GAME THEORETIC ANALYSIS OF IDEOLOGICALLY BIASED CLICKBAIT OR FAKE NEWS, AND REAL NEWS

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A decision and game theoretic model is developed for how one and two news organisations strike balances between producing clickbait or fake news, and real news. Each news organisation seeks to attract gullible consumers who consume more clickbait or fake news than real news, and non-gullible consumers who conscientiously consume only real news. Increasing a news organisation budget results in obtaining both more clickbait or fake news, and more real news. More clickbait or fake news is produced if the news organisation's unit cost of effort to produce real news, the production efficiency for clickbait or fake news, and the fraction of consumers consuming clickbait or fake news, increase. In contrast, less clickbait or fake news is produced if a news organisation's unit cost of effort to produce clickbait or fake news, and the production efficiency for real news, increase, and the gullible consumers consume real news with a higher frequency. Lower unit effort costs and higher budget and production efficiencies cause higher utility for a news organisation and lower utility for the competing news organisation. Higher weight assigned to the contest over clickbait or fake news induces both news organisations to exert higher effort to produce clickbait or fake news. When the gullible consumers of a news organisation consume a relatively large amount of real news in comparison to the consumers of another news organisation, then the first news organisation exerts higher effort to produce real news and obtains higher utility than the other news organisation.

Keywords: *strategy, decision, news, fake news, real news, ideology, company, consumers*

1. Introduction

1.1. Background

What clickbait, i.e., content designed to encourage consumers to click on a link to a web page and fake news have in common is that they may conflict with real truthful

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news. News organisations face three challenges modelled in this article. The first is between producing clickbait or fake news, and real news. The second is to assess gullible consumers consuming a combination of news, and non-gullible consumers conscientiously seeking out and consuming only real news. The third is competition between news organisations, also facing the first two challenges.

The three challenges are impacted by each news organisation's potential ideological preference for what kind of clickbait or fake news to produce, as opposed to producing real and ideologically neutral news. A news organisation may be sponsored and controlled by one or several companies with ideological preferences. The control or influence may take various forms, such as decisions pertaining to hiring, firing, salaries, promotions, career opportunities, and political influence. These decisions may impact a news organisation positively if it is willing to produce clickbait or fake news in accordance with the interests of the ideologically biased company.

Potential ideological impact on news organisations may be influenced by changes in the news landscape. Over the last century examples of concentrated control over independent news media have emerged. For example, Lutz [8] reports that in 1983, 50 companies owned 90% of the American media. However, in 2011, only six companies, i.e., General Electric, News Corp, Disney, Viacom, Time Warner, and CBS, owned the same 90% of the American media.

Further impact on news organisations follows from the extent to which consumers consume news, which increases revenue from subscriptions and advertisers. Some advertisers may prefer consumption as such, regardless of whether the consumed news is clickbait or fake news, or real news. Other advertisers may prefer consumers of one or the other type.

The distinction between gullible and non-gullible consumers may tentatively be obtained by some kind of objective assessment, or assessment based on various criteria to be determined. While others may see consumers of fake news as gullible, fake news consumers may not see this as gullibility, but rather as loyalty to their group. One feature of contemporary mass media journalism seems to be a tendency or fixation on aligning with partisan 'narratives', i.e., what the entertainment industry usually terms 'tropes', i.e., fitting observed facts selectively to align with the narrative rather than with reality. Such narratives are usually crafted to align with various biases.

1.2. Contribution

The independent decision making process and the strategic interactions between news agencies in producing fake news have not been extensively studied. This paper fills this gap by first developing a decision model for one news organisation, and thereafter by studying a game theoretical model between two news organisation. The model is developed where each news organisation chooses which fraction of each budget to

allocate into producing clickbait or fake news. The remaining fraction is allocated into producing real news. In making its decision, each news organisation accounts for which fraction of the consumers is gullible, in the sense of consuming clickbait or fake news more than real news, and which fraction is non-gullible, in the sense of consuming only real news. Each news organisation further accounts for competition with the other news organisation, which can be interpreted as the rest of the news industry, analogously determining which fractions of their budgets to allocate to clickbait or fake news, versus real news, while seeking to attract the same gullible and non-gullible consumers.

News organisations and consumers are in a symbiotic relationship. Ideological and other biases usually exist, on the one hand, within news organisations, their sponsoring and controlling company (or companies), owners, managers and personnel and, on the other hand, among consumers. How, when, and where the biases emerge can be hard to determine, and may be due to back and forth causation over time. On the one hand, the frequent and public altercations between US president Donald Trump and a number of major media owners (including CNN) suggest biases within news organisations and those that control these. However, more generally, if a media organisation produces biased content that does not sell, then it will go bankrupt and cease to exist, unless heavily subsidised by its owner. Hence, on the other hand, bias in news organisations may be an adaptation to bias in the news consumer market. News organisations then staff their organisations and align their narratives to meet market demand. An example of this is the Macedonian fake news industry in 2016, catering to conservative audiences in the US and generating revenue from online advertising services [10]. The model in this article does not specify how, when, and where biases emerge, but assumes that biases may exist. The model then illustrates how news organisations and consumers interact, given their preferences and beliefs.

1.3. Literature

Regarding clickbait, Khoja [5] examines frequently shared articles, finding that 79% had an element of shock in the title, 67% contained an unknown or new concept, 63% also mentioned recent events in the news and media, 63% made a pop culture reference or mentioned food, 29% of the most shared titles mentioned 'you', 'I' or hinted at a personal story, 17% were listicles, and 8% mentioned an animal. Furthermore, 4% of the assessed titles contained only one of the seven factors, 8% of the titles two clickbait factors, 46% of titles three of the factors, and 42% four of the clickbait factors mentioned in this article. For further research on clickbait, see Blom and Hansen [2] and Zannettou et al. [12]. See also Kshetri and Voas [6] for some economic considerations of fake news, and Allcott and Gentzkow [1] regarding social media and fake news in the 2016 US election. See Hausken [4] for a game theoretic analysis of two media organizations exerting manipulation efforts to support their preferred actor among two

actors interacting controversially. Tribe [11] illustrates implicit ideological biases in tools applied into policy science. Levins [7] and Nagy et al. [9] suggest that truth may be approximated by multiple independent models.

