

Monopoly and Competition in the Markets for Information

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January 20, 2026

Abstract

This paper studies how market structure shapes the quality and provision of information products. Information sellers invest in producing statistical experiments and offer menus of experiments to buyers with heterogeneous prior beliefs. I characterize the monopoly optimum and analyze duopoly competition, where sellers specialize in different signals and buyers sort across providers. Under general cost structures, monopoly dominates duopoly in both the informativeness of experiments and market coverage. The welfare loss arises because competition channels investment into partial specialization rather than comprehensive accuracy. These results apply to credit ratings, artificial intelligence markets, and ESG assessments.

(JEL: D42, D81, D82, D83)

Keywords: *Selling Information; Statistical Experiments; Duopoly Competition; Information Quality*

*Yingju Ma is with the University of Cambridge. I am grateful to Ichiro Obara, Simon Board, Alessandro Bonatti, Nima Haghpahan, Moritz Meyer-ter-Vehn, Joe Ostroy, Marek Pycia, Tomasz Sadzik, and Robert M. Townsend for these suggestions and comments, and also to the seminar participants and the discussant at UCLA, MIT, Cambridge, and the Oligo 2025 Workshop. All errors are mine. Email: ym459@cam.ac.uk

1 Introduction

The rapid advancement of artificial intelligence is transforming information markets. Leading technology firms have committed hundreds of billions of dollars to developing foundation models.¹ However, whether such large-scale investment and competition will lead to an increase in social welfare remains contentious.² This tension is not unique to AI. In credit rating markets, the entry of a third major agency coincided with a *decline* in rating quality rather than an improvement.³ In ESG ratings, competing providers produce assessments that diverge substantially from one another.⁴ These examples suggest that the relationship between competition and information quality may differ fundamentally from that in conventional product markets.

Whether rating creditworthiness, assessing sustainability, or serving as an AI co-pilot, these services fundamentally provide information ([Agrawal, Gans, and Goldfarb, 2022](#)). Their value lies in helping heterogeneous decision-makers act on private beliefs, and producing high-quality information requires substantial upfront investment. The central question is whether competition among information sellers improves the quality of information available to the market, or whether it dissipates investment incentives and fragments product offerings.

In this paper, I develop a framework to analyze the production and competition in the markets of information products. Buyers face a decision problem with uncertainty of two states. They can purchase additional information (experiments) to augment their private information. A buyer's willingness to pay for an experiment depends on his private information. If a buyer is very certain about one state, he does not value additional information very much. On the other hand, if a buyer is completely unsure about the states, any information has some value to him.⁵

¹In 2025, Alphabet, Amazon, Meta, and Microsoft collectively planned over \$380 billion in AI-related capital expenditure, more than double the level two years prior. See <https://www.goldmansachs.com/insights/articles/why-ai-companies-may-invest-more-than-500-billion-in-2026>

²In the testimony before a Senate Committee hearing, Daron Acemoglu stated, "We have widely different paths ahead of us on how AI technologies will develop and their implications for productivity, inequality, social norms and democracy. . . . we are currently heading in the wrong direction" ([Acemoglu, 2023](#)).

³[Becker and Milbourn \(2011\)](#) show that as Fitch gained market share, the incumbent agencies' ratings became less informative: rating levels increased, the correlation between ratings and market-implied yields declined, and the predictive power of ratings for default deteriorated.

⁴[Berg, Kölbel, and Rigobon \(2022\)](#) document that pairwise correlations across six major ESG rating agencies average only 0.54. They decompose the divergence into measurement differences (56%), scope differences (38%), and weighting differences (6%), and identify a rater effect in which a provider's overall view of a firm influences its assessment of specific categories.

⁵[Bergemann and Bonatti \(2018\)](#) summarize a number of markets for information products and current research about these markets. They also provide a framework to categorize different information products.

To generate these experiments, sellers have to make an investment, which determines the most informative experiment a seller can provide. Once the investment is made, the seller can provide the most informative experiment to any number of buyers with zero marginal cost. The seller can also babble on this experiment and provide any less informative experiment at no cost. Since buyers' value for an information product is private, I assume the seller post a menu of experiments and prices. Buyers then choose one experiment from the menu. When there are two sellers, they compete with investment.

The main results are: (i) I characterize the optimal menu given any investment level and derive the optimal investment; (ii) I characterize an asymmetric equilibrium of market segmentation when two sellers compete with investment; (iii) by comparing the information generated and provided by monopoly and duopoly sellers, I find that monopoly always provides more informative experiments and serves more buyers than the case of duopoly competition.

One special feature of information products is that the value of information depends on both the quality of information and the buyers' beliefs. Consider an experiment sending two signals (bad news and good news) about two states (good state and bad state). The more accurate both signals are, the higher the value is for all buyers. Thus it has a vertical element (quality). On the other hand, for any two experiments, different buyers may have opposite preferences. Pessimistic buyers prefer the experiment to give more accurate good news since it is more valuable to acquiring knowledge about the state he is less confident in. While optimistic buyers prefer more accurate bad news. So the value of information also has a horizontal element (position).

Since the buyers' beliefs are unobservable, sellers need to screen among buyers by providing an incentive-compatible menu, which includes some experiments and the corresponding prices. The first result (Proposition 1) gives a characterization of the optimal menu. Given any investment level, the optimal menu includes at most two experiments. It always includes the most informative experiment feasible to the seller. When there are more pessimistic buyers, the seller might provide additional experiments targeting some of the pessimistic buyers who otherwise are excluded from the market.

