Optimal Choice of Biased and Neutral News Sources*

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Abstract

This paper investigates the demand for neutral and biased news sources through a theoretical model where individuals with limited attention choose a portfolio of news outlets to learn about the true state of the world. Drawing on insights from contemporary psychology and behavioral economics, the study highlights how confirmation bias —– the tendency to favor sources that reinforce preexisting beliefs —– naturally arises as the benchmark result in the presence of biased sources. However, I identify conditions under which individuals deliberately seek neutral sources or those contradicting their prior beliefs. Specifically, this behavior emerges among those with weak prior beliefs, for whom consuming a mix of contradictory and neutral information is optimal, as these sources serve as strategic complements. Furthermore, the paper explores the implications of this news consumption model for polarization. I demonstrate that the relationship between source error and polarization follows an inverse-U shape. However, because individuals can endogenously switch to biased sources, this endogeneous source switch can disrupt the expected pattern of polarization.

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1 Introduction

In the contemporary information landscape, both biased and unbiased sources coexist, significantly shaping news consumption patterns. Confirmation bias represents one of the well-documented phenomena related to the choice of information sources in the social sciences literature (e.g., Lord, Ross, & Lepper, 1979; Rabin & Schrag, 1999; Gentzkow & Shapiro, 2006). Individuals exhibiting confirmation bias tend to seek out, prioritize, and more readily recall information that aligns with their pre-existing beliefs. This selective exposure to information can contribute to the creation of echo chambers — environments where individuals predominantly encounter views that reinforce and amplify their initial opinions.

Nevertheless, the patterns related to media consumption keep evolving quite rapidly with the constant introduction of new technologies and online platforms. As a result, revisiting the well-established behavioral phenomena in the context of novel media platforms may yield valuable insights. I consider confirmation bias to be an ideal candidate for such re-examination. In everyday experience, we observe that news outlets and social networks do not typically present users with a stream of content that simply reinforces their existing beliefs. Instead, they often offer a diverse portfolio of opinions, some of which align with the user's views while others do not. Several studies have documented that consumers can find satisfaction when being presented with contradictory opinions (Bursztyn et al., 2022; Levy, 2021). While this reaction may partly stem from the emotional impact of opposing opinions (such as inducing anger), my focus is on exploring rational motivations that may underlie this phenomenon.

In this paper, I examine the conditions under which consumers deliberately step outside their echo chambers to engage with a broader range of perspectives, including neutral or even contradictory opinions. I develop a simple theoretical model in which individuals with limited attention select a portfolio of news sources to learn about the true state of the world. The key intuition is that the agents consider confirmatory sources —– those aligned with their prior beliefs — induce sharper posterior beliefs and are thus more convenient for achieving high expected payoff. However, when neutral sources are of sufficiently high quality, the sharpest posterior belief is achieved by consuming either neutral news or a combination of neutral and contradictory news. This allows me to identify the conditions under which consumers deviate from traditional confirmation bias.

Moreover, I also adopt the perspective of a social planner who cares about polarization in society. I show that polarization has an inverse-U dependence on the error of the source. This is driven by two forces: first, the higher the error, the less power the media has to change the agents' beliefs. However, high error also enhances the probability that similar agents get different signals. Moreover, since we allow for endogenous choice of signal portfolios, this relation may be disrupted by portfolio choice shifts.

The key contribution of this paper is a novel description of the role of neutral and biased sources on the media market, highlighting the importance of neutral sources, which can not only become an optimal choice for agents with weak beliefs, but also direct the attention of some agents towards a contradictory source they would otherwise never consume.

The rest of this paper is organized as follows: Section 2 reviews the most relevant literature; Section 3 sets up the theoretical model; Section 4 presents the results and discusses their implications; Section 6 concludes.

2 Related Literature and Contribution

My research contributes to the literature on confirmation bias, which lies in the intersection of psychology and economics. Nickerson (1998) summarizes the earlier literature on this topic. Subsequent contributions from economists have offered various explanations for the phenomenon, including signal misinterpretation (Rabin & Schrag, 1999), reputation concerns (Gentzkow & Shapiro, 2006), preference for consistency (Yariv, 2005), bounded memory (Wilson, 2014), the dimensionality of information (Andreoni & Mylovanov, 2012), and different models of optimal information acquisition (Hu et al., 2024; Jann & Schottmüller, 2023; Allon et al., 2021; Montanari & Nunnari, 2023). Among these, the last class of models aligns most closely with the framework I develop in this paper. The primary innovation of my model lies in its ability to describe not only confirmation bias but also behaviors that diverge from it.

In general, theoretical literature describing the circumstances under which agents acquire diverse opinions is quite scarce. Che and Mierendorff (2019) show that such behavior can arise once we introduce a dynamic trade-off between learning the information early and learning it more precisely. The basic features of their model are similar to mine; however, the key innovation of my paper is that I allow for the existence of unbiased news sources, which turn out to be essential for my main result and induce the demand for contradictory sources, even without assuming any dynamic trade-offs. Moreover, I study the case of simultaneous information source choice and full commitment, where the agents cannot alter their information source choices once they have observed the signals. Therefore, my model is a suitable description of the situations where the agent does not dynamically re-optimize her choices and instead chooses a limited amount of news to consume, and then she sticks to her choice for all future topics she gets informed about. This could, for instance, describe purchasing subscriptions or choosing which accounts to follow on social media. Once the choice is made, there are some monetary, or at least attention costs, associated with rebalancing the source portfolio, which could keep the agent committed to her initial choice.

Several other papers also document the choice of contradictory news sources. Charness et al.

(2021) derive that this pattern may occur when the sources are biased by omission — in case the state of the world is contradictory to their bias, they do not send any signal. Jann and Schottmüller (2024) demonstrate the consumption of a contradictory source when deriving utility also from learning the opinions of other agents.

In terms of experimental evidence, Ambuehl and Li (2018) find that when facing biased information sources, agents underrespond to a subjective increase in the informativeness of the source and overvalue sources providing certainty. Calford and Chakraborty (2023) run an experiment with costly biased signals and reports that equal the cost, agents choose a diverse portfolio of signals. In a setting similar to mine, Montanari and Nunnari (2023) experimentally show that even though it would be optimal for a Bayesian agent to always acquire a confirmatory signal, agents sometimes tend to choose the contradicting signal. They also bring many important insights about how agents incorporate the different signals acquired into their decision-making.

Furthermore, my research contributes to the growing literature on media bias, a topic thoroughly described by Gentzkow et al. (2015), and related phenomena, including polarization and fake news. For brevity, I focus only on the most recent findings relevant to contemporary media environments. A handful of studies identify the presence of confirmation bias on the side of news outlets (Flaxman et al., 2013; Budak et al., 2016). Other studies focus on the demand for media bias under government control (Simonov & Rao, 2022) or when there is an accuracy-confirmation trade-off (Chopra et al., 2024). There is also a strand of literature describing the impact of media coverage on society as a whole, including the support for the current government and polarization of opinions (Enikolopov et al., 2022; Martin & Yurukoglu, 2017). I contribute to this literature by describing the optimal information design for a social planner that aims to minimize polarization in society.

3 Theoretical Model

3.1 Intution

I illustrate the basic intuition behind my theoretical model with a simple example. Imagine a question of whether to adopt some policy (e.g., the European Green Deal) or not. The exact effects of the policy are not known to the agents by the time society makes a decision. However, the citizens may learn about the effect of the policy from media outlets. There are media outlets biased towards the policy, against the policy, and also some neutral, yet still potentially imprecise. Assume that there is an agent who thinks that the policy is quite good, but she does not know for sure. Assume that reading online news takes time, and she can consume only a limited number of articles.

From the perspective of the agent, reading from a source that is biased towards the policy would probably confirm her opinion, making the agent quite confident about the policy being good. The confirmatory source can also claim that it is bad, which is so surprising for the confirmatory source that it would make the agent absolutely sure about the bad nature of the policy. In both cases, after consuming this signal, the agent is quite confident about her opinion.

Conversely, consuming news from a contradictory source would most probably lead to receiving information that the policy is bad. However, after receiving this signal, an agent ex-ante optimistic about the policy will doubt whether this signal was sent due to the bias of the source or due to the policy actually being bad. That leaves the agent unsure about the nature of the policy, which is something she wants to avoid.

Finally, the neutral source never makes the agent absolutely sure about the true state of the policy, as there is always a chance that it makes a random mistake. However, if the agent has sufficient trust in this source, they might choose it over the confirmatory one.

Charness et al. (2021) and Montanari and Nunnari (2023) use similar intuition to show the classical confirmation bias result for acquiring one signal from either confirmatory or contradictory source. However, the main novelty of my setting is that I allow for the existence of neutral sources, and instead of focusing only on the oversimplified case of reading one article, I also describe the optimal composition of two-source portfolios, where it turns out that certain source combination elicits yet undescribed complementarities. Particularly, I show that interesting complementarity could arise between the neutral and the contradictory source, implying a potential violation of confirmation bias.

