Bias Out Of The Blue

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Abstract

We present a model of the market for news with rational voters who seek information to make a better decision and a profit-maximizing media outlet who maximizes viewership and generate some interior bias which is consistent with the empirical literature. The innovation of our model is that bias emerges even though there is no exogenous asymmetry in the game. The first driver of the emergence of bias is that we define it as the difference between the numbers of journalists from two opposite political camps a media outlet hires whereas in most of the literature, bias is defined over reporting strategies only. The second driver of the bias is the resulting convexity of the media outlet's profit function. Having a continuum of voters with uniformly distributed priors to attract, a media outlet might choose to hire more of a certain type of journalists to receive better information about a certain state depending on his income and technology level. This is the same reason why voters prefer receiving information from a media outlet while they have access to a public signal such as social media. It is because media outlets can hire credible journalists, columnists or reporters to distribute more precise information. We also provide some comparative statics which say surprisingly that higher income and technology of media outlets trigger bias whereas higher precision of a public signal alleviate it.

1 Introduction

Media is considered the fourth pillar of democracy. It is an informative bridge between governing bodies and public. For this reason, it is important for media to be independent of the other three bodies.

Empirical research on media began in the 1930s mostly affected by Hitler's and Mussolini's use of media as a heavy propaganda tool. Hence, there is no surprise that the conventional wisdom was that the bias is a result of ideological media outlets trying to manipulate public opinion. However, this view has been challenged by recent empirical studies. Shapiro & Gentzkow (2010) suggests that media bias should be explained with the idea of profit-maximizing outlets comforting to consumer beliefs. Our model follows their approach on firm side meaning that the media outlet we consider is purely profit-maximizing. Some blame Fox News or other right-wing media for the outcome of the 2016 presidential elections in the US. However, this does not mean that those outlets are taking an ideological stance. A New York Magazine article outlining mostly the details of Roger Ailes case by Gabriel **(author?)** (2015) also states that Fox News owner Rupert Murdoch instructed Fox News executives to take down Donald Trump. However, as the primary results came out, there was a shift in Fox News's attitude towards Trump. We think that this cannot be explained by simply a sudden change of political views of the Fox News owner. We believe that media firms are worth too much to risk for a political view.

There are different views also on consumer side. One is that consumers demand biased news because of its entertainment value. For example, a liberal voter might enjoy reading unfavorable news about a Republican candidate. Consistent with the literature, we call those individuals who receive entertainment value from news reports biased and those who care about media only as an information source rational. Mullainathan & Shleifer (**(year?)**) claims that the only way media bias exists is with biased readers. This kind of models in which consumers are not rational, the bias of a consumer is represented by an additive term in the utility function which captures the consumer's extra payoff from her subjective beliefs being reinforced. The other view contains economically a more standard approach in which a consumer takes an action and receive a payoff depending only on her action and the true state of the world. Then, media serves as an information source which helps individuals make better decisions and has a welfare-improving role. We take the latter approach on consumer side. However, it is worthwhile to note that rational consumers who have different opinions about a state of the world process the same message differently than each other. This leads to beliefs diverging and polarization that we observe especially in the political environment of the U.S. This paper contains a static model for the time being so we do not offer any asymptotic analysis.

Given our approaches on the supply and the demand side, the question becomes how media bias emerges with profit-maximizing firms and rational individuals. The answer that Shapiro & Gentzkow (2006) came up with is non-uniform belief. Consider a binary state of the world. If a decision maker's belief over the right state occurring is strictly more than half, the media outlet would slant its reports to the right. Our model relaxes their assumption of belief asymmetry. Instead, we have a continuum of voters whose beliefs over one state out of a binary are uniformly distributed with full support. We show that it is still possible to see media bias.

In this paper, we design a model of a news market where a media outlet maximizes the number of his audience who has subjective prior beliefs and consumes news reports to inform their private decisions. The media outlet has the option to hire different types of journalists. Each type of journalist has a network on different candidate. So a left-wing type of journalist brings favorable news about L and unfavorable news about R and vice versa for a right-wing type of journalist. In real politics, majority of journalists are associated with either the right or the left wing. Moreover, those journalists who are considered to be from the left-wing (the right-wing) have closer relations with Liberal (Republican) candidate campaigns. This is what we base our assumption on that certain type of journalist brings certain type of message to the outlet. Note that apart from being one of the types, the journalists are identical in terms of hiring cost and precision to preserve the symmetry that we promised.

Given subjective prior beliefs, voters might value certain types of signals more than others and hence prefer the outlets which employ those signals. However, the prior belief distribution is symmetric around the uniform one so media outlets that seek to maximize profits do not trivially choose to slant their reports. In short, the question that we seek to answer is what is the best catering strategy to uniformly distributed subjective priors.

Our result says that the optimal strategy of the media outlet depends on the convexity of the cost function associated with acquiring signals. The convexity of the cost function favors unbiasedness, whereas the opposite leads to bias. If the cost function is concave or linear, the equilibrium is extremely biased. Otherwise, we might have interior or no bias. Our contribution is to generate bias out of the blue, without any exogenous asymmetry.

This paper has also a say on increasing trend of media bias. There is no consensus that competition among media outlets leads to more extreme biases in different directions, namely polarization even though majority of the recent literature says it does. **(author?)** (2006) documents that the media underwent fundamental changes in the U.S. between 1870 and 1920 in the direction of non-partisan reporting accompanied with rising competition. This contradicts the idea of positive relation between bias and competition. Our model predicts that competition does not change the intensity of bias whereas it leads to polarization.

There is no doubt that social media has become a significant source of information in news market. Even though we do not have any strong stance or claim on how social media functions in this paper, we think it is worth to mention because there are some parts that the reader might relate to social media. Sometimes, it is the case that we observe reports earlier on Twitter or on other social platforms by a tweet or a port of first witnesses of a scene and then see it published on mass media. Nevertheless, people still choose to receive information from news outlets or confirm the information that they gathered from social media. This implies that media outlets offer something that readers find valuable on top of the information coming from social media. Media outlets have resources dedicated to picking up credible evidence when they display a report whereas social media contains a lot of unreliable information which might be hard to distinguish from reliable ones. This distinctive feature of media outlets that makes them attract voters is precision and credibility in our model. They offer exclusive reporting and framing. People do want to know what Maureen Dowd, David Brooks or Jonah Goldberg thinks on some certain issues and they believe the information their favorite columnists deliver more than anything else. Moreover, in real life, the state of the world is not usually binary and neither the message space is. This might lead to disinformation originating from social media because there are many individual users who post biased reports. Some think that social media is a platform which brings millions together and so the precision of information coming from social media goes to 1. There are also some who think that social media is platform not producing information but allowing people share their subjective opinions. If the reader would like to interpret the public signal in our model as social media, the approach would something in between the former and the latter.

