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MEDIA BIAS AND POLARIZATION

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Dedico este trabajo a:
mis padres Patricia y Alfredo,
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"The scientist does not study nature because it is useful, he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful it would not be worth knowing, and if nature were not worth knowing, life would not be worth living."

Jules Henri Poincaré

Abstract

In this work I study production and consumption of information in group settings, with a communication model of a sender-receiver game for the market of news, with readers who have beliefs that they would like to see confirmed, and profit-maximizing media that can slant stories towards those beliefs. Using a model of spatial competition on a two-dimensional space, I show that, under monopoly market structure, slanting and price strategies are determined by the homogeneous beliefs shared by all readers and the correlation between the components of the two dimensional state of the world. Under duopoly competition, the determinants of slanting and price strategies are now heterogeneous beliefs and the type of complementarity between news and bias. Competition indeed lowers the prices and newspapers segment the market leading to social polarization.

Keywords: Media bias, Media slant, Polarization, Confirmation bias, Competition
JEL codes: L82, D4

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Chapter 1

Introduction

When mass media slant their news towards readers' beliefs, news issues may end up reported less accurately. Mullainathan and Shleifer (2005) found that homogeneity in beliefs and media competition do not favor accuracy. Competition results in lower prices, but common slanting towards readers' biases. Furthermore, newspapers segment the market and slant towards extreme positions on topics where readers beliefs diverge. Mullainathan and Shleifer studied the interaction between readers with beliefs that they would like to see confirmed and newspapers that slant news to cater such beliefs. They did so in a setting of a single dimensional state of the world, considering homogeneous and heterogeneous beliefs as two different cases. Their work is an example of demand-driven bias. Media bias is also driven by supply. Incentives internal to the firm could include direct political or business-related preferences of media owners, or arise indirectly, from the preferences of reporters or editors.

The determinants of bias can be organized on supply-side forces (e.g. Gentzkow & Shapiro, 2006; Chan & Suen, 2008) and demand-side forces and the effects of competition on bias and consumer welfare are in general ambiguous. Models of product differentiation typically assume a one-dimensional characteristics space. This dissertation studies a model of spatial competition on a two-dimensional space. In other models, the nature of the decision facing the media outlets is either to lie or to simply suppress information. In this model, media sends a two-dimensional announcement, before observing a noisy signal of a two-dimensional state variable whose entries might be correlated, to conform to readers' prior beliefs. Polarization arises when media differentiation is even more extreme than the most extreme consumers.

Media content may contribute to social division even if they are not interested in persuading the public to take certain action other than buying their content. What is then dividing us? Under what conditions optimal media slant is more informative in monopoly and duopoly market structures, and what is the magnitude with which it arises? How does media accuracy change as the environment changes? What effect does adding a dimension to the state of the world have on the information that readers receive? How do strategic complementarities influence media slanting strategies? The main theoretical contribution of the model is to characterize slanting strategies, and to show that the forces driving media slant differ cruccially between monopoly and duopoly.

The key features of the model are as follows. I consider a two dimensional state of the world. To illustrate this, consider a new security bill. The measure has the potential to affect many aspects of social life, and readers may assess these aspects differently. Most readers may empathize with government initiatives to improve overall security quality (homogeneous beliefs), while holding opposing views on open or closed borders (heterogeneous beliefs). Readers obtain psychological utility from having their prior beliefs confirmed, and newspapers slant news towards these beliefs. The model considers a continuum of readers, either one or two newspapers, and the slanting strategies turn out to depend on different variables in monopoly and duopoly. The main contribution of the model relative to previous work is that, by including the key ingredients of a multidimensional state of the world, correlation between its entries, strategic complementarities between news and bias, a desire to read news that confirm prior beliefs, two different market structures and a novel specification of preferences, the model permits a definition of slanting strategies that captures its important features, and permits a tractable analysis of how firms specialize in response to competition. Crucially, the model allows us to understand how these strategies differ for different market structures, and how they depend on the correlation coefficient and on the strategic complementarities.

In the second chapter, I present a review of the main literature. In the third chapter, I describe the model. Finally, I present the conclusions that this dissertation has attained.

Chapter 2

Literature review

The examination of media accuracy depends largely on how the demand for news is conceptualized. Readers, in the conventional sense, desire precise and true information, which is more valuable the closer it is to reality. Media, on the other hand, strive to sell newspapers and advertising programs; they are not just information suppliers, but also entertainers. Readers want their sources to explain, interpret, convince, and entertain them in addition to informing them. As Gentzkow and Shapiro (2006) analyze, many individuals mistrust the media's ability to offer reliable political information. People on both sides of the political spectrum believe that news reporting favors one side over the other.

The concept of media slant have been of interest in the political economy literature. There are several papers that model bias as a distortion (e.g Mullainathan & Shleifer, 2005; Gentzkow & Shapiro, 2006; Bernhardt, Krasa, & Polborn, 2008), and there are some other papers that model bias as information filtering (e.g Chan & Suen, 2008). It appears that filtering, in the form of selection, plays a significant role in media bias. Chan and Suen (2008) also looked at a scenario with rational customers and biased media. Their model includes endogenous platforms and two-party political rivalry. The payoffs to voters are determined by the winning party's platform and an unobserved state or the world. Chan and Suen (2008) examine two scenarios: one in which the media just reports each party's program, and another in which the media reports the platforms while simultaneously providing a cheap talk state report. They discover that in the first situation, the parties are disorganized and select radical, polarized agendas, which are harmful to society. Platform convergence, which they picture as ideal, is not an equilibrium since each party would have an incentive to deviate, and voters would be unable to detect and punish a unilateral deviator. In the second example of the model, however, the media report, even if biased, moderates the policies because if one party deviates and proposes a more radical policy, voters may identify this party based on the media report. More competition boosts this moderation even more.

A subtle conclusion is that bias does not influence policy, but rather polarizes candidate platforms. It's a form of distortion bias since the report is just cheap talk. The degree of bias is limited not by the necessity to maintain the audience, but by the alignment of media and public preferences. One significant contributor to bias is consumer demand. Consumers favor media whose biases reflect their own interests or prior beliefs. Even profit-maximizing media companies that are unconcerned about influencing consumers' beliefs may pick slanted reporting in the presence of such inclinations. If customers are rational and prefer more information to less, demand-side incentives will induce filtering bias but not distortion. The exception is when companies are concerned about their image and cannot commit to accurate reporting, as in Gentzkow and Shapiro (2006).

The impact of competition on bias is less clear. If a duopoly caters to one side of the ideological spectrum while the monopoly seeks to appeal to both, the duopoly may embrace more severe biases than a monopoly. And while competition generally enhances consumer welfare, the larger advantages of competition might be less obvious if more polarized media sources cause unfavorable political externalities.

One reason for why people want confirming news is that it is particular to the scenario of bias in the form of filtering. The value of a signal to a rational consumer will be determined by the consumer's priors and preferences in this instance. According to Suen (2004), consumers whose preferences favor one state would get higher expected utility from biased signals that favor that state. As a result, even rational customers will choose confirming news.

Chan and Suen (2008) includes political competition, consumers are all interested in news on a single topic, a one-dimensional state of the world, but they have different thoughts about which political party to vote for in each state. Although the true state is continuous, the media can only report a binary signal, so consumers have different preferences for reporting strategies. Some want the media to only endorse the leftist party in extreme states, while others want the rightist party to be endorsed only rarely, and still others want a more balanced mix. Endogenous filtering bias emerges as a result of this. Due to the continuous heterogeneity of consumer preferences, rival duopoly outlets adopt the same viewpoint.

Consider the scenario where customers derive direct benefit from news whose bias corresponds to their own prior beliefs. Only bias and consumers' priors determine this "psychological" utility. Both psychology and economics have contributed to the development of preferences over bias Tirole (2002). A preference for self-image, esteem, or consistency, a desire to avoid complication, or other factors might all contribute to this preference. There is a tradeoff between more consumers receiving news and consumers receiving less informative news when comparing monopoly versus duopoly welfare. If distortion bias is less expensive, duopolists may decide to apply it instead of filtering bias in this scenario. It is also worth noting that this is the only instance in which 100% bias is feasible, making news totally uninformative. If psychological utility is important enough, this happens.

Mullainathan and Shleifer (2005) presents a model in which the state of the world is a continuous random variable, utility is lost when news deviates from the consumer's prior mean, and media companies are primarily interested in profit. Their model involves pricing competition as well. They illustrate that in many different sorts of equilibria, uninformative distortion bias can arise. They also show that duopoly decreases price but not bias when consumers are homogeneous; however, when consumers are heterogeneous, duopoly difference is even more severe than the most extreme consumers, softening price competition. The authors also explore at a scenario in which consumers in a duopoly may cross-check news and show that they can become better informed than they would be in a monopoly.

Bernhardt et al. (2008) explores a voting model in which media consumers analyze information rationally, but partisan voters benefit from negative news about the opposition party. Despite the fact that voters make valid inferences from their news, they select news to maximize the psychological utility they derive from it, given that their votes are not pivotal, and they are frequently underinformed. As a result, their article emphasizes the significance of knowledge externalities. Consumers demand information, which eliminates distortion bias, however in this case it is via omission. Suboptimal election results can arise when voters are not fully informed; this is more likely when the voter preference distribution is asymmetric, and the median voter is partisan. Electoral errors may occur even when the median voter is neutral and gets impartial news, since partisan people may vote (ex post) wrongly owing to news distortions.

Consumers may also get confirmatory news because they trust the companies who deliver it more. When the reports from an information source match the consumer's priors, a rational consumer who is unsure of its veracity will likely rate this one as better quality. As a result, firms may be motivated to provide confirmatory news to increase their reputations and enhance future demand. This idea is central in the exploration of media markets by Gentzkow and Shapiro (2006). In this example, there are two key takeaways. First, if firms are unable to commit to their strategies in advance, their incentives to establish a reputation for quality can lead them to engage in distortion bias in equilibrium, even though this severely reduces the value of their reports to consumers and can harm both them and consumers. Second, there is indeed a new element to such link between bias and competition. Additionally, consumers may cross-check one outlet's claims with another, which may reduce firms' incentives to slant their reports. Even though it makes all market players strictly worse off, bias can exist in equilibrium. Consumer welfare is always affected by bias. Surprisingly, it can also reduce company profits.

Perego and Yuksel (2022) provide a model with a three-dimensional state of the world, one component where readers' preferences are identical, and two components where readers' preferences are heterogeneous. Specialization in this model occurs at the expense of knowledge about the dimension on which preferences are homogeneous, which benefits all customers, in favor of other aspects that benefit just a specialized sector.