When two sellers compete in the market with investments, the second main result (Proposition 3) is that there exists an equilibrium where one seller specializes in producing good news and only serves the pessimistic buyers. While the other seller serves optimistic buyers with more accurate bad news. Pessimistic buyers strictly prefer the good news seller since it gives them bigger improvement in decision-making problems. Even if two sellers have the same investment level, I have this market segmentation.

The answer to the question of whether competition leads to better-informed outcomes

is the third result (Theorem 1). Monopoly makes higher investments and provides more informative experiments than duopoly. First, because of a duopoly, both sellers have to invest in generating informative products, and they split the market. So the benefit from investment is less than the case of monopoly. However, since duopoly seller faces a submarket with more concentrated beliefs (either pessimistic buyers or optimistic buyers), they can specialize in providing the signals that are favoured by the submarket. I show that the first factor becomes dominate in equilibrium.

Related Literature.

Selling information and data. The most related work is [Bergemann, Bonatti, and Smolin \(2018\)](#), which analyzes the problem of a monopoly seller selling information. In their model, the seller can access the complete information. They characterize the revenue-maximizing menu of experiments. Their main results show that the optimal menu includes at most two experiments. A fully informative experiment is always provided. The seller might provide a second partial informative experiment by adding noises on one signal. Based on their framework, I examine the design and pricing problem of a seller whose most informative experiment is limited. Then, I consider the optimal investment, which determines the most informative experiment, and study the case of competing sellers. In a related work, [Bimpikis, Crapis, and Tahbaz-Salehi \(2019\)](#) studies the information market where the buyers of the information products compete in a downstream market. Unlike their focus on downstream interactions, I directly analyze competition among information sellers. Related studies consider verifiable information ([Ali et al., 2022](#)), strategic quality–pricing interactions ([Rodríguez Olivera, 2024](#)), bundled information–product sale ([Kwon, 2018](#)), and buyer-optimal recommendations ([Ichihashi and Smolin, 2024](#)). A growing literature studies data markets and privacy ([Jones and Tonetti, 2020](#); [Bergemann and Bonatti, 2024](#); [Ichihashi, 2020](#); [Acemoglu et al., 2022](#); [Yang, 2022](#); [Bergemann, Bonatti, and Gan, 2022](#); [Galperti, Levkun, and Perego, 2024](#); [Kovbasyuk and Spagnolo, 2024](#); [Liu, Ma, and Veldkamp, 2025](#)); see [Bergemann and Ottaviani \(2021\)](#) for a survey.

Competition in persuasion and information design. [Gentzkow and Kamenica \(2017\)](#) show that when senders send coordinated signals, additional senders increase the amount of information. [Li and Norman \(2021\)](#) generalize their setting by allowing sequential senders and show that with independent signals, the result might fail. This literature has been extended to private and sequential communication ([Arieli and Babichenko, 2019](#); [Wu, 2023](#); [Doval and Ely, 2020](#)) and to Bayesian persuasion with privately informed receivers

([Bergemann and Morris, 2019](#); [Dworczak and Martini, 2019](#); [Guo and Shmaya, 2019](#)). In these settings, senders send information to persuade receivers to take an action, while in my model, the sender (seller) is providing information for revenue rather than persuasion. [Board and Lu \(2018\)](#) considers a model where buyers search for a product that fits their needs best, and sellers of a product use information disclosure policies to manage the buyers' search incentives. In my model, information itself is the product the seller sells. Another recent paper [Boleslavsky, Hwang, and Kim \(2018\)](#) studies an oligopoly market where each seller chooses both the price of the product and how much information he will disclose to buyers. [Terstiege and Vigier \(2025\)](#) study endogenous market segmentation. Compared to these papers, I provide a case where competition leads to a less informative outcome. In the persuasion literature, senders' payoffs derive from preferences over receivers' actions or product sales; in my model, the only payoff is monetary transfers, and sellers acquire their informational advantage through costly investment.

Costly information acquisition. My model connects investment cost structures to welfare consequences in information markets. Several papers develop theoretical foundations for information costs ([Gentzkow and Kamenica, 2014](#); [Frankel and Kamenica, 2019](#); [Pomatto, Strack, and Tamuz, 2023](#); [Bloedel and Zhong, 2024](#); [Mandler, 2024](#); [Caplin and Dean, 2015](#); [Zhong, 2022](#)); my analysis allows a general class of cost functions compatible with these frameworks. The production technology of information has a feature of large fixed costs and small marginal costs. In a seminal paper, [Spence \(1976\)](#) analyzes the impact of fixed cost on the selection of products. [Ronnen \(1991\)](#) considers the influence of a minimum quality standard on the product qualities. In my model, the seller chooses the quality of a multidimensional information product, and I show that competition may not lead to quality improvement.

Mechanism design and screening. In seminal work on selling information, [Admati and Pfleiderer \(1986\)](#); [Admati and Pfleiderer \(1990\)](#) study the case when information buyers are *ex-ante* homogeneous and trade an asset after they get supplemental information. In contrast, buyers in my model are heterogeneous and face individual decision problems. [Roesler and Szentes \(2017\)](#) show that buyer-optimal information leads to efficient monopoly pricing; in my setting, it is the seller who designs information products. Related work on multi-dimensional screening, bundling, and competitive pricing includes [Deb and Roesler \(2024\)](#), [Haghpanah and Hartline \(2021\)](#), [Strack and Yang \(2024\)](#), [Rhodes and Zhou \(2024\)](#), and [Pollrich and Strausz \(2024\)](#).