3.2 Model Set-up

I formalize the intuition into a simple model of information acquisition. I assume that there are two states of the world $\omega \in \{a, b\}$ ex-ante equally likely to occur. The agent (news consumer) starts with some prior belief represented by the probability she assigns to the state of the world being a. I denote this prior belief by q. The objective of the agent is to match her action t to the true state of the world, in which case she gets a payoff of one; and a payoff of zero otherwise. That implies a utility function

$$U(t) = \begin{cases} 1, & \text{if } t = \omega \\ 0, & \text{if } t \neq \omega \end{cases} \tag{1}$$

Before taking the action, the agent can consume news articles from three different news sources available — $M \in (\alpha, \nu, \beta)$. These sources send signals $s \in \{A, B\}$ (representing short news articles). Each source, however, is imprecise and sometimes sends a signal that is not in line with the actual state of the world. The probability of the mistake depends on the true state of the world and on the source. There is a source that is biased towards a, a neutral source, and a source biased towards b. Table 1 defines the mistake probabilities for different information sources[1]. I assume that the biases of the biased sources are of equal magnitudes, described by $e \in (0{,}1)$, whereas the bias of the neutral source $e_\nu \in (0{,}0.5)$, may differ.

Table 1: The news sources and their biases

news sources		
α	ν	β
biased towards a	neutral	biased towards b
$P(A_\alpha \vert b) = e$	$P(A_\nu \vert b) = e_\nu$	$P(A_\beta \vert b) = 0$
$P(B_\alpha \vert a) = 0$	$P(B_\nu \vert a) = e_\nu$	$P(B_\beta \vert a) = e$

The agent is exogenously limited with the number of signals n she can consume. Her task is to choose a portfolio of news outlets from which she consumes the signals. In terms of my model, she chooses an unordered n-tuple P from elements of the set $M \in (\alpha, \nu, \beta)$ (the portfolio of news outlets) to maximize her expected payoff.

The problem of the agent is

$$\max_{(t, P \in \{\alpha,\nu,\beta\}^n)} \mathbf{E}\left[U(t) | q, P\right], \tag{2}$$

$$\text{given } q, n, e, e_\nu$$

where $U(t)$ and q, n, e, e_ν are defined above.

This problem prescribes that once the realization of all signals S is observed, the optimal action of the agent is

$$t = \begin{cases} a, & \text{if } r_{PqS} > 0.5 \\ b, & \text{if } r_{PqS} < 0.5 \\ a \text{ or } b, & \text{if } r_{PqS} = 0.5 \end{cases}, \tag{3}$$

where $r_{PqS} = \mathbf{E}\left[\mathbf{I}_{\omega=a} | q, S, P\right]$, denotes the posterior belief of the agent induced by the signal received.

Since the optimal action of the agent depends only on her posterior belief, the relationship between the posterior belief of the agent r_{PqS} and her expected payoff is a simple, partially linear function.

$$\mathbf{E}\left[U(t) | r_{PqS}\right] = \max\left(r_{PqS}, 1 - r_{PqS}\right) \tag{4}$$

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[1] In my notation, I distinguish the source that sent the signal — I denote it with a lower index next to the signal realization. For instance, A_α denotes signal A from source α.

Figure 1 plots this function, which will be later useful when developing intuition for the choices of the agent. Basically, the agent derives the highest utility from being close to 0 or 1; in other words, the agent aims to be as sure as possible after consuming the signal.

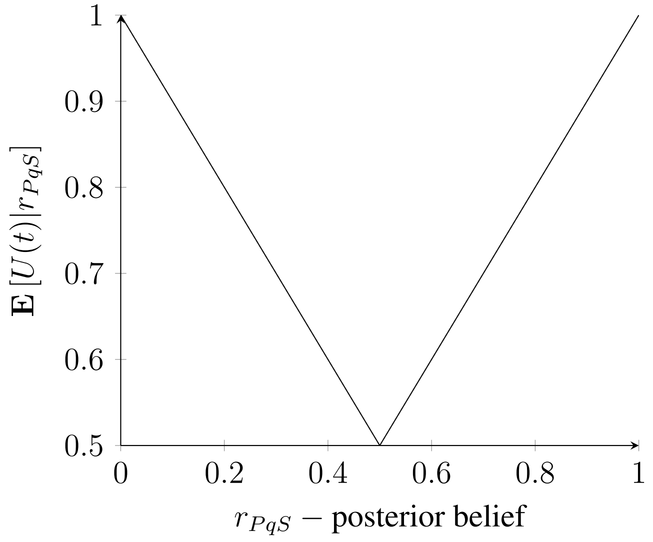


Figure 1: Optimal signal choice for different parameter combinations

4 Results

4.1 Demand for One Signal

I start by analyzing a simple case where $n = 1$ and the agent can read only a single article. The choice of P thus reduces to choosing one source from the triplet $\{\alpha, \beta, \nu\}$. I derive the expected utility given q for each source separately and discuss the optimal choice of signal. First, I consider source α and perform an ex-ante analysis from the perspective of the agent. With probability $q + e(1 - q)$, this source sends signal A leading the agent to form a belief of $\frac{q}{q+e(1-q)}$. This posterior belief translates into an expected payoff of max $\left\{\frac{q}{q+e(1-q)}; 1 - \frac{q}{q+e(1-q)}\right\}$. Otherwise, the source sends signal B, and the agent forms a belief of $q = 0$ and gets a payoff of 1 Given that, the expected payoff for source α is

$$\mathbf{E}\left[U|\alpha,q\right] = \left[q + e(1-q)\right] \cdot \max\left[\frac{q}{q+e(1-q)}, 1 - \frac{q}{q+e(1-q)}\right] + (1-e)(1-q), \tag{5}$$

which can be simplified to

$$\mathbf{E}\left[U|\alpha, q\right] = \max\left[q, e(1-q)\right] + (1-e)(1-q). \tag{6}$$

Using similar logic, we get

$$\mathbf{E}\left[U|\beta, q\right] = \max\left[eq, (1-q)\right] + (1-e)q, \tag{7}$$

and

$$\mathbf{E}\left[U|\nu, q\right] = \max\left[e_\nu q, (1-e_\nu)(1-q)\right] + \max\left[(1-e_\nu)q, e_\nu(1-q)\right] \tag{8}$$

Figure 2 demonstrates the considerations of the agents. Again, the figure shows the convex mapping between the posterior belief and the payoff of the agent. The agent starts with a prior belief that is associated with a payoff denoted by the black dot. Then, she chooses one of the signals available. The signal shifts her belief according to the rules described above. Here, we get two possible belief shifts corresponding to two possible signal realizations for each source - they are denoted with red, blue, and green dots. Clearly, receiving signal A from any source shifts the belief to the right, and receiving signal B shifts the belief to the left.

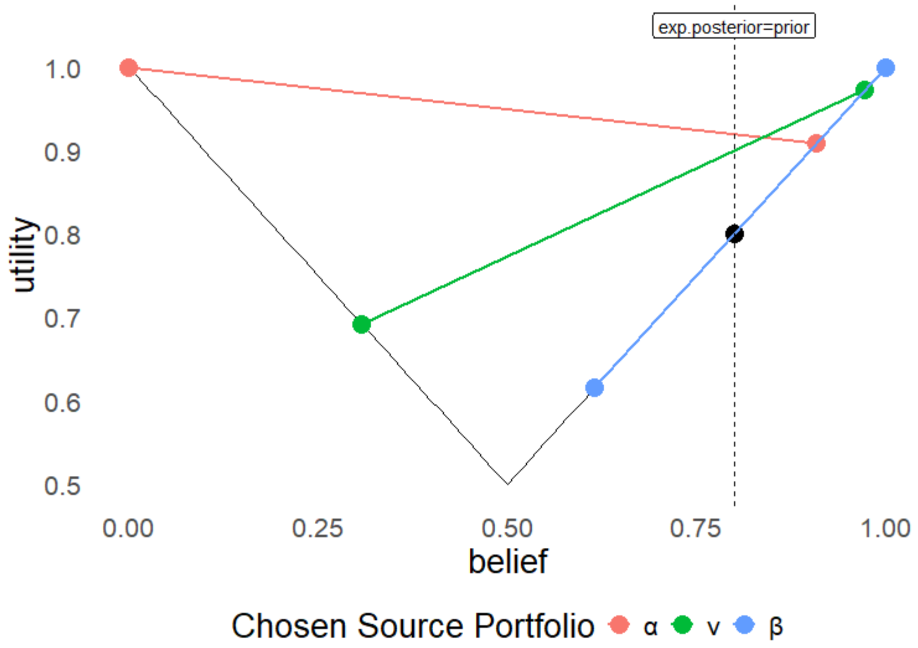
Moreover, given that our agent is Bayesian, there is a simple way to illustrate her expected payoff for each source. The lines connecting the two possible realizations of the signal show all the convex linear combinations of these two payoffs. Furthermore, its intersection with the vertical line drawn at the prior belief of the agent (dashed) determines the overall expected payoff for that source and agent with the given prior belief. This yields from the fact that the expected posterior belief is equal to the prior belief of the agent. Therefore, it is easy to illustrate the intuition behind optimal source choice.

For the confirmatory source α, there is always a chance that it reveals the state of the world being b and sets the belief to 0. If not, it at least always increases the belief of the agent to a value close to 1. In both cases, the expected payoff increases substantially, leading to a high expectation of the payoff when consuming this source.