The difference between this dissertation and the Mullainathan and Shleifer (2005) model is that they treat homogeneous and heterogeneous beliefs as two distinct cases, whereas the Perego and Yuksel (2022) model assumes that readers' heterogeneous beliefs are constrained and that there is a trade-off between the information provided by the media on issues of common interest and other dimensions on which opinions may differ. I investigate the strategic implications of the correlation between the characteristics of the state of nature, as well as whether news and bias are strategic substitutes or strategic complements.

Chapter 3

The model

This is a model of the interaction between readers (agents) who have beliefs they would like to see confirmed and newspapers (firms) that slant news to support those beliefs. Newspapers publish information about an uncertain state of the world and announce the price they charge; readers decide which company to buy information from.

There is an unobserved state of the world $t = (t_1, t_2)$, and its distribution is bi-variate normal, with correlated components, whose values are of interest to readers.

$$t \sim \mathcal{N}\left(\mathbf{0}, \Sigma_t\right), \quad \text{where} \quad \Sigma_t = \begin{pmatrix} v_1 & \rho\,\sigma_1\,\sigma_2 \\ \rho\,\sigma_1\,\sigma_2 & v_2 \end{pmatrix}.$$

3.1 Newspapers

There are either one or two media newspapers indexed by $j \in \{1, 2\}$, and each of them receives the same signal $d = t + \varepsilon$,

$$\varepsilon \sim \mathcal{N}\left(\mathbf{0}, \Sigma_\varepsilon\right), \quad \text{where} \quad \Sigma_\varepsilon = \begin{pmatrix} \nu_1 & 0 \\ 0 & \nu_2 \end{pmatrix}.$$

$$d \sim \mathcal{N}\left(\mathbf{0}, \Sigma_d\right), \quad \text{where} \quad \Sigma_d = \begin{pmatrix} \sigma_1^2 & \rho\,\sigma_1\,\sigma_2 \\ \rho\,\sigma_1\,\sigma_2 & \sigma_2^2 \end{pmatrix} \quad \text{and} \quad \sigma_\ell^2 = v_\ell + \nu_\ell.$$

Before seeing the data $d = (d_1, d_2)$ a newspaper announces (and commits to it) its slanting strategy $s_j(d)$ and the price P_j it charges, then make reports with slant $s_j = (s_1, s_2)$, so the reported news is $n_j = d + s_j$.

$$n_j \sim \mathcal{N}\left(s_j, \Sigma_d\right).$$

Newspapers maximize expected profits, which depend on the readers they serve and the price they charge.

3.2 Readers

There is a continuum of readers indexed by $i \in [0,1]$. Readers hold a biased belief $\beta_i = \left(b, -\alpha\, b_i\right)$,[1] about the mean of t, they have identical beliefs b over t_1 and have heterogeneous beliefs b_i about t_2. The degree of complementarity between beliefs and news is captured with the parameter $\alpha \in [-1,1]$, if $\alpha < 0$ then beliefs and news enter as substitutes in the tastes of the reader and $\alpha > 0$ means beliefs and news are strategic complements. For tractability, I will focus only in the extreme cases of perfect substitutes ($\alpha = -1$) and perfect complements ($\alpha = 1$). Readers know the variance, but might have a biased estimate of mean of t.

Heterogeneous beliefs are distributed uniformly between b_0 and $b_1 > 0$.

$$b_i \sim \mathcal{U}(b_0, b_1).$$

From the perspective of each reader i; the distribution of the state of the world t is $\mathcal{N}\left(\beta_i, \mathbf{\Sigma}_t\right)$.

[1] which for convenience is normalized ($||\beta_i||^2 = b^2 + \alpha^2 b_i^2 = 1$). This not only allows me to model the distance between a point (the news) and a line (prior beliefs) as the cross product of two vectors, it also makes the matrix I use to define optimal slanting strategy idempotent, which simplifies the algebra used.

Strategic complementarities

Strategic substitutes

When $\alpha < 0$ beliefs and news enter as substitutes in the tastes of the reader. If beliefs move on one direction then the reader prefers that the news move in the other direction, e.g., if I begin to dislike certain political measures, then I do not like news that tell me that such political measures are spreading out in the world.

Strategic complements

If $\alpha > 0$, beliefs and news enter as complements, e.g., if I move towards liking more certain political groups, then I am happy if there are more news talking about more parties of such groups.

3.3 Preferences

Readers maximize their expected utility, which depends on reservation utility $\bar{u}$, prior beliefs β_i, newspaper's slant s_j, reported news n_j, the degree of complementarity α between news and bias and the price paid for information P_j.

Consistency of news with bias

Readers get disutility from reading news inconsistent with their beliefs. Consistency is modeled as a function that depends on the reported news n_j, readers' beliefs β_i, and the degree of complementarity α between news and bias. They also dislike extreme slanting, so holding consistency with beliefs, they prefer less slanted news.

Cross product of vectors

The cross product or vector product (occasionally directed area product, to emphasize its geometric significance) is a binary operation on two vectors in a three-dimensional oriented Euclidean vector space, and is denoted by the symbol $\times$. Given two linearly independent vectors a and b, the cross product, $a \times b$ (read "a cross b"), is a vector that is perpendicular to both a and b, and thus normal to the plane containing them.

The cross product $a \times b$ is defined as a vector c that is orthogonal to both a an b, with direction given by the *right-hand rule* and a magnitude equal to the area of the parallelogram that the vectors span.

Definition 1. The cross product is defined by the formula:

$$a \times b = ||a||\,||b||\sin(\theta)\,\hat{e}_n.$$

where:

- θ is the angle between a and b in the plane containing them.
- $||a||$ and $||b||$ are the magnitudes of vector a and b.
- $\hat{e}_n$ is a unit vector perpendicular to the plane containing a and b.

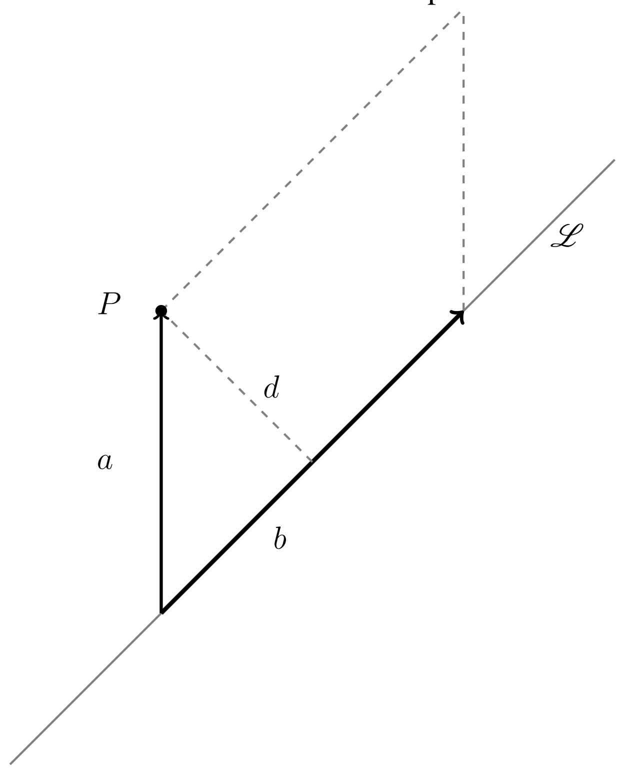
Geometric meaning

The magnitude of the cross product can be interpreted as the positive area of the parallelogram having a and b as sides.

$$||a \times b|| = ||a||\,||b||\,|\sin(\theta)|.$$

If the cross product of two vectors is the zero vector (that is, $a \times b = 0$), then either one or both of the inputs is the zero vector, ($a = 0$ or $b = 0$) or else they are parallel ($a \parallel b$) so that the sine of the angle between them is zero ($\theta = 0$ or $\theta = \pi$ and $\sin\theta = 0$). It also can be used to calculate the shortest distance between a point P and a line $\mathscr{L}$.

Figure 3.1: Shortest distance between point P and line $\mathscr{L}$.



Source: own elaboration.

Note that the vectors a and b define a parallelogram. As we know the area of the parallelogram is $||a \times b||$. Alternatively, the area of any parallelogram is the length of the base times the vertical height. If we make the base of the parallelogram the vector b, the vertical height is exactly d. With this:

$$\text{Area=(Length of base)(Vertical height)} = ||b||d.$$

But we also know that:

$$\text{Area} = ||a \times b||.$$

Therefore,

$$||a \times b|| = ||b||\, d \qquad \Rightarrow \qquad d = \frac{||a \times b||}{||b||}.$$

The cross product gives us an alternative way to calculate the minimum distance.

For vectors $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ it can be computed as:

$$a \times b = (a_2 b_3 - a_3 b_2)\hat{e}_1 + (a_3 b_1 - a_1 b_3)\hat{e}_2 + (a_1 b_2 - a_2 b_1)\hat{e}_3. \tag{3.1}$$

With this in mind, let $||n_j \times \beta_i||$ be the consistency of news j with prior beliefs of reader i, and since I am assuming that $||\beta_i|| = 1$, this is exactly the minimum distance between reported news and bias. Furthermore, it captures the alignment of those parameters, if they are parallel then their cross product has magnitude zero, and it has maximum magnitude when they are orthogonal.

For vectors $n = (n_1, n_2)$ and $\beta_i = (b, -\alpha\, b_i)$,

$$\|n \times \beta_i\|^2 = (b\, n_2 + \alpha\, b_i\, n_1)^2 = b^2\, n_2^2 + b_i^2\, n_1^2 + 2\, \alpha\, b\, b_i\, n_1\, n_2. \tag{3.2}$$

since I am focusing only in perfect substitutes and complements $\alpha^2 = 1$.

Utility function

Reader i gets overall utility of reading newspaper j:

$$U_i = \bar{u} - \chi \, \|s\|^2 - \varphi \, \|n_j \times \beta_i\|^2 - P_j. \tag{3.3}$$

Where $\bar{u}$ is the reservation utility, that I take sufficiently high to ensure that all readers buy the differentiated product, $\chi > 0$ calibrates the cost of slanting, $\varphi > 0$ calibrates its preferences for consistency.

Potential readers buy the paper if the price P_j is lower than the expected utility associated with reading the paper $\mathbb{E}_d\left[U(s(d))\right]$. Readers get a sense of how much enjoyment the paper provides them and base their buying choice upon it. Once readers have decided whether to buy it, the paper watches its signal d and reports n_j. After reading the news, readers get their utilities.

3.4 Defining bias

The amount of newspaper bias in the market is of interest. It is calculated by weighting the average bias of the market's newspapers by their market share.