Applications. My framework speaks to a growing recent literature on information production in several applied domains: the interaction between market structure and information acquisition in finance (He and Manela, 2016; Weller, 2018; Brogaard and Pan, 2022; Glebkin, Gondhi, and Kuong, 2021; Xiong and Yang, 2023; Chen et al., 2022), data abundance and quality in digital platforms (Dugast and Foucault, 2025; Farboodi, Haghpanah, and Shourideh, 2025; Zhong, 2025), and the design of information mechanisms in regulation and policy (Parlatore and Philippon, 2025; Eliaz and Spiegler, 2020).

In the following, I present the main settings of the model in Section 2. Then I analyze the optimal menu and optimal investment of a monopoly seller in Section 3. Section 4 considers the case of duopoly competition and compares the optimal investment between monopoly and duopoly sellers.

2 The Model

In this section, I start by introducing a simplified assumption of buyer's decision-making problems, then define the information product. Then, I analyze the buyer's valuation of the information product and define the seller's problem in choosing both the product design and investment level.

2.1 Buyers' Decision Problem

There are data buyers of measure 1 facing a decision problem under uncertainty. The uncertain state is drawn from set $\Omega = \{\omega_1, \omega_2\}$. A data buyer needs to choose an action a from action set $A = \{a_1, a_2\}$. Without loss of generality, I can normalize the payoff of action a_2 under both states into zero. Therefore, the following matrix can capture the payoffs of buyers' decision problems.

$$\begin{array}{cc} & \begin{array}{cc} a_1 & a_2 \end{array} \\ \begin{array}{c} \omega_1 \\ \omega_2 \end{array} & \begin{pmatrix} u_1 & 0 \\ u_2 & 0 \end{pmatrix} \end{array}$$

We can think of the two actions as “risky” and “safe” actions. Safe action results in zero payoffs for both states. The risky action yields a payoff $u_1 > 0$ under “good” state ω_1 , and $u_2 < 0$ under “bad” state ω_2 . The buyer will take action a_1 if $\theta u_1 + (1 - \theta) u_2 \geq 0$, which implies $\theta \geq \frac{-u_2}{u_1 - u_2}$. Note θ^* as the belief type that is indifferent between two actions.

$$\theta^* u_1 + (1 - \theta^*) u_2 = 0 \Leftrightarrow \theta^* = \frac{-u_2}{u_1 - u_2} \quad (1)$$

To simplify the notation, normalize the difference between risky action's payoffs in two states into 1. Denote $u_1 = 1 - r$ and $u_2 = -r$, where $r > 0$. Then $r = \theta^*$ is the cutoff belief. The buyer's payoff matrix becomes:

$$\begin{array}{cc} & \begin{array}{cc} a_1 & a_2 \end{array} \\ \begin{array}{c} \omega_1 \\ \omega_2 \end{array} & \begin{pmatrix} (1-r) & 0 \\ -r & 0 \end{pmatrix} \end{array}$$

Buyers arrive with a common prior about the state. I assume that each buyer has access to some private information unknown to other buyers and sellers. After receiving private information, buyers update their prior belief to an interim belief $\theta \in [0, 1]$. Assume the interim belief θ satisfies a distribution function $G(\theta)$ and associated density function $g(\theta)$, which are common knowledge. I call belief θ as the type of buyer. The expected utility of the buyer with type θ is,

$$u(\theta) = \max \{ \theta - r, 0 \}. \quad (2)$$

2.2 Information Products

Buyers can buy an information product (or an experiment) E from data sellers, to improve his expected utility from the decision problem. An information product is a likelihood function $\pi : \Omega \rightarrow \Delta S$, where S is the signal space. I can restrict attention to the signal space consists of only two signals $S = \{s_1, s_2\}$, without loss of generality⁶. Denote π_i as the conditional probability of signal s_i in state ω_i ,

$$\pi_i \triangleq \Pr[s_i \mid \omega_i], \quad i = 1, 2.$$

Write an experiment as $E = (\pi_1, \pi_2)$ with the following probabilistic matrix.

E	s_1	s_2
ω_1	π_1	$(1 - \pi_1)$
ω_2	$(1 - \pi_2)$	π_2

Without loss of generality, we can assume $\pi_1 + \pi_2 \geq 1$. It means that signal s_1 is more likely to happen under state ω_1 than under state ω_2 , $\pi_1 \geq (1 - \pi_2)$. Some observations are noteworthy introduced here. (i) The experiment $\bar{E} = (1, 1)$ is the fully informative experiment. (ii) When the sum of π_1 and π_2 equals to 1, we have $\pi_1 = 1 - \pi_2$. Thus, each

⁶For any signal sets consisting of more signals than the number of actions, I can construct an experiment with two signals achieve the same outcome distribution as the initial experiment. This is an implication of the Prop. 1 in [Bergemann, Bonatti, and Smolin \(2018\)](#).