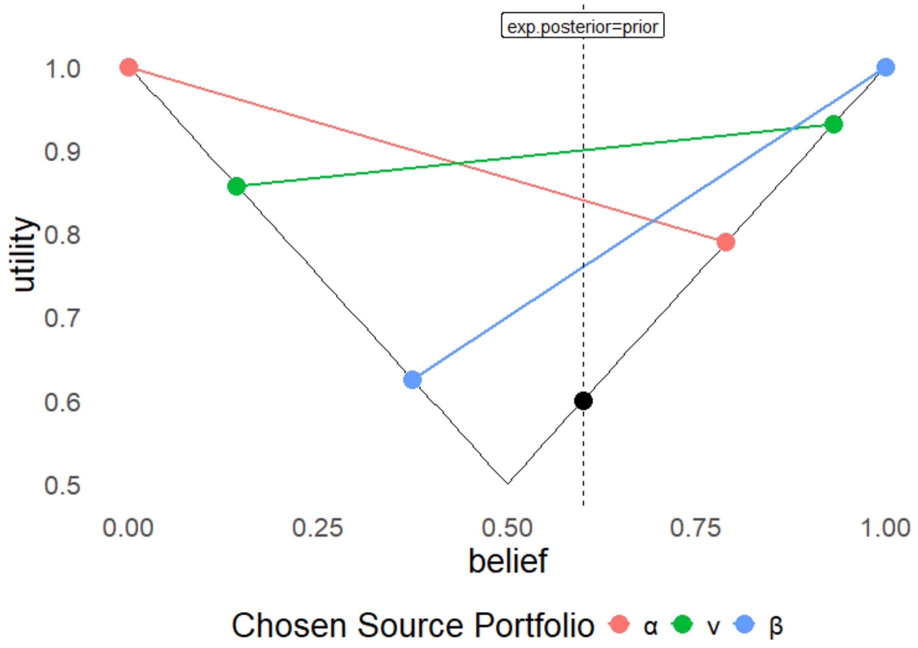
The contradictory source β instead either sets the belief to be equal to 1 (by sending signal A) or lowers it (by sending signal B). In the latter case (which the agent considers to be more likely), the belief of the agent could either end up still being > 0.5, which does not change the action of the agent and therefore does not improve her payoff, or it could end up slightly below the threshold of 0.5, which, however, is associated with a low payoff. Therefore, the contradictory source is always dominated by the confirmatory source and is never an optimal choice.

Furthermore, adding the neutral source into consideration, receiving signal A_ν sets the belief to be higher than the prior (and thus associated with a higher payoff), whereas signal B_ν lowers the belief. The exact posterior beliefs depend on the quality of the neutral source and the prior of the agent. If the agent is sufficiently close to $q = 0.5$, and the source is sufficiently precise, it induces strong posterior beliefs that, in terms of the expected payoff, overrule the confirmatory source.

Panel (a) of Figure 2 illustrates the case of an agent with a strong prior belief. For her, the



(a) strong prior ($q = 0.8$), optimal choice: α



(b) weak prior ($q = 0.6$), optimal choice: ν

Figure 2: Posterior beliefs and expected payoffs for the case of one signal.

For both figures $e_\nu = 0.1$ and $e = 0.4$. The prior of the agent is expressed with a black dot and a dashed black line. The solid black line plots the expected utility as a function of posterior belief. The points demonstrate the potential posterior beliefs and the payoffs associated with them. The intersection of the lines with the dashed line shows the expected payoff for a given source.

highest payoff is achieved by the confirmatory source since the other two sources could result in a weaker belief and lower expected payoff.

Conversely, the agent with a weak prior belief benefits the most from choosing source ν, as demonstrated in Panel (b). Here, the confirmatory source is unable to convince the agent about the state of the world being a as much as the neutral source is.

To describe the optimal signal choices for different configurations of e, and e_ν, I analytically compare the expected utilities for each source computed above. The intuition presented above suggests that agents would never opt for their contradictory signal, however, depending on the strength of their prior belief and the quality of the sources available, they might seek out the neutral source. It turns out that the optimal signal choice is completely determined by q (the prior belief) and the ratio of e_ν and e (capturing the relative bias of the neutral source). Figure 4 shows the relation between these parameters and the optimal signal choice. For $e_\nu/e > 0.5$ it is never optimal to choose the neutral source. However, below this threshold, there is always a band of agents around $q = 0.5$ who find it optimal to choose the neutral source. The width of this band increases with decreasing relative bias of the neutral source.

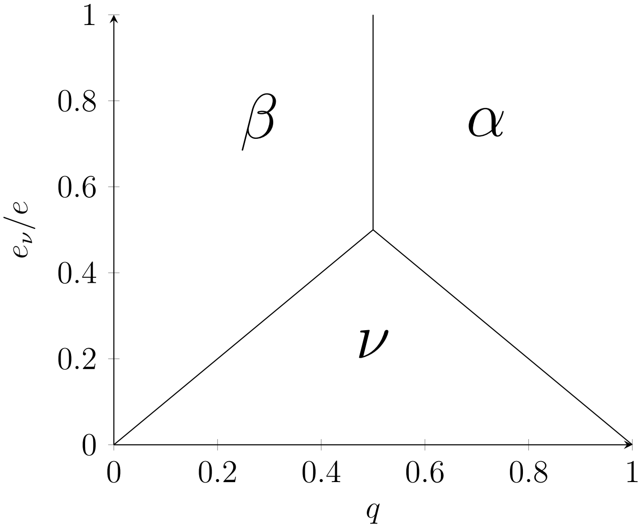


Figure 4: Optimal signal choice for different parameter combinations

This result suggests that absent the neutral media and assuming that the agent pays only a minimal amount of attention, confirmation bias arises even from the simple objective of guessing the true state of the world, given that the agents already have some preexisting beliefs. However, when neutral sources of sufficient quality are introduced, some agents with weak prior beliefs may prefer them over biased sources. Nevertheless, this basic result takes an interesting twist when I allow the agents to choose two signals instead of one, which I show in the following section.

4.2 Demand for Two Signals

Next, I consider the case when the agent simultaneously chooses two sources, allowing the agent to get both signals from the same source. Therefore, there are 6 source portfolios to be considered - $\alpha\alpha$, $\alpha\beta$, $\beta\beta$, $\nu\nu$, $\alpha\nu$, and $\beta\nu$. The agent can distinguish which source sent which signal (which I denote with a subscript next to the signal realization).

Given this design, each source portfolio could be interpreted as a single signal device that offers several signal realizations with given probabilities that shift the agent's belief in a pre-determined way. For instance, the one-sided biased portfolio $\alpha\alpha$, offers only two potential belief shifts. Anytime one of the signal realizations is B_α, it reveals that the state of the world is B with certainty. Therefore, only if the signal realization from this source is $A_\alpha A_\alpha$, the agent is left with a non-trivial posterior belief. Identical logic holds for $\beta\beta$. Eventually, all portfolios could be translated into signal devices with 2-3 payoff-relevant signal realizations. Table 2 lists the probabilities that the agent assigns to the payoff-relevant signal realizations and the beliefs induced.

Table 2: The payoff-relevant signal realizations and implied expected utilities for different information sources when obtaining two signals

$\alpha\alpha$			
S	$A_\alpha A_\alpha$	$A_\alpha B_\alpha, B_\alpha A_\alpha, B_\alpha B_\alpha$	
$P[S\|q,P]$	$q+e^2(1-q)$	$1-q-e^2(1-q)$	
$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	$\frac{q}{q+e^2(1-q)}$	0	
$\alpha\beta$			
S	$A_\alpha A_\beta$	$A_\alpha B_\beta$	$B_\alpha B_\beta$
$P[S\|q,P]$	$(1-e)q$	e	$(1-e)(1-q)$
$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	1	q	0
$\beta\beta$			
S	$A_\beta A_\beta, A_\beta B_\beta, B_\beta A_\beta$	$B_\beta B_\beta$	
$P[S\|q,P]$	$1-e^2q-(1-q)$	$e^2q+(1-q)$	
$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	1	$\frac{e^2q}{e^2q+(1-q)}$	
$\nu\nu$			
S	$A_\nu A_\nu$	$A_\nu B_\nu, B_\nu A_\nu$	$B_\nu B_\nu$
$P[S\|q,P]$	$(1-e_\nu)^2q+e_\nu^2(1-q)$	$2(1-e_\nu)e_\nu$	$e_\nu^2q+(1-e_\nu)^2(1-q)$
$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	$\frac{(1-e_\nu)^2q}{(1-e_\nu)^2q+e_\nu^2(1-q)}$	q	$\frac{e_\nu^2q}{e_\nu^2q+(1-e_\nu)^2(1-q)}$
$\alpha\nu$			
S	$A_\alpha A_\nu$	$A_\alpha B_\nu$	$B_\alpha A_\nu, B_\alpha B_\nu$
$P[S\|q,P]$	$(1-e_\nu)q+ee_\nu(1-q)$	$e_\nu q+e(1-e_\nu)(1-q)$	$(1-e)e_\nu(1-q)+(1-e_\nu)(1-e)(1-q)$
$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	$\frac{(1-e_\nu)q}{(1-e_\nu)q+ee_\nu(1-q)}$	$\frac{e_\nu q}{e_\nu q+e(1-e_\nu)(1-q)}$	0
$\beta\nu$			
S	$A_\beta A_\nu, A_\beta B_\nu$	$B_\beta A_\nu$	$B_\beta B_\nu$
$P\left[S\|q\right]$	$(1-e)(1-e_\nu)q+(1-e)e_\nu q$	$(1-e_\nu)eq+(1-q)e_\nu$	$ee_\nu q+(1-q)(1-e_\nu)$
$\mathbf{E}\left[\mathbf{I}_{\omega=a}\|q,S,P\right]$	1	$\frac{e(1-e_\nu)q}{(1-e_\nu)eq+(1-q)e_\nu}$	$\frac{ee_\nu q}{ee_\nu q+(1-q)(1-e_\nu)}$