Definition 2. The average amount by which the news read deviates from the data for the average reader is defined as bias. Letting n_i be the news read by reader $i \in [0,1]$, bias is:

$$\mathbf{ARB} = \int \mathbb{E}_d \left[||n_i - d||^2 \right] f(b_i) di. \tag{3.4}$$

Timing

1. Each newspaper announces simultaneously its slanting strategy $s_j(d_1, d_2)$ with which it will report the news.
2. Prices P_j are announced simultaneously by each paper.
3. Reader i decide whether to buy the paper j based on average utility associated with its strategy and price.
4. Newspaper j receives data $d = (d_1, d_2)$ and report news $n_j = d + s_j$.
5. If individuals buy the paper, they read the news and receive utility.

Comments on setup

This model combines the assumptions that readers prefer news consistent with their beliefs, and that newspapers can slant their stories toward these beliefs.

However, by modeling the state of nature as a two-dimensional variable, my model allows media slanting strategy to define the relative emphasis of news on different issues of relevance to readers and the effect correlation between reported news has.

Consistency is motivated by the cross product of two vectors, news n_j and bias β_i whose magnitude is equal to the area of the parallelogram that the vectors span, if the cross product of two vectors is the zero vector, then either one or both inputs is the zero vector, or else they are parallel, and has maximum magnitude when they are orthogonal. In this way, if news and bias are aligned then the reader gets news that are consistent with his beliefs.[2]

The model also captures the strategic effect of bias and news. The cross product of a vector gives another vector, in this sense it has direction, it can be either positive or negative, I use the sign of the direction of this vector to relate it to the strategic effect.

I also examine two cases of market structure, a single monopolistic newspaper, and in the second case two newspapers competing for the audience.

[2] In two dimensions there is no natural "distance" in a space of characteristics. The Euclidean distance can be used, but many other possibilities are available.

Chapter 4

Equilibrium Analysis

This section presents the results of the model. I show that in equilibrium slanting and pricing strategies depends on correlation ρ, the degree of complementarity α between news n_j and beliefs β_i.

4.1 Slanting strategy

The slanting strategy is obtained by a maximization process, the newspapers want to reach as many readers as possible, readers will buy the newspaper if they derive positive utility from reading it.

Proposition 1. Newspaper slant news towards readers beliefs, considering an arbitrary point of reference B to consider a bias around it. The optimal slanting strategy of a newspaper that biases around point $B = (B_1, B_2)$ is:

$$s^B(d_1, d_2) \equiv -\frac{\varphi}{\chi + \varphi} \begin{pmatrix} B_2^2 & \alpha\, B_1\, B_2 \\ \alpha\, B_1\, B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} \tag{4.1}$$

Proof. See Appendix for all proofs. □

Optimal slanting strategy depends on readers' beliefs and the information the firm receives.

Proposition 2. Under this slanting strategy, then the reader's expected utility (gross of price) of reading such newspaper is:

$$\mathbb{E}_d\left[U_i\left(s^B(d_1,d_2)\right)\right] = \bar{u} - \left(\frac{\varphi^2\,\left(B_1-b\right)^2+\varphi\,\chi b^2}{\varphi+\chi}\right)\sigma_2^2 \\ - \frac{2\,\varphi\,\chi}{\varphi+\chi}\alpha\, b\, b_i\,\rho\,\sigma_1\,\sigma_2 - \left(\frac{\varphi^2\left(B_2-b_i\right)^2+\varphi\,\chi b_i^2}{\varphi+\chi}\right)\sigma_1^2. \quad (4.2)$$

4.1.1 Monopoly

In this section I analyze the behavior of a monopolist. It turns out that both optimal slanting choice and the optimal pricing rule depend on the relative size of the parameters involved in the model.

There are two types of beliefs, a homogeneous generalized belief b, and a set of differentiated beliefs b_i. As a first step to analyze the outcome of this game, the following proposition summarizes the strategy of a monopolist.

Proposition 3. There exists a constant C_m, which depends on the parameters of the model, that determines the monopolist's strategy. If $b_0 - b_1 < C_m$,
monopolist maximizes his audience when he biases around point $(b, -\alpha\,\rho\, b\,\frac{\sigma_2}{\sigma_1})$. Optimal monopolist slanting strategy is:

$$s^*_{\text{mon}}(d_1,d_2) \equiv -\frac{\varphi\, b^2}{\chi+\varphi}\begin{pmatrix}\rho^2\,\dfrac{\sigma_2^2}{\sigma_1^2} & -\rho\,\dfrac{\sigma_2}{\sigma_1}\\ & \\ -\rho\,\dfrac{\sigma_2}{\sigma_1} & 1\end{pmatrix}\begin{pmatrix}d_1\\ d_2\end{pmatrix}. \quad (4.3)$$

The optimal position is not the center of the bias distribution, but the center of the semicircle that defines indifferent readers. If $b_0 - b_1 > C_m$, not all readers read the paper.

There are two factors that determine the newspaper strategy, whether the two entries of the state of the world exhibit positive or negative correlation ρ, and whether news and beliefs are strategic substitutes ($\alpha = -1$) or strategic complements ($\alpha = 1$). If the newspaper increases his price too far he gradually lose readers, but he does not lose all. Many readers will still prefer to read it's newspaper because their bias is near the slant of the paper.

From proposition 3, I can see that the monopolist will choose to slant both dimensions towards homogeneous beliefs, taking advantage of the correlation between the entries of the state of the world, if $|\rho| \to 1$ media inform about t_1, and t_2 with the bias of the homogeneous entry b. And as $\rho \to 0$, media only slants in one dimension, and in the other reports the data he receive.

The magnitude of slanting is:

$$||s^*_{\text{mon}}(d_1, d_2)|| = \left(\frac{\varphi\, b}{\chi + \varphi}\right)\left(d_2 - \rho\,\frac{\sigma_2}{\sigma_1} d_1\right)$$

Corollary 1. Slanting increases with the reader preferences for hearing confirmatory news, decline with the cost of slanting and its decreasing with respect to the correlation coefficient.

$$\frac{\partial ||s^*_{\text{mon}}(d_1, d_2)||}{\partial \varphi} > 0, \qquad \frac{\partial ||s^*_{\text{mon}}(d_1, d_2)||}{\partial \chi} < 0, \qquad \frac{\partial ||s^*_{\text{mon}}(d_1, d_2)||}{\partial \rho} < 0.$$

Proposition 4. Monopolist can cover the whole market, so he set a price equal to the boundary reader's utility:

If $\alpha\rho > 0$,

$$P^*_{\text{mon}} = \bar{u} - \frac{\varphi\,(\chi + \rho^2\,\varphi)}{\varphi + \chi} b^2\,\sigma_2^2 - \varphi\,\chi\,b_0^2\,\sigma_1^2 - 2\,\varphi\,\alpha\,\rho\,b\,b_0\,\sigma_2\,\sigma_1. \tag{4.4}$$

If $\alpha\rho < 0$,

$$P^*_{\text{mon}} = \bar{u} - \frac{\varphi\,(\chi + \rho^2\,\varphi)}{\varphi + \chi} b^2\,\sigma_2^2 - \varphi\,\chi\,b_1^2\,\sigma_1^2 - 2\,\varphi\,\alpha\,\rho\,b\,b_1\,\sigma_2\,\sigma_1. \tag{4.5}$$

The strategic complementarity with correlation coefficient can both rise or lower prices in the monopoly market.

Finally, the reported news is:

$$n^*_{\text{mon}} = \begin{pmatrix} 1 - \dfrac{\varphi\,\rho^2\,b^2\,\sigma_2^2}{(\chi+\varphi)\sigma_1^2} & \dfrac{b^2\,\varphi\,\rho\,\sigma_2}{(\chi+\varphi)\sigma_1} \\ \\ \dfrac{b^2\,\varphi\,\rho\,\sigma_2}{(\chi+\varphi)\sigma_1} & 1 - \dfrac{\varphi\,b^2}{\chi+\varphi} \end{pmatrix} \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix} \tag{4.6}$$

To compare how informative news are, I compare different scenarios in the reported news for a monopoly.

First, let's see what would happen if the homogeneous biased belief is *zero*.

$$\lim_{b\to 0} n^*_{\text{mon}} = \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}$$

In this case, the monopoly will report his noisy signal, just as he received it.

Then, let's see what would happen in the limit case where there is no correlation.

$$\lim_{\rho\to 0} n^*_{\text{mon}} = \begin{pmatrix} d_1 \\ \\ \left(1 - \dfrac{\varphi\,b^2}{\chi+\varphi}\right) d_2 \end{pmatrix} \tag{4.7}$$

In this case the firm reports about t_1 the data he received, and slants its reports about t_2.

Corollary 2. Given the strategy $s^*_{\text{mon}}(d)$:

$$\mathbf{ARB}_{mon} = \left(\frac{\varphi\,b\,\sigma_2}{\chi+\varphi}\right)^2 \left(1 - \rho^2\right). \tag{4.8}$$

In the monopoly case, as $|\rho| \to 1$ the average bias of the newspaper in the market tends to *zero*.

4.1.2 Duopoly

Readers are price-takers. They maximize their utility, given the slant and prices offered in the market. Given a choice of $s^{(1)}$ at price P_1 and a choice $s^{(2)}$ at price P_2, consumer with bias β_i reads the newspaper that maximizes her utility. There are two newspapers. Newspaper 1 report news with slant $s^{(1)}$, and newspaper 2 with slant $s^{(2)}$. In the market game the strategic variables of each newspaper are price and slant. Newspapers j's profit function Π_j is a function of its own price P_j with parameters the price of the rival media and both bias z_1, z_2 :

$$\begin{aligned}\Pi_1\left(P_1, P_2; z_1, z_2\right) &\equiv P_1 D_1\left(P_1, P_2; z_1, z_2\right), \\ \Pi_2\left(P_1, P_2; z_1, z_2\right) &\equiv P_2 D_2\left(P_1, P_2; z_1, z_2\right).\end{aligned} \tag{4.9}$$

The solution concept is the non-cooperative equilibrium. Duopoly acts totally different.

Proposition 5. There exists a constant C_d such that if $b_1 < C_d$ optimal duopoly slanting strategy is:

$$s^*_{\text{duo},j}(d_1, d_2) \equiv -\frac{\varphi}{\chi+\varphi}\begin{pmatrix}\frac{9}{4}\,b_j^2 & \frac{3}{2}\alpha\, b\, b_j \\ \\ \frac{3}{2}\alpha\, b\, b_j & b^2\end{pmatrix}\begin{pmatrix} d_1 \\ \\ d_2\end{pmatrix}. \tag{4.10}$$

Where it is assumed that firm 1 slants toward the left and firm 2 slants towards the right. In this case, the correlation ρ does not play any role in the magnitude of the slanting strategy, this happens because firms differentiate themselves and cater opposite sides of the market.