Article organisation. Sections 2 and 3 present models with one and two news organisations, respectively, with their analysis. Section 4 concludes the examination.

2. One news organisation

2.1. The model

Assume that news organisation i, $i = 1, \ldots, n$, $n \geq 1$, has a budget b_i that is converted into exerting effort f_i to produce clickbait or fake news at unit cost a_i. Effort f_i is news organisation i's one and only strategic choice variable. The remaining budget is used to exert effort r_i into producing real news at unit cost d_i, i.e.

$$b_i = a_i f_i + d_i r_i \tag{1}$$

The unit cost a_i of producing clickbait or fake news can be higher, but it is usually lower than the unit cost d_i of producing real news. It can also be significantly lower, expressed as $a_i \ll d_i$, as there is usually no requirement for validation of the news content. Much fake news is produced when journalists encounter an appealing and possibly untrue factoid that aligns with a narrative, and use it as a basis of a report without determining its veracity. Additionally, a_i depends on news organisation i's value system, including which kinds of clickbait or fake news it is willing to produce. The budget may consist of monetary resources M_i and non-monetary resources N_i drawn from non-monetary valuation systems, i.e.

$$b_i = M_i + N_i \tag{2}$$

Distinguishing between monetary and non-monetary resources is akin to distinguishing between economic value, influence value (including symbolic, political, and economic prestige), and human value [3]. That is, news organisation i first determines its monetary budget M_i, and thereafter its non-monetary budget N_i which depends on its value system. News organisations vary greatly in their value systems which may cause, widely different budgets b_i for organisations with the same monetary budget M_i. This, in turn, impacts the news organisations' ability and willingness to produce clickbait or fake news, or real news.

Assume a production function

$$F_i = A_i f_i^{k_i} \tag{3}$$

for clickbait or fake news, where $A_i > 0$ is the production efficiency and k_i is a parameter which determines concave production when $0 < k_i < 1$, linear production when $k_i = 1$, and convex production when $k_i > 1$. Assume a production function

$$R_i = D_i r_i^{h_i} = D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \tag{4}$$

for real news, where (1) has been inserted, $D_i > 0$ is the production efficiency, and h_i is a parameter which determines concave production when $0 < h_i < 1$, linear production when $h_i = 1$, and convex production when $h_i > 1$.

We measure F_i and R_i in various ways, such as number of views, advertising revenue, subscriptions, etc. A cheaply produced news item with a catchy heading may potentially be a huge and heavily consumed news item. An expensively produced documentary may be equally much consumed, but is more expensive to produce.

News organisation i cannot be expected to announce its effort f_i publicly. Its management deliberately or implicitly chooses f_i, as observed by neutral fact checkers. We define $f_i = 0$ as no effort towards clickbait or fake news, i.e., 100% effort towards real news, and $f_i = f_i^{max} = b_i/a_i$ as 100% effort towards clickbait or fake news. The benchmark $f_i = 0$ of no effort towards clickbait or fake news is assumed descriptive of an ideologically neutral and independent news organisation focused on providing real news to the customers. The other extreme $f_i = b_i/a_i$ can describe an ideologically biased news organisation, possibly controlled by an ideologically biased company, and possibly providing news to gullible consumers with limited or no ability or interest to distinguish between clickbait or fake news, and real news.

We assume a fraction g_i of gullible consumers towards news organisation i, $0 \leq g_i \leq 1$, consuming both clickbait or fake news, and real news. The clickbait or fake news is often or usually designed and presented to get more attention and thus consumption. We model this so that the fraction g_i of gullible consumers on average consumes an item of real news v_i times as likely as an item of clickbait or fake news, where $0 \leq v_i \leq 1$. Thus,

$$G_i = F_i + v_i R_i \tag{5}$$

measures news consumption from organisation i by the gullible consumers. That is, $v_i = 0$ means that only clickbait or fake news is consumed, while $v_i = 1$ means that all items of news are equally consumed.

Not all consumers are gullible. Otherwise, no upper limit would exist for clickbait or fake news. The remaining fraction $1 - g_i$ of consumers consume only real news, and no clickbait or fake news from news organisation i. These consumers have incorporated their preference for real news into their news consumption. They consume real news

more conscientiously and deliberately. We assume that they fact check across sources and are able to distinguish real news from clickbait or fake news. We do not model external regulators, fact checkers, watchdogs, and law enforcement impacting players, preferences, and utilities.

News organisation i receives its utility from consumption by the fraction g_i of gullible consumers, and the fraction $1 - g_i$ of non-gullible consumers. If the fraction g_i is large, news organisation i prefers to exert high effort f_i towards producing clickbait or fake news. In contrast, if g_i is low, news organisation i prefers to exert low effort f_i to attract the non-gullible consumers.

With these assumptions, and assuming the Cobb–Douglas utility with elasticities g_i and $1 - g_i$ for the gullible and non-gullible consumers, respectively, news organisation i's utility is

$$u_i = G_i^{g_i} R_i^{1-g_i} = \left(A_i f_i^{k_i} + v_i D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \right)^{g_i} \left(D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \right)^{1-g_i} \tag{6}$$

where (1), (3), (4) and (5) have been inserted. We apply the Cobb–Douglas utility since it is one of the most commonly used utility functions in economics, especially applicable when a balance or trade-off has to be struck between two objectives, such as recruiting gullible versus non-gullible consumers. The Cobb–Douglas utility is often also analytically tractable, at least to some extent, see Appendix. Equation (6) shows how organisation i strikes a balance between choosing high effort f_i to attract the gullible consumers, and low effort f_i to attract the non-gullible consumers.

