proposition 1 of PET 2013, $B^E < \frac{2}{3}b_0$

to the most extremist readers' opinions decrease with α. The more decisive the UGC plays in the role of the online content of a newspaper, the more extreme the reporting positions of a (print and digital) newspaper get.

ii) When $\alpha < \frac{1}{4}$, the (print and digital) newspapers' reporting opinions are more extreme than when there are only print newspapers in the news market, i.e. $B^{(sw)} > \frac{3}{2}b_0$;

iii) $B_i^o > B_i$. The digital version of a newspaper are always more extreme than the print ones.

A.7.2 Scenario 2: The impact of UGC on online variant of a digital newspaper is dominant.

Now if we suppose that the UGC has a dominant power in deciding the online variant of a digital newspaper's content, i.e.:

$B_1^o = B_1 + \frac{(-b_o+\hat{b}_1)}{2}, B_2^o = B_2 + \frac{(b_o+\hat{b}_2)}{2}$.

We can get:

$$\begin{cases} -B_1^{(sw)} & = B_2^{(sw)} = 0, \\ (B_1^o)^{(sw)} & = \frac{-\hat{b}_{ind}-b_0}{2} = \frac{\hat{b}_1-b_0}{2}, \\ (B_2^o)^{(sw)} & = \frac{-\hat{b}_{ind}+b_0}{2} = \frac{\hat{b}_2+b_0}{2}. \end{cases}$$

The symmetric equilibrium results are then: $-B_1^{(sw)} = B_2^{(sw)} = 0, -(B_1^o)^{(sw)} = (B_2^o)^{(sw)} = \frac{-b_0}{2}$.

A.8 Proof of Proposition 6

When there is an unique price $\overline{P}$ for the print newspapers and $\overline{K}$ for the digital versions, the new payoff functions of the two private newspapers become:

$$\overline{\Pi}_1 = \frac{(\hat{b}_1 + b_0)}{2b_0}\overline{K} + \frac{(b_{ind} - \hat{b}_1)}{2b_0}\overline{P};$$
$$\overline{\Pi}_2 = \frac{(b_0 - \hat{b}_2)}{2b_0}\overline{K} + \frac{(\hat{b}_2 - b_{ind})}{2b_0}\overline{P}.$$

Recall that in the model of PET 2013: $b_{ind} = \frac{B_2+B_1}{2} + \frac{(P_2-P_1)}{(B_2-B_1)}\frac{(\chi+\varphi)}{2(\varphi)^2}$ and $\hat{b}_i = \frac{(B_i^o+B_i)}{2} + \frac{(\varphi+\chi)}{2\varphi^2}\frac{(P_i-K_i)}{(B_i-B_i^o)}$. As now under price regulation, $P_2 = P_1 = \overline{P}$ and $K_2 = K_1 = \overline{K}$, so $b_{ind} = \frac{B_2+B_1}{2}$ and $\hat{b}_i = \frac{(B_i^o+B_i)}{2} + \frac{(\varphi+\chi)}{2\varphi^2}\frac{(\overline{P}-\overline{K})}{(B_i-B_i^o)}$.

Replace b_{ind} and $\hat{b}_i$ into the payoff functions under price regulation, we have:

$$\overline{\Pi}_1 = \frac{\overline{K}}{2b_0}\left(b_0 + \frac{(B_1^o + B_1)}{2} + \frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)}\frac{(\chi+\varphi)}{2(\varphi)^2}\right)$$
$$+\frac{\overline{P}}{2b_0}\left(\frac{(B_1 + B_2)}{2} - \frac{(B_1^o + B_1)}{2} + \frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)}\frac{(\chi+\varphi)}{2(\varphi)^2}\right);$$
$$\overline{\Pi}_2 = \frac{\overline{K}}{2b_0}\left(b_0 + \frac{(B_2^o + B_2)}{2} + \frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)}\frac{(\chi+\varphi)}{2(\varphi)^2}\right)$$
$$+\frac{\overline{P}}{2b_0}\left(-\frac{(B_1 + B_2)}{2} + \frac{(B_2^o + B_2)}{2} + \frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)}\frac{(\chi+\varphi)}{2(\varphi)^2}\right).$$