Duopolies slants news towards $\frac{3}{2}b_j$, with b_j the end points of the reader bias distribution. Points are more extreme than the most extreme readers in the population. This is an implication to polarization; media firms choose this extreme slanting to maximize profits. There is also an implication for readers, their beliefs are strengthened, and cannot get closer to a medium point.

The magnitude of slanting is:

$$||s^*_{\text{j}}(d_1, d_2)|| = \left(\frac{\varphi}{\chi+\varphi}\right)\left(b\, d_2 + \frac{3}{2}\,\alpha\, b_j\, d_1\right)$$

Corollary 3. Slanting can either decrease or increase with the degree of strategic effect between news and bias.

$$sign\left(\frac{\partial||s^*_{\mathrm{j}}(d_1,d_2)||}{\partial\alpha}\right) = sign(\alpha).$$

Proposition 6. Prices are set to obtain a Nash equilibrium. Duopolies set prices:

$$P^*_{\text{duo}} = \frac{6\,\varphi^2\sigma_1^2}{\varphi+\chi}b_1^2. \tag{4.11}$$

Competition in fact lower prices, but duopoly segment the market to cater readers' prior beliefs.

Each duopolist position himself as far away from the other as possible. The reported news in this case is:

$$n^*_j = \begin{pmatrix} 1-\dfrac{9\,\varphi}{4(\chi+\varphi)}b_j^2 & -\dfrac{3\,\alpha\,\varphi\;b\,b_j}{2\,(\chi+\varphi)} \\ \\ -\dfrac{3\,\alpha\,\varphi\;b\,b_j}{2\,(\chi+\varphi)} & 1-\dfrac{\varphi}{\chi+\varphi}b^2 \end{pmatrix}\begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix} \tag{4.12}$$

Let me analyze the case where the homogeneous belief $b \to 0$.

$$\lim_{b\to 0} n^*_{\text{duo},j} = \begin{pmatrix} -\frac{\varphi}{\chi+\varphi}\dfrac{9}{4}\,b_j^2\,d_1 \\ \\ d_2 \end{pmatrix}$$

In such case, there will be information about both dimensions of the state of the world, but it will be biased for t_1 in contrast with the monopoly case, where the firm reports his signal without slanting.

Corollary 4. Competition increases average bias of the newspapers.

Given the strategy $s^*_{\text{duo},j}(d)$:

$$\mathbf{ARB}_{duo} = \left(\frac{\varphi}{\chi+\varphi}\right)^2\frac{(3\,b_1^2\,\sigma_1^2+4\,b^2\,\sigma_2^2)}{4}. \tag{4.13}$$

For the duopoly case, there is no case in which the average bias of the newspapers is zero.

Chapter 5

Conclusions

In this dissertation I introduced a model of media competition on two-dimensional space with which I derived the equilibrium slanting strategies and prices. The model provides several theoretical contributions.

First, I provide a novel specification for preferences which captures some features of consistency of news with bias: (a) news stories, beyond the strategic inferences drawn by readers, are not informative *per se,* (b) firms specialize in response to competition by slanting news, resulting in a less informed society, and (c) polarization is the business models of various media. I then showed how different market structures leads to choose different variables for optimal strategies.

Second, the model shows that competition permits readers to enjoy more news about the component of the state of nature in which beliefs diverge at lower prices. While this seems intuitively desirable on an individual level, it has social consequences.

Third, the model illustrates the parameters that affect the slanting strategies. The market structure has an impact on the relevant variables for the strategies. For the monopoly case the slanting strategy ignores the heterogeneous bias of readers. Monopolists choose to slant towards b in both dimensions. Considering the correlation between the dimensions of the state of the world, if its magnitude is high, what he reports about t_1 also brings information about

t_2. Therefore, monopolist slants its report towards beliefs shared by all readers. Whether the monopolist will cover the whole market depends upon the strategic complementarity between news and bias and in the correlation between the dimensions of the state of the world. If there is low correlation, monopolist rise his price to cover the whole market.

Strategic complementarities and correlation also play a role in the final prices offered by the monopolist. When the magnitude of the correlation between t_1 and t_2 tends to one, the average bias of the newspaper tends to zero. This result is contrasting with single dimensional model of Mullainathan and Shleifer (2005), where only for "rational" readers (those who dislike slanting $\varphi = 0$) the average bias of newspapers is zero.

Duopoly slanting strategy ignores correlation between t_1 and t_2 since both firms differentiate themselves catering audience by slanting its reports towards t_2, where the audience have heterogeneous beliefs. What they do consider is the degree of complementarity between news and bias. Firms position themselves at more extreme points than the endpoints of the reader bias distribution of the readers. We can say that competition leads to informational specialization, if we let be more firms in the market, it might be the case that there is a single media firm for each reader, that gives her the information accordingly to her beliefs.

Competition lowers prices, which unlike the monopoly case are fixed, i.e., prices does not depend on correlation or the strategic complementarity between news and bias. But competition increases the average bias of the newspapers. Bias persists in media markets when consumers perceive biased media to be more informative or more enjoyable. When readers demand bias, competition leads to more severe biases that conform to their preferences. Policy may be influenced not just by the volume of coverage but also by its distribution. Excessive coverage of particular subjects may distract political focus away from more socially relevant activities. The media tends to focus on topics that affect a large proportion of their audience. Politically, this may harm minorities and special interests while benefiting large groups such as dominant ethnic groups and dispersed consumer interests. Media can occasionally persuade politicians to work on the wrong causes. The distribution of news by the media benefits groups with significant audience shares, groups that care about important problems, and groups to which it is inexpensive to send news.

Appendix A

Slanting strategy

Proof of proposition 1. The slanting strategy is obtained by a maximization process, the newspapers want to reach as many readers as possible, readers will buy the newspaper if they derive positive utility from reading it.

$$
\begin{aligned}
s^*(d_1, d_2) = \arg\max_{s_1, s_2}\ & \bar{u} - \chi\left(s_1^2 + s_2^2\right) \\
& - \varphi\left(b_i^2\ (s_1 + d_1)^2 + b^2\ (s_2 + d_2)^2 + 2\,\alpha\, b\, b_i\ (s_1 + d_1)\ (s_2 + d_2)\right)
\end{aligned}
\tag{A.1}
$$

Differentiating with respect to s_2 and s_1 produces the first-order conditions:

$$s_1^*(s_2) = -\frac{\varphi\left(b_i^2\, d_1 + \alpha\, b\, b_i\,(s_2 + d_2)\right)}{\chi + \varphi\, b_i^2}$$

$$s_2^*(s_1) = -\frac{\varphi\left(b^2\, d_2 + \alpha\, b\, b_i\,(s_1 + d_1)\right)}{\chi + \varphi\, b^2}.$$

Solving this pair of simultaneous equations:

$$s_1^* = -\frac{\varphi\chi\,(b_i^2\,d_1 + \alpha\,b\,b_i\,d_2) + \varphi^2\,b\,b_i^2\,(1-\alpha^2)\,d_1}{\chi^2 + \varphi^2\,b^2\,b_i^2\,(1-\alpha^2) + \varphi\,\chi\,\left(b^2 + b_i^2\right)}$$

$$s_2^* = -\frac{\varphi\chi\,(b^2\,d_2 + \alpha\,b\,b_i\,d_1) + \varphi^2\,b\,b_i^2\,(1-\alpha^2)\,d_2}{\chi^2 + \varphi^2\,b^2\,b_i^2\,(1-\alpha^2) + \varphi\,\chi\,\left(b^2 + b_i^2\right)}$$

Since $\alpha \in \{-1, 1\}$ then $\alpha^2 = 1$, and $b^2 + b_i^2 = 1$, therefore,

$$\begin{aligned} s_1^* &= -\frac{\varphi\,(b_i^2\,d_1 + \alpha\,b\,b_i\,d_2)}{\chi + \varphi} \\ s_2^* &= -\frac{\varphi\,(b^2\,d_2 + \alpha\,b\,b_i\,d_1)}{\chi + \varphi} \end{aligned} \tag{A.2}$$

The slanting strategy can be expressed in terms of the product of a matrix and a vector:

$$s^B(d_1, d_2) \equiv -\frac{\varphi}{\chi + \varphi} \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}.$$

□

A.1 Useful terms

Here I compute the terms that come into the preferences of the reader.

The matrix used to define slanting strategies is symmetric:

$$\begin{pmatrix} B_2^2 & \alpha\,B_1\,B_2 \\ \alpha\,B_1\,B_2 & B_1^2 \end{pmatrix}^T = \begin{pmatrix} B_2^2 & \alpha\,B_1\,B_2 \\ \alpha\,B_1\,B_2 & B_1^2 \end{pmatrix}.$$

It is also idempotent:

$$\begin{pmatrix} B_2^2 & \alpha\, B_1\, B_2 \\ \alpha\, B_1\, B_2 & B_1^2 \end{pmatrix}^2 = \begin{pmatrix} B_2^2 & \alpha\, B_1\, B_2 \\ \alpha\, B_1\, B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} B_2^2 & \alpha\, B_1\, B_2 \\ \alpha\, B_1\, B_2 & B_1^2 \end{pmatrix}$$

$$= \begin{pmatrix} B_2^2\,(B_2^2 + \alpha^2 B_1^2) & \alpha\, B_1\, B_2\,(B_2^2 + B_1^2) \\ \alpha\, B_1\, B_2\,(B_2^2 + B_1^2) & B_1^2\,(B_2^2 + \alpha^2 B_1^2) \end{pmatrix} = \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix}.$$

This is because $\alpha^2 = 1$ and $B_2^2 + B_1^2 = 1$.