The rest of the paper is organized as follows. We review the media literature in Section 2. Section 3 describes the model. In Section 4, we solve the model and present our main result. In Section 5, we display comparative statics with computer simulations. Section 6 concludes the paper.

2 Literature Review

Even though empirical studies go back to as early as 1940s (Lazarsfeld et. al., **(year?)**), theoretical literature on media bias began and has been growing recently. A significant question that researchers have been trying to answer in media literature is if bias is originating from the supply (Anderson & Mclaren **(year?)**, **(author?)** 2006, **(author?)** 2006) or demand side, or both. Recent studies suggest that it is coming from the demand side. Mullainathan and Shleifer (2005) claim that unless consumers enjoy entertainment value of news, there is no room for bias. By enjoying entertainment value, what we mean is that consumers get some extra payoff from media firms reinforcing their priors. Shapiro and Gentzkow (**(year?)**) and **(author?)** (2008) use a fact that has been useful in media literature to improve this result. That is, a Bayesian consumer who is uncertain about the quality of information infers that the source is of higher quality if the information caters to the consumer's prior belief. Then, in order to maximize the posterior of the consumer over the source being of higher quality, a media outlet slants its reports to whichever direction the consumer's prior is leaned to. They use the term rational consumers to refer to those whose utility does not include any entertainment value as it is common in the literature. In other words, rational consumers simply seek the truth. However, Shapiro & Gentzkow (2006) has single consumer in their model.

With multiple consumers, it is complicated to characterize the interior solution that empirical studies point at (Shapiro & Gentzkow **(year?)**, **(author?)** 2005, **(author?)** 2012). **(author?)** (2011) does that to some extent with a biased expert and an uninformed decision maker with uniformly distributed intrinsic preference. Since the timeline is a cheap talk setting, the decision maker is not influenced by the reports that are unfavorable to the expert's preference. As we mentioned earlier, our model relaxes the assumption of the sender being biased.

Earlier empirical studies (Glasser, Allen, and Blanks (**(year?)**), Pritchard (**(year?)**)) relied on judgement to measure the slant. Groseclose & Milyo (2005) made an important contribution by proposing a new measure of ideological content. They counted the times that a media outlet cites various think tanks. Their results are interesting, or maybe not: they say that there is a significant liberal bias in the U.S. media. All of the news outlets they analysed except Fox News' Special Report received a score to the left of the average member of Congress. Similarly, Shapiro & Gentzkow (2010) compare phrase frequencies in a newspaper to identify whether that newspaper's language is more similar to that of a congressional Republican or Democrat. Another method to measure bias is to count the number of coverages of issues that are owned by the Democratic or the Republican Party based on a predetermined issue ownership list (**(author?)** 2015, **(author?)** 2011). **(author?)** (2011) develop an econometric model to show that voters rely on the media for information during campaigns but the extent of this reliance depends upon the degree and direction of any bias. To be more precise, endorsements for the Democratic candidate from left-leaning newspapers are less influential than are endorsements from neutral or right-leaning newspapers. This result supports our rationality assumption on the consumer side.

Our model is similar to both **(author?)** (2014) and Oliveros and Vardy (**(year?)**) in terms of information acquisition. Bias is defined over the choice of sources that information is received by media outlets. However, we relax the assumption of a strictly positive probability of a partisan voter and ideological editors.

There is a number of dynamic models as well. (Bernhardt et. al. **(year?)**, **(author?)** 2006). For the time being, we do not focus on asymptotic properties of belief distribution of consumers and leave the model static. Also, it is worthwhile that even though the media outlet chooses what type of journalists he will hire more and less in this model, the resulting bias is not editorial (**(author?)** 2005, **(author?)** 2007). For a deeper and more comprehensive survey of the media literature, see **(author?)** (2015).

3 The Model

3.1 The Environment

There is a continuum of voters and a media outlet. The mass of voters is normalized to unity. There is a binary state of the world $S \in \{L, R\}$. Consider L as representing that a liberal candidate is the right choice to be elected and R that a republican candidate is. A more common way that this is introduced in the literature is that there are two candidates and voters want to choose the candidate with higher valence. Voters are unsure about which candidate has higher valence and they all have different opinions on that.

3.2 The Players

A type of a voter is identified by her subjective belief θ on the state being right. Beliefs are distributed uniformly on $[0, 1]$ with full support. An alternative way to identify a voter would be by an intrinsic (**(author?)** 2011) or an idiosyncratic preference (**(author?)** 2014) which both capture an euclidean distance between her preference and true state of the world instead of a subjective prior. In that case, we would assume a common prior based on the true distribution of the state. As long as the distribution of intrinsic or idiosyncratic preferences is the same with the distribution of subjective priors, the results would be the same. As our results do not depend on whether a voter is identified by her prior or intrinsic or idiosyncratic preference, we prefer going with the former approach without loss of generality.

A media outlet has a uniform belief over the two states so the probability that he assigns to the state being R or L is 0.5. However, his action is independent of his belief over the state because his profit only depends on viewership which we will formalize in the next subsection. Therefore, the prior belief of the media outlet does not play any role in this game. We assume a uniform prior for the media outlet for the sake of consistency of his prior with those of voters.

3.3 The Game and The Payoffs

3.3.1 Information Acquisition

Every player in this model has access to a public signal $y \in \{l, r\}$ with a precision $\pi = Pr(y = l|S = L) = Pr(y = r|S = R) \in [0.5, 1]$. One can interpret this as social media or an agent's own ability to gather information from friends, colleagues, neighbours and so on. In addition to the public signal, the media outlet has an option to hire certain journalists and reporters who conduct investigations to acquire information with perfect precision ($Pr(s = l|S = L) = Pr(s = r|S = R) = 1$) on a certain state. As an example, consider New York Times hiring more leftist staff to receive better information about news that favor the left state. This part of information acquisition structure is essentially no different than what Kamenica & Gentzkow (**(year?)**) has.

The media outlet does not have enough budget to hire all of the journalists out there. Let us assume that he has to pay a fixed amount of salary for every journalist that he hires and N is maximum number of journalists that he can hire given his budget constraint. Let N_l and N_r be the numbers of left-wing and right-wing journalists that the outlet hires. We will normalize N_l and N_r by $n_l = \frac{N_l}{N}$ and $n_r = \frac{N_r}{N}$ so that n_l and n_r are in $[0, 1]$. The reason we do this normalization is that we assume that the media outlet has a general form Cobb-Douglas production function: $f(k, n_{s\in\{l,r\}}) = k^{\beta} n^{\alpha}_{s\in\{l,r\}}$ where α and β are the elasticities of labor and endowment, and the endowment is fixed. Endowment can be interpreted as any other means of the media outlet to acquire information. The reason for calling it endowment is that we implicitly assume that a media outlet's ability to receive information net of his labor work is positively related to his total endowment. Consider New York Times having contracts with Associated Press, United Press International and some individual reporters ("nightcrawlers") to gather information. As a media outlet is endowed with more resources, his ability to gather information will be higher.