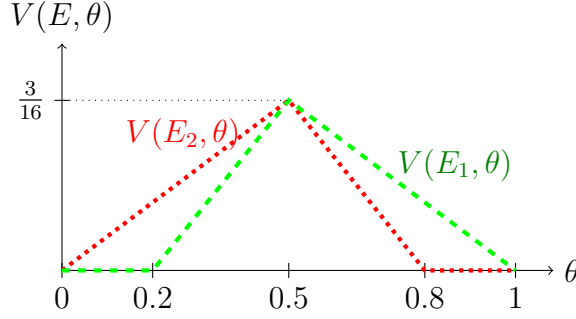


Figure 1: Value of Information for Different Buyers

signal is sent with equal probabilities under any state and hence is uninformative. Any experiment $E = (\pi, 1 - \pi)$ is completely uninformative for any π . (iii) Fixing π_1 , a higher π_2 implies that the probability of sending s_1 in state ω_2 is smaller. Therefore the signal s_1 , or the good news, is more accurate. Similarly, a higher π_1 implies more accurate bad news in the experiment.

The binary structure captures many economically important decisions, such as approving or rejecting a loan and investing or not, and the two-dimensional accuracy (π_1, π_2) reflects the fundamental tradeoff between sensitivity and specificity.⁷ The key insight, that competing sellers specialize along signal dimensions and reduce total informativeness, would persist in a richer N -state model.

2.3 Value of Information

Consider a buyer with type θ who buys the above experiment E . The buyer will update his belief after receiving each signal. Denote $\tilde{\theta}_i$ as the posterior belief after receiving signal $s_i, i \in \{1, 2\}$. I define the value of information product E for buyer θ as the improvement of *expected* utility after updating his beliefs.

$$V(E, \theta) = \mathbb{E}_s \left[u \left(\tilde{\theta}_i \right) \right] - u(\theta) \quad (3)$$

The expectation is taken over all signals. Since $\tilde{\theta}_1 = \frac{\theta\pi_1}{P(s_1)}$ and $\tilde{\theta}_2 = \frac{\theta(1-\pi_1)}{P(s_2)}$, we have

⁷In credit markets, the states map to repay (ω_1) versus default (ω_2), and the actions to approve (a_1) versus reject (a_2). In medical diagnostics, disease-present versus disease-absent. In large language models, whether the query has a reliable answer in the training data versus whether the model is likely to produce a hallucination.

$$V_0(E, \theta) = \max \{ (1-r) \theta \pi_1 - r (1-\theta) (1-\pi_2), 0 \} + \max \{ \theta (1-r) (1-\pi_1) - r (1-\theta) \pi_2, 0 \} - u(\theta) \quad (4)$$

The value of information $V(E, \theta)$ is always non-negative. Note that an uninformative experiment always gives zero value. Furthermore, for a buyer who has an extreme belief, if the experiment fails to send accurate enough contrary information, he will ignore the signal and take his initial action. Therefore he gets zero value from the experiment.

Figure (1) gives an illustration of how the value of an experiment is determined. Let $r = \frac{1}{2}$ and consider two experiments $E_1 = (1, 0.75)$ and $E_2 = (0.75, 1)$. Two buyers $\theta_A = \frac{1}{3}$ and $\theta_B = \frac{2}{3}$. Then I have $V(E_1, \frac{1}{3}) = \frac{1}{12}$ and $V(E_2, \frac{1}{3}) = \frac{1}{8}$. The pessimistic buyer θ_A prefers E_2 , which sends more accurate good news. Since $V(E_1, \frac{2}{3}) = \frac{1}{8}$ and $V(E_2, \frac{2}{3}) = \frac{1}{12}$. The optimistic buyer θ_B prefers E_1 which sends more accurate bad news. Therefore, buyers prefer experiments that provide contrary information that disproves their private information.

2.4 The Production of Information

To be able to provide information products with a certain quality, the data seller needs to make an investment of I . Investment determines the most informative experiment the seller can ever provide. Specifically, assume a cost function $C(\pi_1, \pi_2)$ that measures the cost incurred in collecting data, developing technologies, and building statistical models to provide an experiment $E = (\pi_1, \pi_2)$. The most informative experiment $E^* = (\pi_1^*, \pi_2^*)$ which the seller can provide to buyers should satisfy $C(\pi_1^*, \pi_2^*) \leq I$. Once the investment is made, the seller need to choose the most informative experiment E^* . Despite selling E^* , the seller can add some noise and produce an experiment less informative than E^* . This is natural, given the nature of information products. Assume downgrading an experiment is free. Furthermore, I assume the uninformative experiments are also available. Then the feasible set of experiments of a seller choosing E^* is

$$Y(\pi_1^*, \pi_2^*) \triangleq \{ (\pi_1, \pi_2) \mid \pi_1 + \pi_2 \geq 1, \text{ and } \pi_1 \leq \pi_1^*, \pi_2 \leq \pi_2^*, \text{ where } C(\pi_1^*, \pi_2^*) \leq I \} \quad (5)$$

Figure (2) illustrates the feasible set under (π_1^*, π_2^*) . In [Bergemann, Bonatti, and Smolin \(2018\)](#), fully informative experiment is available, $(\pi_1^*, \pi_2^*) = (1, 1)$. Therefore the feasible set becomes the largest upper triangle. Here I endogenize the choice of (π_1^*, π_2^*) and analyze what experiments will be provided given any feasible set.