Let us consider the two extreme alternatives of (6). First, assume that news organisation i prefers only non-gullible consumers, i.e., ignores its gullible consumers. Inserting $g_i = 0$ into (6) gives

$$u_i = D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \tag{7}$$

which is maximised by choosing zero $f_i^* = 0$ into producing clickbait or fake news, and thus maximum effort $r_i^* = r_i^{\max} = b_i/d_i$ into producing real news, causing utility $u_i^* = D_i (b_i/d_i)^{h_i}$, where superscript * means optimal value. In order to make this problem more interesting, assume that news organisation i actually has to strike a balance between two objectives, so that g_i is intermediate between 0 and 1. The two types of consumers may be relabelled as extremely non-gullible and moderately non-gullible consumers, or as interested in two different subject areas, such as politics and science. Second, assume that news organisation i prefers only gullible consumers, i.e., ignores its non-gullible consumers. Inserting $g_i = 1$ into (6) gives

$$u_i = A_i f_i^{k_i} + v_i D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \qquad (8)$$

If $v_i > 0$, then f_i^* is intermediate between $f_i^* = 0$ and $f_i = f_i^{\max} = b_i/a_i$. However, if $v_i = 0$, so that the gullible consumers have no added interest in real news, news organisation i maximizes its utility in (8) by choosing maximum effort $f_i^* = f_i^{\max} = b_i/a_i$ into producing clickbait or fake news, causing utility $u_i^* = A_i(b_i/a_i)^{k_i}$. Also, for this alternative, in order to make this problem more interesting, assume that news organisation i actually has to strike a balance between two objectives, so that g_i is intermediate between 0 and 1. The two types of consumers may be relabelled as extremely gullible and moderately gullible consumers, or as interested in two different subject areas within which gullibility may play a role, such as politics and entertainment.

We define news organisation i's trustworthiness T_i as its ratio of produced real news R_i relative to its produced news if it were to choose effort $f_i = 0$ towards producing clickbait or fake news, i.e.

$$T_i = \frac{R_i}{D_i \left(\frac{b_i}{d_i} \right)^{h_i}} = \frac{D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i}}{D_i \left(\frac{b_i}{d_i} \right)^{h_i}} = \frac{(b_i - a_i f_i)^{h_i}}{b_i^{h_i}} \qquad (9)$$

Hence, no trustworthiness means $T_i = 0$, and maximum trustworthiness means $T_i = 1$, where $0 \leq T_i \leq 1$.

2.2. Analysis

To determine its optimal effort f_i, news organisation i differentiates its utility in (6) and equates with zero, i.e.

$$\frac{du_i}{df_i} = \frac{\left(D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \right)^{1-g_i} \left(A_i f_i^{k_i} + v_i D_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} \right)^{-1+g_i}}{f_i (b_i - a_i f_i)}$$

$$\times \left(A_i f_i^{k_i} \left((b_i - a_i f_i) g_i k_i - a_i f_i (1 - g_i) h_i \right) - a_i D_i f_i \left(\frac{b_i - a_i f_i}{d_i} \right)^{h_i} h_i v_i \right) = 0 \quad (10)$$

Setting $k_i = h_i = 1$, solving (10) when $A_i d_i g_i \geq a_i D_i g_i$ gives

$$f_i^* = \frac{b_i\left(A_i d_i g_i - a_i D_i v_i\right)}{a_i\left(A_i d_i - a_i D_i v_i\right)}, \quad u_i^* = \frac{A_i b_i D_i^{1-g_i} g_i^{g_i}\left(1-g_i\right)^{1-g_i}}{a_i^{g_i}\left(A_i d_i - a_i D_i v_i\right)^{1-g_i}} \tag{11}$$

where superscript * means optimal value. When $A_i d_i g_i < a_i D_i v_i$, then $\dfrac{du_i}{df_i} < 0$ for all

$f_i > 0,$ and hence

$$f_i^* = 0, \quad u_i^* = \frac{b_i D_i v_i^{g_i}}{d_i} \tag{12}$$

Differentiating (10) and inserting (11) gives

$$\left.\frac{d^2 u_i}{df_i^2}\right|_{f_i = f_i^*} = -\frac{a_i^{2-g_i} D_i^{1-g_i}\left(A_i d_i - a_i D_i v_i\right)^{1+g_i}}{A_i b_i d_i^2\left(1-g_i\right)^{g_i} g_i^{1-g_i}} \tag{13}$$

which is negative when $A_i d_i \geq a_i D_i v_i$, which is satisfied when $A_i d_i g_i \geq a_i D_i v_i$ in (11).
Hence, the second order conditions are satisfied when $k_i = h_i = 1$.

Property 1. If $k_i = h_i = 1$ and $A_i d_i g_i > a_i D_i v_i,$

$$\frac{df_i^*}{db_i} \geq 0, \quad \frac{df_i^*}{da_i} \leq 0, \quad \frac{df_i^*}{dd_i} \geq 0, \quad \frac{df_i^*}{dA_i} \geq 0, \quad \frac{df_i^*}{dD_i} \leq 0, \quad \frac{df_i^*}{dg_i} \geq 0, \quad \frac{df_i^*}{dv_i} \leq 0$$

if $k_i = h_i = 1$ and $A_i d_i g_i \leq a_i D_i v_i, f_i = 0.$

Proof. Follows from Appendix and (11).

Property 1 states that for the interior solution where $k_i = h_i = 1$ and $A_i d_i g_i > a_i D_i v_i$, news organisation i's effort f_i^* to produce clickbait or fake news increases as the following four parameter values increase. First, its budget b_i, which enables higher effort. Second, its unit effort cost d_i to produce real news, which makes it more expensive to produce real news. Third, its production efficiency A_i for clickbait or fake news, which causes effort f_i^* to have higher impact. Fourth, the fraction g_i of consumers consuming clickbait or fake news, which incentivises news organisation i to exert higher effort f_i^*.

In contrast, f_i^* decreases as the following three parameter values increase. First, its unit effort cost a_i to produce clickbait or fake news, which makes it more costly to exert effort f_i^*. Second, the production efficiency D_i for real news, which incentivises exerting effort r_i^* to produce real news rather than effort f_i^* to produce clickbait or fake news. Third, how many times as likely, i.e., v_i, the fraction g_i of gullible consumers

consumes an item of real news rather than an item of clickbait or fake news. The parameter v_i places larger emphasis on real news in how gullible consumers consume news, as expressed by G_i in (5).