The second term in reader's utility involves $s_1^2 + s_2^2 = s^T s$.

$$s^T s = \left(\frac{\varphi}{\chi+\varphi}\right)^2 \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}^T \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix}^T \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$= \left(\frac{\varphi}{\chi+\varphi}\right)^2 \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}^T \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} = \left(\frac{\varphi}{\chi+\varphi}\right)^2 \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}^T \begin{pmatrix} B_2^2\, d_1 + \alpha B_1 B_2 d_2 \\ B_1^2 d_2 + \alpha B_1 B_2 d_1 \end{pmatrix}$$

$$= \left(\frac{\varphi}{\chi+\varphi}\right)^2 \left(B_2^2\, d_1^2 + 2\alpha B_1 B_2 d_2 d_1 + B_1^2 d_2^2\right)$$

$$= \left(\frac{\varphi}{\chi+\varphi}\right)^2 (B_2\, d_1 + \alpha B_1\, d_2)^2\,. \tag{A.3}$$

The reported news is $n = d + s$:

$$n = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} - \frac{\varphi}{\chi+\varphi} \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$= \left[\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} - \frac{\varphi}{\chi+\varphi} \begin{pmatrix} B_2^2 & \alpha B_1 B_2 \\ \alpha B_1 B_2 & B_1^2 \end{pmatrix}\right] \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$= \begin{pmatrix} 1 - \dfrac{\varphi\, B_2^2}{\chi + \varphi} & -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} \\ \\ -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} & 1 - \dfrac{\varphi B_1^2}{\chi + \varphi} \end{pmatrix} \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}$$

This matrix is also symmetric.

In order to facilitate the calculation of $b_i^2\, n_1^2 + b^2\, n_2^2$ I compute the following matrix operation:

$$\begin{pmatrix} n_1 \\ \\ n_2 \end{pmatrix}^T \begin{pmatrix} b_i^2 & 0 \\ \\ 0 & b^2 \end{pmatrix} \begin{pmatrix} n_1 \\ \\ n_2 \end{pmatrix} = \begin{pmatrix} n_1 \\ \\ n_2 \end{pmatrix}^T \begin{pmatrix} b_i^2\, n_1 \\ \\ b^2\, n_2 \end{pmatrix} = b_i^2\, n_1^2 + b^2\, n_2^2.$$

Using the values of n :

$$\begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}^T \begin{pmatrix} 1 - \dfrac{\varphi\, B_2^2}{\chi + \varphi} & -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} \\ \\ -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} & 1 - \dfrac{\varphi B_1^2}{\chi + \varphi} \end{pmatrix} \begin{pmatrix} b_i^2 & 0 \\ \\ 0 & b^2 \end{pmatrix} \begin{pmatrix} 1 - \dfrac{\varphi\, B_2^2}{\chi + \varphi} & -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} \\ \\ -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} & 1 - \dfrac{\varphi B_1^2}{\chi + \varphi} \end{pmatrix} \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}$$

$$= \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}^T \begin{pmatrix} 1 - \dfrac{\varphi\, B_2^2}{\chi + \varphi} & -\dfrac{\alpha\, B_1\, B_2\, \varphi}{\chi + \varphi} \\ \\ -\dfrac{\alpha\, B_1\, B_2\, \varphi}{\chi + \varphi} & 1 - \dfrac{\varphi B_1^2}{\chi + \varphi} \end{pmatrix} \begin{pmatrix} \left(1 - \dfrac{\varphi\, B_2^2}{\chi + \varphi}\right) b_i^2 & -\dfrac{\alpha\, B_1\, B_2\, \varphi\, b_i^2}{\chi + \varphi} \\ \\ -\dfrac{\alpha\, B_1\, B_2\, \varphi\, b^2}{\chi + \varphi} & \left(1 - \dfrac{\varphi B_1^2}{\chi + \varphi}\right) b^2 \end{pmatrix} \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}$$

$$= \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}^T \begin{pmatrix} \left(1 - \dfrac{\varphi B_2^2}{\chi + \varphi}\right)^2 b_i^2 + \dfrac{B_1^2 B_2^2 \varphi^2}{(\chi + \varphi)^2} b^2 & -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} + \dfrac{\alpha B_1 B_2 \varphi^2}{(\chi + \varphi)^2} \left(B_1^2 b^2 + B_2^2 b_i^2\right) \\ \\ -\dfrac{\alpha B_1 B_2 \varphi}{\chi + \varphi} + \dfrac{\alpha B_1 B_2 \varphi^2}{(\chi + \varphi)^2} \left(B_1^2 b^2 + B_2^2 b_i^2\right) & \left(1 - \dfrac{\varphi B_1^2}{\chi + \varphi}\right)^2 b^2 + \dfrac{B_1^2 B_2^2 \varphi}{(\chi + \varphi)^2} b_i^2 \end{pmatrix} \begin{pmatrix} d_1 \\ \\ d_2 \end{pmatrix}$$

$$= \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}^T \begin{pmatrix} \left(\left(1 - \frac{\varphi B_2^2}{\chi+\varphi}\right)^2 b_i^2 + \frac{B_1^2 B_2^2 \varphi^2}{(\chi+\varphi)^2} b^2\right) d_1 + \left(-\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} + \frac{\alpha B_1 B_2 \varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2 + B_2^2 b_i^2\right)\right) d_2 \\ \left(-\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} + \frac{\alpha B_1 B_2 \varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2 + B_2^2 b_i^2\right)\right) d_1 + \left(\left(1 - \frac{\varphi B_1^2}{\chi+\varphi}\right)^2 b^2 + \frac{B_1^2 B_2^2 \varphi}{(\chi+\varphi)^2} b_i^2\right) d_2 \end{pmatrix}$$

$$\begin{aligned} = &\left(\left(1 - \frac{\varphi B_2^2}{\chi+\varphi}\right)^2 b_i^2 + \frac{B_1^2 B_2^2 \varphi^2}{(\chi+\varphi)^2} b^2\right) d_1^2 + 2\left(-\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} + \frac{\alpha B_1 B_2 \varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2 + B_2^2 b_i^2\right)\right) d_1 d_2 \\ &+ \left(\left(1 - \frac{\varphi B_1^2}{\chi+\varphi}\right)^2 b^2 + \frac{B_1^2 B_2^2 \varphi^2}{(\chi+\varphi)^2} b_i^2\right) d_2^2 \end{aligned} \tag{A.4}$$

It only remains to compute the last term for the utility of the reader, $2\,\alpha\, b\, b_i\, n_1\, n_2$. Recall that

$$n = \begin{pmatrix} 1 - \frac{\varphi\, B_2^2}{\chi+\varphi} & -\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} \\ -\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} & 1 - \frac{\varphi B_1^2}{\chi+\varphi} \end{pmatrix} \begin{pmatrix} d_1 \\ d_2 \end{pmatrix},$$

so n_1 times n_2 is equal to

$$\begin{aligned} &\left[\left(1 - \frac{\varphi\, B_2^2}{\chi+\varphi}\right) d_1 - \frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} d_2\right]\left[\left(-\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} d_1\right) + \left(1 - \frac{\varphi B_1^2}{\chi+\varphi}\right) d_2\right] \\ &= -\left(1 - \frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi}\right) d_1^2 - \left(1 - \frac{\varphi B_1^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi}\right) d_2^2 \\ &\quad + \left[\left(1 - \frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(1 - \frac{\varphi B_1^2}{\chi+\varphi}\right) + \frac{B_1^2 B_2^2 \varphi^2}{(\chi+\varphi)^2}\right] d_1 d_2. \end{aligned} \tag{A.5}$$

Appendix B

Utility

Proof of proposition 2. The reader's utility is

$$
\begin{aligned}
U_i\left(s^B(d)\right) = \bar{u} - P_j - \chi\left(s_1^2 + s_2^2\right) \\
- \varphi\left(b_i^2\ (s_1 + d_1)^2 + b^2\ (s_2 + d_2)^2 + 2\,\alpha\, b\, b_i\ (s_1 + d_1)\ (s_2 + d_2)\right).
\end{aligned}
$$

When newspaper slants news around the point (B_1, B_2), reader gets utility:

$$
\begin{aligned}
U_i\left(s^B(z)\right) = \bar{u} - \chi\left(\frac{\varphi}{\varphi+\chi}\right)^2\left(B_1^2 d_2^2 - 2B_1B_2d_1d_2 + B_2^2 d_1^2\right) \\
-\varphi\Bigg\{\left[\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right)^2 b^2 + \frac{B_1^2B_2^2\varphi^2}{(\chi+\varphi)^2} b_i^2 - 2\,\alpha\, b\, b_i\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi}\right)\right] d_2^2 \\
+\left[\left(1-\frac{\varphi B_2^2}{\chi+\varphi}\right)^2 b_i^2 + \frac{B_1^2B_2^2\varphi^2}{(\chi+\varphi)^2} b^2 - 2\,\alpha\, b\, b_i\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi}\right)\right] d_1^2 \\
+\left[2\left(-\frac{\alpha B_1 B_2 \varphi}{\chi+\varphi} + \frac{\alpha B_1 B_2 \varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2 + B_2^2 b_i^2\right)\right)\right. \\
\left. +\ 2\,\alpha\, b\, b_i\left(\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right) + \frac{B_1^2B_2^2\varphi^2}{(\chi+\varphi)^2}\right)\right] d_1 d_2\Bigg\}.
\end{aligned}
\tag{B.1}
$$

Terms whose coefficient is d_2^2, in the third term

$$
\begin{aligned}
&\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right)^2 b^2+\frac{B_1^2 B_2^2\varphi^2}{(\chi+\varphi)^2}b_i^2-2\,\alpha\, b\, b_i\,\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2\varphi}{\chi+\varphi}\right)\\
&=\left(b^2-\frac{2\,\varphi\, B_1^2\, b^2}{\chi+\varphi}+\frac{\varphi^2\, B_1^4\, b^2}{(\chi+\varphi)^2}\right)+\frac{B_1^2\, B_2^2\,\varphi^2\, b_i^2}{(\chi+\varphi)^2}-\frac{2\, B_1\, b\, B_2\, b_i\,\varphi}{\chi+\varphi}+\frac{2\, B_1^2\, B_1\, b\, B_2\, b_i\varphi^2}{(\chi+\varphi)^2}\\
&=b^2-\frac{2\,\varphi\, B_1\, b}{\chi+\varphi}\left(B_1\, b+\ B_2\, b_i\right)+\frac{\varphi^2\, B_1^2}{(\chi+\varphi)^2}\left(B_1^2\, b^2+2\, B_1\, b\, B_2\, b_i+B_2^2\, b_i^2\right)\\
&=b^2-\frac{2\,\varphi\, B_1\, b}{\chi+\varphi}\left(B_1\, b+\ B_2\, b_i\right)+\frac{\varphi^2\, B_1^2}{(\chi+\varphi)^2}\left(B_1\, b+B_2\, b_i\right)^2
\end{aligned}
$$

$$
=\left(\frac{\varphi\, B_1}{\chi+\varphi}\left(B_1\, b+B_2\, b_i\right)-b\right)^2. \tag{B.2}
$$