We define bias as $b = n_r - n_l$, the difference between the number of right-wing and left-wing journalists that the outlet has. A positive b implies right bias and a negative one implies left bias. The media outlet chooses a pair of (n_l, n_r). By choosing any arbitrary (n_l, n_r), the outlet guarantees to receive perfect signal with probability $f(k, n_l)$ when the true state is left and with probability $f(k, n_r)$ when the true state is right. Let $\sigma_l = f(k, n_l)$ and $\sigma_r = f(k, n_r)$.

Even though the information acquisition is as in standard Bayesian persuasion case, the media outlet is not committed to reporting his signal truthfully. However, Blackwell's (1951) theorem says that an experiment γ that provides information about the state of the world is preferred by every decision maker to an experiment γ' if and only if γ' is a garble of γ. Hence, the media outlet does not have incentive to garble his signals and so we consider the media outlet's strategy as simply choosing (σ_l, σ_r).

3.3.2 The Media Outlet's Decision and Payoff

Since $n_l + n_r \leq 1$, it follows that

$$\sigma_l^{\frac{1}{\alpha}} + \sigma_r^{\frac{1}{\alpha}} \leq k^{\frac{\beta}{\alpha}} \tag{1}$$

Let us call $q = k^{\frac{\beta}{\alpha}}$ and interpret the inequality (1) as the media outlet being endowed with a limited resource q that can be spent on acquiring information. He allocates this resource between acquiring perfect signals about left and right states. Let us restrict q to be weakly smaller than 1 in order to secure σ_l and σ_r from exceeding 1. Inequality (1) represents the cost function in terms of (σ_l, σ_r) so let $C(\sigma_l, \sigma_r) = \sigma_l^{\frac{1}{\alpha}} + \sigma_r^{\frac{1}{\alpha}}$. We can either say that the media outlet's decision is to choose (n_l, n_r) such that $n_l + n_r \leq 1$ or (σ_l, σ_r) such that $C(\sigma_l, \sigma_r) \leq q$. We prefer the latter for the sake of simplicity. Note that (n_l, n_r) is on a discrete space. However, we will work on continuous space for the ease of computations. It will not change the essence of our results as long as N is not too small.

Figure 1 displays the media outlet's strategy (σ_l, σ_r) from the perspective of voter with prior θ. Nature determines the state to be R with probability θ or L with probability $1-\theta$. Suppose the state is R. Then, with probability σ_r, the game moves on to the node where the journalists of the outlet brings him right message and the outlet truthfully reports this message; or with probability $1-\sigma_r$, it goes to the node where the outlet does not receive any message from his staff and reports the public signal which is right with probability π and left with probability $1-\pi$. Note that the report space of the outlet is $\{l, r\}$, so he does not have the option to not report or report any other news than r or l. The other parts of the tree are interpreted similarly.

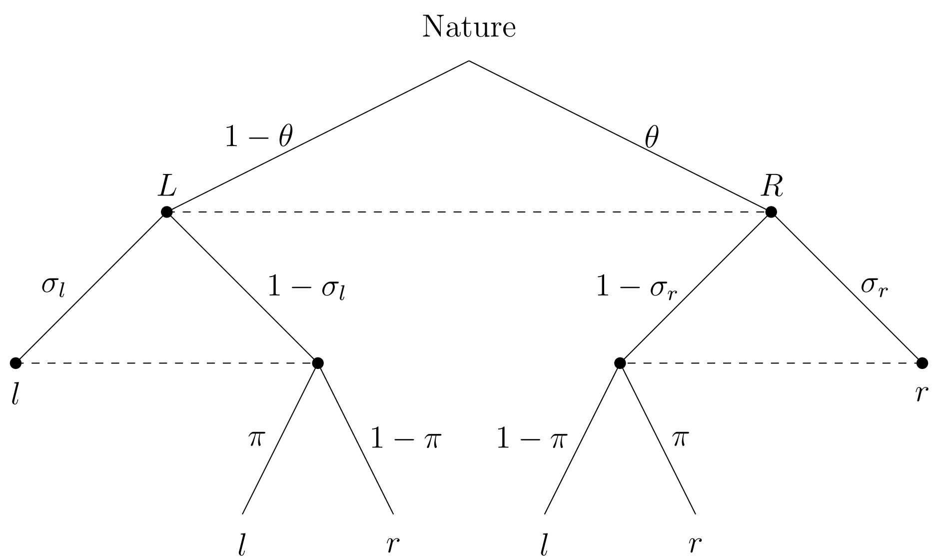

Figure 1: How voter with prior θ sees the media outlet's strategy (σ_l, σ_r).

The media outlet maximizes his profit which is assumed to be an increasing affine function of the total utility of his audience. It is worthwhile to note that a more common assumption in the literature is that media outlet's profit is an affine function of the measure of his audience to capture the fact that the majority of outlets' profits come from advertising. We capture the very same situation. However, advertising revenue is based on the number of page views. We believe that not every reader views the same number of pages on a media outlet. Our implicit assumption is that the number of page views by a voter is an affine function of her payoff from receiving information from the media outlet. Therefore, the outlet maximizes the viewership instead of readership. In our understanding, viewership is represented by total utility of the audience whereas readership is represented by measure of the audience. We think that it is reasonable or even necessary to assume that a more dedicated reader visits more pages, read more columns which increase the advertising revenue of the outlet.

We furthermore assume that there is no subscription fee or any price to view the reports so the cost of reading the outlet is arbitrarily small as it is the case for most of the digital news outlets. Thus, voters choose to receive information from the media outlet whenever the outlet yields them a strictly positive extra payoff. The outlet's problem can be written as

$$\max_{\sigma_l,\sigma_r} V = \int_0^1 \mathbb{1}_{(\theta|\pi,\sigma_l,\sigma_r)} \times U(\theta,\pi,\sigma_l,\sigma_r)d\theta \tag{2}$$
$$st \;\; C(\sigma_l,\sigma_r) \leq q$$

where $\mathbb{1}_{(\theta|\pi,\sigma_l,\sigma_r)}$ is 1 if the voter θ reads the media outlet with the strategy (σ_l,σ_r), 0 otherwise and $U(\theta,\pi,\sigma_l,\sigma_r)$ is the net payoff of voter with prior θ from receiving information from the outlet given the precision of public signal π and the outlet's strategy (σ_l,σ_r).

3.3.3 Voter's Decision and Payoff

Each voter makes a decision between two actions or votes which we denote by $d = (L, R)$. Correctly matching her vote to the state yields payoff 1, whereas mismatching results in payoff 0.

