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MEDIA BIAS, COMPETITION AND LIMITED RESOURCES: THE ROLE OF REPUTATION

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PRESENTA

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Abstract

Media news is the primary source of information for many people and decision-making processes. Usually, media companies are perceived as biased. In fact, media companies adopt specific political discourses and give preference to some news over others. This specialization on the media market can occur due to resource constrains. Previous literature considers different causes of media bias, however, the specialization on some type of news is usually ignored. This thesis has the objective to contribute to filling the gap in the literature on the consequence of competition in media markets and media bias when firms are able to specialize on certain news. To do so, it develops a model of competition in a media market where firms seek to maximize their reputation for providing information to a representative reader who rates their quality. More importantly, this model incorporates the fact that information is multidimensional and firms face constraints in their ability to learn from all relevant features for making a decision to incorporate the fact that firms can specialize. The results show that competition reduces bias via two channels: first, competition incentives firms to allocate their resources in a way such that they have more precision than their competitors; second, more competition leads to more accuracy, and more accuracy incentives firms to report honestly.

Keywords: Bias, media, reputation, specialization
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Content

List of figures

Chapter 1

Introduction

Media companies want to sell information while displaying an image of neutrality in the search for true information to the audiences. As the source of relevant information for any decision-making process, the media must portrait themselves to their audience as a reliable source. In practice, however, media companies tend to specialize in political discourses and highlight some news over others, that is, media companies provide biased information. For example, Fox News and CNN are two companies that are considered, in general, as objective by their respective audiences. Nevertheless, both highlight different news and present them from usually opposed political perspectives.

Economic literature about media bias has identified different incentives that drive the provision of news in media markets. Among those, reputation is a crucial feature for media companies. Viewers and readers might base their decisions on the information they obtain from the media. Thus we might expect news readers to look for the most reliable source of information. But as in the previous example, this does not necessarily occur. Furthermore, the current literature on media bias has not addressed the fact that information has multiple dimensions and media firms face limitations on learning all from those dimensions.

To illustrate this, consider the following example. Suppose that a legislative body is working on an immigration reform. This reform can lead to different outcomes. First, it can result in a boost to the economy due to the arrival of skilled workers, but it can also not affect the economy at all. Second, it can lead to an increase in crime, or crime might not change at all. Both aspects have relevant consequences for an average citizen. Nevertheless, media companies have limited resources to acquire information, thus they might not learn all the possible consequences of the reform. In the best scenario where media companies can get all information, they still face limited time to transmit this information to their audiences. In consequence, media companies must decide which features are more relevant. In the process, however, firms might end up reporting incomplete information and biasing their audience decisions.

The current dissertation has the objective to analyze the role of reputation when media firms compete among them, they can specialize in certain news, and face limited resources. Furthermore, this thesis attempts to explore the consequences on decision-makers welfare. To achieve this objective, the current dissertation presents a model based on Gentzkow and Shapiro (2006) – GS (2006) henceforth. The proposed model consists of a game where two media firms compete to provide information to a representative decision-maker, a representative reader. Firms can be of high-quality, that is, are honest firms and face no resource constraints, or of normal-quality, that is, can distort signals and face resource constraints. The decision-maker wants to match an unknown, two-dimensional state of the world. Furthermore, media companies, constrained by their resources, can acquire information from both dimensions of the state of the world. By taking into account a two-dimensional state and media firms' resources constrains, we can capture the fact that firms can specialize on some types of news. The representative reader, based on how she perceives the accuracy of the information, evaluates firms' quality. The two dimensions of the state of the world attempt to capture the fact that information has multiple relevant features in the decision-making process. Meanwhile, the resource constraint attempts to capture the fact that firms face limited resources and consequently can not learn everything from both dimensions and must decide which one is more relevant or convenient for them.

The results from this framework are close to GS (2006). First of all, a normal-quality firm reports information honestly about the state of the world that is more likely to occur and will distort all other signals to the report that signals the most likely outcome. This bias, however, can be reduced by increasing competition in the media market. First, competition with other firms will incentivize the normal-quality firm to allocate its resources in a way such that it acquires information with higher accuracy than the rest of its competitors. The firm will succeed if it has better technology in both dimensions. From the reader's perspective, this will increase the probability that the reader learns the true state of the world and hence make her better off. However, the normal-quality firm will not necessarily allocate optimally his resources. As shown in Chapter 3, a higher accuracy level increases the probability that a firm is normal after the reader sees a particular message. Consequently, it reduces the probability that a firm is of high-quality and a normal-quality firm faces a trade-off between increasing the probability that he learns the true state of the world and reducing the potential score that a normal gives to him. Second, more competition can incentivize firms to report more honestly. Since competition increases accuracy and accuracy allows the normal-quality to make fewer mistakes, a normal-quality firm is incentivized to behave as a high-quality firm, leading to honest reporting.

1.1 Literature review

The consequences of competition in media markets are diverse and ambiguous. The economic literature on media bias has identified different incentives that determine media firms' behavior. Focusing on each different incentive, competition can exacerbate media bias or reduce it.

Firstly, an obvious incentive is profit maximization. For example, Ellman and Germano (2009) consider in particular, advertising profits. Under their framework, Ellman and Germano show that advertising profits incentives media firms to seek to reach out to as many readers as possible. When readers have the objective to know the truth, providing accurate information is the best strategy for media companies. Gentzkow and Shapiro (2006) arrive at a similar result with a different incentive: the media firm's reputation. GS (2006) framework show that, on the one hand, when there is low competition or low access to reliable information, media firms tend to report dishonestly and according to readers' beliefs. This translates into media bias. On the other hand, more competition implies higher probability of learning the truth for readers, leading to a reduction in bias.

With a behavioral approach, Mullainathan and Shleifer (2005) show that competition in media markets does not always leads to less bias. Mullainathan and Shleifer develop a model where readers like to see their beliefs confirmed. Media firms, driven by profit incentives, can manipulate the news to satisfy readers' prior beliefs. Under this framework, Mullainathan and Shleifer find that firms tend to specialize on readers' beliefs, and that news accuracy depends more on readers' prior beliefs rather than on competition. Gentzkow, Shapiro, and Sinkinson (2014) provide evidence of how media differentiation and competition interact. Using historical data from newspapers in the twentieth century in America, they show that households prefer like-minded newspapers, consequently, newspapers affiliate with specific political orientations as a differentiation strategy, and more competition increases political ideology diversity. As Gentzkow et al. (2014), Raymond and Taylor (2021) attempt to measure media bias using historical data of *The New York Times* on weather reports with the guidance of a theoretical framework. Interestingly, they find a correlation between sports schedules and weather reports, particularly that when the local baseball team played at home, weather reports were more optimistic.

Another source of bias is identified by Baron (2006). Baron (2006) provide a theoretical framework to explain how media bias results from journalist competition. The career incentives can push journalists to exaggerate some news to gain more audience and to be published on the front cover. This results in increased skepticism among readers, news quality diminished, and lower prices. Interestingly, Baron highlights that competition under these circumstances can be harmful to readers and media bias is not always driven by political affiliations. Also, media bias might be present in firms' own beliefs.

Furthermore, literature on media bias has focused on the consequences of political outcomes. Bernhardt, Krasa, and Polborn (2008) develop a model where media firms can suppress information and readers rely on those firms to make decisions. Although readers are aware of media bias, they cannot recover the suppressed information, and thus make biased decisions and potentially harmful to readers. Chiang and Knight (2011) show that firms have a huge influence over readers when endorsing candidates, however, readers discount the information they receive from media according to their perceived bias. DellaVigna and Kaplan (2007) provide evidence on how media bias affects readers' turnout. In particular, DellaVigna and Kaplan analyze the effect of the introduction of Fox News during the late 1990s and early 2000s across the United States. Their results show that Fox News's introduction in some counties leads republicans to go out and vote.