Maximize the payoff functions regarding B_i and B_i^0 respectively:

$$\frac{\partial\overline{\Pi}_1}{\partial B_1} = \frac{\overline{K}}{2b_0}\left(\frac{1}{2} - \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)^2}\right) + \frac{\overline{P}}{2b_0}\frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)^2} = 0;$$
$$\frac{\partial\overline{\Pi}_1}{\partial B_1^0} = \frac{\overline{K}}{2b_0}\left(\frac{1}{2} + \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)^2}\right) + \frac{\overline{P}}{2b_0}\left(-\frac{1}{2} - \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_1 - B_1^o)^2}\right) = 0;$$
$$\frac{\partial\overline{\Pi}_2}{\partial B_2} = \frac{\overline{K}}{2b_0}\left(-\frac{1}{2} + \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)^2}\right) - \frac{\overline{P}}{2b_0}\frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)^2} = 0;$$
$$\frac{\partial\overline{\Pi}_2}{\partial B_2^0} = \frac{\overline{K}}{2b_0}\left(-\frac{1}{2} - \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)^2}\right) + \frac{\overline{P}}{2b_0}\left(\frac{1}{2} + \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{(\overline{P} - \overline{K})}{(B_2 - B_2^o)^2}\right) = 0.$$
(Eq.(A.11))

If we add $\frac{\partial\overline{\Pi}_1}{\partial B_1}$ and $\frac{\partial\overline{\Pi}_1}{\partial B_1^0}$ up, or $\frac{\partial\overline{\Pi}_2}{\partial B_2}$ and $\frac{\partial\overline{\Pi}_2}{\partial B_2^0}$, we get $\overline{P} = 2\overline{K}$. Replace $\overline{P} = 2\overline{K}$

into (Eq.(A.11)), we then have:

$$\frac{\partial\overline{\Pi}_1}{\partial B_1} = \frac{\overline{K}}{2b_0}\left(\frac{1}{2} + \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{\overline{K}}{(B_1-B_1^o)^2}\right) > 0;$$
$$\frac{\partial\overline{\Pi}_1}{\partial B_1^0} = \frac{\overline{K}}{2b_0}\left(-\frac{1}{2} - \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{\overline{K}}{(B_1-B_1^o)^2}\right) < 0;$$
$$\frac{\partial\overline{\Pi}_2}{\partial B_2} = \frac{\overline{K}}{2b_0}\left(-\frac{1}{2} - \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{\overline{K}}{(B_2-B_2^o)^2}\right) < 0;$$
$$\frac{\partial\overline{\Pi}_2}{\partial B_2^0} = \frac{\overline{K}}{2b_0}\left(\frac{1}{2} + \frac{(\chi+\varphi)}{2(\varphi)^2}\frac{\overline{K}}{(B_2-B_2^o)^2}\right) > 0.$$

And as we suppose that $B_1 < B_2$ in the beginning of this paper, so the payoff of print version of newspaper i increases as its reporting position converges to the centre,i.e. when $B_1 = B_2 = 0$; while the digital newspapers' payoffs maximize when its reporting position online become most extreme, i.e. when $-B_1^0 = B_2^0 = b_0$.

When $B_1 = B_2 = 0$, b_{ind} becomes 0, together with $\overline{P} = 2\overline{K}$, we have the payoff functions at equilibrium:

$$\overline{\Pi}_1 = \frac{\overline{P}}{2b_0}\frac{(b_0-\hat{b}_1)}{2} = \frac{3}{4}\overline{P} - \frac{(\overline{P})^2}{(b_0)^2}\frac{(\chi+\varphi)}{8(\varphi)^2} \geq 0;$$
$$\overline{\Pi}_2 = \frac{\overline{P}}{2b_0}\frac{(b_0-\hat{b}_1)}{2} = \frac{1}{2}\overline{P} - \frac{(\overline{P})^2}{(b_0)^2}\frac{(\chi+\varphi)}{8(\varphi)^2} \leq 0$$

The only equilibrium payoff realizes when $\overline{P} = 0$, where the two newspaper firms' payoffs are 0.