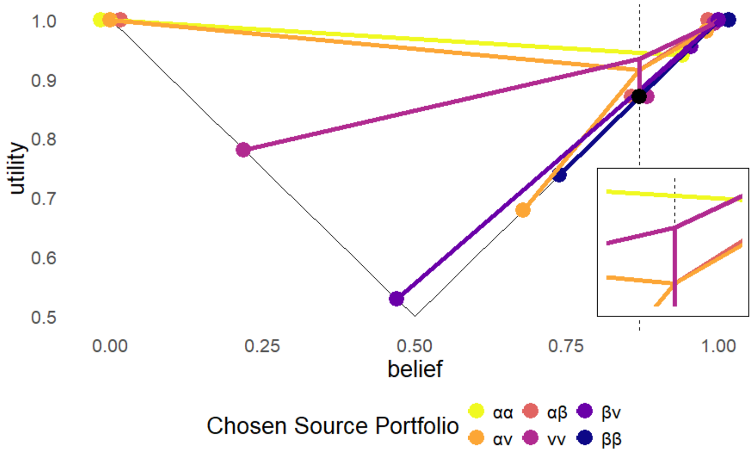
This offer of source portfolios introduces novel trade-offs into the consideration of the agent. The intuition for the one-sided biased source portfolios $\alpha\alpha$ and $\beta\beta$ is similar as in the case of one signal. If the agent chooses $\nu\nu$, she faces some probability that she will end up with a posterior equal to her prior (when she gets two signals contradicting each other). A similar threat is associated with portfolio $\alpha\beta$, which only rarely helps the agent improve her belief.

Figure 5 demonstrates the choice between source portfolios using similar plots as in the case of one signal. Since some of the source portfolios offer three different payoff-relevant signal realizations, it is no longer possible to illustrate the expected payoff as a simple intersection of two lines. However, the logic remains the same - the expected payoff of a given source is the weighted average of the three potential payoffs and is shown at the vertical dashed line representing the prior belief.

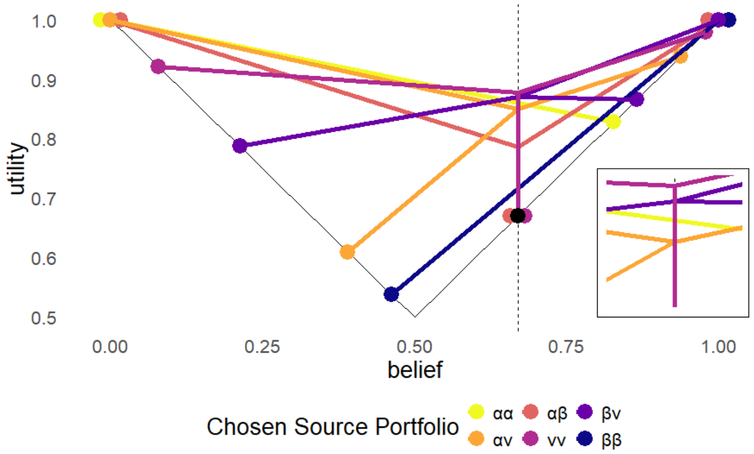
Panel (a) demonstrates that for agents with a strong belief, no other source can overrule the one-sided confirmatory portfolio $\alpha\alpha$ as it always induces a sharp belief.

Nevertheless, as the prior beliefs of the agents get weaker, portfolios, including the neutral source, become appealing. Panel (b) shows an agent with a medium belief, for whom the combination $\nu\nu$ delivers the highest payoff. The source $\nu\nu$ is always associated with some probability of receiving two opposing signals and being left with the prior belief, but if it is of sufficient quality, this option happens only with a little probability and at the same time, the beliefs when the signals align are sufficiently sharp for this portfolio to still be the optimal choice.

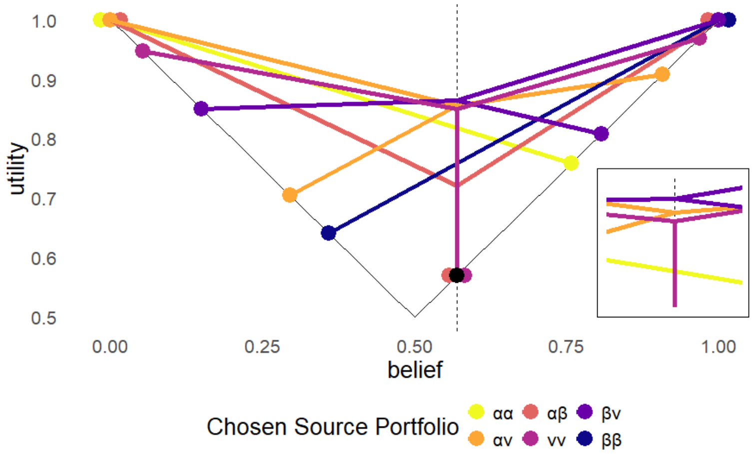
Panel (c) shows perhaps the most surprising result of this exercise. If the belief of the agent is very weak, $\beta\nu$ becomes the optimal choice. That implies that some agents may opt for a contradictory source along with a neutral source violating the general confirmation bias pattern. This source portfolio offers three payoff-relevant signal realizations, each of them quite convenient. Either, by sending signal A_β, the source reveals the true state of the world completely. If not (and the agent gets B_β, she can benefit from the signal acquired from the neutral source, which has quite a substantial impact on her belief, as has already been demonstrated in the previous chapter. The posterior belief will, in all cases, be quite close to either 0 or 1, which makes this combination an optimal portfolio choice. Interestingly, $\beta\nu$ overrules even the confirmatory-neutral combination $\alpha\nu$. This is mainly driven by the threat of receiving signal $A_\alpha B_\nu$. This signal does not provide certainty regarding the true state of the world; moreover, it always decreases the belief of the agent since source ν is, in general, more trusted than source α for around-the-middle agents. Consequently, the belief ends up being close to 0.5, substantially decreasing the expected payoff. At the same time, no similar threat is associated with portfolio $\beta\nu$. To see this, notice that even when the signals from β and ν contradict each other, and the state of the world is not revealed (that means signal $B_\beta A_\nu$ is sent), the belief of the agent increases, since source ν is, in general, more trusted, increasing the expected payoff.



(a) strong prior ($q = 0.87$), optimal choice: $\alpha\alpha$



(b) medium prior ($q = 0.67$), optimal choice: $\nu\nu$



(c) weak prior ($q = 0.57$), optimal choice: $\beta\nu$

Figure 5: Posterior beliefs and expected payoffs for the case of two signals.

For both figures $e_\nu = 0.17$ and $e = 0.65$. The prior of the agent is expressed with a black dot and a dashed black line. The solid black line plots the expected utility. Points show the potential belief shifts achieved by consuming the given source. The intersection of the lines with the dashed line shows the expected payoff for a given source. The frame in the bottom-right corner zooms in the area where most intersections occur.

In the case of one signal, the optimal choice of sources was completely determined by the combination of q and e_ν/e. For two signals, the optimal signal choice depends on the particular values of all three parameters — e, e_ν, and q. Therefore, the relationship is difficult to visualize. Figure 7 shows the optimal choices of sources for different parameter configurations.

For low values of e, we get the classical confirmation bias result — it is always optimal to choose two signals from the confirmatory source. Nevertheless, once e reaches a certain threshold, and e_ν remains sufficiently small, for q around 0.5, it is optimal to choose the contradictory source along with the neutral one. As e further increases, two signals from the neutral source become optimal for medium priors. However, some agents with weak beliefs are always left with the neutral and the contradictory source combination.