Denter, Dumav, and Ginzburg (2020) consider a model where media is used as a political tool to persuade readers, and readers can interact with them. In their interaction, readers neglect the correlation within the information all of them receive. Denter et al. (2020) show that with a higher interaction among readers – more connectivity with others–, readers can learn the true state of the world and make the right decision. Gehlbach and Sonin (2014) develop a similar model where the government controls media but focuses on how advertising competition reduces media bias in both private and state media. The literature shows that, although rationality and particularly skepticism as a tool can allow readers to shield their decisions from media bias, media still has a huge influence over readers which can be harmful.

Literature on media bias and competition most of the time focuses on one-dimensional states of the world and one-dimensional signals. As explained above, media firms have access to information (sometimes imperfect) about the state of the world and can transmit it to one or more decision-makers (consumers, readers). Additionally, these signals are often costsless for the media firms. In practice, information has more dimensions or more than one relevant attribute to the decision-making process. Two-dimensional models usually involve persuasion games where an action depends on a state of the world with two or more relevant features.

A two-dimensional state of the world allows to consider different features of a product or relevant aspects involved in the decision-making process. Additionally, a two-dimensional state of the world allows can capture the fact that information can be transmitted under different in via different channels and ways. For example, Dziuda (2011) provides a theoretical framework to explain the incentives behind the decision of an informed adviser of sharing negative attributes to a decision maker, negative attributes that could go against his interests. To do so, Dzuida develops a model where a persuader has hard information which has two dimensions and that is relevant to a decision-maker. By providing negatives features, but not all, the persuader can convince the decision-maker of taking a particular action. Another example is Jain (2018), where a two-dimensional model is developed to explain under which conditions cheap talk style information, i.e., recommendation letters, is relevant when other types of information, i.e., exams or test results, are available too. Although cheap talk information is less reliable for a decision-maker, this type of information becomes relevant when other sources become less accurate. Multidimensional environments can leave room for firms to specialize, especially when they are constrained in their resources.

An exception in the literature that considers a multidimensional environment is Perego and Yuksel (2018). Perego and Yuksel consider an environment where media firms compete and provide information to a group of readers. Firms tend to specialize in certain features according to readers' preferences, particularly in the features where there is no common ground. This leads to polarization and more competition exacerbates this disagreement. Thus, media firms not only generate bias in the way they transmit information but also in what information they decide to cover. With an empirical approach, Le Moglie and Turati (2019) study how media companies associated with specific political discourse cover corruption scandals during electoral cycles, which supports the previous idea. In practice, firms tend to specialize beyond political discourses. The current dissertation has the objective to study media competition and bias under a two-dimensional framework, but when reputation is the main incentive that drives firms' behavior.

The remaining of the thesis is structured as follows. Chapter 2 introduces the model framework and presents the equilibrium of the game, in particular the role of reputation, considering only one firm, and next explores how competition takes place in this news market. Chapter 3 discusses the results and limitations of the framework, and further research.

Chapter 2

Media Bias and Specialization

Consider the following game based on Gentzkow and Shapiro (2006).

Players. From a pool of readers, there is a representative reader (to which we refer as she) and two media firms (each of them, he), $i \in \{1, 2\}$. All players are fully rational. The reader wants to match an unknown, bi-dimensional state of the world $\omega \in \Omega = \{L, R\} \times \{U, D\}$. Let ω_k be realization of the state of the world on dimension k, with $k \in \{1, 2\}$, such that $\omega = (\omega_1, \omega_2) \in \Omega$. So, the reader takes a private action $a \in \Omega$ and her preferences are represented by the next utility function:

$$u(a, \omega) = \begin{cases} 1 \quad \text{if} \quad a = \omega \\ \\ -1 \quad \text{if} \quad a \neq \omega \end{cases} .$$

Prior beliefs. Each dimension of the state of the world is drawn independently from the other. That is, the fact that the first dimension is L or R does not provides any information about the second dimension being U or D. The representative reader assigns probability ρ_1 to the first dimension being $\omega_1 = L$ and ρ_2 to the second dimension being $\omega_2 = U$. Consequently, since both dimensions are independent, then the reader believes that the state (L, U) will take place with probability $P(L, U) = \rho_1 \rho_2$. Equivalently, firm i assigns probability ρ_1^i to $S_1 = L$ and ρ_2^i to $\omega_2 = U$. Let $\rho_1^i, \rho_2^i > \frac{1}{2}$ and $\rho_1^i \rho_2^i > \frac{1}{2}$ for all i. This last restriction implies that both firms perceive (L, U) as the most likely state of the world.

Information provision. In order to make a decision, the representative reader can consult any of the media firms. Each firm can receive a bi-dimensional signal, $s_i = (s_{i1}, s_{i2}) \in \{l, r\} \times \{u, d\}$ for $i \in \{1, 2\}$, that is correlated to the state of the world and that is drawn independently across dimensions and firms.

Signals' accuracy depends on the quality of the firm. With probability $\lambda \in [0, 1]$ firm i is of high-quality, otherwise he is of normal-quality. Firm's quality is private information. If firm i is of high-quality, he receives a perfect correlated signal to the state of the world, that is, $s_i = \omega$. On the contrary, a normal-quality firm receives a noisy signal which accuracy depends on firm i's resources.

Let the accuracy of a normal firm i's signal on dimension k be $P(s_{ik} = \omega_k | \omega_k) = \frac{1}{2} + \pi_k^i$, that is, the probability that the signal correctly matches the dimension k of the state of the world. Accuracy $P(s_{ik} = \omega_k | \omega_k)$ is subject to $0 < a_i \pi_1^i + b_i \pi_2^i < \frac{1}{2}$ and $\pi_k^i > 0$, with $a_i, b_i \in \mathbb{R}_+$, where π_k^i are the resources that firm i allocates to dimension k when of normal quality. That is, a firm can increase the accuracy of the signal on dimension k, however, at the expense of decreasing the accuracy of the other signal. Constants a_i and b_i denote firm's i technology or ability of acquiring information on the first and second dimensions, respectively.[1] Similar to GS (2006), signal's accuracy has as lower bound $\frac{1}{2} < P(s_{ik} = \omega_k | \omega_k)$ in order to keep the relevance of the signal and as upper bound $P(s_{ik} = \omega_k | \omega_k) < 1$ to differentiate a normal quality firm from a high quality one. Let us assume, following GS (2006), that the representative reader prior beliefs that the first dimension is L is $\rho_1 \in [\frac{1}{2}, \frac{1}{2} + \pi_1^i)$ and that the second one is U is $\rho_2 \in [\frac{1}{2}, \frac{1}{2} + \pi_2^i)$ to make the signal relevant information for the reader; firm i's prior beliefs are $\rho_1^i \in (\frac{1}{2} - \pi_k^i, \frac{1}{2} + \pi_k^i)$ for dimension dimension one being L and $\rho_2^i \in (\frac{1}{2} - \pi_k^i, \frac{1}{2} + \pi_k^i)$ for the second dimension being U so that after the firm updates his beliefs, his priors are outweighed. After observing such signals, firm i sends a report $\hat{s}_i = (\hat{s}_1, \hat{s}_2) \in \{\hat{l}, \hat{r}\} \times \{\hat{u}, \hat{d}\}$. Conditional on observing

[1] Media firms can face resources constrains, as Perego and Yuksel (2018) highlights, in allocating time and money to investigate a particular event or sending journalist to cover more than one event that occur at the same time. Alternatively, we can interpret π_k^i as the time or resources firm i takes on transmitting information about dimension i to their audience, i.e., broadcast time. Consequently, a normal-quality firm will increase the precision on learning about one dimension at the expense of learning about the other, which can lead to the risk of learning less information about the state of the world as a whole.

a certain signal, a high quality firm always reports the signal he gets, that is, $P(s_i|\omega) = 1$, we say he reports honestly. In contrast, a normal quality firm faces no constraints and can report dishonestly, $P(s_i|\omega) \in [0, 1]$

Reputation. After receiving all reports from both firms, she updates her beliefs about the state of the world and make a decision. However, the reader only listens one of the firms' reports. In practice, for example, a consumer can read two different newspapers or watch two different news channel, but in the end she only uses information from one of the consulted sources. Then she receives feedback $\chi \in \{(\omega_1, \omega_2), 0\}$, in particular, she learns the state of the world, $\chi = \omega$, with probability $\mu \in [0, 1]$. When $\chi = 0$, there is no feedback. Let $\hat{\lambda}_i(\hat{s}_i, \chi)$ be the ex-post probability that the reader assigns to firm i of being a high quality type. After learning (or not) the true state of the world, the reader assigns a score to the firm that she listened. The reader scores the quality of each firm on its ability of providing information. This score is a continuous payoff denoted by $f(\hat{\lambda}_i)$ for firm i. Function f is a continuous and strictly increasing function. If firm i is not listened by the representative reader, then he gets a payoff of 0.