By a similar calculation for the coefficient of d_1^2 in the third term,

$$
\begin{aligned}
&\left(1-\frac{\varphi B_2^2}{\chi+\varphi}\right)^2 b_i^2+\frac{B_1^2 B_2^2\varphi^2}{(\chi+\varphi)^2}b^2-2\,\alpha\, b\, b_i\,\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(\frac{\alpha B_1 B_2\varphi}{\chi+\varphi}\right)\\
&=\left(\frac{\varphi\, B_2}{\chi+\varphi}\left(B_1\, b+B_2\, b_i\right)-b_i\right)^2.
\end{aligned} \tag{B.3}
$$

And the remaining elements for $d_1 d_2$

$$
\begin{aligned}
&2\left(-\frac{\alpha B_1 B_2\varphi}{\chi+\varphi}+\frac{\alpha B_1 B_2\varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2+B_2^2 b_i^2\right)\right)+2\,\alpha\, b\, b_i\,\left(\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}\right)\left(1-\frac{\varphi B_1^2}{\chi+\varphi}\right)+\frac{B_1^2 B_2^2\varphi^2}{(\chi+\varphi)^2}\right)\\
&=-\frac{2\alpha B_1 B_2\varphi}{\chi+\varphi}+\frac{2\alpha B_1 B_2\varphi^2}{(\chi+\varphi)^2}\left(B_1^2 b^2+B_2^2 b_i^2\right)+2\,\alpha\, b\, b_i\,\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}-\frac{\varphi B_1^2}{\chi+\varphi}+\frac{2\, B_1^2\, B_2^2\,\varphi^2}{(\chi+\varphi)^2}\right)\\
&=\frac{2\,\alpha\, B_1\, B_2\,\varphi^2}{(\chi+\varphi)^2}\left(B_1^2\, b^2+B_2^2\, b_i^2+2\, b\, b_i\, B_1\, B_2\right)-\frac{2\,\alpha\, B_1\, B_2\,\varphi}{\chi+\varphi}+2\,\alpha\, b\, b_i\,\left(1-\frac{\varphi\, B_2^2}{\chi+\varphi}-\frac{\varphi B_1^2}{\chi+\varphi}\right)
\end{aligned}
$$

$$
=\frac{2\,\alpha\, B_1\, B_2\,\varphi^2}{(\chi+\varphi)^2}\left(B_1\, b+B_2\, b_i\right)^2-\frac{2\,\alpha\,\varphi}{\chi+\varphi}\left(B_1\, B_2+b\, b_i\right)+2\,\alpha\, b\, b_i. \tag{B.4}
$$

With this calculations I can write the utility for the reader with beliefs β_i and the newspapers with slanting strategy (4.1):

$$U_i\left(s^B(z)\right) = \bar{u} - \chi\left(\frac{\varphi}{\varphi+\chi}\right)^2\left(B_1^2 d_2^2 + 2\,\alpha\,B_1\,B_2\,d_1, d_2 + B_2^2\,d_1^2\right)$$
$$-\varphi\left\{\left(\frac{\varphi\,B_1}{\chi+\varphi}\left(B_1\,b + B_2\,b_i\right) - b\right)^2 d_2^2 + \left(\frac{\varphi\,B_2}{\chi+\varphi}\left(B_1\,b + B_2\,b_i\right) - b_i\right)^2 d_1^2\right.$$
$$\left.+\left[\left(\frac{\varphi}{\varphi+\chi}\right)^2 2\,\alpha\,B_1\,B_2\left(B_1 b + B_2 b_i\right)^2 - \frac{2\,\alpha\,\varphi}{\varphi+\chi}\left(B_1 B_2 + b\,b_i\right) + 2\alpha\,b\,b_i\right] d_1 d_2\right\}. \quad \text{(B.5)}$$

Here I conveniently set $B_1 b + B_2 b_i = 1$ and assume that, subject to this constraint, the reader's belief β_i is independently drawn from the uniform distribution specified before.

With this assumption, reader's utility is

$$U_i\left(s^B(z)\right) = \bar{u} - \chi\left(\frac{\varphi}{\varphi+\chi}\right)^2\left(B_1^2 d_2^2 + 2\alpha\,B_1\,B_2\,d_1\,d_2 + B_2^2 d_1^2\right)$$
$$-\,\varphi\left\{\left(\frac{\varphi}{\chi+\varphi}B_1 - b\right)^2 d_2^2 + \left(\frac{\varphi\,B_2}{\chi+\varphi} - b_i\right)^2 d_1^2\right.$$
$$\left.+\left[\left(\frac{\varphi}{\varphi+\chi}\right)^2 2\,\alpha\,B_1\,B_2 - \frac{2\,\alpha\,\varphi}{\varphi+\chi}\left(B_1 B_2 + b\,b_i\right) + 2\alpha\,b\,b_i\right] d_1 d_2\right\}. \quad \text{(B.6)}$$

Collecting terms in d_1,

$$-d_1^2\left[\left(\frac{\varphi}{\varphi+\chi}\right)^2\chi B_2^2+\varphi\left(\frac{\varphi\,B_2}{\chi+\varphi}-b_i\right)^2\right]=-d_1^2\left(\frac{\varphi^2\,B_2^2}{\varphi+\chi}-\frac{2\,\varphi^2\,B_2\,b_i}{\chi+\varphi}+\varphi\,b_i^2\right)$$
$$=-d_1^2\left(\frac{\varphi^2\,B_2^2-2\,\varphi^2\,B_2\,b_i+\varphi^2\,b_i^2+\,\varphi\,\chi\,\,b_i^2}{\varphi+\chi}\right)=-d_1^2\left(\frac{\varphi^2\,(\,B_2-b_i)^2+\,\varphi\,\chi\,\,b_i^2}{\varphi+\chi}\right).$$

Similarly for the terms in d_2,

$$-d_2^2\left[\left(\frac{\varphi}{\varphi+\chi}\right)^2\chi B_1^2+\varphi\left(\frac{\varphi\,B_1}{\chi+\varphi}-b\right)^2\right]=-d_2^2\left(\frac{\varphi^2\,(\,B_1-b)^2+\,\varphi\,\chi\,\,b^2}{\varphi+\chi}\right).$$

And the terms in d_1d_2,

$$2\left[-\left(\frac{\varphi}{\varphi+\chi}\right)^2\alpha\,\chi\,B_1\,B_2-\left(\frac{\varphi}{\varphi+\chi}\right)^2\alpha\,\varphi\,B_1\,B_2+\frac{\alpha\,\varphi^2}{\varphi+\chi}\,(B_1B_2+b\,b_i)-\alpha\,\varphi\,b\,b_i\right]d_1d_2$$
$$=2\left[-\frac{\alpha\,\varphi^2\,B_1\,B_2}{(\varphi+\chi)^2}\,(\chi+\varphi)+\frac{\alpha\,\varphi^2\,B_1\,B_2}{\varphi+\chi}+\frac{\alpha\,\varphi^2\,b\,b_i}{\varphi+\chi}-\frac{\alpha\,\varphi\,b\,b_i(\varphi+\chi)}{\varphi+\chi}\right]d_1d_2$$
$$=2\left(\frac{-\alpha\,\varphi^2\,B_1\,B_2+\alpha\,\varphi^2\,B_1\,B_2+\alpha\,\varphi^2\,b\,b_i-\alpha\,\varphi\,b\,b_i(\varphi+\chi)}{(\varphi+\chi)}\right)d_1d_2$$
$$=-\frac{2\,\alpha\,\varphi\,\chi\,b\,b_i}{\varphi+\chi}d_1\,d_2.$$

Then the reader's utility (gross of price) of reading such newspaper is:

$$U_i\left(s^B(d_1,d_2)\right)=\bar{u}-\left(\frac{\varphi^2\,(B_1-b)^2+\varphi\chi b^2}{\varphi+\chi}\right)d_2^2$$
$$-\frac{2\,\varphi\,\chi}{\varphi+\chi}\alpha\,b\,b_i\,d_1\,d_2-\left(\frac{\varphi^2\,(B_2-b_i)^2+\varphi\chi b_i^2}{\varphi+\chi}\right)d_1^2. \quad \text{(B.7)}$$

Now, taking the expectation $\mathbb{E}_d\left[U_i\left(s^B(d_1,d_2)\right)\right]$ with respect to d:

$$\mathbb{E}_d\left[U_i\left(s^B(d_1,d_2)\right)\right] = \bar{u} - \left(\frac{\varphi^2\,\left(B_1 - b\right)^2 + \varphi\,\chi b^2}{\varphi+\chi}\right)\sigma_2^2 - \frac{2\,\varphi\,\chi}{\varphi+\chi}\alpha\, b\, b_i\,\rho\,\sigma_1\,\sigma_2 - \left(\frac{\varphi^2\left(B_2 - b_i\right)^2 + \varphi\,\chi b_i^2}{\varphi+\chi}\right)\sigma_1^2. \quad \text{(B.8)}$$

This result is because the expectation of the square of this random variable is its variance, $\mathbb{E}_d\left[\,d_\ell^2\,\right] = \sigma_\ell^2$ for $\ell \in \{1, 2\}$, and the expectation of the product of the two random variables d_1 and d_2 is its covariance, $\mathbb{E}_d\left[\,d_1\,d_2\,\right] = \rho\,\sigma_1\,\sigma_2$.

□

Proof of proposition 3. For a reader to read the paper it must be the case that

$$\bar{u} - \left(\frac{\varphi^2\,\left(B_1 - b\right)^2 + \varphi\,\chi b^2}{\varphi+\chi}\right)\sigma_2^2 - \frac{2\,\varphi\,\chi}{\varphi+\chi}\alpha\, b\, b_i\,\rho\,\sigma_1\,\sigma_2 - \left(\frac{\varphi^2\left(B_2 - b_i\right)^2 + \varphi\,\chi b_i^2}{\varphi+\chi}\right)\sigma_1^2 \geq P. \quad \text{(B.9)}$$

Since the monopolist can extract all surplus, and readers hold the same beliefs b in one dimension of the state of the world, he maximizes expected utility by choosing $B_1 = b$,

In the dimension where readers differ in their beliefs, newspapers must decide which of the heterogeneous reader group is its target audience.

Now, I need to show which strategy a monopolist would choose, and which is the optimal bias.

Reader with bias β_i and with the monopolist choosing $B_1 = b$ receives utility:

$$\bar{u} - P - \frac{\varphi\,\chi}{\varphi+\chi}b^2\,\sigma_2^2 - \frac{2\,\varphi\,\chi}{\varphi+\chi}\alpha\, b\, b_i\,\rho\,\sigma_1\,\sigma_2 - \left(\frac{\varphi^2\left(B_2 - b_i\right)^2 + \varphi\,\chi\, b_i^2}{\varphi+\chi}\right)\sigma_1^2.$$

All readers for whom this term is positive will read the paper, indifferent readers can be defined from this equation.