A.9 Proof of Proposition 7

With a tax for fake news - $\boldsymbol{T}$, the payoffs of the two private newspapers become:

$$\begin{aligned}\Pi_1^T &= \frac{(\hat{b}_1+b_0)\overline{K}}{2b_0} + \frac{(b_{ind}-\hat{b}_1)\overline{P}}{2b_0} - T\left(E_d(s_1(d_1)^2) + E_d({s_d}^0(d_1)^2)\right)\\ &= \frac{(\hat{b}_1+b_0)\overline{K}}{2b_0} + \frac{(b_{ind}-\hat{b}_1)\overline{P}}{2b_0} - \frac{T\varphi^2}{(\varphi+\chi)^2}\left((B_1)^2 + (B_1^0)^2\right);\\ \Pi_2^T &= \frac{(b_0-\hat{b}_2)\overline{K}}{2b_0} + \frac{(\hat{b}_2-b_{ind})\overline{P}}{2b_0} - \frac{T\varphi^2}{(\varphi+\chi)^2}\left((B_2)^2 + (B_2^0)^2\right).\end{aligned}$$

Maximize the payoff functions under tax regarding to the prices P_i and K_i, we get:

$$P_1^T = c + \frac{\varphi^2}{(\varphi+\chi)^2}(B_2 - B_1)(\frac{(B_2+B_1)}{3} + 2b_0);$$
$$P_2^T = c + \frac{\varphi^2}{(\varphi+\chi)^2}(B_2 - B_1)(-\frac{(B_2+B_1)}{3} + 2b_0);$$
$$K_1^T - P_1^T = -c(1-\delta) + \frac{\varphi^2}{(\varphi+\chi)^2}\frac{(b_0+\hat{b}_1)(b_0 - 3\hat{b}_1 + 2B_1)}{2};$$
$$K_2^T - P_2^T = -c(1-\delta) + \frac{\varphi^2}{(\varphi+\chi)^2}\frac{(b_0-\hat{b}_2)(b_0 + 3\hat{b}_2 - 2B_2)}{2}$$

To simplify, we only consider the symmetric equilibrium results with $-B_1 = B_2 = B$, and suppose that costs are zero. Then $P_1^T = P^T = \frac{\varphi^2}{(\varphi+\chi)^2}4b_0B$ Substitute the P_1^T and K_1^T into the payoff functions under tax and maximize the new payoff functions regarding B_i and B_i^0, taking B_2 for example:

$$\frac{\partial \Pi_2^T}{\partial B_2} = \frac{\partial \Pi_2}{\partial \hat{b}_2}\frac{\partial \hat{b}_2}{\partial B_2} + \frac{\partial \Pi_2}{\partial b_{ind}}\frac{\partial b_{ind}}{\partial B_2} + \frac{\partial \Pi_2}{\partial b_{ind}}\frac{\partial b_{ind}}{\partial P_1}\frac{\partial P_1}{\partial B_2} - 2B_2T\frac{\varphi^2}{(\varphi+\chi)^2} = 0$$
$$\xrightarrow[(-B_1=B_2=B)]{\text{(Symmetric Solutions)}} B^T = \frac{\left((\hat{b}_2)^2 + (b_0)^2\right)}{b_0}\frac{1}{(\frac{4T}{(\varphi+\chi)} + \frac{1}{3})}$$
$$\Rightarrow P^T = \frac{2\varphi^2}{4T + \frac{(\varphi+\chi)}{3}}\left((\hat{b}_2)^2 + (b_0)^2\right)$$

A.10 Proof of Proposition 8

The average bias level (**ARB**) for the heterogeneous readers is:

$$ARB = \int_b E_d[(n_i - d_i)^2]$$
$$= \frac{(\hat{b}_1+b_0)}{2b_0}E[s_1^0(d_1)^2] + \frac{(b_{ind}-\hat{b}_1)}{2b_0}E[s_1(d_1)^2] + \frac{(\hat{b}_2-b_{ind})}{2b_0}E[s_2(d_2)^2] + \frac{(b_0-\hat{b}_2)}{2b_0}E[s_2^0(d_2)^2] =$$
$$\frac{\varphi^2}{2b_0(\varphi+\chi)^2}\left((\hat{b}_1+b_0)(B_1^0)^2 + (b_{ind}-\hat{b}_1)(B_1)^2 + (\hat{b}_2-b_{ind})(B_2)^2 + (b_0-\hat{b}_2)(B_2^0)^2\right)$$

Again, to better compare the different scenarios, we only consider the symmetric equilibrium:

1) Social optimally, $(-B_1^0, B_1, B_2, B_2^0) = (-\frac{b_0}{2}, 0, 0, \frac{b_0}{2})$, so:

$$
\begin{aligned}
(ARB)^{(SW)} &= \frac{\varphi^2}{2b_0(\varphi+\chi)^2}\left((\hat{b}_1 + b_0)\frac{(b_0)^2}{4} + (b_0 - \hat{b}_2)\frac{(b_0)^2}{4}\right) \\
&= \frac{\varphi^2 b_0}{8(\varphi+\chi)^2}(2b_0 + \hat{b}_1 - \hat{b}_2) \\
&= \frac{\varphi^2}{(\varphi+\chi)^2}\frac{b_0(b_0 - \hat{b})}{4}
\end{aligned}
$$

2) Under price regulation, $(-B_1^0, B_1, B_2, B_2^0) = (-b_0, 0, 0, b_0)$, so:

$$
(ARB)^{(PR)} = \frac{\varphi^2}{2b_0(\varphi+\chi)^2}\left((\hat{b}_1 + b_0)(b_0)^2 + (b_0 - \hat{b}_2)(b_0)^2\right) = \frac{\varphi^2}{(\varphi+\chi)^2} b_0(b_0 - \hat{b})
$$

3) Under tax regulation:

$$
(ARB)^T = \frac{\varphi^2}{(\varphi+\chi)^2}\left((B^T)^2 + \frac{((b_0)^2 - (\hat{b})^2)}{b_0}B^T + \frac{(b_0 - \hat{b})(b_0 + \hat{b})^2}{4b_0}\right)
$$

Further, under extremest conditions where there are only digital newspapers, i.e. $-\hat{b}_1 = \hat{b}_2 = \hat{b} = 0$, we finally have:

$$
\begin{aligned}
(ARB)^{(SW)} &= \frac{\varphi^2}{(\varphi+\chi)^2}\frac{(b_0)^2}{4}, \\
(ARB)^{(PR)} &= \frac{\varphi^2}{(\varphi+\chi)^2}(b_0)^2, \\
(ARB)^T = \frac{\varphi^2}{(\varphi+\chi)^2}(B^T + \frac{b_0}{2})^2, \text{with} B^T &= \frac{b_0}{(\frac{4T}{(\varphi+\chi)} + \frac{1}{3})}
\end{aligned}
$$

So as long as the tax level $T \leq \frac{5(\varphi+\chi)}{12}$, the average bias level under tax regulation is the lowest.

B List of Figures

List of Figures

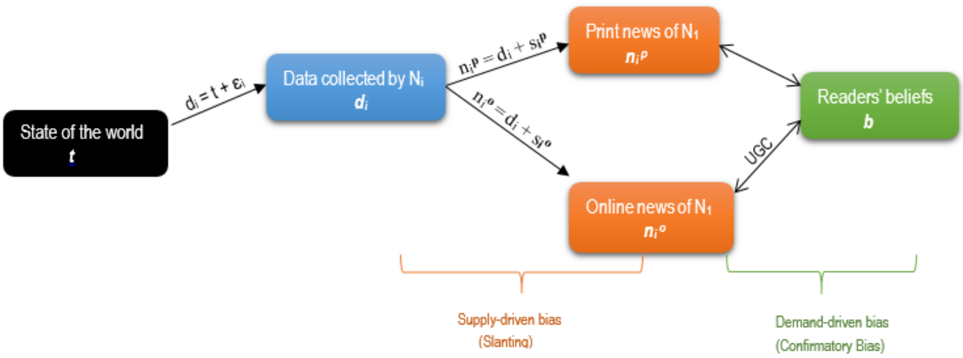


Figure 1: *Timing of the game in a Duopolistic Newspaper Market.*

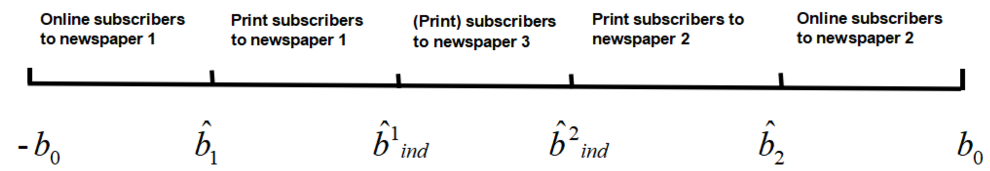


Figure 2: *Segmentation of the newspaper market, when a third public newspaper is introduced to a duopolistic market of two private newspapers.*