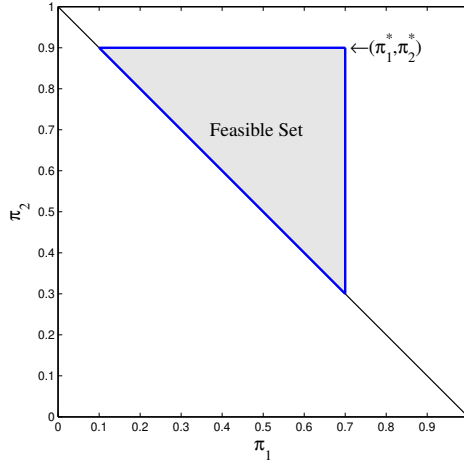


Figure 2: Feasible Set of Experiments

Note that the straight line $\pi_1 + \pi_2 = 1$ represents all uninformative experiments. However, an experiment may not be responsive. For example, consider $(\pi_1^*, 1 - \pi_1^*)$ for a buyer with belief $\theta > r$. The buyer always chooses action a_1 and does not follow the recommendation of signal s_2 . For technical convenience, I replace $(\pi_1^*, 1 - \pi_1^*)$ with $(1, 0)$. The latter one is responsive since the buyer only receives signal s_1 . Then for the following analysis I consider the feasible set $Y(\pi_1^*, \pi_2^*) \cup \{\pi_1 + \pi_2 = 1, \pi_i \in [0, 1]\}$.

Here I borrow from the directed search literature and assume information sellers compete for consumers through the signal of investment level. Like in [Kim and Kircher \(2015\)](#), sellers make no commitment when buyers choose which seller to visit. They show that when sellers use cheap talk messages to convey their private reservation values, efficiency can be achieved if sellers run a first-price auction after buyers come.

2.5 Menu of Information Products

A buyer's value of an experiment depends on his private belief θ , which is unknown to the seller. To maximize her profit, the seller will screen buyers by providing a menu of products. A menu of experiments, $\mathcal{M} = \{(E, t_E)\}$, consists of a collection of experiments E and their associated prices t_E . The seller posts her menu to the buyers. Then buyers can choose to buy one experiment E from $\mathcal{M}$ and pay the price t_E , or walk away with no additional information.

3 Monopoly

We now analyze the model with a monopoly seller. The timing is as follows:

- (i) The seller chooses an investment I and the most informative experiment E^* ;
- (ii) The seller posts a menu $\mathcal{M}$;
- (iii) The state ω is realized while unobserved. Buyers receive private information and type θ is realized;
- (iv) Every buyer chooses a product E from the menu and pays t_E ;
- (v) Every buyer observes a signal in experiment E and chooses an action.

The seller's problem is first to choose an investment level I and the most informative experiment E^* , then to design an incentive compatible menu $\mathcal{M}$. To find the profit maximizing investment level, I need to characterize the optimal menu under all the possible E^* .

3.1 Revenue Maximized Menu

Fixing the most informative experiment $E^* = (\pi_1^*, \pi_2^*)$, in principle, the optimal menu $\mathcal{M}$ should include one experiment for each buyer. In this subsection, I follow section III.C of [Bergemann, Bonatti, and Smolin \(2018\)](#), where $E^* = (1, 1)$. I apply their solution method to the general case of (π_1^*, π_2^*) . I simplify the seller's problem in three steps. First, exclude those buyers who never buy an informative experiment. Second, restrict the attention to responsive experiments. Third, argue that the seller will not add noises to both two signals, therefore reducing the problem to one dimensional.

Since the informativeness of E^* is limited, a buyer with extreme belief might choose not to follow the recommendations for all feasible experiments. Therefore I can restrict the attention on buyers who have a positive value of the most informative experiment E^* . It is not difficult to derive that buyers with belief $\theta \notin [\theta_1, \theta_2]$ give zero value over all experiments in the feasible set, where $\theta_1 = \frac{(1-\pi_2^*)r}{\pi_1^*(1-r)+(1-\pi_2^*)r}$ and $\theta_2 = \frac{\pi_2^*r}{(1-\pi_1^*)(1-r)+\pi_2^*r}$. These buyers have too strong beliefs and have zero value over all experiments in the feasible set. Therefore, they can only get uninformative experiments in the market.

Since $\pi_1^* + \pi_2^* \geq 1$, I always have $\theta_1 \leq \theta^*$ and $\theta_2 \geq \theta^*$. If fully informative experiment is available, then $\theta_1 = 0$ and $\theta_2 = 1$. Now I can restrict the attention on those potential

buyers with belief $\theta \in [\theta_1, \theta_2]$. Note the truncated distribution of potential buyers as

$$f(\theta) = \frac{g(\theta)}{G(\theta_2) - G(\theta_1)}, \quad F(\theta) = \int_{\theta_1}^{\theta} f(x)dx, \quad \forall \theta \in [\theta_1, \theta_2].$$

Since a buyer will only pay for an experiment if it has a positive value. I can show that the value of an experiment that is positive is equivalent to that the buyer will follow the recommendation of both signals. This fits Blackwell's insight that the information is valuable only if it changes the decision maker's optimal actions.