3.3.4 Voter With No Information

If the voter with prior θ did not have access to any information, her payoff would be

$$E[u(\theta)] = \begin{cases} \theta & \text{if } \theta \in [0.5, 1] \\ 1 - \theta & \text{if } \theta \in [0, 0.5] \end{cases} \tag{3}$$

The first and second lines of equation (1) are voter's expected payoffs when she votes for the right and the left candidate respectively. It is obvious that those whose prior is greater than 0.5 votes for the right and those whose prior is less than 0.5 votes for the left. The median voter whose prior is 0.5 is indifferent and it does not matter for which candidate she votes and if she chooses to receive information from the outlet because any belief has zero measure. Note that there is no cost of voting since it would not play a role in our bias analysis. We will make it clear why a positive cost of voting would not play any role in our model in the subsequent section. Figure 2 exhibits the payoff distribution of voters without any information source. Horizontal axis accounts for the priors and the vertical represents the payoffs.

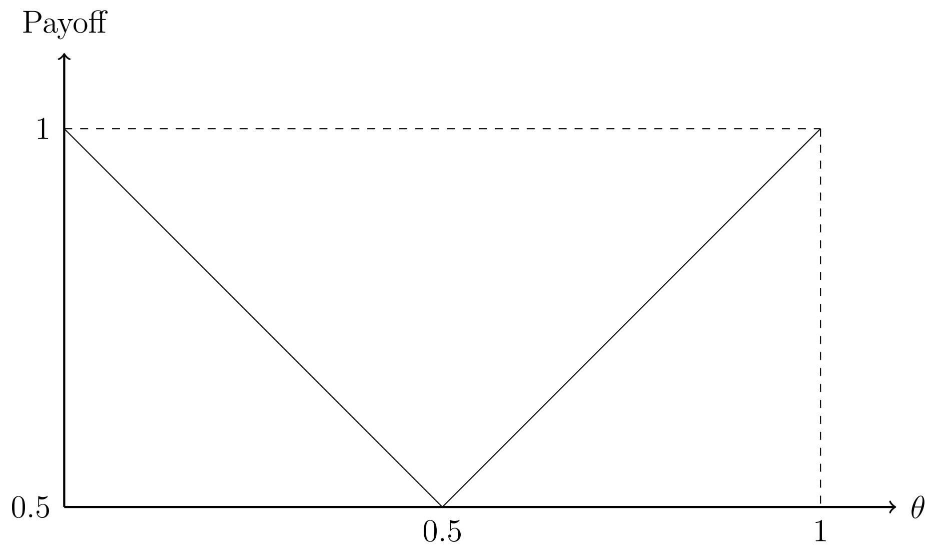

Figure 2: Payoff distribution of voters with respect to the priors without any information.

3.3.5 Voter With Access To The Public Signal

A voter observes one message which is the public signal in this case. Then, her action space becomes:

1. always voting for L,
2. always voting for R,
3. voting for L after public signal l and voting for R after public signal r.

We denote these actions by (L,L), (R,R) and (L,R). Notice that voting for L after public signal r and voting for R after public signal l ((R,L)) is strictly dominated unless π and θ are both 0.5.

Observing the public signal yields some extra payoff to some moderate voters who take the last action (L,R). While partisan voters are not persuaded with the public signal and vote for their favorite candidate no matter what the public signal is, some moderates vote for the candidate that the public signal favors. If a voter is moderate enough to benefit from the public signal, her expected payoff is

$$\begin{aligned} E[U(\theta,\pi)] &= Pr(y=l) \times Pr(S=L|y=l) + Pr(y=r) \times Pr(S=R|y=r) \\ &= [(1-\theta)\pi + \theta(1-\pi)]\frac{(1-\theta)\pi}{(1-\theta)\pi+\theta(1-\pi)} \\ &+ [\theta\pi + (1-\theta)(1-\pi)]\frac{\theta\pi}{\theta\pi+(1-\theta)(1-\pi)} \\ &= \pi \end{aligned} \tag{4}$$

Otherwise, her payoff remains either as θ or $1-\theta$ depending on if she is a partisan rightist or leftist. Therefore, the utility for any voter with prior θ is given by

$$E[u(\theta,\pi)] = \begin{cases} \theta & \text{if } \theta \in [\pi, 1] \\ \pi & \text{if } \theta \in [1-\pi, \pi] \\ 1-\theta & \text{if } \theta \in [0, 1-\pi] \end{cases} \tag{5}$$

The extra payoff by the public signal for voters is displayed by Figure 3.

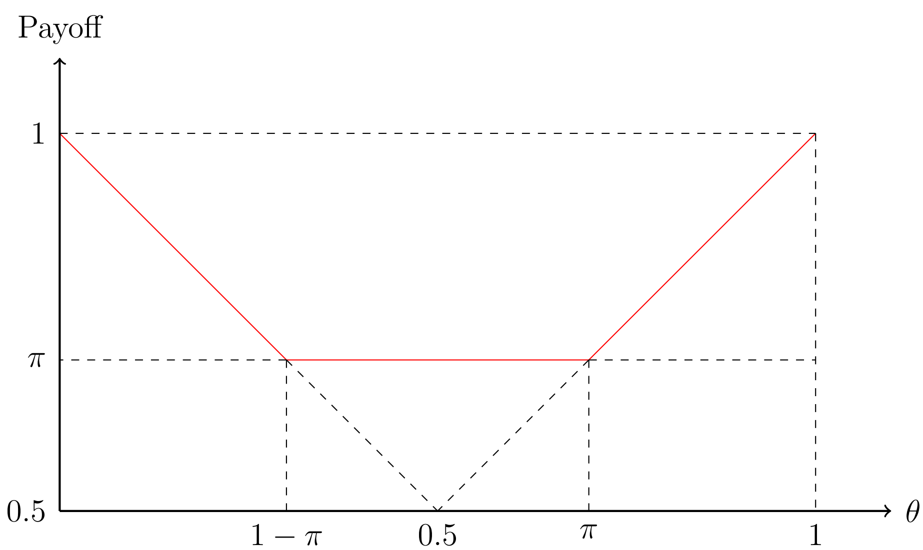

Figure 3: Payoff distribution of voters with respect to the priors having access to the public signal.

3.3.6 Voter With Access To The Public Signal and The Media

This time, a voter observes one public signal and one media report. Her action space then becomes

1. (L,L,R,L),

2. (R,L,R,R) and

3. (L,L,R,R)

where the first component is the choice in the first stage; the second is her vote when the media report and the public signal are both l; the third is her vote when the media report is l and the public signal is r; the fourth is her vote when the media report is r and the public signal is l; and the fifth is her vote when the media report and the public signal are both r. Notice that $(1, R, L, R, L)$ is strictly dominated again. In addition, when the media report and the public signal differ as in the third and the fourth component, a voter is sure that the state is what the media outlet reports because it is for certain that the report came from a journalist who has perfect precision.

We can think of media as sending two types of messages: conclusive and inconclusive. We define a conclusive message as one which is different than the public signal. Therefore, conclusive messages completely identify the state. We define an inconclusive message as one which is the same as the public signal. This means that unless σ_l or σ_r is 1, inconclusive messages do not identify the state.