Timing. The steps of the model are the following.

1. Nature selects the state of the world.
2. Firms allocate resources on their information acquisition on each dimension.
3. Nature selects firms' type and sends a private signal to each firm according to their type.
4. Firms send a report conditional on the signal they received and their type.
5. The reader update her beliefs about the state of the world and choose an action.
6. The reader learns (or not) the true state of the world.
7. The reader updates her beliefs about both firms' quality, listens only one and sets a score to the firm that she decided to listen to while the other do not builds his reputation.
8. All players receive their respective payoffs.

To solve this game we require to use backward induction. So first, we need to find which firm the representative reader would listen to and how the representative reader rates firm's quality. Second, derive a normal-quality firm's strategy, that is, with which probability a normal firm sends a report after seeing certain signal. Recall that high-quality firms always report honestly and always learn the true state of the world. Finally, understand how in general firms allocate their resources.

2.1 The Role of Reputation

What is the role of reputation on media firms provision of information? To address this question, let us consider the following case. Suppose that there is only one firm –that is, there is no competition–, which is of normal quality and the reader receives no feedback at all ($\mu = 0$). Without loss of generality, let us focus on the strategy where the firm sends report the $\hat{s}_i = (\hat{l}, \hat{u})$, which indicates the state with higher probability to occur to the reader. For a normal firm, the accuracy of the signal that he receives about dimension k is $\hat{\pi}_k^i = \frac{1}{2} + \pi_k^i$. This accuracy depends on the assignation π_k^i that the firm previously decided. Following GS (2006), let $\sigma_{(l,u)}((\hat{l}, \hat{u})) = P((\hat{l}, \hat{u})|(l, u)$ be firm i's strategy of sending report $(\hat{l}, \hat{u})$ when he observes signal (l, u). Similarly, let $\sigma_{(l,d)}((\hat{l}, \hat{u}))$, $\sigma_{(r,u)}((\hat{l}, \hat{u}))$ and $\sigma_{(r,d)}((\hat{l}, \hat{u}))$ the probabilities for which firm i reports $(\hat{l}, \hat{u})$ after seeing signal (l, d), (r, u) and (r, d), respectively.

Recall that the representative reader scores firm i's quality using her posterior beliefs over firm's quality after receiving firm i's signal and feedback. So, we need to compute the probability that each possible state of the world ω takes place times the strategy of firm i conditional on the signal he receives and the signals accuracy. Since a high-quality firm will always reports honestly and its signal is perfectly correlated to the state of the world ω, reporting $(\hat{l}, \hat{u})$ will only depend on the probability of state (L, U) taking place, that is $\rho_1\rho_2$. In contrast, a normal-quality firm has the option to distort some signals and the signal he receives is noisy. Let us n and m the indexes for the possible states of the world and signals that a firm can receive, respectively. Let $\omega^1 = (L, U)$, $\omega^2 = (L, D)$, $\omega^3 = (R, U)$ and $\omega^4 = (R, D)$ and $s_i^1 = (l, u)$, $s_i^2 = (l, d)$, $s_i^3 = (r, u)$ and $s_i^4 = (r, d)$. We will index the states and signals with α and β, respectively. A normal-quality firm will report $(\hat{l}, \hat{u})$ with probability $\sum_{\alpha=1}^{4} P(\omega^\alpha) \sum_{\beta=1}^{4} \sigma_{s_i^\beta}((\hat{l}, \hat{u}))P(s_i^\beta = \omega^\alpha|\omega^\alpha)$.[2] So, the reader's posteriors $\hat{\lambda}((\hat{l}, \hat{u}), 0)$ under no feedback are positively related with the following ratio

$$\frac{P((\hat{l}, \hat{u})|high)}{P((\hat{l}, \hat{u})|normal)} = \frac{\rho_1 \rho_2}{\sum_{\alpha=1}^{4} P(\omega^\alpha) \sum_{\beta=1}^{4} \sigma_{s_i^\beta}((\hat{l}, \hat{u}))P(s_i^\beta = \omega^\alpha|\omega^\alpha)}. \tag{2.1}$$

From this expression we can see that, as a normal firm sends report $(\hat{l}, \hat{u})$ with a higher probability, the reader will set a lower probability that the firm is of high-quality after seeing report $(\hat{l}, \hat{u})$. Furthermore, the intuition behind the rate is close to GS (2006) results. First, as either ρ_1 or ρ_2 increases, the representative reader perceives L and U as more likely outcomes on the first and second dimension, respectively. Consequently, the reader values more reports that contain a message where l and u are present for each case since a high-quality firm will report more often such a signal in comparison to a normal-quality firm. Second, when the firm reports more honestly, that is, $\sigma_{(l,u)}((\hat{l}, \hat{u}))$ increases, or the firm distorts signals towards $(\hat{l}, \hat{u})$, it will decrease the ratio. The reason behind this is that a normal-quality firm's strategies will not affect a high-quality firm's behavior. For a moment, lets drop the assumption that increasing accuracy on one dimension decreases the accuracy on the other. So, as the signal's accuracy in dimension k of a normal firm increases, $\frac{1}{2} + \pi_k^i$, it increases the probability that a normal-quality firm sends report $(\hat{l}, \hat{u})$, but does not affects the behavior of a high-quality firm. Consequently, the reader will perceive as less likely that the firm is of high-quality.

Regarding the resource allocation of π_k^i on dimension k, the effect of π_k^i will depend on the firm's ability of acquiring information, that is, the level of a_i and b_i. For each possible value of a_i and b_i, there is a threshold that determines when it is convenient for the firm to allocate more resources towards one dimension instead of the other. Nevertheless, for the imposed restrictions,

[2] The Appendix shows the expressions for the four possible reports.

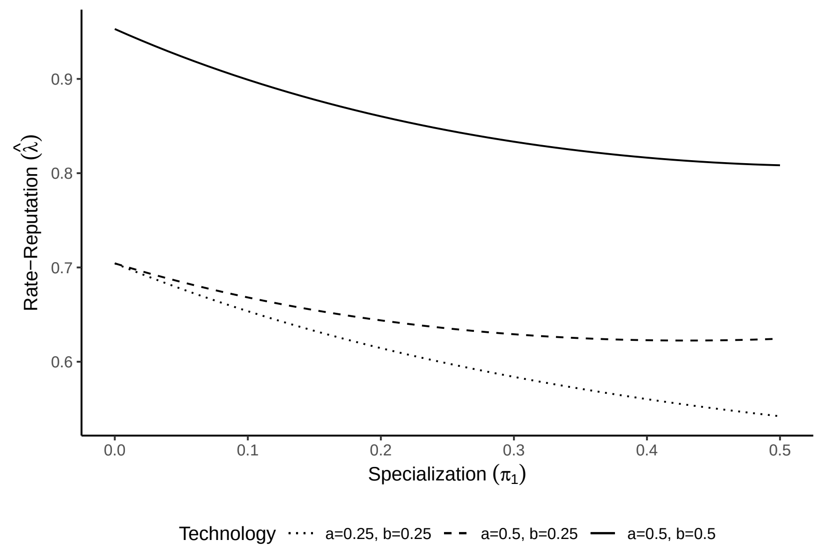
some are feasible while others not (look at Appendix). So, there is a point at which allocating more resources towards one dimension can increase the precision of the signal on both dimensions that a normal-quality firm receives. However, increasing the precision also increases the probability for which a normal-quality firm sends a particular report. Furthermore, the accuracy of the signal also affects the precision of the other three signals that the firm can receive, including all those signals that are not completely informative about the true state of the world. That is, the signal can be right about one dimension but not about the other.