We call an experiment E a *responsive experiment* for buyer θ if the buyer follows the recommendations of both signals. Then I can eliminate the first max operator in the value function for responsive experiments.

$$V_1(E, \theta) = (1 - r) \theta \pi_1 - r (1 - \theta) (1 - \pi_2) - \max \{ \theta - r, 0 \}. \quad (6)$$

Lemma 1. *The value of an information product E for buyer θ is positive, if and only if the buyer strictly prefer to following the recommendations, i.e., choosing a_i after receiving s_i , $i = 1, 2$. The outcome of every menu can be attained by a responsive menu, in which $E(\theta)$ is a responsive experiment for type θ , for all $\theta \in [\theta_1, \theta_2]$.*

Lemma 1 implies that an experiment is responsive for a buyer if and only if the value of information after following both recommendations, $V_1(E, \theta)$, is nonnegative. Now I can focus on responsive menus; hence, the value of information $V_0(E, \theta)$ can be replaced by $V_1(E, \theta)$.

The seller's problem is on a two dimensional set. I now give the following characterization of the optimal menu, which eliminates buyer's uncertainty as much as possible, at least along one dimension.

Lemma 2. *If an experiment $E = (\pi_1, \pi_2)$ is in the optimal menu $\mathcal{M}$, then either one of the following two conditions holds:*

- (i) E is uninformative.
- (ii) $\pi_1 = \pi_1^*$ or $\pi_2 = \pi_2^*$.

Therefore, any experiment in the optimal menu either contains no information or achieves maximal accuracy on one signal. Now I can replace the experiment (π_1, π_2) with a one dimensional measure. Rewrite equation (6) as

$$V(E, \theta) = \max \{ \theta [\pi_1 (1 - r) + (1 - \pi_2) r] - (1 - \pi_2) r - \max \{ \theta - r, 0 \}, 0 \} \quad (7)$$

For type θ , define the following one-dimensional value

$$q(\theta) \triangleq \pi_1(\theta)(1-r) + (1-\pi_2(\theta))r \in [0, 1].$$

Notice that the endpoints of the interval correspond to two uninformative experiments $(0, 1)$ and $(1, 0)$. The most informative experiment E^* gives $q_0 = \pi_1^*(1-r) + (1-\pi_2^*)r = \pi_1^* + r(1-\pi_1^*-\pi_2^*)$. Lemma 2 implies that if $q \neq 0$ and $q \neq 1$, then I have either $\pi_1 = \pi_1^*$ or $\pi_2 = \pi_2^*$. Therefore $0 < q < q_0$ implies $\pi_2 = \pi_2^*$, and $q_0 < q < 1$ implies $\pi_1 = \pi_1^*$. Now I can rewrite the term $-(1-\pi_2)r$ in equation (7) as

$$-(1-\pi_2)r = 1_{\{q \neq 0\}} \cdot [\min\{q_0 - q, 0\} - (1-\pi_2^*)r].$$

Therefore the value function can be reduced to a function of q :

$$V(q, \theta) = \max\{\theta q + 1_{\{q \neq 0\}} \cdot [\min\{q_0 - q, 0\} - (1-\pi_2^*)r] - \max\{\theta - r, 0\}, 0\}. \quad (8)$$

From equation (8) we can infer the main features of a seller's screening problem. First, the most informative experiment $q = q_0$ is the most valuable for all buyers θ . Second, the indifferent buyer type $\theta = r$ has the highest value for any experiment q . Third, $V(q, \theta)$ has the single crossing property in (q, θ) , which essentially implies that the incentive compatible menu has an increasing $q(\theta)$.

From now on, I will focus on responsive menus. Lemma 1 implies the value of following both signals, $V_1(q(\theta), \theta)$, should be nonnegative. Then, with equation (8), I can derive the necessary and sufficient conditions of a responsive menu.

$$q(\theta) \in Q(\theta) = \begin{cases} \left[\frac{(1-\pi_2^*)r}{\theta}, \frac{\pi_1^*(1-r)}{1-\theta} \right] \cup \{0\} & \text{if } \theta \in [\theta_1, r] \\ \left[1 - \frac{\pi_2^*r}{\theta}, 1 - \frac{(1-\pi_1^*)(1-r)}{1-\theta} \right] \cup \{1\} & \text{if } \theta \in [r, \theta_2] \end{cases} \quad (9)$$

Now the seller's problem is choosing $q(\theta)$ for $\theta \in [\theta_1, \theta_2]$ to maximize her revenue such that all buyers are incentive compatible. Then I can apply the method of [Bergemann, Bonatti, and Smolin \(2018\)](#), where $E^* = (1, 1)$. I generalize their solution and derive the following characterizations of the optimal menu. The formal proof is left in the appendix.

Proposition 1. *Given $E^* = (\pi_1^*, \pi_2^*)$, the optimal menu includes at most two informative experiments. Let $\phi_1 = \theta f(\theta) + F(\theta)$ and $\phi_2 = (\theta - 1)f(\theta) + F(\theta)$ be the virtual values when $q \leq q_0$ and $q > q_0$ respectively. Let $\bar{\phi}_1, \bar{\phi}_2$ be the ironed virtual values. The necessary and sufficient conditions of the optimal menu $\mathcal{M} = \{(q^*(\theta), t^*(\theta))_{\theta \in [0, 1]}\}$ are:*

(i) there exists $\lambda^* > 0$ such that $q^*(\theta)$ maximizes function $H(q, \theta)$ for all θ , where

$$H(q, \theta) = \begin{cases} \bar{\phi}_1(\theta) q(\theta) - \lambda^* q(\theta) & \text{if } q \leq q_0 \\ \bar{\phi}_2(\theta) q(\theta) + q_0 f(\theta) - \lambda^* q(\theta) & \text{if } q > q_0 \end{cases}; \quad (10)$$

(ii) $q^*(\theta)$ is non-decreasing;

(iii) $\int_{\theta_1}^{\theta_2} q^*(\theta) d\theta = \theta_2 - r$;

(iv) $q^*(\theta) \in Q(\theta)$;

(v) if the ironed virtual value is constant on an interval, $q^*(\theta)$ gives the same experiment on the interval.