Given a conclusive message by the media outlet, a voter's action is a no-brainer. If the message is inconclusive, some moderate voters' decisions will be influenced by the media so even receiving an inconclusive message from the outlet yields extra payoff to them. There may also be some stubborn voters with partisan right-wing or left-wing beliefs that do not change their voting behavior whatever the inconclusive message is so the media sending inconclusive message does not affect their payoffs.

For instance, suppose the public signal delivered l and everyone observes this. This can be interpreted as a situation when there is a mild perception on an issue in the society. Let us say that the media outlet reports r. Then, the media's information becomes very valuable to all because it implies that the state is R for certain. We need to consider 4 cases separately: media reporting r, public signal delivering l; media reporting l, public signal delivering r; media reporting r, public signal delivering r; media reporting l, public signal delivering l.

The probabilities of the 4 cases happening according to a voter with prior θ are

$$Pr(r,l|\theta) = \theta\sigma_r(1-\pi) \tag{6}$$

$$Pr(l,r|\theta) = (1-\theta)\sigma_l(1-\pi) \tag{7}$$

$$Pr(r,r|\theta) = \theta\pi + (1-\theta)(1-\sigma_l)(1-\pi) \tag{8}$$

$$Pr(l,l|\theta) = (1-\theta)\pi + \theta(1-\sigma_r)(1-\pi) \tag{9}$$

and the posteriors associated with the 4 cases follow as

$$Pr(R|\theta,r,l) = 1 \tag{10}$$

$$Pr(R|\theta,l,r) = 0 \tag{11}$$

$$Pr(R|\theta,r,r) = \frac{\theta\pi}{\theta\pi + (1-\theta)(1-\sigma_l)(1-\pi)} \tag{12}$$

$$Pr(R|\theta,l,l) = \frac{\theta(1-\sigma_r)(1-\pi)}{(1-\theta)\pi + \theta(1-\sigma_r)(1-\pi)} \tag{13}$$

If a voter is moderate enough so that her vote is influenced by an inconclusive message, her expected payoff becomes

$$E[U(\theta,\pi,\sigma_l,\sigma_r)] = \theta\sigma_r(1-\pi) + (1-\theta)\sigma_l(1-\pi) + \pi \tag{14}$$

If a voter is partisan enough to vote for the right candidate independent of conclusive messages, her payoff is

$$E[U(\theta,\pi,\sigma_l,\sigma_r)] = \theta + (1-\theta)\sigma_l(1-\pi) \tag{15}$$

Finally, if a voter is partisan leftist, her payoff is as follows

$$E[U(\theta,\pi,\sigma_l,\sigma_r)] = 1 - \theta + \theta\sigma_r(1-\pi) \tag{16}$$

In general, we can write the utility of any voter with θ as

$$E[U(\theta,\pi,\sigma_l,\sigma_r)] = \begin{cases} \theta + (1-\theta)\sigma_l(1-\pi) & \text{if } \theta \in [\frac{\pi}{1-\sigma_r(1-\pi)}, 1] \\ \theta\sigma_r(1-\pi) + (1-\theta)\sigma_l(1-\pi) + \pi & \text{if } \theta \in [1 - \frac{\pi}{1-\sigma_l(1-\pi)}, \frac{\pi}{1-\sigma_r(1-\pi)}] \\ 1 - \theta + \theta\sigma_r(1-\pi) & \text{if } \theta \in [0, 1 - \frac{\pi}{1-\sigma_l(1-\pi)}] \end{cases} \tag{17}$$

Figure 4 shows the payoff distribution of voters with access to the public signal and the media. The red line refers to Figure 3 which shows the payoffs with the public signal. If there is also media, the payoffs go up to the green line. The middle piece being positively sloped means that σ_r is higher than σ_l. Note that as long as σ_l or σ_r is positive, the measure of moderates whose votes are influences by inconclusive messages ($\bar{\theta} - \underline{\theta}$) is higher than that of those voters whose votes are affected by the public signal.

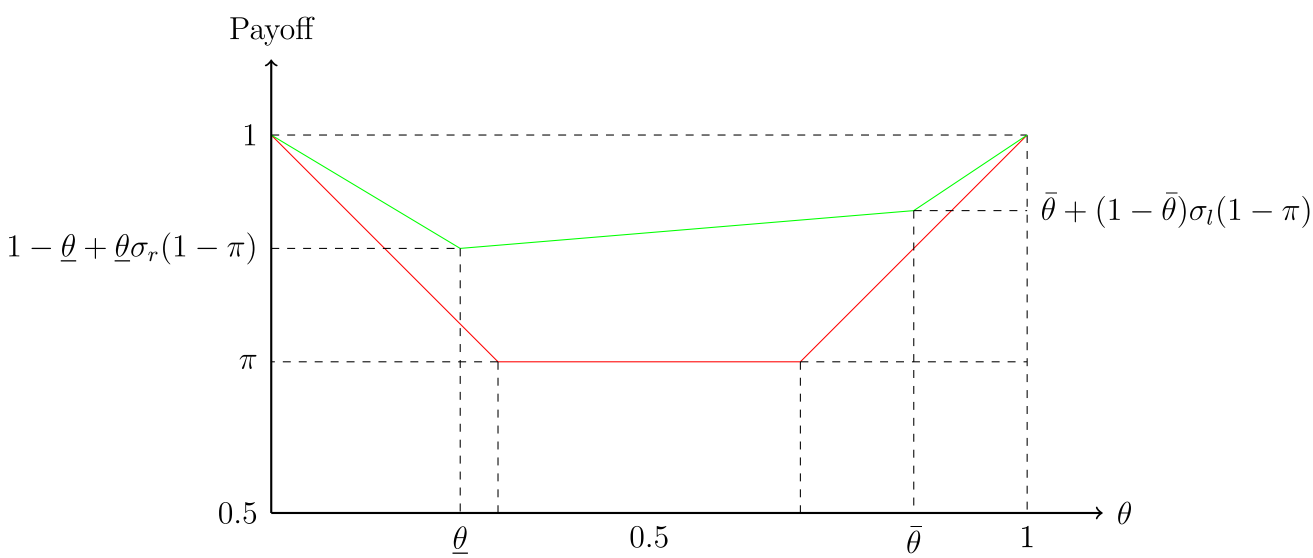

Figure 4: Payoff distribution of voters with access to the public signal and the media by the green line.