Figure 2.1 attempts to illustrate the effect of allocating resources from one dimension to another for three combinations of a_i and b_i. The continuous line takes values of $a_i = b_i = .5$; for those values it is convenient to specialize on the second dimension. The dashed line takes values of $a_i = .5$ and $b_i = .25$; for such values, specializing is not convenient. Finally, the dotted line takes $a_i = .25$ and $b_i = .25$. It seems that a better technology can lead to more precision, but more precision leads to a lower reputation rate. Nevertheless, as accuracy increases, a normal-quality firm learns the true state almost as a high-quality firm. So, to be rated as a high-quality firm, the normal-quality firm will try to behave as a high-quality firm and to do so the best strategy for him is to report as honest as possible.

As in the uni-dimensional case studied by GS (2006), in equilibrium we must have that $\hat{\lambda}((\hat{l}, \hat{u}), 0) = \hat{\lambda}((\hat{l}, \hat{d}), 0) = \hat{\lambda}((\hat{r}, \hat{u}), 0) = \hat{\lambda}((\hat{r}, \hat{d}), 0)$. That is, the reader must give the same score for all possible messages that he can observe. For example, if $\hat{\lambda}((\hat{l}, \hat{u}), 0)$ was higher than all the other payoffs, then firm i would have incentives to always report $(\hat{l}, \hat{u})$. However, the reader will infer that if she sees any signal different from $(\hat{l}, \hat{u})$, the firm for sure most be of high quality. Furthermore, when firm i is of normal quality, he will try to behave as a high quality firm, i.e., a pooling equilibrium. This will make the firm to garble the less likely signals towards the one that is more likely. All these intuitions are condense in the next lemma.

Lemma 1. *If a normal-quality firm i sends any report $\hat{s}_i \in \{(\hat{l}, \hat{u}), (\hat{l}, \hat{d}), (\hat{r}, \hat{u}), (\hat{r}, \hat{d})\}$ with positive probability, with $\rho_1 \rho_2 > \frac{1}{2}$ and $s_i \in \{(l, u), (l, d), (r, u), (r, d)\}$, then $\hat{\lambda}(\hat{s}_i, 0)$ increases as the probability of each realization of the state in dimension k ρ_k increase for $k \in \{1, 2\}$. It*

Figure 2.1: Firm's Rate Reputation



Source: Own elaboration.
Note: Firm's reputation ratio as a function of resources allocated towards the first dimension for different technologies. The continuous line corresponds to technology $a_i = .5$, $b_i = .5$; the dashed line to technology $a_i = 1$, $b_i = .5$; the dotted line to technology $a_i = .25$, $b_i = .25$.

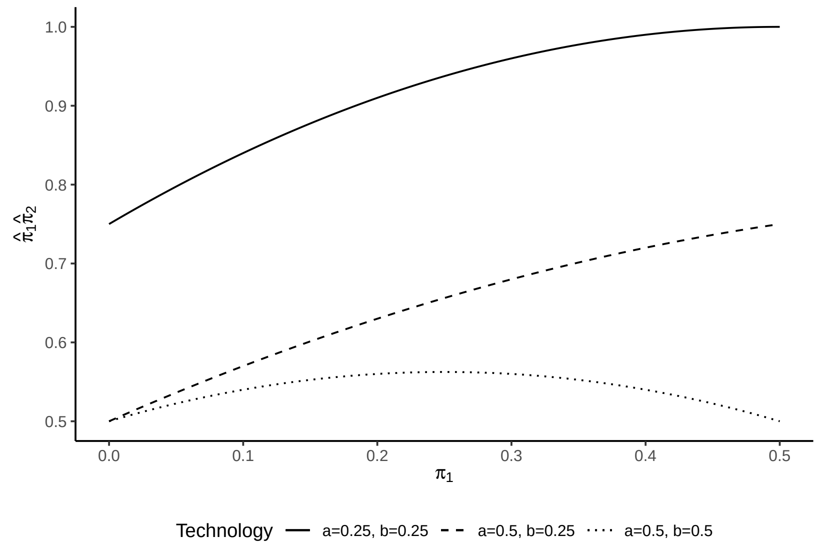
decreases if the normal-quality firm reports more truthfully, $\sigma_{s_i}(\hat{s}_i)$*, and if distorts more signals,* $\sigma_{s_i}(\hat{s}_i)$*. For some values of* a_i *and* b_i*, there is a threshold for which, when* π_1^i *is bellow it, increasing* π_1^i *reduces the rate* $\hat{\lambda}(\hat{s}_i, 0)$*, and when* π_1^i *is above this threshold, it increases.*

Now, let us focus on the case where the firm is of normal-quality and there is always feedback ($\mu = 1$). Since the representative reader always learns the true state of the world, she can always distinguish a normal-quality from a high-quality whenever the firm fails to match the state of the world. To asses this, the firm best strategy is to report honestly. As GS (2006) highlights, honest reporting implies that, for all possible reports and when the firm matches the true state of the world, the reader will set the same payoff $\hat{\lambda}(\hat{s}_i, \omega)$.[3]

Furthermore, firm i would want to match both dimensions of the state of the world with the highest precision. Consequently, firm i can take advantage of specializing on one dimension.

[3]Also, not matching the state of the world indicates the reader that the firm is for sure not of high-quality, thus she sets $\lambda(\hat{s}_i, \omega) = 0$ whenever this occurs

Figure 2.2: Firm's Accuracy



Source: Own elaboration.
Note: Firm's total accuracy for different technologies. The continuous line corresponds to technology $a_i = .5$, $b_i = .5$; the dashed line to technology $a_i = 1$, $b_i = .5$; the dotted line to technology $a_i = .25$, $b_i = .25$.

However, the firm wants to maximize his reputation as well. This represents a trade-off for normal-quality firm: A higher precision increases the chance of the firm to correctly match the state of the world, but it reduces the score that the reader gives to the firm. Recall that a higher accuracy increases the probability that a normal-quality firm sends a particular signal, but does no affects how a high-quality firm reports that same signal; thus, it reduces the probability that the firm is of high-quality.

A normal firm i will correctly match the state of the world with probability $\left(\frac{1}{2}+\pi_1^i\right)\left(\frac{1}{2}+\pi_2^i\right)$. Recall that the firm faces the resources constrain $a_i\pi_1^i + b_i\pi_2^i = \frac{1}{2}$. By clearing π_2^i from the previous equation, we get $\pi_2^i = \frac{1}{2b_i} - \frac{a_i}{b_i}\pi_1^i$. With this expression we can rewrite the probability which a normal-quality firm i's signal correctly matches the state of the world: $\left(\frac{1}{2}+\pi_1^i\right)\left(\frac{1}{2b_i} - \frac{a_i}{b_i}\pi_1^i\right)$.

By taking into account this previous considerations, the firm's trade-off can be translated to the next problem

$$\max_{\pi_1^i} \left(\frac{1}{2}+\pi_1^i\right)\left(\frac{1}{2b_i}-\frac{a_i}{b_i}\pi_1^i\right)\sum_{\alpha=1}^{4} P(s_i=\omega^\alpha|s_i)\hat{\lambda}(\hat{s}_i,\omega^\alpha,\pi_1^i) \tag{2.2}$$

where $P(s_i=\omega^\alpha|s_i)$ are the firm i's beliefs about the state of the world ω^α after seeing signal s and $\hat{\lambda}(\hat{s}_i,\omega^\alpha,\pi_1^i)$ is the score that the reader gives to the firm when the firm matches ω^α. Recall that the score, $\hat{\lambda}(\hat{s}_i,\omega^\alpha)$, the signal accuracy and the firm i's posterior beliefs, $P(s_i=\omega^\alpha|s_i)$, depend directly and indirectly on the resources allocated towards the first dimension, π_1^i. A higher precision increases the firm i's accuracy, but it also decreases the score that the firm receives from the reader, $\hat{\lambda}(\hat{s}_i,\omega^\alpha,\pi_1^i)$. Although we can not obtain an explicit expression for the optimal resource allocation π_1^i, we can argue that it will be below the maximum accuracy that firm can set as long as the gains of in reputation out-weight the loss of not matching a state. This leads us to the following lemma.