Property 2. If $k_i = h_i = 1$ and $A_i d_i g_i \geq a_i D_i v_i$,

$$\frac{du_i^*}{db_i} \geq 0, \quad \frac{du_i^*}{da_i} \leq 0, \quad \frac{du_i^*}{dd_i} \leq 0, \quad \frac{du_i^*}{dA_i} \geq 0, \quad \frac{du_i^*}{dD_i} \geq 0, \quad \frac{du_i^*}{dg_i} \leq 0$$

if $\dfrac{a_i D_i (1 - g_i)}{g_i (A_i d_i - a_i D_i v_i)} \geq 1, \quad \dfrac{du_i^*}{dv_i} \geq 0.$

If $k_i = h_i = 1$ and $A_i d_i g_i < a_i D_i v_i$,

$$\frac{du_i^*}{db_i} \geq 0, \quad \frac{du_i^*}{da_i} = 0, \quad \frac{du_i^*}{dd_i} \leq 0, \quad \frac{du_i^*}{dA_i} = 0, \quad \frac{du_i^*}{dD_i} \geq 0, \quad \frac{du_i^*}{dg_i} \geq 0.$$

Proof. Appendix.

Property 2 states that for the interior solution, where $k_i = h_i = 1$ and $A_i d_i g_i \geq a_i D_i v_i$, news organisation i's utility u_i^* increases as the following four parameter values increase. First, its budget b_i, which is beneficial. Second, its production efficiency A_i for clickbait or fake news, which causes more clickbait or fake news for a given effort f_i^*. Third, its production efficiency D_i for real news, which causes more real news for a given effort r_i^*. Fourth, how many times as likely, i.e., v_i, the fraction g_i of gullible consumers consumes an item of real news rather than an item of clickbait or fake news. A higher parameter value v_i gives a higher measure G_i in (5) for how gullible consumers consume news, which is beneficial for news organisation i.

In contrast, u_i^* decreases as the following two parameter values increase. First, its unit effort cost a_i to produce clickbait or fake news, which causes news organisation i to incur a higher cost for a given effort f_i^*. Second, its unit effort cost d_i to produce real news, which causes news organisation i to incur a higher cost for a given effort r_i^*.

Finally, u_i^* decreases as the fraction g_i of consumers consuming clickbait or fake news increases provided that $\dfrac{a_i D_i (1 - g_i)}{g_i (A_i d_i - a_i D_i v_i)} > 1$, increases as g_i increases provided that $\dfrac{a_i D_i (1 - g_i)}{g_i (A_i d_i - a_i D_i v_i)} < 1$, and is otherwise independent of g_i. When g_i is low while, $A_i d_i g_i \geq a_i D_i v_i$, $\dfrac{a_i D_i (1 - g_i)}{g_i (A_i d_i - a_i D_i v_i)} > 1$ is satisfied, causing u_i^* to decrease as g_i increases.

As g_i approaches $g_i = 1$, $\dfrac{a_i D_i (1 - g_i)}{g_i (A_i d_i - a_i D_i v_i)} > 1$ is not satisfied, causing u_i^* to increase as g_i increases. This suggests that some intermediate fraction g_i of gullible consumers causes low utility u_i^*, while lower or higher g_i causes higher utility. (11) is $v_i = 0$, which means that the fraction g_i of gullible consumers consumes only clickbait or fake news, and no real news. Inserting $v_i = 0$ into (11) gives

$$f_i^* = \frac{b_i g_i}{a_i}, \quad u_i^* = \frac{b_i A_i^{g_i} D_i^{1-g_i} g_i^{g_i} \left(1 - g_i\right)^{1-g_i}}{a_i^{g_i} d_i^{1-g_i}} \tag{14}$$

3. Two competing news organisations

3.1. The model

This section considers two competing news organisations i and j, which can be interpreted as one organisation i competing against the rest of the news industry expressed as j, as shown in Fig. 1.
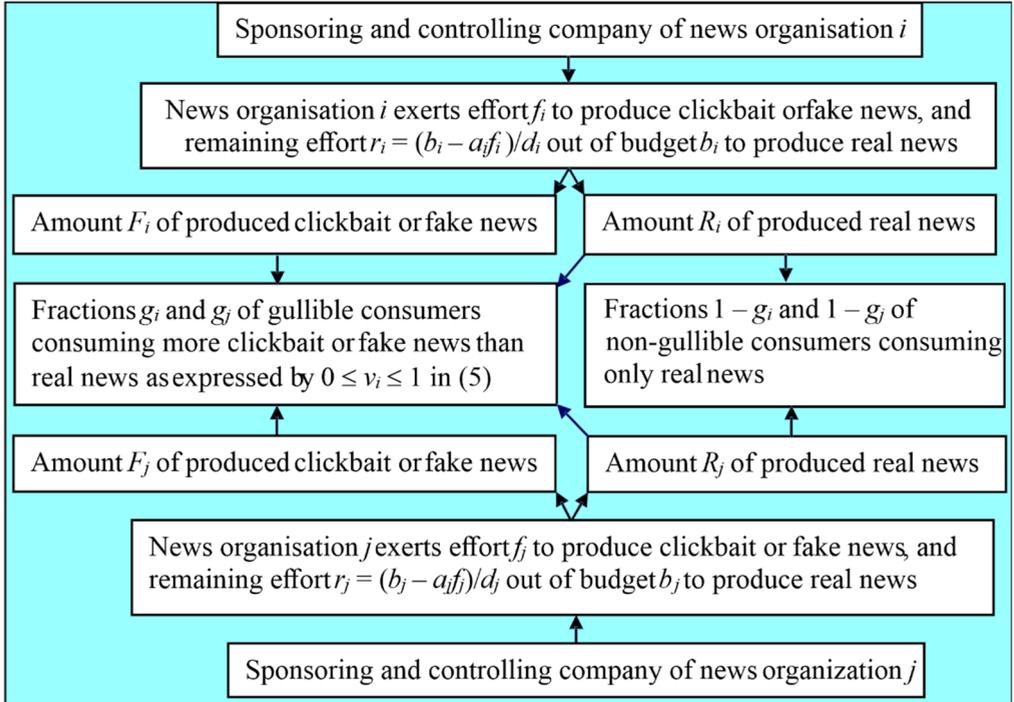
Fig. 1. Two news organisations i and j competing for gullible and non-gullible consumers