3.3.7 Strictly Positive Cost Of Voting

So far, we have assumed that voter turnout is 100% because there is no cost of voting and a voter's payoff depends only on her own action and the true state so we do not have the pivotal voter issue. We relax the first assumption here. Suppose that cost of voting is ε. With compulsory voting, all the lines in Figures 3 and 4 would be shifted down by ε as shown in the upper panel of Figure 5 so the profit of the outlet which is represented by the gray shaded area would remain the same for a given strategy. Hence, the problem of the outlet would not be affected. If voting is not compulsory, a voter has the option to abstain. Then, her action space

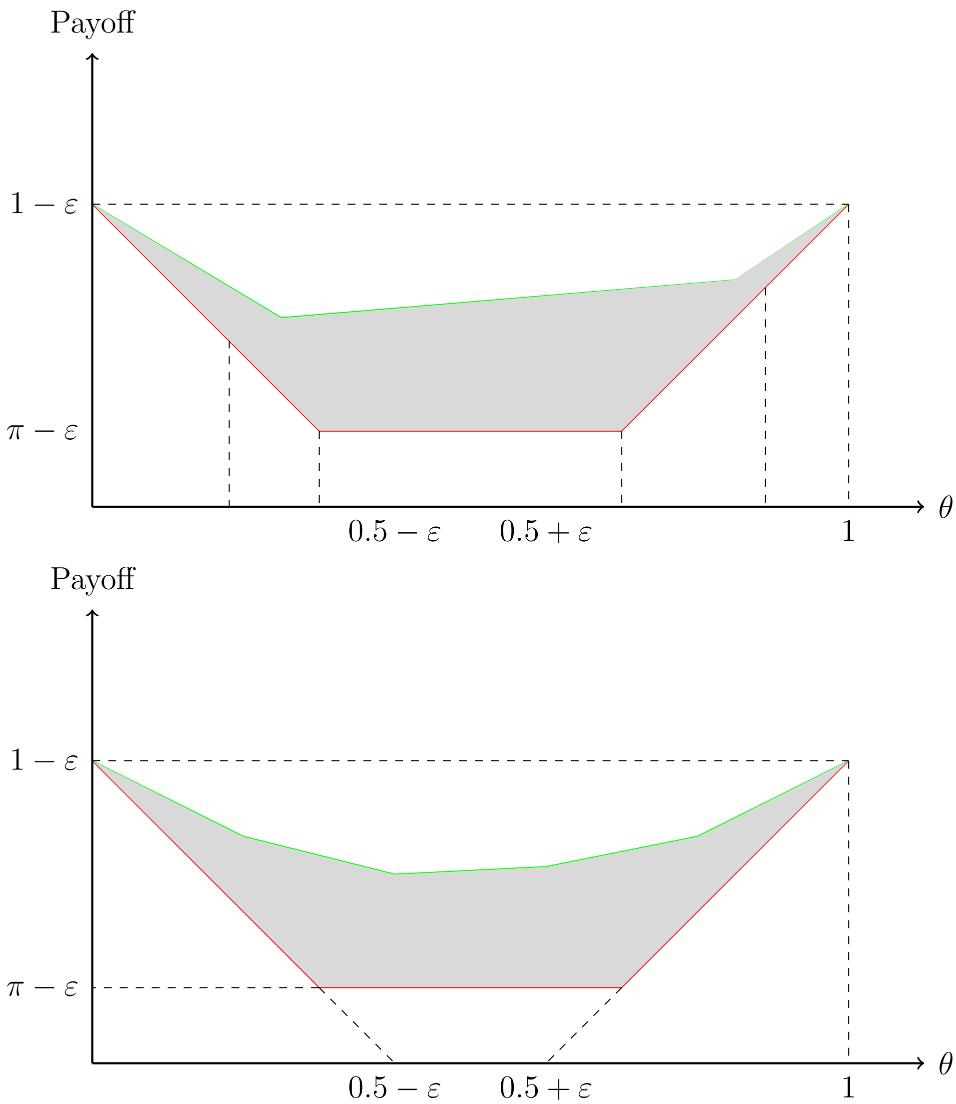

Figure 5: Payoff distribution of voters with cost of voting ε: Upper panel for compulsory voting, the lower for with abstaining option

becomes

(L,L,R,L), (L,L,R,A), (L,L,R,R), (A,L,R,A), (A,L,R,R) and (R,L,R,R) where A denotes abstain. Of course, there are some strictly dominated strategies which have not been exhibited. Similar to the previous analysis, left partisan voters play (L, L, R, L). Moderately left-wing voters play (L, L, R, A). The next switch occurs between (L, L, R, A) and either (L, L, R, R) or (A, L, R, A). The rest follows similarly. As a result, the payoff distribution is as shown in the lower panel of Figure 5. As we will see in the next section, the main driver of our result is the convexity of the green line which persists in the existence of cost of voting. Hence, we assume that it is zero for the ease of exposition.

4 Equilibrium Analysis

First, let us draw some results from equations (5) and (17). By comparing the second line of both equations, we see that the media outlet yields a strictly better payoff to any voter than the public signal as long as he spends some of his endowment.

4.1 Profit Of The Media Outlet

Figure 6 displays the profit of the media outlet for an arbitrary strategy (σ_l, σ_r). The red and the green lines represent the payoffs with access to the public signal and with access to the media along with the public signal respectively as in Figures 3 and 4. Then, the gray shaded region becomes the profit of the outlet which we will denote by V. We can write V with respect to (σ_l, σ_r) as the following:

$$
\begin{aligned}
V = & \frac{1}{2}\sigma_r(1-\pi)\big(1-\frac{\pi}{1-\sigma_l(1-\pi)}\big)^2 \\
& + \frac{1}{2}\Big[(1-\pi)\big(\frac{\sigma_r+\sigma_l}{2}\big)+\pi-0.5+\sigma_r(1-\pi)\big(1-\frac{\pi}{1-\sigma_l(1-\pi)}\big)\Big]\Big[\frac{\pi}{1-\sigma_l(1-\pi)}-0.5\Big] \\
& + \frac{1}{2}\Big[(1-\pi)\big(\frac{\sigma_r+\sigma_l}{2}\big)+\pi-0.5+\sigma_l(1-\pi)\big(1-\frac{\pi}{1-\sigma_r(1-\pi)}\big)\Big]\Big[\frac{\pi}{1-\sigma_r(1-\pi)}-0.5\Big] \\
& + \frac{1}{2}\sigma_l(1-\pi)\big(1-\frac{\pi}{1-\sigma_r(1-\pi)}\big)^2 \\
& - \frac{(2\pi-1)(\pi-0.5)}{2}
\end{aligned} \tag{18}
$$