Lemma 2. *Under perfect feedback ($\mu=1$), a normal-quality firm i reports truthfully all signals, $\sigma_{s_i}(\hat{s}_i)=1$, so no signal is distorted. Suppose that for the firm's technology is such that a_i and b_i are too high and thus it is hard for the firm to acquire information from each dimension of ω. Then, the firm allocates his resources over the first dimension $\pi_1^i>0$, but different from $\frac{1+b_i-a_i}{4a_i}$. For sufficiently small a_i and b_i, the firm sets $\pi_1^{i*}=\frac{1+b_i-a_i}{4a_i}$.*

When a firm allocates his resources according to $\pi_1^{i*}=\frac{1+b_i-a_i}{4a_i}$, the firm is maximizing the accuracy with which he is matching correctly the true state of the world. Lower values of a_i allows firm i to allocate more resources towards the first dimension. It is less costly to acquire information on that dimension. Similarly, higher values of b_i make more costly to acquire information on the second dimension, thus it is better for the firm to allocate resources towards the first dimension. Notice that it could be that π_1^{i*} is negative if $1+b_i<a_i$. This will imply that the cost of acquiring information on the first dimension is too high, thus it is not convenient for the firm to allocate any of his resources towards this dimension. Also, recall that $\frac{1}{2}+\pi_1^i<1$, so if $\frac{1+b_i-a_i}{4a_i}\geq\frac{1}{2}$, the firm practically faces no cost on allocating resources in the first dimension. From the rest of the thesis, we will consider only a_i and b_i such that $\frac{1+b_i-a_i}{4a_i} \in (0, \frac{1}{2})$.

Following GS (2006), let us focus on the case where $\mu \in (0,1)$. That is, when the representative reader is uncertain about whether she will receive or not feedback about the state of the world. Let $P(\omega|s_i)$ the posteriors of the firm about an specific realization of ω after seeing signal s_i and the expected gain of reporting $(\hat{l}, \hat{u})$ be

$$\Delta(s_i) = (1-\mu)\Delta^{nf} + \mu\Delta^f$$

where

$$\Delta^{nf} = \hat{\lambda}((\hat{l},\hat{u}),0) - \hat{\lambda}((\hat{l},\hat{d}),0) - \hat{\lambda}((\hat{r},\hat{u}),0) - \hat{\lambda}((\hat{r},\hat{d}),0)$$

$$\Delta^f(s) = P((L,U)|s_i)\hat{\lambda}((\hat{l},\hat{u}),(L,U)) - P((L,D)|s_i)\hat{\lambda}((\hat{l},\hat{d}),(L,D))$$

$$-P((R,U)|s_i)\hat{\lambda}((\hat{r},\hat{u}),(R,U)) - P((R,D)|s_i)\hat{\lambda}((\hat{r},\hat{d}),(R,D))$$

the gains in reporting $(\hat{l}, \hat{u})$ under no feedback and under feedback, respectively.

Recall that when there is feedback, the reader sets the same score for all messages when the firm matches ω, $\hat{\lambda}(\hat{s},\omega)$>0, and when the firm does not matches the state, which is 0. This implies that $\Delta^f((l,u)) > 0$ and all other payoffs are negative since firms posteriors out-weight his prior beliefs. In consequence, firm i has incentive to always report truthful signals (l,u) and distort all other signals. This distortion will increase when the probability of feedback reduces, $\mu \to 0$. In contrast, when firm i allocates his resources so he gets closer to the maximum level of accuracy given his technology, it allows him to increase the probability of matching the true state of the world, thus $\Delta^f((l,u))$ will increase while Δ^{nf} will decrease, incentivizing the firm to report truthfully. This intuitions are formalized in the next proposition.

Proposition 1. *A normal firm will report truthful signals (l,u), $\sigma_{(l,u)}((\hat{l},\hat{u})) = 1$, and distort all other signals towards report $(\hat{l},\hat{u})$ with a probability between $[0,1)$. As the firm allocates his resources to maximize his total accuracy $\pi_1 \to \frac{1+b_i-a_i}{4a_i}$, the bias $\sigma_{s_i}((\hat{l},\hat{u}))$ decreases, with $s_i \in \{(l,d),(r,u),(r,d)\}$. In particular, for sufficiently small a_i and b_i, when the firm* *allocates resources* $\pi_1^i = \frac{1+b_i-a_i}{4a_i}$, $\left(\frac{1}{2}+\pi_1^i\right)\left(\frac{1}{2b_i}-\frac{a_i}{b_i}\pi_1^i\right) \to 1$, *thus* $\sigma_{s_i}((\hat{l},\hat{u})) \to 0$, *with* $s_i \in \{(l,d),(r,u),(r,d)\}$.

2.2 Competition

Now let us move forward and study the role of competition. Consider the scenario where two firms, $i \in \{1,2\}$ can provide information to the representative reader. Recall that the reader will only *listen* the report of one of the firms and set a score to the quality of that same firm; the firm that was not listened receives a payoff of 0. That is, only one firm gets the chance of building reputation.

Which firm does the representative reader listen to? The reader wants to match the state of the of world with the higher probability. Thus, the reader will select the firm that provides information with more accuracy and reports as honestly as possible. Recall that a firm's quality can be either high or normal. This leads to three possible cases: Both firms are of normal-quality, both firms are of high-quality, and one firm is of normal-quality while the other is of high-quality. In each case, the reader is unable to distinguish firms' quality, she can only try to infer each firm's quality by comparing the signals that each firm reports with the feedback she receives – if she receives any feedback at all. Also, recall that prior to knowing its quality, both firms allocate their resources and the reader is aware of this.

Moreover, if the firm that the reader decides to listen is of normal-quality, he will behave as discussed in the previous section. That is, he will report honestly the state that is most likely occur and garble all other reports. If the firm is of high-quality, he will always report honestly by definition. Nevertheless, conditional on receiving feedback, the reader will only know whether the firm matched the state of the world or not. So, the reader will only worry to choose the firm with the highest total accuracy.

If the representative reader listens to firm i, then she will expect to match the state of the world ω with probability $\left(\frac{1}{2}+\pi_1^i\right)\left(\frac{1}{2b_i}-\frac{a_i}{b_i}\pi_1^i\right)$. Consequently, the reader will chose to listen the firm that provides information with the higher accuracy. So, in the duopoly case, both firm 1 and 2 will try to allocate their resources to at least have as much as accuracy as their competitor, but not necessarily the maximum. For example, suppose that firm i's technology allows him to set a higher signal accuracy than firm j. This ensures that the reader listens firm i's report. However, the firm faces problem 2.2. If firm i receives higher gains than loses in his expected reputation score by increasing his accuracy, then he will optimally set $\pi_1^{i*} = \frac{1+b_i-a_i}{4a_i}$. Otherwise, he will allocate resources towards the first dimension somewhere between $\pi_1^i \in (\frac{a+b_j-a_j}{4a_j}, \frac{a+b_i-a_i}{4a_i})$. This leads to the next proposition.