We assume two contests between the two news organisations. The first contest is for the gullible consumers. The second contest is for the non-gullible consumers. The Cobb–Douglas utility elasticities for the two contests are g_i and $1 - g_i$ for organisation i, and g_j and $1 - g_j$ for organisation j. The two organisations' utilities are

$$u_i = \left(\frac{G_i}{G_i + G_j} \right)^{g_i} \left(\frac{R_i}{R_i + R_j} \right)^{1-g_i} , \quad u_j = \left(\frac{G_j}{G_i + G_j} \right)^{g_j} \left(\frac{R_j}{R_i + R_j} \right)^{1-g_j} \tag{15}$$

where G_i and R_i are given by (5) and (4), and G_j and R_j are given by (5) and (4) replacing i with j. In (15), organisation i seeks high G_i relative to G_j, and high R_i relative to R_j, regulated by g_i and $1 - g_i$, which means that two kinds of balances have to be struck. Organisation i strikes a balance between producing fake news to attract gullible customers and producing real news to attract non-gullible customers, while competing with the other news organisation j. More specifically, first, organisation i strikes a balance between choosing high effort f_i to attract the gullible consumers in the first ratio in (15), and low effort f_i to attract the non-gullible consumers in the second ratio in (15). Second, organisation i strikes a balance between choosing high effort f_i to compete with organisation j, which also strikes a balance between choosing high effort f_i in the first ratio in (15), while simultaneously choosing low effort f_i to compete with organisation j also choosing low effort f_j in the second ratio in (15). Organisation j reasons analogously. The two news organisations i and j choose their free choice variables f_i and f_j simultaneously and independently.

3.2. Analysis

To determine news organisations i's and j's optimal efforts f_i^* and f_j^*, their utilities in (15) are differentiated and equated to zero, i.e.

$$\frac{du_i}{df_i} = 0, \quad \frac{du_j}{df_j} = 0 \tag{16}$$

which for $k_i = h_i = 1$ are solved to yield

$$f_i^* = \begin{cases} \dfrac{b_i \left(\dfrac{A_j d_j f_j^* Q}{b_j - a_j f_j^*} - \left(D_i v_i - D_j Q v_j \right) \right)}{A_i d_i + a_i \left(\dfrac{A_j d_j f_j^* Q}{b_j - a_j f_j^*} \right) - \left(D_i v_i - D_j Q v_j \right)} = f_{ii}^* \text{ if } f_{ii}^* \geq 0 \\ 0 \text{ otherwise} \end{cases}$$

$$Q = \begin{cases} \sqrt{\dfrac{\left(a_j D_i g_i \left(1-g_j\right)\left(A_i d_i - a_i D_i v_i\right)\right)}{\left(a_i D_j g_j \left(1-g_i\right)\left(A_j d_j - a_j D_j v_j\right)\right)}} & \text{if } A_i d_i \geq a_i D_i v_i \text{ and } A_j d_j \geq a_j D_j v_j \\ 0 \text{ otherwise} \end{cases} \quad (17)$$

Inserting (17) into $\dfrac{du_j}{df_j} = 0$ in (16) gives a second order equation in f_j^*, which

takes too much space to present. For the special case of two equivalent news organisa-tions, i.e., $b_j = b_i$, $a_j = a_i$, $d_j = d_i$, $A_j = A_i$, $D_j = D_i$, $g_j = g_i$, $v_j = v_i$, (17) simplifies to

$$f_i^* = f_j^* = \begin{cases} \dfrac{b_i\left(A_i d_i g_i - a_i D_i v_i\right)}{a_i\left(A_i d_i - a_i D_i v_i\right)} & \text{if } A_i d_i g_i \geq a_i D_i v_i, \ u_i^* = u_j^* = \dfrac{1}{2} \\ 0 \text{ otherwise} \end{cases} \quad (18)$$

Equation (18) shows the same efforts $f_i^* = f_j^*$ as for one news organisation in (11), while the utilities $u_i^* = u_j^*$ are always equal for equal efforts because of the contests in (15), which contrasts with no contest for one news organisation.

Figure 2 plots the two news organisations i's and j's efforts $f_i^*, f_j^*, r_i^*, r_j^*$ and utili-ties u_i^* and u_j^* as functions of the seven parameters b_i, a_i, d_i, A_i, D_i, g_i, v_i relative to the benchmark $b_i = b_j = a_i = a_j = d_i = d_j = A_i = A_j = D_i = D_j = 1$, $g_i = g_j = 1/2$, and $v_i = v_j = 1/4$. This benchmark is chosen since it is simple, intermediate, and plausible. $g_i = g_j = 1/2$ in (6) is intermediate between $g_i = g_j = 0$ and $g_i = g_j = 1$, which means that clickbait or fake news, and real news, have equal elasticities, and thus have equal impact on the utilities u_i^* and u_j^*. $v_i = v_j = 1/4$ in (5) means that clickbait or fake news is weighted four times more than real news, which may be a plausible assessment of gullible consumers' news consumption. Inserting the benchmark into (18) in all the seven panels the bench-mark causes equal efforts $f_i^* = f_j^* = 1/3$ and equal utilities $u_i^* = u_j^* = 1/2$.

In panel a), organisation i's effort f_i^* to produce clickbait or fake news, and effort r_i^* to produce real news increase linearly, and organisation i's utility u_i^* increases con-cavely as its budget b_i increases. Increasing budget b_i is beneficial for organisation i and causes convexly decreasing utility u_j^* for organisation j due to lower budget $b_j = 1$.