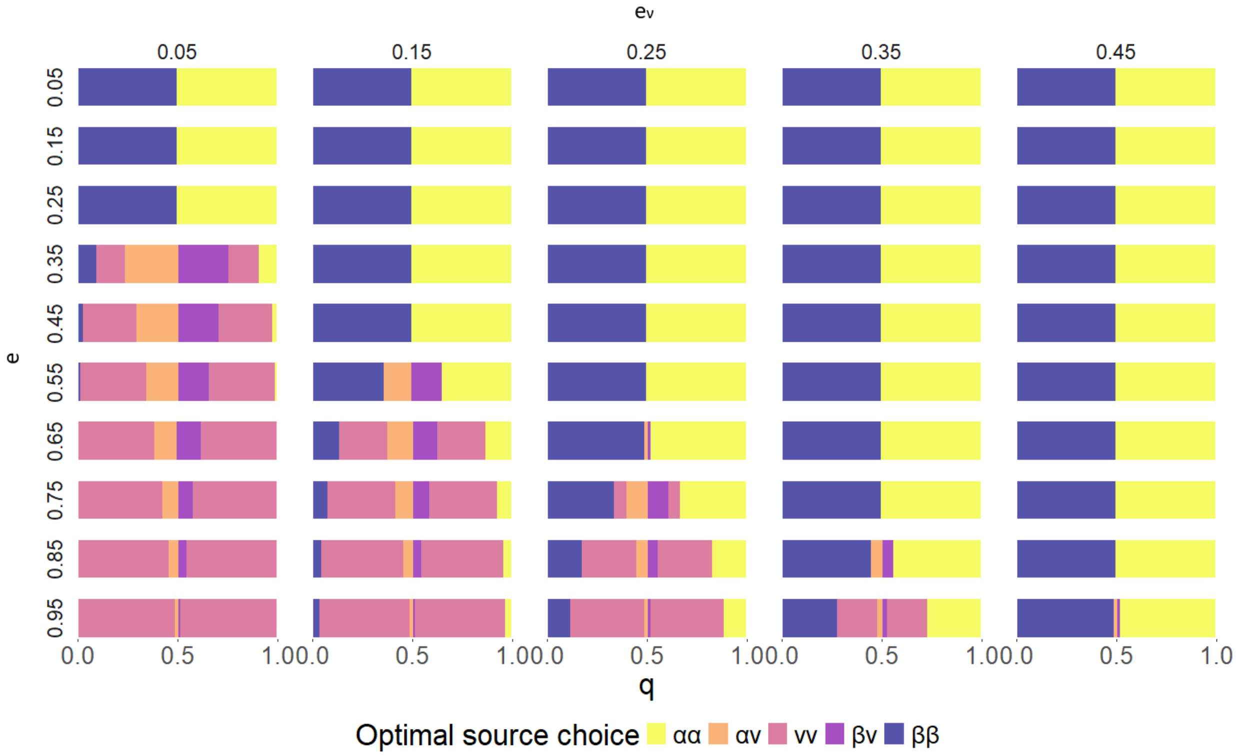


Figure 7: Optimal choice of two sources for different parameter combinations

The results for two signals suggest that if neutral sources of sufficient quality are available, the baseline tendency to consume the confirmatory sources only is violated. The mechanism of this violation is twofold. The first intuitive mechanism is the generally higher precision of the neutral source compared to the biased sources, which works similarly to the case of one source described in the previous subsection.

The second mechanism operates through the complementarity of neutral sources with the contradictory source and may lead some agents with weak prior beliefs to choose the contradictory source along with the neutral one. This combination offers a considerable probability of immediate uncertainty resolution (provided by the contradictory source) and a reliable way to establish a strong belief if the contradictory source does not reveal the state of the world (provided by the neutral source).

In principle, a similar approach could be used to study the demand for a general number of signals k. However, with increasing k, the number of source portfolios to consider grows rapidly, which impairs their comparison in terms of expected utilities. In Appendix Section A.1, I derive that in the absence of neutral sources, it is always optimal to choose only the one-sided confirmatory portfolio and present the general formulation of the news consumer problem, which could be further solved using numerical methods.

Nevertheless, the main focus of my research is on agents with substantially limited attention and showing the basic complementarities between biased and neutral sources, which is already achieved for the case of two signals. Thus, in this paper, I do not develop the problem of k signals further.

4.3 Polarization

My model not only describes the demand for news sources but also can be used to sketch the impact of biased and neutral media on polarization.

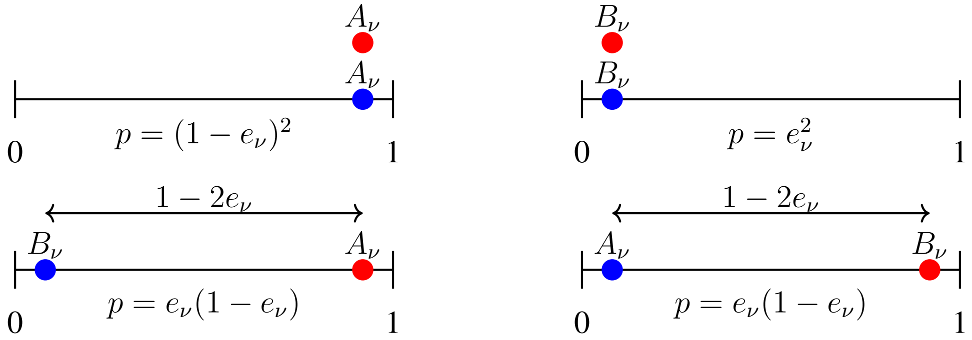
For simplicity, I assume that there are two agents (I denote them as high and low) with a flat prior belief ($q_H = q_L = 0.5$). The agents consume news in line with my model. I assume that if the agent is indifferent between two source portfolios, the high agent always consumes the source portfolio that an agent with a slightly higher belief would consume, and the low agent always consumes the source that an agent with a slightly lower belief would consume. For instance, in the case of one source and $e_\nu/e > 0.5$ (which means that only biased sources are chosen), the high agent chooses α, and the low agent chooses β.

Furthermore, there is a social planner who cares about the ideological distance between the two agents. I define the ideological distance (ID) as the absolute value of the expected distance between the posterior beliefs r_{Pq_LS} and r_{Pq_HS}.

$$\mathbf{E}\left[ID\right] = \mathbf{E}\left[\left|r_{Pq_HS} - r_{Pq_LS}\right|\right]. \tag{9}$$

The social planner does not know the true state of the world or the realizations of the signals. Nevertheless, she assumes that the agents consume media following the pattern described above. I demonstrate the consideration of the social planner using the case of the agents acquiring one signal. There, the demand for news sources is quite clear - if the neutral sources are too imprecise ($e_\nu/e > 0.5$), the high agent chooses α, whereas the low agent chooses β, whereas if the neutral sources are sufficiently precise ($e_\nu/e < 0.5$, both choose ν). Figure 8 demonstrates the posterior beliefs in both cases. This Figure assumes that the state of the world is a with no loss of generality as the social planner considers both states of the world to be equally likely, and the problem would be symmetrical for state b.

(a) $e_\nu/e > 0.5$, optimal choice: α or β



(b) $e_\nu/e > 0.5$, optimal choice: ν

Figure 8: Posterior beliefs and ideological distances for two agents with a flat prior

The red dot denotes the belief of the high agent, and the blue dot denotes the belief of the low agent. Without loss of generality, I assume that the state of the world is a. The arrow denotes the ideological distance between the agents, and p is the probability of this signal realization from the perspective of the social planner.

Panel (a) shows the posterior beliefs for the case when agents consume only from biased sources. There, either both agents get the same signal, and their ideological distance is quite small, or they get opposing signals, where each source sends the signal aligned with its bias. The case that a low agent gets signal B_α and the high agent gets A_β has zero probability since this result could not be supported by either state of the world.

Panel (b) shows that if both agents choose the neutral source, then either they get the same signal (true or false), form identical beliefs, and the ideological distance is zero, or they get opposing signals, and their beliefs end up being different.

This already shows that the impact of the error of the source on the expected ideological distance is twofold. First, since the error of the sources is known to the agents, the degree to which it affects their posterior beliefs decreases with the error. If the given source has a high probability of error, the agents assign less weight to it, and it has lower power to polarize them. However, the error of the source also decreases the correlation between the two signals that the agents get.

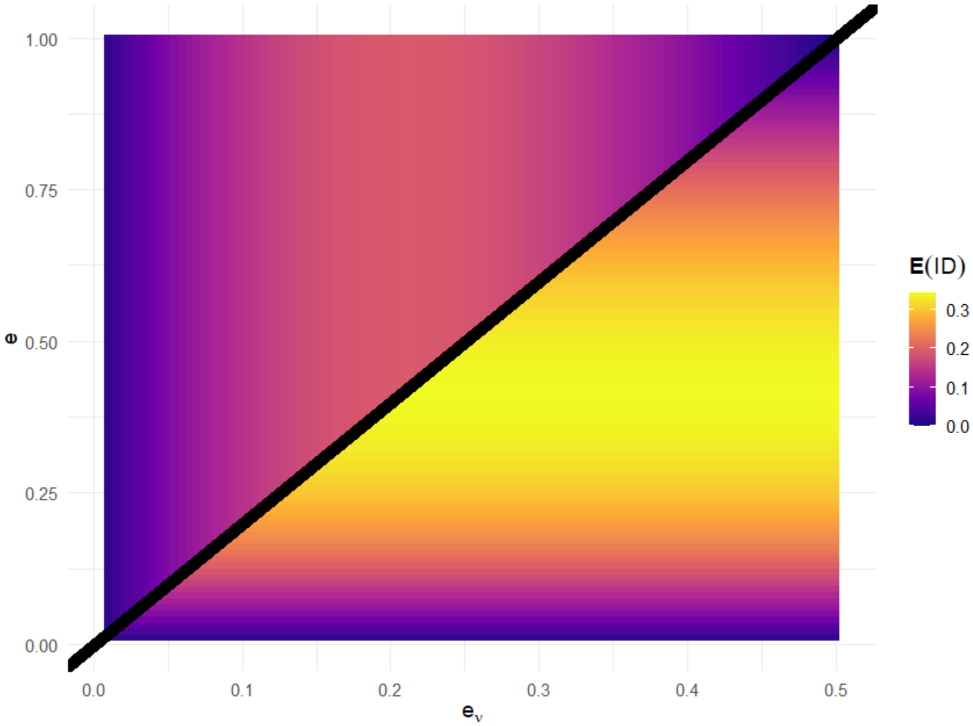


Figure 10: The expected ideological distance of two agents with flat beliefs for different parameter combinations.