The payment of type θ is

$$t^*(\theta) = \theta q^*(\theta) + 1_{\{q^* \neq 0\}} \cdot [\min\{q_0 - q^*, 0\} - (1 - \pi_2^*)r] - \int_{\theta_1}^{\theta} q^*(s) ds. \quad (11)$$

Here I discuss some intuitions of the optimal menu. The cardinality of the optimal menu is from the linear property of the value function. The single crossing properties of the value function in q and θ imply that q should increase in θ . For any experiment, the value is continuous and differentiable in the intervals $[\theta_1, r]$ and $[r, \theta_2]$ separately. Then I have condition (iii) by applying the Maximal Theorem. In [Bergemann, Bonatti, and Smolin \(2018\)](#), condition (iv) is implied by conditions (ii) and (iii), but it is not the case here.

In general, the optimal menu gives $q(\theta) = 0$ for buyers with extremely pessimistic beliefs and $q(\theta) = 1$ for those with relatively optimistic beliefs. Since buyers with an extreme prior belief have low values for any experiment, they are excluded from the market. For buyers with beliefs around r , $q(\theta) = q_0$ and they get the most informative experiment. Depending on the shape of virtual values, the optimal menu may include a second informative experiment. Technically, only if the two virtual values need to be ironed does the optimal menu include two experiments. Since two sides of buyers have different preferences, the second experiment will target those buyers with larger sizes. For example, if the density function has two peaks, one around a pessimistic belief θ_A and the other around the cutoff belief r . The second experiment is (π_1, π_2^*) where $\pi_1 < \pi_1^*$. The seller downgrade the experiment E^* to attract those buyers around θ_A , who prefer more accurate good news, i.e., a higher π_2 . In the following, I restrict the attention to the case that the optimal menu only includes one product. The following proposition summarizes the sufficient conditions of a single-item optimal menu.

Corollary 1. *The optimal menu contains a single item if any of the following conditions (single-item conditions) holds:*

- (i) (one-sided distribution) *Almost all types have congruent beliefs, $F(r) \in \{0, 1\}$;*
- (ii) (regularity) *Both virtual values $\phi_1(\theta)$ and $\phi_2(\theta)$ are strictly increasing;*
- (iii) (symmetricity) *The monopoly price for experiment E^* is equal on $[\theta_1, \theta_0]$ and $[\theta_0, \theta_2]$.*

Condition (i) means that all buyers are optimistic or pessimistic. Hence, buyers have similar preferences over the experiment. Then the seller does not need to provide an extra experiment to satisfy a subgroup of buyers with different preferences. Condition (ii) is a regularity condition on the distribution functions. Density functions with one peak satisfy this condition. Condition (iii) states that if the optimistic and pessimistic buyers with binding a participation constraint have the same willingness to pay, the seller will not provide an extra experiment to attract more buyers.

We say the distribution function satisfies *single-item conditions*, if it satisfies one of the conditions in Corollary 1. In this case, I only need to determine the cutoff beliefs of buyers who are provided with experiment E^* . Notice condition (10) implies that if two ironed values have a nonempty intersection of their image, the two cutoff beliefs will make two ironed values equal, i.e., $\bar{\phi}_1(\theta_1^*) = \bar{\phi}_2(\theta_2^*)$. If no such cutoff beliefs can make the two ironed values equal, all buyers on $[\theta_1, \theta_2]$ will be served.

Corollary 2. *Suppose the distribution function satisfies the single-item conditions (ii) or (iii), if $\bar{\phi}_1([\theta_1, \theta_2]) \cap \bar{\phi}_2([\theta_1, \theta_2]) \neq \emptyset$, the seller provides E^* to buyers on $[\theta_1^*, \theta_2^*]$. The endpoints can be solved with*

$$\begin{cases} f(\theta_1^*)\theta_1^* + F(\theta_1^*) = f(\theta_2^*)(\theta_2^* - 1) + F(\theta_2^*) \\ q_0(\theta_2^* - \theta_1^*) = \theta_2^* - r \end{cases} \quad (12)$$

The price of E^* is given by $t^* = \theta_1\pi_1^*(1-r) - (1-\theta_1^*)(1-\pi_2^*)r$. The seller's revenue is $R(\pi_1^*, \pi_2^*) = t^* \cdot (\theta_2^* - \theta_1^*)$.

3.2 Optimal Investment

Once I have the distribution of buyers belief $G(\cdot)$, I can solve the cutoff beliefs of buyers served in the market, $[\theta_1^*, \theta_2^*]$, and the revenue function $R(\pi_1^*, \pi_2^*)$ with equations (12).. Together with the cost function, I can solve for the monopoly seller's optimal investment choice and the most informative experiment (π_1^*, π_2^*) . In the following, I give a closed solution when the types follow a uniform distribution and discuss the optimal investment.