In panel b), organisation i's effort f_i^* and utility u_i^* decrease convexly as its unit cost of effort a_i to produce clickbait or fake news increases, reaching zero and a constant, respectively, when $a_i \geq 2.33$. Too high a_i induces organisation i not to produce clickbait or fake news, and instead focus exclusively on producing real news. On the other hand,
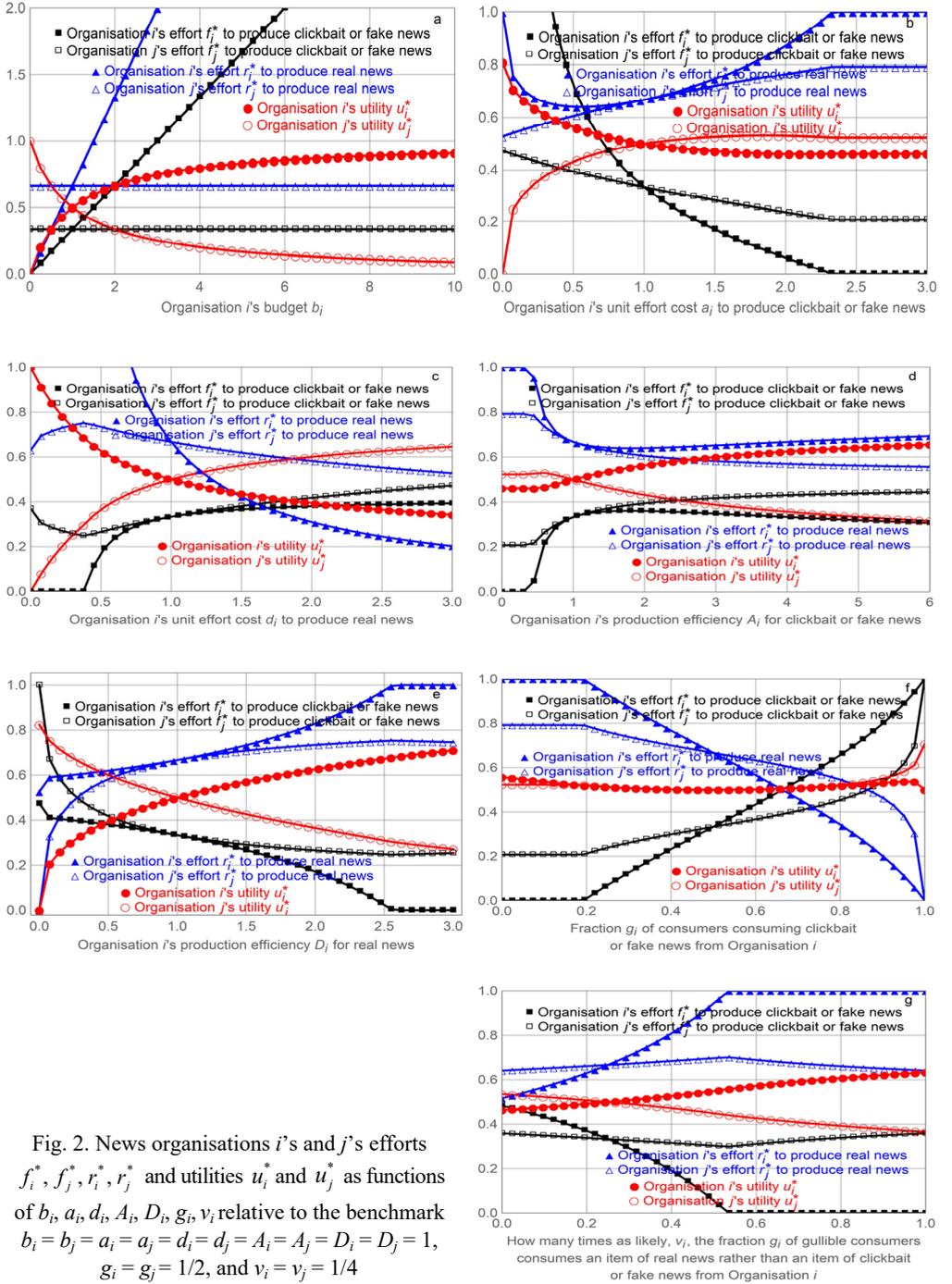
Fig. 2. News organisations i's and j's efforts f_i^*, f_j^*, r_i^*, r_j^* and utilities u_i^* and u_j^* as functions of b_i, a_i, d_i, A_i, D_i, g_i, v_i relative to the benchmark $b_i = b_j = a_i = a_j = d_i = d_j = A_i = A_j = D_i = D_j = 1$, $g_i = g_j = 1/2$, and $v_i = v_j = 1/4$

organisation j benefits from increasing a_i which enables it to exert lower effort f_j^* at fixed unit cost $a_j = 1$, and earn concavely increasing utility u_j^* which, eventually, decreases slightly towards a constant.

In panel c), organisation i's effort f_i^* increases concavely as its unit effort cost d_i to produce real news increases, equalling zero when $d_i \leq 0.39$. Both too low d_i, and too high a_i induce organisation i not to produce clickbait or fake news, and instead focus exclusively on producing real news. As d_i increases, organisation i's utility u_i^* decrease convexly, and organisation j's utility u_j^* increase concavely. Determined numerically, $\lim_{d_i \to \infty} f_i^* = 0.41$ and $\lim_{d_i \to \infty} u_i^* = 0$, since organisation i cannot compete effectively on real news with organisation j when its unit effort cost d_i is too high. Furthermore, $\lim_{d_i \to \infty} f_j^* = 1$, since clickbait or fake news is where the competition is, and $\lim_{d_i \to \infty} u_j^* = 0.84$.

In panel d), organisation i's effort f_i^* increases logistically towards a maximum $f_i^* = 0.36$ when $A_i = 1.80$, and thereafter decreases convexly as its production efficiency A_i for clickbait or fake news increases, equalling zero when $A_i \leq 0.43$. Too low A_i or d_i, or too high a_i, causes $f_i^* = 0$ since clickbait or fake news is not cost efficient to produce. Too high A_i expresses a luxury problem for organisation i where excessive clickbait or fake news can be produced at low effort f_i^*. Determined numerically, $\lim_{A_i \to \infty} f_i^* = \lim_{A_i \to \infty} u_j^*$ $= 0, \lim_{A_i \to \infty} u_i^* = 0.81, \lim_{A_i \to \infty} f_j^* = 0.47$.