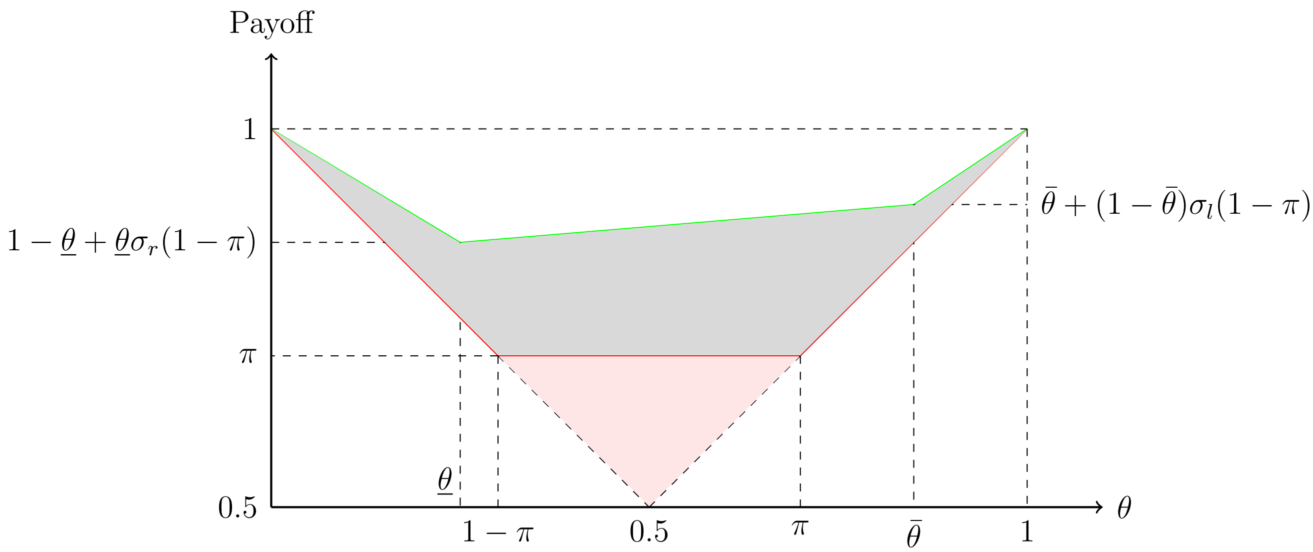

Figure 6: Payoff distribution of voters with respect to the priors given a strategy of the outlet and the resulting profit of the outlet represented by the gray shaded region.

which can now be simplified as

$$V=\frac{2\pi-1}{4}\Big(\frac{\pi}{1-\sigma_l(1-\pi)}+\frac{\pi}{1-\sigma_r(1-\pi)}-2\pi\Big)+\frac{\pi(1-\pi)}{4}\Big(\frac{\sigma_l}{1-\sigma_l(1-\pi)}+\frac{\sigma_r}{1-\sigma_r(1-\pi)}\Big) \tag{19}$$

4.2 Boundary Solutions

From equation (19), it follows

$$\frac{\partial V}{\partial \sigma_r}=\frac{\pi^2(1-\pi)}{2[1-\sigma_r(1-\pi)]^2} \tag{20}$$

and

$$\frac{\partial V}{\partial \sigma_l}=\frac{\pi^2(1-\pi)}{2[1-\sigma_l(1-\pi)]^2} \tag{21}$$

which are both positive. Moreover, we have:

$$\frac{\partial^2 V}{\partial \sigma_r^2}=\frac{\pi^2(1-\pi)^2}{[1-\sigma_r(1-\pi)]^3} \tag{22}$$

and

$$\frac{\partial^2 V}{\partial \sigma_l^2} = \frac{\pi^2(1-\pi)^2}{[1-\sigma_l(1-\pi)]^3} \tag{23}$$

which are both positive as well. We also have

$$\frac{\partial^2 V}{\partial \sigma_r \sigma_l} = 0 \tag{24}$$

which makes us conclude that $V(\sigma_l, \sigma_r)$ is convex and separable.

The partial derivatives of V being positive results in the following lemma.

Lemma 4.1. *Budget constraint of the media outlet binds.*

Proof. (20) and (21) being positive means that the objective function is increasing with the inputs. Thus, as long as α is a finite number, the lemma follows. □

Since we take the outlet's strategy as (σ_l, σ_r) instead of (n_l, n_r), let us modify the definition of bias as $b = \sigma_r - \sigma_l$. Then, we have the following definitions:

Definition 1. Given that the budget constraint binds, the unique unbiased strategy is $\left(\left(\frac{q}{2}\right)^\alpha, \left(\frac{q}{2}\right)^\alpha\right)$.

Definition 2. Extreme bias is either $(0, q^\alpha)$ or $(q^\alpha, 0)$.

4.3 Non-convex Cost

As the driver of emergence of bias, we have convexity of the objective function defined over a feasible set which is convex or concave depending on the cost function. Let us assume for now that $\alpha \geq 1$ so that the cost function is non-convex. This leads to the following lemma.

Lemma 4.2. *For $\alpha \geq 1$, the equilibrium strategy is extreme bias.*

Proof. Since we have a symmetric and convex objective function defined over a symmetric weakly concave set, the solution is at the corners which represent extreme bias strategies. □

4.4 Convex Cost

If α is smaller than 1, we have to deal with a non-convex optimization that we cannot solve analytically. Nevertheless, we are able to give a proof for the following proposition.

Proposition 1. *There exists an* $\underline{\alpha} < 0.5$ *such that for every* $\alpha > \underline{\alpha}$*, there exist* π *and* q *which make the equilibrium strategy is biased.*

Proof. One might consider writing σ_l in terms of σ_r, plug it in the objective function and search for a global maximum. However, there is a neater way which is gradient approach. Consider the gradient of the value function in equation (19) at any (σ_l, σ_r):

$$\frac{\frac{\partial V}{\partial \sigma_r}}{\frac{\partial V}{\partial \sigma_l}} = \frac{[1 - \sigma_l(1-\pi)]^2}{[1 - \sigma_r(1-\pi)]^2} \tag{25}$$

Also, consider the gradient of the cost function

$$\frac{\frac{\partial C}{\partial \sigma_r}}{\frac{\partial C}{\partial \sigma_l}} = \frac{\sigma_r^{\frac{1-\alpha}{\alpha}}}{\sigma_l^{\frac{1-\alpha}{\alpha}}} \tag{26}$$

At the unbiased strategy when $\sigma_l = \sigma_r$, (25) and (26) are both 1. This means that the unbiased strategy is a critical point. However, we do not know neither if it is a local or global nor if it is a maximum or minimum. In order to know if the unbiased strategy is a global maximum or minimum, we first need to know if the function (19) is concave or convex around the unbiased strategy. Note that (25) and (26) are both symmetric around the unbiased strategy. Therefore, we will only restrict attention to cases where $\sigma_r > \sigma_l$.

Notice that (26) is decreasing with α whenever $\sigma_r > \sigma_l$. This increases the odds to have an unbiased equilibrium as α decreases, which is intuitive because as the cost function gets more convex, we approach to the unbiased solution. Thus, if there is any, the unbiased equilibrium is at lower α. Hence, it is enough to show that there exists an unbiased equilibrium when $\alpha = 0.5$.