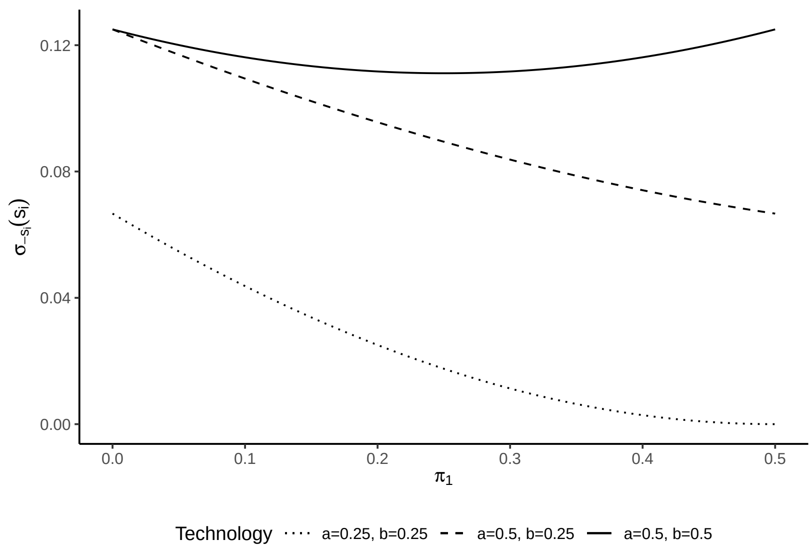
Proposition 2. *For $\mu \in (0,1)$ and when two firms, $i \in \{1,2\}$, can provide information about the state of the world, each firm reports truthfully. The reader will listen the report of the firm with the higher accuracy level, that is,* $\max\{\frac{1+b_1-a_1}{4a_1}, \frac{1+b_2-a_2}{4a_2}\}$*. The firm whose report the reader decides to listen, will set allocate resources towards the first dimension $\pi_1^i \in (\frac{1+b_j-a_j}{4a_j}, \frac{1+b_i-a_i}{4a_i}]$, with $i \neq j$. If the firm's technology is sufficiently efficient, that is, a_i and b_i are sufficiently small, then the firm will allocate his resources optimally $\pi_1^{i*} = \frac{1+b_i-a_i}{4a_i}$.*

2.3 Bias and Welfare

Do the representative reader benefits from more competition? First, from the previous results, notice that competition incentives firms to allocate resources in a way such that their accuracy is as high as the accuracy of their competitor. Second, as Figure 2.3 shows, media bias is reduced when firms have better technology since better technology allows them to achieve higher precision and thus learn with a higher frequency the true state of the world. This is from the reader's perspective.

Notice that competition also leads firms to avoid specialization in one dimension. To ensure that the firm will be listened to by the reader, the firm is forced to allocate its resources more efficiently to gain more precision than the precision of its competitors. This reduces specialization towards one dimension, which, from a normal firm perspective, is desirable. However, when

Figure 2.3: Firm's Bias



Source: Own elaboration.
Note: Firm's bias as a function of resources allocate towards the first dimension for different technologies. The continuous line corresponds to technology $a_i = 1$, $b_i = 1$; the dashed line to technology $a_i = .5$, $b_i = 1$; the dotted line to technology $a_i = .5$, $b_i = .5$.

more than there is more than one group of readers, having more firms might not reduce bias. In the duopoly case, each firm could target one group by biasing its reports to such group's beliefs. If, by contrast, there were more media firms, then we can expect that the more competitive firms be incentivized to have an accuracy as good as their competitors, as seen in the previous section, while targeting one group of readers.

Chapter 3

Conclusions

As the source of information for many people, it is key that the media market is as free of bias as possible. Nevertheless, media companies, in the end, are firms that want to profit from providing information. As such, media companies can take any strategy that allows them to maximize their profits, even if it leads to biased information. Also, media companies, although they have access to more economic resources, can not cover all events that occur in this instance and have to allocate their resources in the best way they consider. This restriction can be a source of bias since media companies might not obtain all the relevant features for decision-making processes. For example, during elections media companies have to decide which candidate to give more coverage to and even which scandals to cover; when policymakers present initiatives or projects, media companies have to decide which feature of the policy is more relevant or can have more consequences. These results shed some light on explaining why despite the presence of more radical but smaller media firms, big media companies do not take extreme positions on most topics. The latter is the primary source of information for many people even if the smaller and extremer companies provide news more consistent with their beliefs.

The framework of this thesis recovers the role of reputation previously studied by Gentzkow and Shapiro (2006). The novelty of this work relies on the incorporation of, first, the multidimensionality of information and, second, the fact that firms face resource constraints and might not be able to learn all relevant features for making a decision. Furthermore, this dissertation explores how competition affects bias in media markets under the previous assumptions. The results presented in the previous chapters show that competition reduces bias via two channels. First, competition incentivizes the most efficient firm to allocate its resources to have an accuracy at least as good as the accuracy of its competitor. This is relevant because a normal-quality firm does not necessarily allocates its resources to maximize its precision in its information acquisition process. Second, as competition increases a normal-quality firm's accuracy, more accuracy can incentivize the firm to report as honestly as possible in order to behave as a high-quality firm.

This thesis faces some limitations, which can lead to future research. First, this thesis limits its analysis to the case where there is a representative reader from a set of homogeneous readers. In reality, readers and consumers have heterogeneous preferences. Considering this fact can explain how media companies specialize in certain political discourses by targeting some demographic groups. Second, media companies can have policy and political interests, so they can use their influence over a wide sector of the population to determine some outcomes. In interaction with reputation, it will be interesting to see how both incentives affect a firm's behavior and if the consequences on consumers' welfare. Moreover, although firms face resource constraints, this framework does not consider the fact that acquiring information is costly, an important limitation for firms, and the fact that they might not obtain information at all. Another assumption to relax is that dimensions of an state of the world might not be independent from one-another. Correlation among some outcomes could provide more information about the true state of the world or bias information transmission.

Appendix A

Proofs

Let $\hat{s} \in \{(\hat{l}, \hat{u}), (\hat{l}, \hat{d}), (\hat{r}, \hat{u}), (\hat{r}, \hat{d})\}$ the report that the firm sends to the representative reader. When the firm is of normal quality, he sends report $\hat{s}$ with probability

$$\sum_{\alpha=1}^{4} P(\omega^\alpha) \sum_{\beta=1}^{4} \sigma_{s_i^\beta}(\hat{s}_i) P(s^\beta|\omega^\alpha) =$$

$$\rho_1\rho_2[\sigma_{(l,u)}(\hat{s}_i)\hat{\pi}_1\hat{\pi}_2 + \sigma_{(l,d)}(\hat{s}_i)\hat{\pi}_1(1-\hat{\pi}_2) + \sigma_{(r,u)}(\hat{s}_i)(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(r,d)}(\hat{s}_i)(1-\hat{\pi}_1)(1-\hat{\pi}_2)]+$$

$$\rho_1(1-\rho_2)[\sigma_{(l,u)}(\hat{s}_i)\hat{\pi}_1(1-\hat{\pi}_2)+\sigma_{(l,d)}(\hat{s}_i)\hat{\pi}_1\hat{\pi}_2+\sigma_{(r,u)}(\hat{s}_i)(1-\hat{\pi}_1)(1-\hat{\pi}_2)+\sigma_{(r,d)}(\hat{s}_i)(1-\hat{\pi}_1)\hat{\pi}_2]+$$

$$(1-\rho_1)\rho_2[\sigma_{(l,u)}(\hat{s}_i)(1-\hat{\pi}_1)\hat{\pi}_2+\sigma_{(l,d)}(\hat{s}_i)(1-\hat{\pi}_1)(1-\hat{\pi}_2)+\sigma_{(r,u)}(\hat{s}_i)\hat{\pi}_1\hat{\pi}_2+\sigma_{(r,d)}(\hat{s}_i)\hat{\pi}_1(1-\hat{\pi}_2)]+$$

$$(1-\rho_1)(1-\rho_2)[\sigma_{(l,u)}(\hat{s}_i)(1-\hat{\pi}_1)(1-\hat{\pi}_2)+\sigma_{(l,d)}(\hat{s}_i)(1-\hat{\pi}_1)\hat{\pi}_2+\sigma_{(r,u)}(\hat{s}_i)\hat{\pi}_1(1-\hat{\pi}_2)+\sigma_{(r,d)}(\hat{s}_i)\hat{\pi}_1\hat{\pi}_2].$$

Proof of Lemma 1. Recall equation 2.1. Let

$$A = \sum_{\alpha=1}^{4} P(\omega^\alpha) \sum_{\beta=1}^{4} \sigma_{s^\beta}((\hat{l}, \hat{u})) P(s_i^\beta|\omega^\alpha).$$

First, take the derivative of the ratio of equation 2.1 respect ρ_k for any $k \in \{1, 2\}$; without loss of generality, take $k = 1$.

$$\frac{\partial \frac{Pr(\hat{s}_i|high)}{Pr(\hat{s}_i|normal)}}{\partial \rho_1} = \rho_2 \left(\frac{A - \rho_1 \frac{\partial A}{\partial \rho_1}}{A^2} \right).$$