Let

$$K(P) \equiv \bar{u} - P - \frac{\varphi\chi}{\varphi+\chi} b^2 \sigma_2^2, \tag{B.10}$$

then the reader is indifferent if:

$$-\varphi\,\sigma_1^2\,b_i^2 + \frac{2\,\varphi\,\sigma_1\,(\varphi\,B_2\,\sigma_1 - \alpha\,\chi\,b\,\rho\,\sigma_2)}{\varphi+\chi} b_i - \frac{\varphi^2\,B_2^2\,\sigma_1^2}{\varphi+\chi} + K(P) = 0,$$

the roots of this polynomial are:

$$b_{i\pm} = \frac{\varphi\,B_2\,\sigma_1 - \alpha\,\chi\,b\,\rho\,\sigma_2 \pm \sqrt{\chi\,b\,\rho\,\sigma_2\,(\chi\,b\,\rho\,\sigma_2 - 2\,\alpha\,\varphi\,\sigma_1\,B_2) - \chi\,\varphi\,\sigma_1^2\,B_2^2 + \frac{K(P)}{\varphi}\,(\chi+\varphi)^2}}{\sigma_1(\varphi+\chi)}$$

Considering the case where the boundaries of the reader bias distribution are defined by this quadratic equation:

$$b_+(P) - b_-(P) = \frac{2\,\sqrt{\chi\,b\,\rho\,\sigma_2\,(\chi\,b\,\rho\,\sigma_2 - 2\,\alpha\,\varphi\,\sigma_1\,B_2) - \chi\,\varphi\,\sigma_1^2\,B_2^2 + \frac{K(P)}{\varphi}\,(\chi+\varphi)^2}}{\sigma_1(\varphi+\chi)} \tag{B.11}$$

The constant K is independent from B_2, so I can check the monotonicity of this function to find B_2 optimum.

The derivative of this expression with respect to B_2 is:

$$\frac{-2\,\alpha\,b\,\rho\,\sigma_1\,\sigma_2\,\varphi\,\chi - 2\,B_2\,\sigma_1^2\,\varphi\,\chi}{\sigma_1(\varphi+\chi)\sqrt{\chi\,b\,\rho\,\sigma_2\,(\chi\,b\,\rho\,\sigma_2 - 2\,\alpha\,\varphi\,\sigma_1\,B_2) - \chi\,\varphi\,\sigma_1^2\,B_2^2 + \frac{K(P)}{\varphi}\,(\chi+\varphi)^2}}. \tag{B.12}$$

This derivative is zero when:

$$B_2 = -\alpha\,b\,\rho\,\frac{\sigma_2}{\sigma_1}. \tag{B.13}$$

There are two factors that determine the newspaper strategy, whether the two states of the world exhibit positive or negative correlation ρ, and whether news and beliefs are strategic substitutes ($\alpha = -1$) or strategic complements ($\alpha = 1$).

To gain some intuition let express equation (B.11) in simple terms, we are interested in how it behaves in terms of α, ρ and B_2, so let the other constants be equal to 1 and $B_2 \equiv x$. So I am left with:

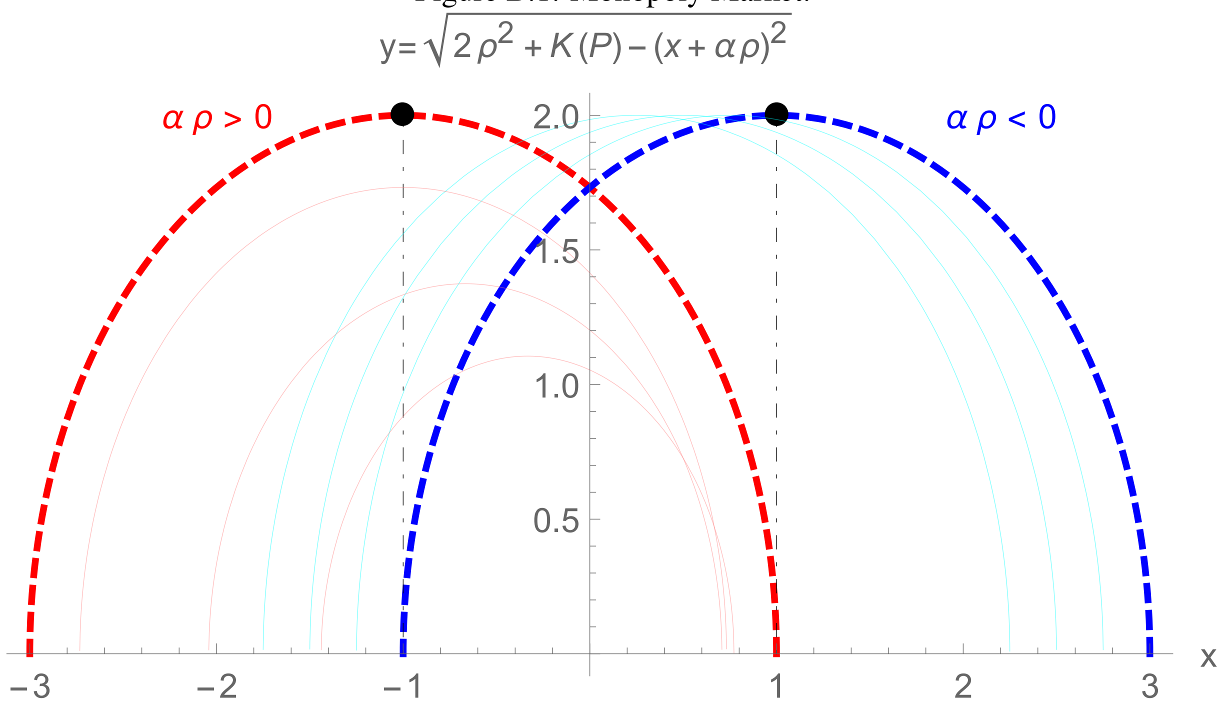
$$y = \sqrt{\rho(\rho + 2\alpha\, x) - x^2 + K(P)},$$

rewriting this equation,

$$y^2 + (x + \alpha\, \rho)^2 = 2\, \rho^2 + K(P),$$

is easy to see that it is a semicircle, with center in $(-\alpha\, \rho, 0)$ and radius $\sqrt{2\, \rho^2 + K(P)}$.

Figure B.1: Monopoly Market.



Source: own elaboration.

In figure B.1 we can see that the market the monopolist will cover depends on the magnitude of the correlation ρ between the dimensions of the state of the world and the price it charges. The blue and red dashed lines are for the extreme values of ρ either 1 or -1. The cyan lines are for different values of ρ. and $K(P)$ when the monopoly can cover the whole market. Pink lines are for values of ρ and $K(P)$ when the monopoly cannot cover the whole market. At $B_1 = b$, and $B_2 = -\alpha\, b\, \rho\, \frac{\sigma_2}{\sigma_1}$, and substituting $K(P)$ from equation (B.10) the monopolist profit is:

$$\Pi^*_{\text{mon}} = \frac{2\,P}{\sigma_1(\varphi+\chi)}\sqrt{\chi\;(\chi+\varphi)\,(1+\rho^2)\;b^2\,\sigma_2^2 + \frac{(\bar{u}-P)\,(\varphi+\chi)^2}{\varphi}},$$

This function has a global maximum at:

$$P^m = \frac{2}{3}\bar{u} + \frac{2\,\varphi\,\chi\,b^2\,(1+\rho^2)\,\sigma_2^2}{3(\varphi+\chi)}$$

At this maximum:

$$b_+ - b_- = \frac{2\sqrt{(\varphi+\chi)\,(\bar{u}(\varphi+\chi)+\varphi\,\chi\,b^2(\rho^2-5)\,\sigma_2^2}}{(\varphi+\chi)\sqrt{3\,\varphi}} \equiv C_m. \tag{B.14}$$

Optimal monopolist slanting strategy is:

$$s^*_{\text{mon}}(d_1,d_2) \equiv -\frac{\varphi\,b^2}{\chi+\varphi}\begin{pmatrix} \rho^2\,\frac{\sigma_2^2}{\sigma_1^2} & -\rho\,\frac{\sigma_2}{\sigma_1} \\ & \\ -\rho\,\frac{\sigma_2}{\sigma_1} & 1 \end{pmatrix}\begin{pmatrix} d_1 \\ d_2 \end{pmatrix}. \tag{B.15}$$

□

$$\mathbf{ARB}_{mon} = \mathbb{E}_d\left[||n-d||^2\right],$$

For the monopoly case, given the strategy $s^*_{\text{mon}}(d)$

$$\begin{aligned}\mathbf{ARB}_{mon} &= \left(\frac{\varphi}{\chi+\varphi}\right)^2\mathbb{E}_d\left[\left(\rho^2\,b^2\,\frac{\sigma_2^2}{\sigma_1^2}\,d_1^2 - 2\,b^2\,\rho\,\frac{\sigma_2}{\sigma_1}\,d_2\,d_1 + b^2\,d_2^2\right)\right] \\ &= \left(\frac{\varphi\,b}{\chi+\varphi}\right)^2\left(\rho^2\,\sigma_2^2 - 2\,\rho^2\,\sigma_2^2+\sigma_2^2\right) = \left(\frac{\varphi\,b\,\sigma_2}{\chi+\varphi}\right)^2\left(1-\,\rho^2\right).\end{aligned}$$

$$\mathbf{ARB}_{mon} = \left(\frac{\varphi\, b\, \sigma_2}{\chi + \varphi}\right)^2 \left(1 - \rho^2\right). \tag{B.16}$$

Proof of propositions 5 and 6. Newspapers chooses to slant their stories around point $B^{(j)} = (y_j, z_j)$, the expected utility for a reader with bias $\beta_i = (b, x)$ choosing the paper j is:

$$\bar{u} - P_1 - \left(\frac{\varphi^2\,(y_1 - b)^2 + \varphi\,\chi b^2}{\varphi + \chi}\right)\sigma_2^2 - \frac{2\,\varphi\,\chi}{\varphi + \chi}\alpha\, b\, x\, \rho\, \sigma_1\, \sigma_2 - \left(\frac{\varphi^2\,(z_1 - x)^2 + \varphi\,\chi\, x^2}{\varphi + \chi}\right)\sigma_1^2$$
$$= \bar{u} - P_2 - \left(\frac{\varphi^2\,(y_2 - b)^2 + \varphi\,\chi b^2}{\varphi + \chi}\right)\sigma_2^2 - \frac{2\,\varphi\,\chi}{\varphi + \chi}\alpha\, b\, x\, \rho\, \sigma_1\, \sigma_2 - \left(\frac{\varphi^2\,(z_2 - x)^2 + \varphi\,\chi\, x^2}{\varphi + \chi}\right)\sigma_1^2.$$