If the error is high, the chance that the agents get opposing signals is quite substantive, which could, in the end, increase polarization. As a result, the relation between the error of the source and polarization is nonmonotonic and has an inverse U-shape.

The probabilities of signal realizations and corresponding ideological distances discussed above imply that the expected ideological distance can be expressed as a function of e and e_ν

$$\mathbf{E}\left[ID\right] = \begin{cases} \frac{2e(1-e)}{1+e}, & \text{if } e_\nu/e > 0.5 \\ 2e_\nu(1-e_\nu)(1-2e_\nu), & \text{if } e_\nu/e < 0.5 \end{cases}. \tag{10}$$

Figure 10 illustrates the expected ideological distance as a function of e and e_ν. The plot is separated into two triangular areas by the line $e_\nu/e = 0.5$ representing the threshold where agents change their news consumption patterns. The ideological distance has a substantive upward jump at this threshold when going from the top-left part (where the neutral source is chosen) to the bottom-right part (where biased sources are chosen). On both sides of the threshold, the relation between the error and ideological distance is non-monotonic and has an inverse-U shape. Figures 11 and 12 further illustrate this relation by fixing one of the errors in question and plotting the relationship between the other error and the expected ideological distance.

This relationship between the errors and a measure of polarization could have interesting im-

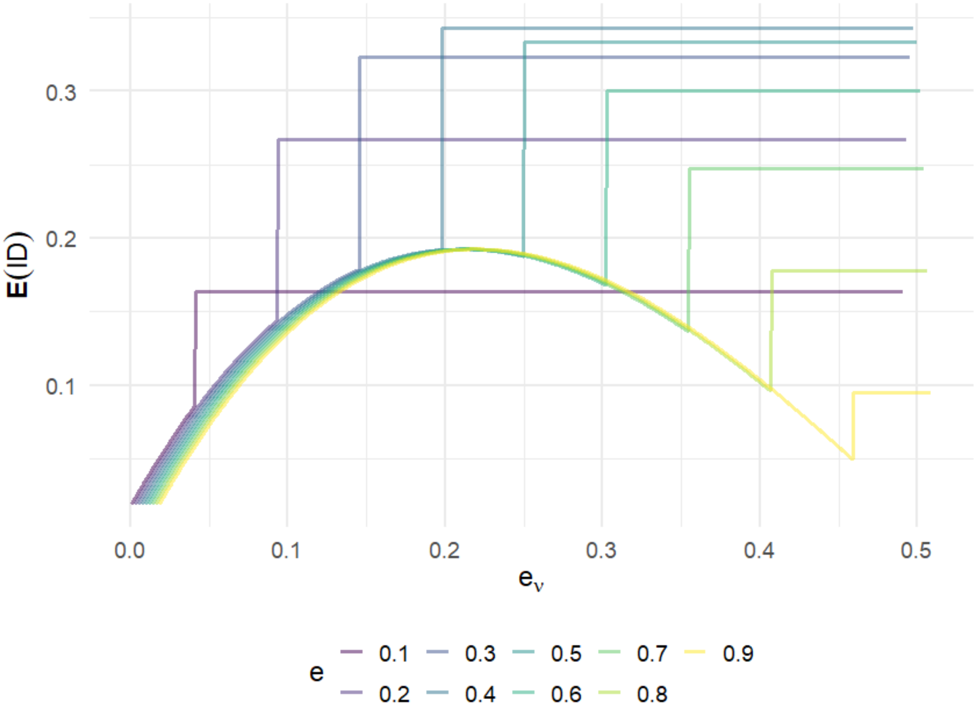


Figure 11: Expected ideological distance as a function of the error of the neutral source.

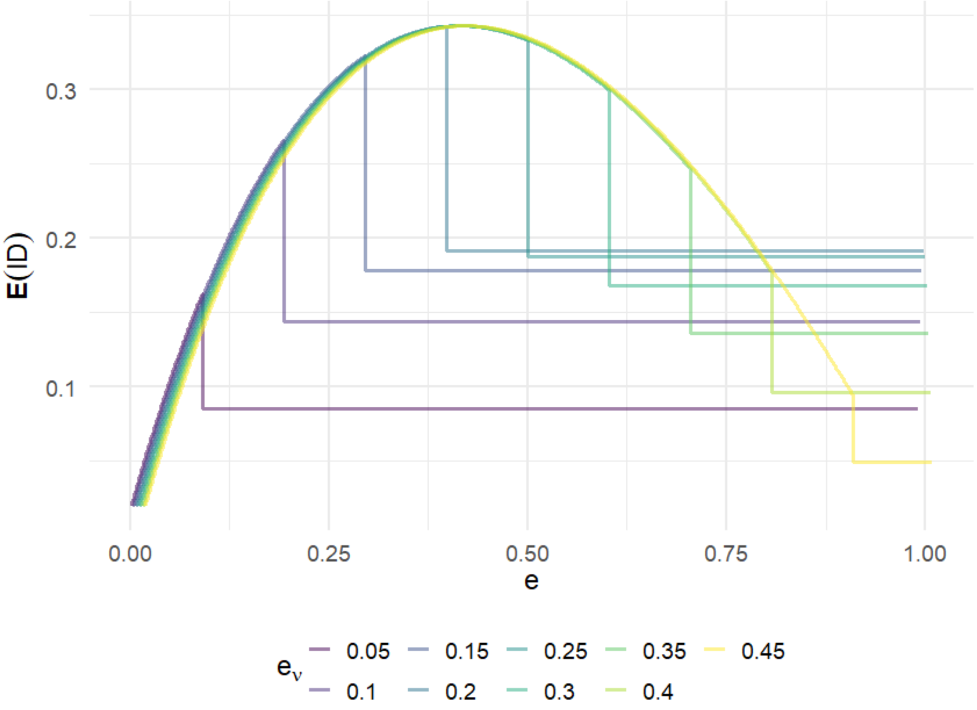


Figure 12: Expected ideological distance as a function of the error of the biased sources.

plications for the role of neutral sources in the media market.

Assume that the social planner aims to achieve a low level of polarization and that she can only control the error of the neutral source, the error of biased sources is set exogenously. Given the non-monotonic relationship between the error of the neutral source and polarization, she has two options. First, she can push the error to be as low as possible. However, that might be associated with large investments in the quality of the media. Second, she can try to increase the error to get over the peak into the are where the polarization is low enough. However, if she overdoes it, the agents may switch to biased sources, causing an upward jump in polarization and not paying attention to neutral media at all.

Alternatively, I could assume that the social planner takes the quality of neutral media as given and tries to calibrate the error of the biased media. There, again, two strategies are available. Either she can push the error of the biased media to be as low as possible (which can again be too costly or difficult), or she can decrease the polarization by increasing the error, which either results in getting to the decreasing part of the error-polarization function or changing the news consumption patterns in favor of neutral sources and an instant downward jump in polarization.

This intuition also holds for the case when agents consume two signals. There, there is always a band of agents around the flat belief who either consume only their confirmatory source $\alpha\alpha$ and $\beta\beta$, or the contradictory source along with the neutral source $\alpha\nu$ and $\beta\nu$. This, in general, smooths out the relation between error and polarization but, at the same time, preserves the inverse-U shape presented above and the direction of the jumps. For the derivation, see Appendix section A.2.

5 Conclusion

This paper examines the role of biased and neutral sources in the media market. Specifically, it explores the conditions under which consumers engage with news articles that contradict their prior beliefs — a behavior that contrasts with the traditional confirmation bias extensively studied in the literature.

I develop a simple model of endogenous information acquisition, where agents choose between media sources with varying error structures. I derive that while confirmation bias remains the dominant behavior, agents with weaker prior beliefs may choose to consume exclusively neutral sources or even combine neutral and contradictory sources, which exhibit strong mutual complementarity.

Additionally, I discuss the implications of these consumption patterns for polarization. I demonstrate that the relationship between source error and polarization follows an inverse-U shape. However, given the relative errors of respective sources, agents may reoptimize their news portfolios, leading to a disruption of this pattern.

My research could be relevant to policymakers seeking to understand the dynamics of media consumption and its impact on public opinion. In particular, it highlights the potential for interventions aimed at encouraging the consumption of diverse news sources, which could mitigate polarization and promote more balanced media landscape.

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A Appendix

A.1 Demand for More Signals

The next logical step could be to examine the case where the agent can receive $n > 2$ signals. Her problem would be to choose source portfolio represented by an ordered triplet $(k_\alpha, k_\nu, k_\beta)$, where $k_\alpha \geq 0, k_\nu \geq 0, k_\beta \geq 0$, and $k_\alpha + k_\nu + k_\beta = n$. That brings $\binom{3+n-1}{n}$ options for a given n. Therefore, with increasing n, it might no longer be efficient to compute the expected utility for each option separately, and the problem would require a more systematic approach. For instance, I could build on the work of Frankel and Kamenica (2019), who introduce a general framework for measuring the informativeness of signals across different prior beliefs.

No neutral source

I start by showing that when a neutral source is unavailable (or very imprecise), and the agent chooses only from sources α and β, it is never optimal to choose a combination of these sources. Conversely, the agent chooses to consume only from source α, or only from source β, and the choice always follows her private belief. The agent always chooses to acquire all signals from her confirmatory source, which means α for agents with $q > 0.5$ and β for agents with $q < 0.5$

In this simplified problem, the agent chooses k_α, and k_β such that $k_\alpha + k_\beta = n$. Then, she gets k_α signals from source α and k_β signals from source β. Let me denote by $k_{\alpha B}$ the number of signals B sent by source α, and by $k_{\beta A}$ the number of signals A sent by source β. Given the design of our sources, we can use these two numbers to classify all the possible signal realizations the agent might get.