Our claim can be formulated as

$$\frac{[1-\sigma_l(1-\pi)]^2}{[1-\sigma_r(1-\pi)]^2} > \frac{\sigma_r}{\sigma_l} \tag{27}$$

for any $\sigma_r > \sigma_l$. It follows that

$$\begin{aligned} & 2(\sigma_r^2-\sigma_l^2)(1-\pi) > (\sigma_r-\sigma_l) + (\sigma_r^3-\sigma_l^2)(1-\pi)^2 \\ \Rightarrow\ & 2(\sigma_r+\sigma_l)(1-\pi) > 1 + (\sigma_r^2+\sigma_r\sigma_l+\sigma_l^2)(1-\pi)^2 \\ \Rightarrow\ & 2(\sigma_r+\sigma_l)(1-\pi) > 1 + (q+\sigma_r\sigma_l)(1-\pi)^2 \end{aligned} \tag{28}$$

Right-hand side of inequality (28) converges to $4\sqrt{q/2}(1-\pi)$ and the left-hand side to $1 + 3q/2(1-\pi)^2$ as σ_r approaches down to σ_l. Let $q = 1$ and $\pi = 0.5$ as the simulations in the next section suggest that tendency to be biased increases with q and decreases with π. Those values makes inequality (28) hold, which completes the proof. □

5 Simulations and Comparative Statics

As non-convex optimization problems usually rely on heuristic approach, we present some simulations to give a sense of how the equilibrium looks like for particular cases. First, we would like to present how the equilibrium changes with respect to q. Upper-left panel displays how the equilibrium shifts with different values of q. The horizontal axis represents bias values. As q increases, maximum bias that can be reached goes up. In order for bias to reach 1 or -1, q must be 1 so that the strategy can be $(1, 0)$ or $(0, 1)$. Otherwise, by Lemma 1, The maximum that the bias can reach in absolute terms is less than 1. The public signal precision and the convexity of the cost function are fixed at $\pi = 0.5$ and $\alpha = 0.8$. The graphs suggest that the equilibrium tends to be more biased as q increases and that higher endowed outlets have higher advertising revenues.

Upper-right panel fixes π and q to be 0.5. As we argued before, higher α leads to bias. The bottom panel fixes q to be 0.5 and α to be 0.8. The simulation suggests that as precision of the public signal goes up, the profit of the media outlet drops and it tends to be less biased. Notice that there is a parameter set ($\pi = 0.5, \alpha = 0.8, q = 0.5$) which is present in all the panels and it is associated with the same interior bias solution in each panel.

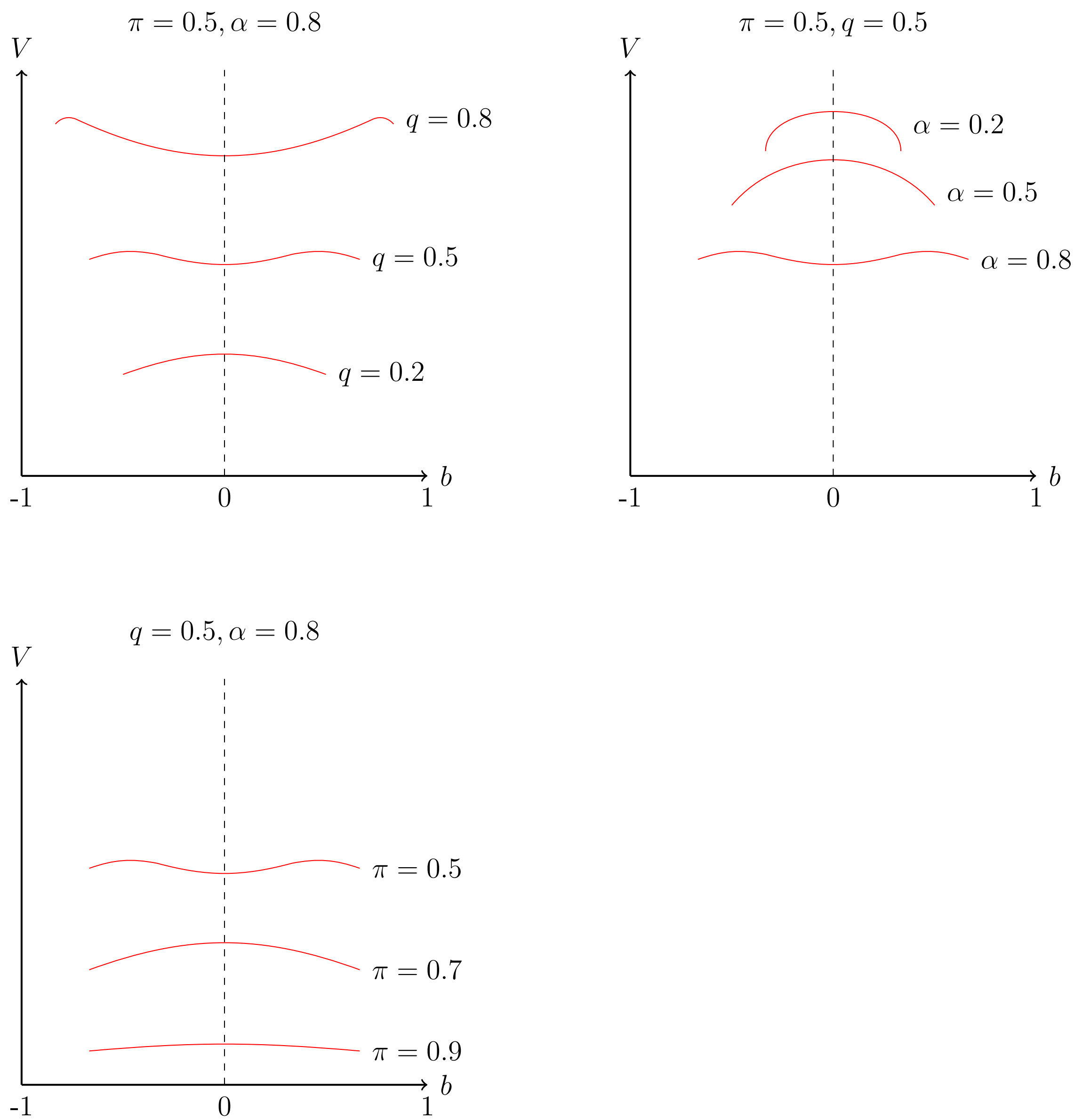

Figure 7: Profit of the outlet with respect to different parameter sets.

6 Conclusion

We design a model of the market for news with rational consumers and a profit-maximizing media outlet in which media bias arises endogenously depending on the marginal cost of acquiring information. The novelty of our paper is introducing a public signal and the way we define the bias. There two innovations provide us the convexity of the profit function of the outlet which is the main driver of the bias. In contrast to the existing literature, our model does not have any exogenous asymmetry in the sense that voters have a common utility function, the distribution of priors is symmetric and journalists have symmetric 2 types.

One possible extension of this model might be analysing industrial organization aspects. To be more specific, solving this model for duopoly and oligopoly would be more helpful to understand the media polarization that we observe in the U.S. and to find out the impact of competition in the bias.

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