Solving for x,

$$P_2 - P_1 = \left(\frac{\varphi^2\,(z_1 - x)^2 + \varphi\,\chi\, x^2}{\varphi + \chi}\right)\sigma_1^2 - \left(\frac{\varphi^2\,(z_2 - x)^2 + \varphi\,\chi\, x^2}{\varphi + \chi}\right)\sigma_1^2$$
$$+ \left(\frac{\varphi^2\,(y_1 - b)^2 + \varphi\,\chi b^2}{\varphi + \chi}\right)\sigma_2^2 - \left(\frac{\varphi^2\,(y_2 - b)^2 + \varphi\,\chi b^2}{\varphi + \chi}\right)\sigma_2^2.$$

Simplifying terms,

$$P_2 - P_1 = \frac{\varphi^2\,\sigma_1^2}{\varphi + \chi}\left[(z_1 - x)^2 - (z_2 - x)^2\right] + \frac{\varphi^2\,\sigma_2^2}{\varphi + \chi}\left[(y_1 - b)^2 - (y_2 - b)^2\right].$$

$$P_2 - P_1 = \frac{\varphi^2\,\sigma_1^2}{\varphi + \chi}\left(z_1^2 - 2\, z_1\, x + x^2 - z_2^2 + 2\, z_2\, x - x^2\right) + \frac{\varphi^2\,\sigma_2^2}{\varphi + \chi}\left(y_1^2 - 2\, y_1\, b + b^2 - y_2^2 + 2\, y_2\, b - b^2\right).$$

$$P_2 - P_1 = \frac{\varphi^2\,\sigma_1^2}{\varphi + \chi}\left[2\, x(\, z_2 - z_1) + (z_1 - z_2)(z_1 + z_2)\right] + \frac{\varphi^2\,\sigma_2^2}{\varphi + \chi}\left[2\, b(\, y_2 - y_1) + (y_1 - y_2)(y_1 + y_2)\right].$$

$$P_2 - P_1 = \frac{\varphi^2\,\sigma_1^2}{\varphi+\chi}(\,z_2 - z_1)\,[2\,x - (z_1 + z_2)] + \frac{\varphi^2\,\sigma_2^2}{\varphi+\chi}(y_2 - y_1)\,[2\,b - (y_1 + y_2)]\,.$$

Defining, $\bar{z} \equiv \dfrac{z_1 + z_2}{2}$, $\bar{y} \equiv \dfrac{y_1 + y_2}{2}$, $\Delta P = P_2 - P_1$, $\Delta y = y_2 - y_1$, and $\Delta z = z_2 - z_1$, we get

$$\Delta P = \frac{2\,\varphi^2\,\sigma_1^2}{\varphi+\chi}\Delta z\,[x - \bar{z}] + \frac{\varphi^2\,\sigma_2^2}{\varphi+\chi}(y_2 - y_1)\Delta y\,[b - \bar{y}]\,.$$

So indifferent reader has bias:

$$x(P_1, P_2; y_1, y_2, z_1, z_2) = \bar{z} + \left(\frac{\varphi+\chi}{2\,\varphi^2\,\sigma_1^2}\right)\frac{\Delta P}{\Delta z} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y}) \tag{B.17}$$

Now we can get price best response functions. Firm profits selling to the indifferent reader,

$$\Pi_1\,(P_1, P_2; z_1, z_2) = \frac{P_1}{b_1 - b_0}(x - b_0),$$
$$\Pi_2\,(P_1, P_2; z_1, z_2) = \frac{P_2}{b_1 - b_0}(b_1 - x).$$

Taking derivative of profit function with respect to its own price.

$$\partial_{P_1}\Pi_1 = 0 \Rightarrow x - b_0 + P_1\partial_{P_1}x_1 = 0.$$

$$\bar{z} + \left(\frac{\varphi+\chi}{2\,\varphi^2\,\sigma_1^2}\right)\frac{P_2 - P_1}{\Delta z} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y}) - b_0 + P_1\left(-\frac{\varphi+\chi}{2\,\varphi^2\,\sigma_1^2\,\Delta z}\right) = 0.$$

Solving for P_1,

$$\bar{z} + \left(\frac{\varphi+\chi}{2\,\varphi^2\,\sigma_1^2}\right)\frac{P_2}{\Delta z} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y}) - b_0 = P_1\left(\frac{\varphi+\chi}{\varphi^2\,\sigma_1^2\,\Delta z}\right)$$

$$\left(\frac{\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(\bar{z}-b_0-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right)+\frac{P_2}{2}=P_1$$

Assuming symmetry $b_1 = -b_0$, best response functions are:

$$\begin{aligned} P_1^R(P_2;y_1,y_2,z_1,z_2) &= \frac{P_2}{2}+\left(\frac{\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1+\bar{z}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right)\\ P_2^R(P_2;y_1,y_2,z_1,z_2) &= \frac{P_1}{2}+\left(\frac{\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1-\bar{z}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right) \end{aligned} \tag{B.18}$$

Calculating equilibrium prices and market share. The Nash equilibrium is obtained by solving:

$P_1^* = P_1^R(P_2^R(P_1^*;y_1,y_2,z_1,z_2)),$ and $P_2^* = P_2^R(P_1^R(P_2^*;y_1,y_2,z_1,z_2)).$

For firm 1,

$$\begin{aligned} P_1 = \frac{1}{2}\left(\frac{P_1}{2}+\left(\frac{\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1-\bar{z}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right)\right)\\ +\left(\frac{\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1+\bar{z}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right), \end{aligned}$$

$$P_1^* = \left(\frac{2\,\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1+\frac{\bar{z}}{3}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right). \tag{B.19}$$

Analogously for firm 2,

$$P_2^* = \left(\frac{2\,\varphi^2\,\sigma_1^2\,\Delta z}{\varphi+\chi}\right)\left(b_1-\frac{\bar{z}}{3}-\frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b-\bar{y})\right). \tag{B.20}$$

Difference in prices is:

$$\Delta P = -\frac{4\,\bar{z}\,\sigma_1^2\,\varphi^2\,\Delta z}{3(\varphi+\chi)}$$

Substituting these prices, we can calculate equilibrium market share,

$$x(P_1, P_2; y_1, y_2, z_1, z_2) = \bar{z} + \left(\frac{\varphi + \chi}{2\,\varphi^2\,\sigma_1^2 \Delta z}\right)\left(-\frac{4\,\bar{z}\,\sigma_1^2\,\varphi^2\,\Delta z}{3(\varphi+\chi)}\right) - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y}),$$

$$x^*(y_1, y_2, z_1, z_2) = \frac{\bar{z}}{3} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y}). \tag{B.21}$$

Firms differentiate themselves by choosing bias. Taking the other firm's bias as given, prices and market share can be used to calculate each firm's profits for each bias. Calculating optimal bias for the first stage. Profit functions are,

$$\Pi_1\,(y_1, y_2, z_1, z_2) = \frac{P_1^*(y_1, y_2, z_1, z_2)}{b_1 - b_0}\,(x^*(y_1, y_2, z_1, z_2) - b_0)\,,$$
$$\Pi_2\,(y_1, y_2, z_1, z_2) = \frac{P_2^*(y_1, y_2, z_1, z_2)}{b_1 - b_0}(b_1 - x^*(y_1, y_2, z_1, z_2)).$$

Profits for firm 1 are,

$$\Pi_1 = \left(\frac{2\,\varphi^2\,\sigma_1^2\,\Delta z}{\varphi + \chi}\right)\left(b_1 + \frac{\bar{z}}{3} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y})\right)^2 \tag{B.22}$$

Taking derivative with respect to y_1,

$$\frac{\partial \Pi_1}{\partial y_1} = \left(\frac{4\,\varphi^2\,\sigma_1^2\,\Delta z}{\varphi + \chi}\right)\left(b_1 + \frac{\bar{z}}{3} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y})\right)\frac{\sigma_1^2}{\sigma_2^2\,\Delta z}\left(-\frac{\partial}{\partial y_1}\Delta y(b - \bar{y})\right)$$

$$\frac{\partial \Pi_1}{\partial y_1} = \frac{\sigma_1^2}{\sigma_2^2}\left(\frac{4\,\varphi^2\,\sigma_1^2}{\varphi + \chi}\right)\left(b_1 + \frac{\bar{z}}{3} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y})\right)(\Delta y + (b - \bar{y})) \tag{B.23}$$

$$\frac{\partial \Pi_1}{\partial z_1} = -\left(\frac{2\,\varphi^2\,\sigma_1^2}{\varphi + \chi}\right)\left(b_1 + \frac{\bar{z}}{3} - \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y})\right)\left(b_1 + \frac{\bar{z} - \Delta z}{3} + \frac{\sigma_1^2}{\sigma_2^2}\frac{\Delta y}{\Delta z}(b - \bar{y})\right) \tag{B.24}$$

Since beliefs are homogeneous in the first dimension, both firms choose to slant their news towards the direction that maximize its profits, i.e., they choose $y_1 = y_2 = b$. Thus, in the other dimension their first order condition is:

$$\frac{\partial \Pi_1}{\partial z_1} = -\left(\frac{2\,\varphi^2\,\sigma_1^2}{\varphi + \chi}\right)\left(b_1 + \frac{\bar{z}}{3}\right)\left(b_1 + \frac{\bar{z} - \Delta z}{3}\right)$$

Assuming that we are in the symmetric case where $z_1 = -z_2$. In this case,

$$\frac{\partial \Pi_1}{\partial z_1} = \left(\frac{2\,\varphi^2\,\sigma_1^2}{\varphi + \chi}\right) b_1 \left(-b_1 - \frac{2z_1}{3}\right) \tag{B.25}$$

This derivative is positive when $-2\,z_1 < 3\,b_1$. Analogously for firm 2, $\partial \Pi_2/\partial z_2 > 0$ when $2\,z_2 < 3\,b_1$. Therefore, at $y_2^* = y_1^* = b$, $z_2^* = 3/2\,b_1$ and $z_1^* = -3/2\,b_1$, the firms are at Nash equilibrium.

Evaluating price functions at these values shows that prices are equal to

$$P_j = \frac{6\,\varphi^2\,\sigma_1^2}{\chi + \varphi} b_1^2. \tag{B.26}$$

□

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