There are, in principle, four different cases. First, the case when $k_{\alpha B} > 0$, and $k_{\beta A} = 0$ completely reveals that the state of the world is B. Symmetrically, the case when $k_{\beta A} > 0$, and $k_{\alpha B} = 0$ completely reveals the state of the world being A. Given the structure of our sources, we can easily compute the probabilities the agent assigns to these signal realizations.

The case when both $k_{\beta A}$ and $k_{\alpha B}$ are non-zero has probability zero since no state of the world could support this signal realization.

Only when $k_{\beta A}$ and $k_{\alpha B}$ are equal to zero (which means that both sources sent only the signals in line with their bias). The posterior beliefs of the agents could end up being non-trivial.

Table A.1 presents the probabilities of these signal realizations, the posterior beliefs, and expected payoffs.

Table A.1: Clasification of all possible signal realizations using $k_{\alpha B}$ and $k_{\beta A}$

$k_{\alpha B}$	$k_{\beta A}$	$P[S\|q,P]$	$\mathbf{E}[\mathbf{I}_{\omega=a}\|q,S,P]$	$\mathbf{E}[U\|q,P,S]$
>0	$=0$	$(1-e^{k_\alpha})(1-q)$	0	1
$=0$	>0	$(1-e^{k_\beta})q$	1	1
>0	>0	0	-	-
$=0$	$=0$	$e^{k_\beta}q+e^{k_\alpha}(1-q)$	$\frac{e^{k_\beta}q}{e^{k_\beta}q+e^{k_\alpha}(1-q)}$	$\max\left[\frac{e^{k_\beta}q}{e^{k_\beta}q+e^{k_\alpha}(1-q)},\frac{e^{k_\alpha}(1-q)}{e^{k_\beta}q+e^{k_\alpha}(1-q)}\right]$

Given this, and noticing that it has to be that $k_\alpha + k_\beta = n$, the problem of the agent can be rewritten as

$$\max_{k_\alpha \in [0,n]} \left\{ \max\left[e^{n-k_\alpha}q, e^{k_\alpha}(1-q)\right] + (1-q)(1-e^{k_\alpha}) + q(1-e^{n-k_\alpha}) \right\}. \tag{A.1}$$

Here, for a while, I abstract from the fact that k_α should be an integer and handle it as a real number. I first show that there is no interior solution; therefore, for any n, e, and q, it is optimal to choose 0 or n.

Since the objective function contains a maximum operator, the derivative of the function for $k_\alpha = log_e\left(\sqrt{\frac{qe^n}{1-q}}\right)$ does not exist.

Otherwise, to write the first derivative, we need to distinguish two cases.

$$\text{if} \quad k_\alpha < log_e\left(\sqrt{\frac{qe^n}{1-q}}\right): \quad -(1-q)e^{k_\alpha}, \tag{A.2}$$

$$\text{if} \quad k_\alpha > log_e\left(\sqrt{\frac{qe^n}{1-q}}\right): \quad qe^{n-k_\alpha}. \tag{A.3}$$

This shows that for $k_\alpha < log_e\left(\sqrt{\frac{qe^n}{1-q}}\right)$, the function is strictly decreasing, reaches a local minimum in $k_\alpha = log_e\left(\sqrt{\frac{qe^n}{1-q}}\right)$ and then increases again. Therefore, no interior k_α maximizes the objective function.

This implies that the only optimal choice could be $k_\alpha = n$, or $k_\alpha = 0$. Let me now derive conditions for the optimality of each choice. The expected utilities equal

$$\mathbf{E}\left[U(k_\alpha = 0)|q,P\right] = \max\left[e^n q,(1-q)\right] + q(1-e^n) \tag{A.4}$$

$$\mathbf{E}\left[U(k_\alpha = n)|q,P\right] = \max\left[q,e^n(1-q)\right] + (1-q)(1-e^n) \tag{A.5}$$

The agent always chooses the k_α that delivers higher expected utility. It turns out that

- for $q < 0.5$: $\mathbf{E}\left[U(k_\alpha = 0)|q,P\right] > \mathbf{E}\left[U(k_\alpha = n)|q,P\right]$, and the optimal choice is $k_\alpha = 0$,

- for $q > 0.5$: $\mathbf{E}\left[U(k_\alpha = n)|q{,}P\right] > \mathbf{E}\left[U(k_\alpha = 0)|q{,}P\right]$, and the optimal choice is $k_\alpha = n$.

That means that all agents that initially believed a is more likely to be the state of the world consume only signals from source α, and all agents who initially believed b is more likely to be the true state of the world consume only from source β.

These results show that confirmation bias is the phenomenon that governs the demand for media even when agents are allowed to choose a higher (but still limited) number of confirmation sources. This opens up a space for examining how the addition of neutral sources into this problem shapes the choices of agents.

Including the neutral source

Now, I perform a similar analysis for the original case, where the neutral source is available. Here, the agent chooses k_α, k_ν, k_β. Again, I will denote by $k_{\alpha B}$ the number of signals B received from source α, and similarly by $k_{\beta A}$ the number of signals A received from source β. These numbers can be again used to classify the realizations of signals into 4 different cases. Table A.2 summarizes them assuming that the agent chose to consume k_ν signals from the neutral source and received $k_{\nu A}$ signals A from it

Table A.2: Clasification of all possible signal realizations using $k_{\alpha B}$ and $k_{\beta A}$, and $k_{\nu A}$

$k_{\alpha B}$	$k_{\beta A}$	$P[S\|q{,}P]$	$\mathbf{E}[\mathbf{I}_{\omega=a}\|q{,}S{,}P]$
> 0	$= 0$	$(1 - e^{k_\alpha})(1 - q)e_\nu^{k_{\nu A}}(1 - e_\nu)^{k_\nu - k_{\nu A}}$	0
$= 0$	> 0	$(1 - e^{k_\beta})qe_\nu^{k_\nu - k_{\nu A}}(1 - e_\nu)^{k_{\nu A}}$	1
> 0	> 0	-	-
$= 0$	$= 0$	$e^{k_\beta}qe_\nu^{k_\nu - k_{\nu A}}(1 - e_\nu)^{k_{\nu A}} + e^{k_\alpha}(1 - q)e_\nu^{k_{\nu A}}(1 - e_\nu)^{k_\nu - k_{\nu A}}$	$\frac{e^{k_\beta}qe_\nu^{k_\nu - k_{\nu A}}(1-e_\nu)^{k_{\nu A}}}{e^{k_\beta}qe_\nu^{k_\nu - k_{\nu A}}(1-e_\nu)^{k_{\nu A}} + e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu - k_{\nu A}}}$

The expected utility for a particular choice of k_α,k_ν, and k_β can be computed by taking an expectation of the expected utilities over all possible realizations of $k_{\nu A}$ — the combination of signals delivered by the neutral source. That yields

$$\begin{gathered}\mathbf{E}[U|q,P]=\mathbf{E}[\mathbf{E}[U|q,P,S]|S]=\\ \sum_{k_{\nu A}=0}^{k_\nu}\binom{k_\nu}{k_{\nu A}}(1-e^{k_\alpha})(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}+\\ \sum_{k_{\nu A}=0}^{k_\nu}\binom{k_\nu}{k_{\nu A}}(1-e^{k_\beta})qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}}+\\ \sum_{k_{\nu A}=0}^{k_\nu}\binom{k_\nu}{k_{\nu A}}\left[e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}}+e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}\right]\cdot\\ \max\left(\frac{e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}}}{e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}}+e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}},\right.\\ \left.\frac{e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}}{e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}}+e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}}\right)\end{gathered}\tag{A.6}$$

The first two sums can be modified using the binomial theorem yielding

$$\begin{gathered}\mathbf{E}[U|q,P]=(1-e^{k_\alpha})(1-q)+(1-e^{k_\beta})q+\\ +\sum_{k_{\nu A}=0}^{k_\nu}\binom{k_\nu}{k_{\nu A}}\cdot\max\left[e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}},e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}\right].\end{gathered}\tag{A.7}$$

The general problem of the agent could thus be formulated as

$$\begin{gathered}\max_{k_\alpha,k_\beta,k_\nu}\left\{(1-e^{k_\alpha})(1-q)+(1-e^{k_\beta})q+\right.\\ \left.+\sum_{k_{\nu A}=0}^{k_\nu}\binom{k_\nu}{k_{\nu A}}\cdot\max\left[e^{k_\beta}qe_\nu^{k_\nu-k_{\nu A}}(1-e_\nu)^{k_{\nu A}},e^{k_\alpha}(1-q)e_\nu^{k_{\nu A}}(1-e_\nu)^{k_\nu-k_{\nu A}}\right]\right\},\end{gathered}\tag{A.8}$$

$$k_\alpha+k_\beta+k_\nu=n,\tag{A.9}$$

$$k_\alpha,k_\beta,k_\nu\geq 0.\tag{A.10}$$

Unfortunately, due to the complexity of this function, solving this problem in a closed form is not possible. However, the optimal source portfolios could be determined using numerical methods.