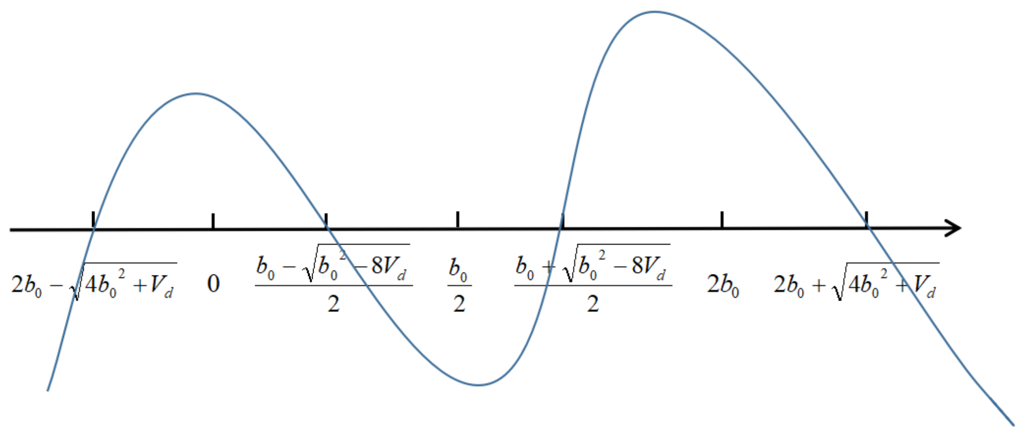


Figure 3: *The ranges of possible values of the equilibrium reporting position of newspaper 2.*

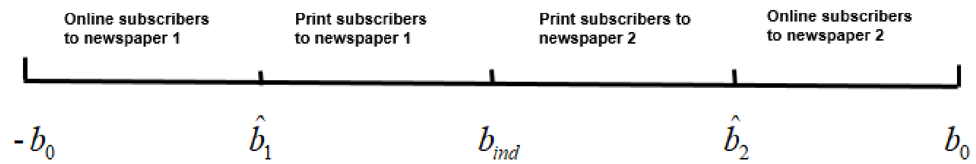
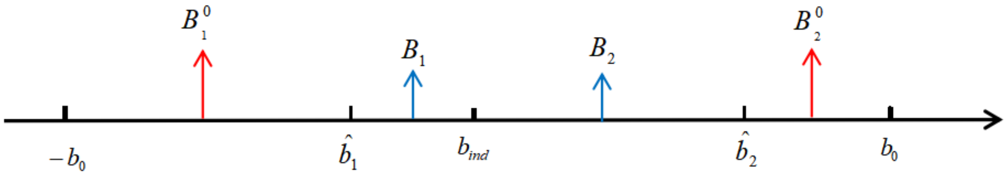
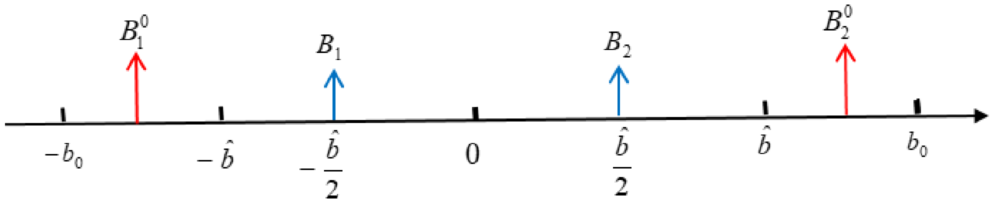


Figure 4: *Segmentation of the newspaper market in the model of PET 2013.*



(a) *The optimal (first-best) reporting location choices with* $0 < \alpha < 1$.



(b) *The symmetric solutions for optimal (first-best) reporting location choices* ($0 < \alpha < 1$).

Figure 5: *The optimal (first-best) reporting location choices.*

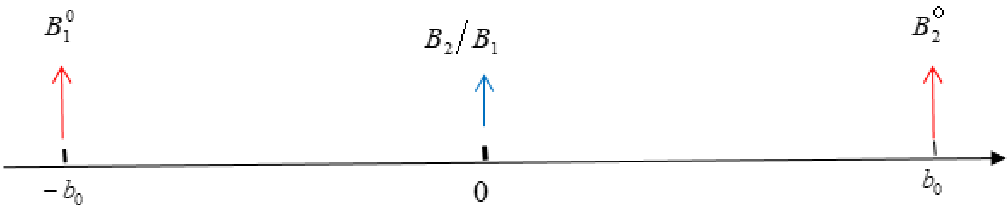


Figure 6: *The reporting positions under price regulation.*