In panel e), organisation i's effort f_i^* decreases convexly (except when D_i is very low) as its production efficiency D_i for real news increases, reaching zero when $D_i \geq 2.56$. Too high D_i or a_i or too low A_i or d_i causes $f_i^* = 0$ since clickbait or fake news is not cost efficient to produce. Organisation i benefits from increasing D_i which causes its utility to increase concavely, eventually reaching $\lim_{D_i \to \infty} u_i^* = 1$, where $\lim_{D_i \to \infty} u_j^* = 0$, and $\lim_{D_i \to \infty} f_i^* = 0.33$.

In panel f), organisation i's effort f_i^* increases circa linearly, and eventually slightly convexly, as its fraction g_i of consumers consuming clickbait or fake news increases to $g_i = 1$, equalling zero when $g_i \leq 0.19$. Too low elasticity or weight $g_i \leq 0.19$ assigned to the contest over clickbait or fake news induces organisation i to focus exclusively on producing real news. Organisation i always produces real news when $g_i < 1$, which follows from the asymmetry caused by the benchmark where

$v_i = v_j = 1/4$ in $G_i = F_i + v_i R_i$ in [6] causes the production of real news to impact the first contest in (15).

In panel g), organisation i's effort f_i^* decreases convexly as v_i increases, reaching zero when $v_i \geq 0,53$, where v_i expresses how many times as likely the fraction g_i of gullible consumers consumes an item of real news rather than an item of clickbait or fake news from news organisation i. Too high v_i or D_i or a_i, or too low A_i or d_i, causes $f_i^* = 0$, since clickbait or fake news is not cost efficient to produce. Organisation i benefits from increasing v_i which causes increasing utility u_i^*. In contrast, organisation j's utility u_j^* decreases as v_i increases.

4. Conclusion

The article first presents a decision theoretic model, and thereafter a game theoretic model, where two news organisations allocate their budgets between producing clickbait or fake news, and real news. They seek to attract gullible consumers who consume clickbait or fake news more than real news, and non-gullible consumers who consume only real news. The two news organisations compete with each other in one contest over clickbait or fake news, and one contest over real news.

The decision theoretic model shows that increasing a news organisation's budget causes both more clickbait or fake news, and more real news, to be produced. More clickbait or fake news is produced if the news organisation's unit effort cost to produce real news increases, its production efficiency for clickbait or fake news increases, and the fraction of consumers consuming clickbait or fake news increases. In contrast, less clickbait or fake news is produced if a news organisation's unit effort cost to produce clickbait or fake news increases, its production efficiency for real news increases, and the gullible consumers consume real news with a higher frequency. The news organisation's utility increases if its budget increases, its production efficiencies for clickbait or fake news, and real news, increase, and if the gullible consumers consume more real news in addition to clickbait or fake news. In contrast, the news organisation's utility decreases if its unit effort costs to produce clickbait or fake news, and real news, increase.

The game theoretic model illustrates seven insights. First, higher budget for one news organisation causes higher effort and utility for this news organisation, and constant effort and decreasing utility for the other news organisation.

Second, higher unit effort cost for clickbait or fake news causes lower and, eventually, no effort, and lower utility. The competing news organisation receives overall higher utility.

Third, low unit effort cost for real news causes no effort to produce clickbait or fake news, and high utility. Higher unit effort cost for real news causes higher effort to produce clickbait or fake news, and lower utility. The competing news organisation receives overall higher utility.

Fourth, sufficiently low production efficiency for clickbait or fake news causes no effort to produce clickbait or fake news. Higher production efficiency for clickbait or fake news causes inverse U-shaped effort to produce clickbait or fake news. For intermediate production efficiency, the competition with the other news organisation is fierce and their utilities are similar. As the production efficiency increases above intermediate, the competition becomes less fierce, and the news organisation can cut back on its effort while receiving higher utility. The competing news organisation receives lower utility.

Fifth, higher production efficiency for real news causes lower effort to produce clickbait or fake news, and higher utility. The competing news organisation receives lower utility. Sufficiently high production efficiency for real news causes no effort to produce clickbait or fake news.

Sixth, sufficiently low weight assigned to the contest over clickbait or fake news induces the news organisation to exert no effort to produce clickbait or fake news. Higher weight assigned to the contest over clickbait or fake news induces both news organisations to exert higher effort to produce clickbait or fake news.

Seventh, as the gullible consumers become more likely to consume real news in addition to fake news, the news organisation exerts lower, and eventually no effort, to produce clickbait or fake news, while receiving higher utility. The competing news organisation receives lower utility.

Future research should incorporate more characteristics into the model, generalise to more than two news organisations, account for dynamics through time, and compile empirical support.

Future research may also assess whether owner biases are more or less prominent than market biases. For example, consumers may reinforce their biases by consuming biased news which may reflect confirmation bias. This, in turn, may reflect social dynamics, such as pluralistic ignorance and group identity, and whether a consumer is a self-respecting member of a politically aligned or biased group. Such consumers may express consternation or outrage at the bias in the media organisations aligned against one's own group, and satisfaction at the bias aligned with one's own group, to minimise internal cognitive dissonance.

Future research may also consider alignment of fake content with biased narratives, and the malinformation problem where a package of facts is selectively pruned to support a biased narrative. This is a common scenario where the effort to produce fake news is comparable or equal to the effort to produce real news. Empirically, this phenomenon is frequently observed, and may represent an equilibrium between competing media producers.