A.2 Expected ideological distance for two sources

I derive the expression for the expected ideological distance after consuming two signals and plot it for different values of e and e_ν. In the paper, I have already demonstrated that the agents with a flat belief of $q = 0.5$ either

- choose the one-sided confirmatory source portfolios - that means $\alpha\alpha$ for the high agent and $\beta\beta$ for the low agent, or
- choose the neutral-contradictory source combination - that means $\beta\nu$ for the high agent and $\alpha\nu$ for the low agent.

The threshold where the news consumption pattern switches is where the agent is indifferent between the expected utility delivered by the choices in question. That means that the threshold is

$$1 - \frac{e^2}{2} = 1 - \frac{e_\nu + e}{2} + \max\left[e_\nu, (1-e_\nu)e\right]. \tag{A.11}$$

The expected ideological distance can then be computed using logic similar to that of one signal. After simplification, the expected ideological distance could be expressed as

$$\mathbf{E}\left[ID\right] = \begin{cases} \frac{2e^2(1-e^2)}{1+e^2}, & \text{if } \frac{e^2}{2} < \frac{e_\nu+e}{2} + \max\left[e_\nu, (1-e_\nu)e\right], \\ ee_\nu \dfrac{(1-e_\nu)^2(1-e) + (1-e_\nu)(1-e)e_\nu}{1-e_\nu+ee_\nu} + \\ + (1-e_\nu)^2 e\left(\dfrac{1-e_\nu}{1-e_\nu+ee_\nu} - \dfrac{e(1-e_\nu)}{(1-e_\nu)e+e_\nu}\right) + \\ + (1-e_\nu)ee_\nu \dfrac{1-e_\nu-ee_\nu}{1-e_\nu+ee_\nu} + \\ + e(1-e_\nu)\dfrac{e_\nu(1-e)(1-e_\nu)+e_\nu^2(1-e)}{e_\nu+e(1-e_\nu)} + \\ + e_\nu e(1-e_\nu)\dfrac{e(1-e_\nu)-e_\nu}{e(1-e_\nu)+e_\nu} + \\ + e_\nu^2 e\left(\dfrac{e_\nu}{e_\nu+e(1-e_\nu)} - \dfrac{ee_\nu}{ee_\nu+1-e_\nu}\right), & \text{if } \dfrac{e^2}{2} > \dfrac{e_\nu+e}{2} \end{cases} . \tag{A.12}$$

Even though the formula seems to be a bit more complex, the main patterns (non-monotonicity, in general, higher polarization for consuming the biased sources only) remain the same as in the case of one signal. Figures A.1, A.2 and A.3 document the relation.

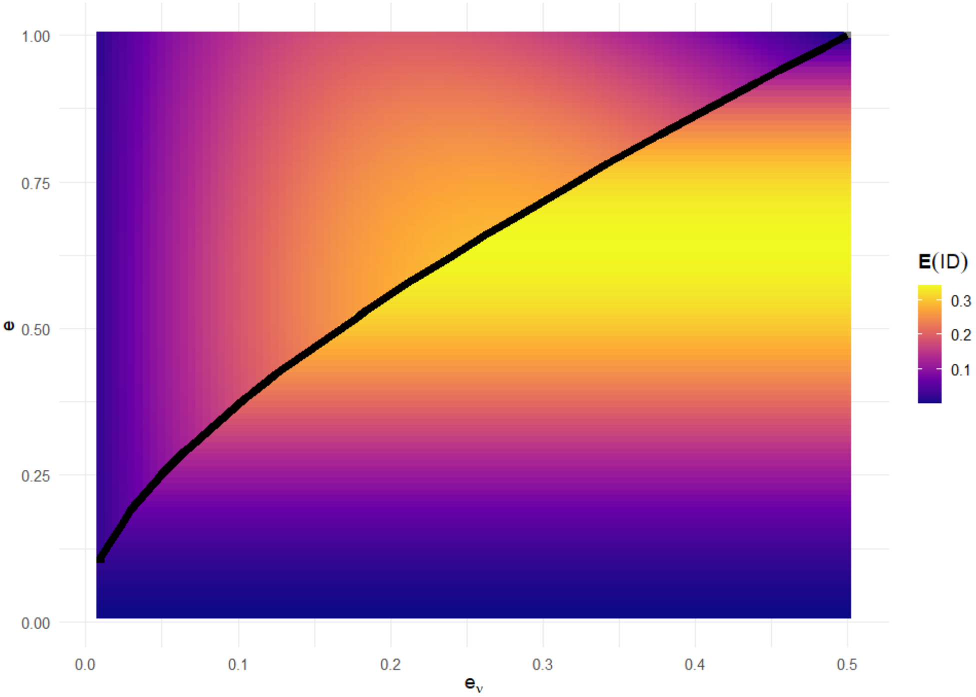

Figure A.1: The expected ideological distance of two agents with flat beliefs for different parameter combinations.

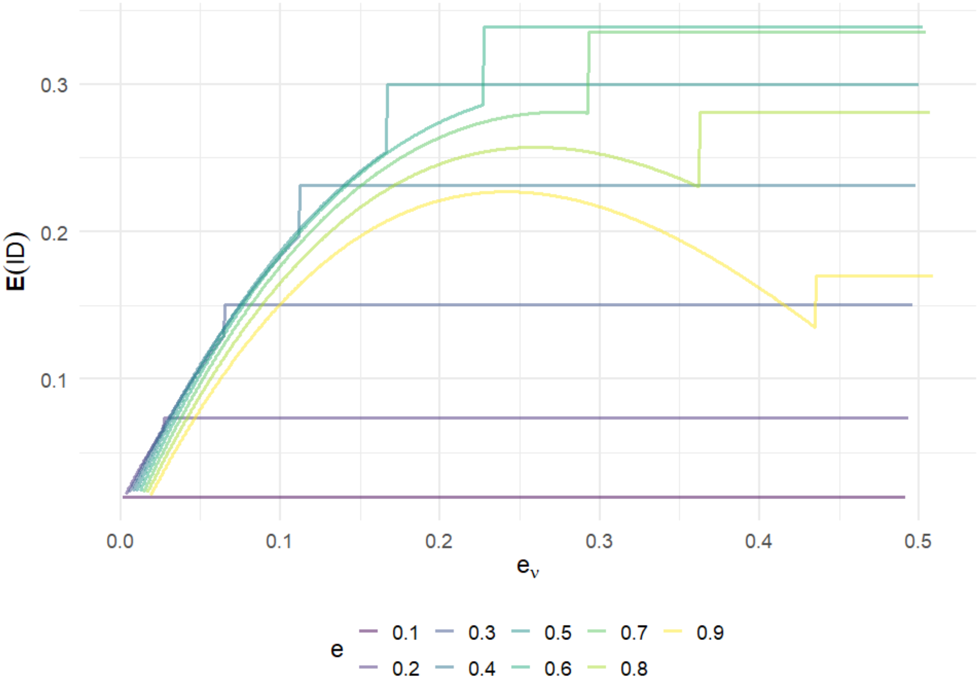

Figure A.2: Expected ideological distance as a function of the error of the neutral source.

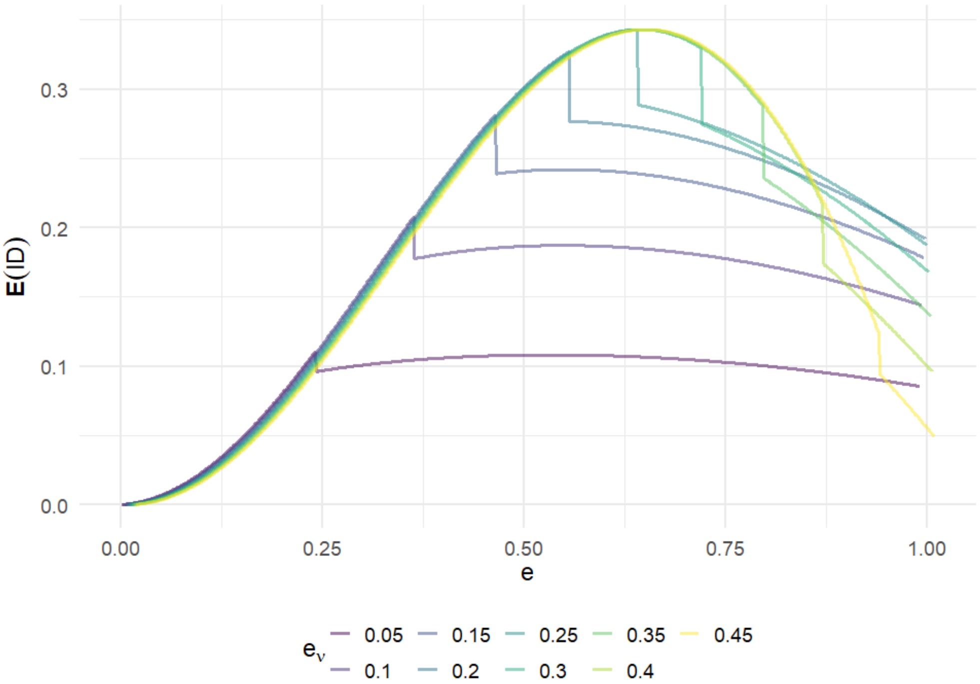

Figure A.3: Expected ideological distance as a function of the error of the biased sources.