Next, we need to show that $\frac{A-\rho_1 \frac{\partial A}{\partial \rho_1}}{A^2} > 0$. Notice that

$$\rho_1 \frac{\partial A}{\partial \rho_1} =$$

$$\rho_1\rho_2[\sigma_{(l,u)}(\hat{s})\hat{\pi}_1\hat{\pi}_2 + \sigma_{(l,d)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2) + \sigma_{(r,u)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(r,d)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2)]$$

$$+\rho_1(1-\rho_2)[\sigma_{(l,u)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2) + \sigma_{(l,d)}(\hat{s})\hat{\pi}_1\hat{\pi}_2 + \sigma_{(r,u)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2) + \sigma_{(r,d)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2]$$

$$-\rho_1\rho_2[\sigma_{(l,u)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(l,d)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2) + \sigma_{(r,u)}(\hat{s})\hat{\pi}_1\hat{\pi}_2 + \sigma_{(r,d)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2)]$$

$$-\rho_1(1-\rho_2)[\sigma_{(l,u)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2) + \sigma_{(l,d)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(r,u)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2) + \sigma_{(r,d)}(\hat{s})\hat{\pi}_1\hat{\pi}_2]$$

Subtracting $\rho_1 \frac{\partial A}{\partial \rho_1}$ from A, we get

$$\frac{A - \rho_1 \frac{\partial A}{\partial \rho_1}}{A^2} =$$

$$[\sigma_{(l,u)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(l,d)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2) + \sigma_{(r,u)}(\hat{s})\hat{\pi}_1\hat{\pi}_2 + \sigma_{(r,d)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2)]$$

$$+(1-\rho_2)[\sigma_{(l,u)}(\hat{s})(1-\hat{\pi}_1)(1-\hat{\pi}_2) + \sigma_{(l,d)}(\hat{s})(1-\hat{\pi}_1)\hat{\pi}_2 + \sigma_{(r,u)}(\hat{s})\hat{\pi}_1(1-\hat{\pi}_2) + \sigma_{(r,d)}(\hat{s})\hat{\pi}_1\hat{\pi}_2],$$

which is positive.

Now, take the derivative of the ratio respect $\sigma_{(l,u)}((\hat{l}, \hat{u}))$ or for any other distorted signal $\sigma_{(s_j}((\hat{l}, \hat{u}))$ with $s_j \in \{(l,d), (r,u), (r,d)\}$. We get

$$\frac{\partial \frac{Pr(\hat{s}_i|high)}{Pr(\hat{s}_i|normal)}}{\partial \sigma_{s_i}(\hat{s}_i)} = -\rho_1\rho_2 A^{-2} \frac{\partial A}{\partial \sigma_{s_i}(\hat{s}_i)}$$

$$= -\rho_1\rho_2 A^{-2}\sum_{\alpha=1}^{4} P(\omega^\alpha)\sum_{\beta=1}^{4} P(s_i^\beta|\omega^\alpha) < 0.$$

Finally, take the derivative of the ratio respect $\hat{\pi}_1\hat{\pi}_2$, so we get

$$\frac{\partial \frac{Pr(\hat{s}_i|high)}{Pr(\hat{s}_i|normal)}}{\partial \pi_1} = -\rho_1\rho_2 A^{-2}\frac{\partial A}{\partial \pi_1}.$$

After taking the derivative of A respect π_1 and rearranging, we get

$$\frac{\partial A}{\partial \pi_1} =$$

$$\frac{\partial \hat{\pi}_1\hat{\pi}_2}{\partial \pi_1}\Big[\rho_1\rho_2\sigma_{(l,u)}((\hat{l},\hat{u})) + \rho_1(1-\rho_2)\sigma_{(l,d)}(\hat{l},\hat{u}) +$$

$$(1-\rho_1)\rho_2\sigma_{(r,u)}(\hat{l},\hat{u}) + (1-\rho_1)(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u})\Big] +$$

$$\frac{\partial \hat{\pi}_1(1-\hat{\pi}_2)}{\partial \pi_1}\Big[\rho_1\rho_2\sigma_{(l,d)}(\hat{l},\hat{u}) + \rho_1(1-\rho_2)\sigma_{(l,u)}(\hat{l},\hat{u}) +$$

$$(1-\rho_1)\rho_2\sigma_{(r,d)}(\hat{l},\hat{u}) + (1-\rho_1)(1-\rho_2)\sigma_{(r,u)}(\hat{l},\hat{u})\Big] +$$

$$\frac{\partial (1-\hat{\pi}_1)\hat{\pi}_2}{\partial \pi_1}\Big[\rho_1\rho_2\sigma_{(r,u)}((\hat{l},\hat{u})) + \rho_1(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u}) +$$

$$(1-\rho_1)\rho_2\sigma_{(l,u)}(\hat{l},\hat{u}) + (1-\rho_1)(1-\rho_2)\sigma_{(l,d)}(\hat{l},\hat{u})\Big] +$$

$$\frac{\partial (1-\hat{\pi}_1)(1-\hat{\pi}_2)}{\partial \pi_1}\Big[\rho_1\rho_2\sigma_{(r,d)}((\hat{l},\hat{u})) + \rho_1(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u}) +$$

$$(1-\rho_1)\rho_2\sigma_{(l,d)}(\hat{l},\hat{u}) + (1-\rho_1)(1-\rho_2)\sigma_{(l,u)}(\hat{l},\hat{u})\Big]$$

with $\frac{\partial \hat{\pi}_1\hat{\pi}_2}{\partial \pi_1} = \frac{1+b_i-a_i}{2b} - \frac{a_i}{2b_i}\pi_1$, $\frac{\partial \hat{\pi}_1(1-\hat{\pi}_2)}{\partial \pi_1} = \frac{1-b_i+a_i}{2b} - \frac{a_i}{2b_i}\pi_1$, $\frac{\partial (1-\hat{\pi}_1)\hat{\pi}_2}{\partial \pi_1} = -\frac{1+b_i+a_i}{2b} + \frac{a_i}{2b_i}\pi_1$, $\frac{\partial (1-\hat{\pi}_1)(1-\hat{\pi}_2)}{\partial \pi_1} = \frac{1-b_i+a_i}{2b} - \frac{a_i}{2b_i}\pi_1$. Let

$c_1 = [\rho_1\rho_2\sigma_{(l,u)}((\hat{l},\hat{u}))+\rho_1(1-\rho_2)\sigma_{(l,d)}(\hat{l},\hat{u})+(1-\rho_1)\rho_2\sigma_{(r,u)}(\hat{l},\hat{u})+(1-\rho_1)(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u})]$,

$c_2 = [\rho_1\rho_2\sigma_{(l,d)}(\hat{l},\hat{u})+\rho_1(1-\rho_2)\sigma_{(l,u)}(\hat{l},\hat{u})+(1-\rho_1)\rho_2\sigma_{(r,d)}(\hat{l},\hat{u})+(1-\rho_1)(1-\rho_2)\sigma_{(r,u)}(\hat{l},\hat{u})]$,

$c_3 = [\rho_1\rho_2\sigma_{(r,u)}((\hat{l},\hat{u}))+\rho_1(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u})+(1-\rho_1)\rho_2\sigma_{(l,u)}(\hat{l},\hat{u})+(1-\rho_1)(1-\rho_2)\sigma_{(l,d)}(\hat{l},\hat{u})]$,

$c_4 = [\rho_1\rho_2\sigma_{(r,d)}((\hat{l},\hat{u}))+\rho_1(1-\rho_2)\sigma_{(r,d)}(\hat{l},\hat{u})+(1-\rho_1)\rho_2\sigma_{(l,d)}(\hat{l},\hat{u})+(1-\rho_1)(1-\rho_2)\sigma_{(l,u)}(\hat{l},\hat{u})]$.

We get that $\frac{\partial A}{\partial \pi_1}$ is positive if

$$\pi_1 > \frac{2b_i}{a_i}\left[\frac{\left(\frac{1+b_i-a_i}{2b}c_1\right)+\left(\frac{1-b_i a_i}{2b}c_2\right)-\left(\frac{1+b_i+a_i}{2b}c_3\right)+\left(\frac{1-b_i+a_i}{2b}c_4\right)}{c_1-c_2-c_3+c_4}\right].$$

For such a π_1, we get that

$$-\rho_1\rho_2 A^{-2}\frac{\partial A}{\partial \pi_1} < 0$$

.