Nomenclature

Parameters

b_z – news organisation z's budget, $z = i, j$
a_z – news organisation z's unit effort cost to produce clickbait or fake news
d_z – news organisation z's unit effort cost to produce real news
A_z – news organisation z's production efficiency for clickbait or fake news
D_z – news organisation z's production efficiency for real news
k_z – news organisation z's parameter for nonlinear impact in production function for clickbait or fake news
h_z – news organisation z's parameter for nonlinear impact in production function for real news
g_z – fraction of consumers consuming clickbait or fake news from news organisation z, $0 \le g_z \le 1$
v_z – how many times as likely the fraction g_z of gullible consumers consumes an item of real news rather than an item of clickbait or fake news from news organisation z, $0 \le v_z \le 1$

Independent variable

f_z – news organisation z's effort to produce clickbait or fake news

Dependent variables

r_z – news organisation z's effort to produce real news
F_z – news organisation z's production function for clickbait or fake news
R_z – news organisation z's production function for real news
G_z – news consumption from organisation z by the gullible consumers
T_z – trustworthiness of news organisation z
u_z – news organisation z's utility

Acknowledgement

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Appendix. Properties 1 and 2

Differentiating f_i in (11) with respect to the various parameters when $A_i d_i g_i > a_i D_i v_i$ gives

$$\frac{df_i^*}{db_i} = \frac{A_i d_i g_i - a_i D_i v_i}{a_i \left(A_i d_i - a_i D_i v_i \right)} \geq 0, \quad \frac{df_i^*}{da_i} = -\frac{b_i g_i}{a_i^2} - \frac{b_i D_i^2 v_i^2 \left(1 - g_i \right)}{\left(A_i d_i - a_i D_i v_i \right)^2} \leq 0$$

$$\frac{df_i^*}{dd_i} = \frac{b_i A_i D_i v_i \left(1 - g_i \right)}{\left(A_i d_i - a_i D_i v_i \right)^2} \geq 0, \quad \frac{df_i^*}{dA_i} = \frac{b_i d_i D_i v_i \left(1 - g_i \right)}{\left(A_i d_i - a_i D_i v_i \right)^2} \geq 0$$

$$\frac{df_i^*}{dD_i} = \frac{b_i d_i A_i v_i \left(1 - g_i \right)}{\left(A_i d_i - a_i D_i v_i \right)^2} \leq 0, \quad \frac{df_i^*}{dg_i} = \frac{b_i A_i d_i}{a_i \left(A_i d_i - a_i D_i v_i \right)} \geq 0 \tag{A1}$$

$$\frac{df_i^*}{dv_i} = -\frac{b_i d_i A_i D_i \left(1 - g_i \right)}{\left(A_i d_i - a_i D_i v_i \right)^2} \leq 0$$

Differentiating u_i in (11) and (12) with respect to the various parameters gives

$$\frac{du_i^*}{db_i} = \begin{cases} \dfrac{A_i D_i^{1-g_i} g_i^{g_i} \left(1 - g_i \right)^{1-g_i}}{a_i^{g_i} \left(A_i d_i - a_i D_i v_i \right)^{1-g_i}} \geq 0 \text{ if } A_i d_i g_i \geq a_i D_i v_i \\[3mm] \dfrac{D_i v_i^{g_i}}{d_i} \geq 0 \text{ otherwise} \end{cases}$$

$$\frac{du_i^*}{da_i} = \begin{cases} -\dfrac{A_i b_i D_i^{1-g_i} g_i^{g_i} \left(1 - g_i \right)^{1-g_i} \left(A_i d_i g_i - a_i D_i v_i \right)}{a_i^{1+g_i} \left(A_i d_i - a_i D_i v_i \right)^{2-g_i}} \leq 0 \text{ if } A_i d_i g_i \geq a_i D_i v_i \\[3mm] 0 \text{ otherwise} \end{cases}$$

$$\frac{du_i^*}{dd_i} = \begin{cases} -\dfrac{A_i^2 b_i D_i^{1-g_i} g_i^{g_i} \left(1-g_i\right)^{2-g_i}}{a_i^{g_i} \left(A_i d_i - a_i D_i v_i\right)^{2-g_i}} \le 0 \text{ if } A_i d_i g_i \ge a_i D_i v_i \\[3mm] -\dfrac{b_i D_i v_i^{g_i}}{d_i^2} \le 0 \text{ otherwise} \end{cases}$$

$$\frac{du_i^*}{dA_i} = \begin{cases} \dfrac{b_i D_i^{1-g_i} g_i^{g_i} \left(1-g_i\right)^{1-g_i} \left(A_i d_i g_i - a_i D_i v_i\right)}{a_i^{g_i} \left(A_i d_i - a_i D_i v_i\right)^{2-g_i}} \ge 0 \text{ if } A_i d_i g_i \ge a_i D_i v_i \\[3mm] 0 \text{ otherwise} \end{cases}$$

$$\frac{du_i^*}{dD_i} = \begin{cases} \dfrac{A_i^2 b_i d_i g_i^{g_i} \left(1-g_i\right)^{2-g_i}}{a_i^{g_i} D_i^{g_i} \left(A_i d_i - a_i D_i v_i\right)^{2-g_i}} \ge 0 \text{ if } A_i d_i g_i \ge a_i D_i v_i \\[3mm] \dfrac{b_i v_i^{g_i}}{d_i} \ge 0 \text{ otherwise} \end{cases} \qquad\qquad \text{(A2)}$$

$$\frac{du_i^*}{dg_i} = \begin{cases} -\dfrac{b_i A_i D_i^{1-g_i} g_i^{g_i} \left(1-g_i\right)^{1-g_i}}{a_i^{g_i} \left(A_i d_i - a_i D_i v_i\right)^{1-g_i}} \ln\left(\dfrac{a_i D_i \left(1-g_i\right)}{g_i \left(A_i d_i - a_i D_i v_i\right)}\right) \le 0 \text{ if } A_i d_i g_i \ge a_i D_i v_i \\[3mm] \dfrac{b_i D_i v_i^{g_i} \ln v_i}{d_i} \le 0 \text{ otherwise} \end{cases}$$

$$\frac{du_i^*}{dv_i} = \begin{cases} \dfrac{b_i A_i a_i^{1-g_i} D_i^{2-g_i} g_i^{g_i} \left(1-g_i\right)^{2-g_i}}{\left(A_i d_i - a_i D_i v_i\right)^{2-g_i}} \ge 0 \text{ if } A_i d_i g_i \ge a_i D_i v_i \\[3mm] \dfrac{b_i D_i g_i}{d_i v_i^{1-g_i}} \ge 0 \text{ otherwise} \end{cases}$$