Different values of a_i and b_i can result in different threshold points. Notice that there is the possibility that some a_i and b_i lead to a negative threshold. This means that for any $\pi_1 \in [0, \frac{1}{2}]$, specializing on the first dimension reduces the rate that the reader assigns to the firm; similarly, for a threshold larger than $\frac{1}{2}$, then all $\pi_1 \in [0, \frac{1}{2}]$, specializing on the first dimension increases the rate that the reader gives to the firm. Finally, there could be a set of a_i and b_i such that there is a threshold that is between $(0, \frac{1}{2})$. When π_1 is above this threshold, the rate decreases, but when it is above it, in increases, so it must be a minimum. □

Proof of Lemma 2. Recall problem 2.2. Suppose that the a_i and b_i are arbitrary large enough so the firm has a low accuracy for all possible allocations of his resources. Then, the accuracy of the signal that the firm receives $\hat{\pi}_1\hat{\pi}_2$ and his posterior beliefs about the state of the world $Pr(\omega|s_i)$ have to result in lower gains than the losses due to the decrease on the reputation score. From the firm's resources constraint, we know that $a_i\pi_1^i + b_i\pi_2^i = \frac{1}{2}$. By clearing π_2^i in the previous equation, we get that $\hat{\pi}_1\hat{\pi}_2 = (\frac{1}{2}+\pi_1^i)(\frac{1}{2b} - \frac{a_i}{b_i}\pi_1^i)$. The total accuracy is concave function of π_1^i, which in fact is a parabola. By taking the first order condition of this function, we can arrive that the accuracy is maximized at $\pi_1^{i*} = \frac{1+b_i-a_i}{4a_i}$. Allocating resources below this point, $\pi_1^i < \pi_1^{i*}$, implies that the firm can increase his accuracy by specializing on the first dimension; above this threshold, $\pi_1^i > \pi_1^{i*}$, the firm precision. So, there should be a point between $(0, \frac{1+b_i-a_i}{4a_i})$ such that the gains and loses are compensated. Thus, the firm sets π_1 above or bellow $\frac{1+b_i-a_i}{4a_i}$. For a sufficiently low values of a_i and b_i, the firm is able to increase his accuracy towards perfect accuracy. That is $\hat{\pi}_1\hat{\pi}_2 \to 1$, thus, the maximizing his score $\hat{\lambda}(\hat{s}, \omega)$

since is able match the state of the world almost as if he was a high quality firm. □

Proof of Proposition 1. Suppose that a normal-quality firm distorts some signals (l, u). That is, for signal (l, u), $\sigma_{(l,u)}((\hat{l}, \hat{u})) < 1$. Consequently, the normal quality firm would always report some of the other possible signals (l, d), (r, u) or (r, d) and report one of this signals honestly. Without loss of generality, suppose that the normal-quality firm in particular distorts signal (l, u) towards $(\hat{r}, \hat{d})$, so $\sigma_{(l,u)}((\hat{r}, \hat{d})) > 0$. Notice that, if firm i distorts signals (l, u) to $(\hat{r}, \hat{d})$, then he will distort all other signals since (l, u) is more likely to occur. This implies that $\sigma_{(r,d)}((\hat{r}, \hat{d})) = 1$ and that firm i is more likely to match the state (R, D) than any of the other states. In particular, this also implies that $\hat{\lambda}((\hat{l}, \hat{u}), (L, U)) > \hat{\lambda}((\hat{r}, \hat{d}), (R, D))$ and $\Delta^f((l, u)) > 0$ since $Pr((L, U)|(l, u)) > \frac{1}{2}$. Furthermore, if the reader sees any other message, he will set a higher probability that firm i is of high quality when the reader receives or not feedback. In particular $\hat{\lambda}((\hat{l}, \hat{u}), 0) > \hat{\lambda}((\hat{r}, \hat{d}), 0)$. Distorting signals towards $(\hat{r}, \hat{d})$ increases, in particular, $\hat{\lambda}((\hat{l}, \hat{u}), 0)$ and decreases $\hat{\lambda}((\hat{r}, \hat{d}), 0)$, thus $\Delta^{nf} > 0$. So, firm i must distorts all other signals towards $(\hat{l}, \hat{u})$, and thus $\sigma_{(l,u)}((\hat{l}, \hat{u})) = 1$.

Next, consider that $\sigma_{(l,u)}((\hat{l}, \hat{u})) = 1$, with $s_j \in \{(l, d), (r, u), (r, d)\}$, that is, firm i distorts all signals towards $(\hat{l}, \hat{u})$. Consequently, if reader receives a report different from $(\hat{l}, \hat{u})$, then she will assign probability 1 to the firm of being of high quality. This will give a higher expected payoff when the firm reports a signal different from $(\hat{l}, \hat{u})$, thus the firm has incentives to report (l, d), (r, u) and (r, d) with a positive probability.

Finally, recall that for sufficiently small a_i and b_i, as $\pi_1 \to \frac{1+b_i-a_i}{4a_i}$, then $\hat{\pi}_1 \hat{\pi}_2 \to 1$. So, firms will match practically all the time the true state of the world. This will set the payoff close to 1 when the firm matches the true state of the world and the reader receives feedback. Thus, the firm will try to report honestly all signals he receives. □

Proof of Proposition 2. First we need to prove that the firm will report honestly signals (l, u) and distort all other signals. For any firm that the reader decides to listen to, a normal quality firm will be rated as if was the only firm in the game. So, from 1 it follows that the firm will report signals (l, u) honestly and will distort all other signals towards $(\hat{l}, \hat{u})$, but not always.

Second, the reader has to choose which firm will listen to. As argued in Chapter 3, the reader wants to match as possible the state of the world. This will lead to the competition between firms in how much information they are able to provide. Recall that from the reader's perspective, she will match the state of the world with probability

$$\rho_1\rho_2\hat{\pi}_1^i\hat{\pi}_2^i + \rho_1(1-\rho_2)\hat{\pi}_1^i\hat{\pi}_2^i + (1-\rho_1)\rho_2\hat{\pi}_1^i\hat{\pi}_2^i + (1-\rho_1)(1-\rho_2)\hat{\pi}_1^i\hat{\pi}_2^i.$$

and maximizing this probability is equivalent to maximizing the firm's accuracy. So, each firm will try to set an accuracy as high as possible and higher than his competitor's accuracy.

Suppose that firm i has better technology than firm j, that is, a_i and b_i allow firm i to set a higher accuracy than firm j's accuracy. That is, for $\pi_1^{i*} = \frac{1+b_i-a_i}{4a_i}$ and $\pi_1^{*j} = \frac{1+b_j-a_j}{4a_j}$, $\hat{\pi}_1^{i*}\hat{\pi}_2^{i*} > \hat{\pi}_1^{*j}\hat{\pi}_2^{*j}$.

Suppose that the reader listens firm i's report and both firms set π_1^i and π_1^j such that $\hat{\pi}_1^j\hat{\pi}_2^j < \hat{\pi}_1^i\hat{\pi}_2^i < \hat{\pi}_1^j\hat{\pi}_2^j$. This gives a positive expected payoff to firm i and 0 to firm j. Then, firm j can set π_1^{j*}, so firm j is listened by the reader and gets a positive expected payoff. To avoid this, firm i must allocate resources towards the first dimension so his accuracy is higher than firm j's accuracy, that is, $\hat{\pi}_1^i\hat{\pi}_2^i > \hat{\pi}_1^{*j}\hat{\pi}_2^{*j}$.

Finally, from Lemma 2 it follows that the firm i, the firm we assumed that the reader will listen, will allocate resources towards the first dimension in a way that his accuracy is between $(\hat{\pi}_1^{*j}\hat{\pi}_2^{*j}, \hat{\pi}_1^{i*}\hat{\pi}_2^{i*}]$. $\square$

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