When $G(\cdot)$ is a uniform distribution, on both sides of the cutoff belief r , half of the potential buyers will be served by the monopoly.

Corollary 3. *If $G(\cdot)$ is a uniform distribution on $[0, 1]$, then given any $E^* = (\pi_1^*, \pi_2^*)$, the seller provides E^* to buyers with belief $\theta \in [\frac{\theta_1+r}{2}, \frac{\theta_2+r}{2}]$.*

The price of experiment E^* is given by $t^* = \theta_1^* q_0 - (1 - \pi_2^*) r = \frac{1}{2} r (1 - r) (\pi_1^* + \pi_2^* - 1)$. Note that the value of E^* for uniformed buyer $\theta = r$ is $V(E^*, r) = r(1 - r)(\pi_1^* + \pi_2^* - 1)$, which is the highest valuation among all buyers. The price equals half of this highest valuation, which is a standard solution when the demand curve is linear. Then I can obtain the seller's total revenue:

$$R^*(\pi_1^*, \pi_2^*) = t^* \cdot \frac{1}{2}(\theta_2 - \theta_1) = \frac{(t^*)^2}{q_0(1 - q_0)} = \frac{[r(1 - r)(\pi_1^* + \pi_2^* - 1)]^2}{4q_0(1 - q_0)} \quad (13)$$

Where $q_0 = \pi_1^* + r(1 - \pi_1^* - \pi_2^*)$. Then for any cost function $C(\pi_1, \pi_2)$, I can find the optimal investment level and most informative experiment of the seller by maximizing $R^*(\pi_1^*, \pi_2^*) - C(\pi_1^*, \pi_2^*)$. Intuitively the more accurate the signals are, the higher cost it should require. One way is to assume $C(\pi_1, \pi_2)$ is a function of $(\pi_1 + \pi_2 - 1)$. In this cost function two signals are perfect substitutes in production. I can also assume it related with how far the signals deviate from an uninformative signal, $\left[(\pi_1^* - \frac{1}{2})^2 + (\pi_2^* - \frac{1}{2})^2\right] \cdot c$. In the following proposition, I give a closed-form solution for the linear cost function, while the properties hold for other meaningful cost functions.

Example 1. Given a cost function $C(\pi_1, \pi_2) = c \cdot (\pi_1 + \pi_2 - 1)$ with $c \in (0, \frac{1}{16}]$, then the optimal investment of seller is: (i) choosing $E^* = (1, 1)$ when $r \in [\frac{1}{2} - \sqrt{\frac{1}{4} - 4c}, \frac{1}{2} + \sqrt{\frac{1}{4} - 4c}]$; (ii) choosing no investment otherwise.

Under linear costs, the optimal investment exhibits a bang-bang structure: the seller either provides complete information or does not enter the market at all. The investment region is centered at $r = \frac{1}{2}$ and shrinks as cost c increases. Intuitively, the seller invests only when the buyer population is sufficiently balanced between optimists and pessimists, so that the revenue from serving both sides justifies the fixed cost.

Proposition 2. *Given a symmetric cost function such that seller does not provide complete information at $r = \frac{1}{2}$, then as r increases, π_2^* increases and π_1^* decreases. Then both decreases after some cutoff $\bar{r} > \frac{1}{2}$. If $\frac{\partial^2 C}{\partial \pi_i^2} > 0$, investment first increases then decreases.*

As r increases, the investment level first increases and then decreases. Two economic forces at work as r increases. First, the value of E^* for the least informed buyer $\theta = r$ decreases since the payoff of good states decreases. Also note $V(E^*, r) = r(1 - r)(\pi_1^* + \pi_2^* - 1)$, then the price of E^* decreases. Second, since the seller specializes in providing the experiment preferred by the pessimistic buyers, therefore among those served in the

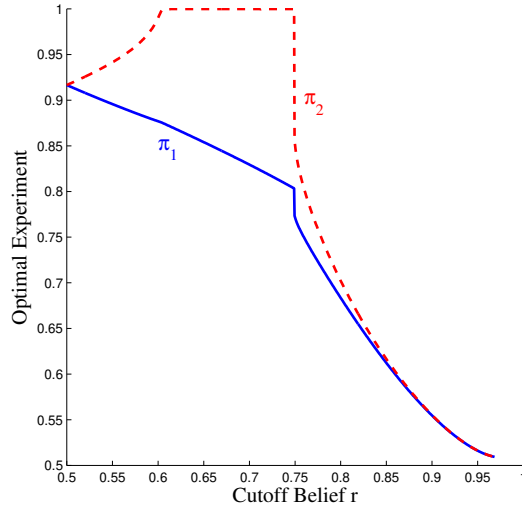


Figure 3: Optimal Experiment for Different Cutoff Belief r

Note: The solid blue line is π_1^* and the dashed red line is π_2^* . The seller always will specialize in one signal when the two sides of buyers are not evenly distributed. When $r > \frac{1}{2}$, there are more pessimistic buyers who prefer higher π_2 . Then optimal experiment is to invest more in π_2 until $\pi_2^* = 1$. As r increases from $\frac{1}{2}$, the investment level first increases since the benefit from specializing is the dominant factor. It then decreases because of the decrease in the size of potential buyers and the decrease in the value of information for all buyers. Cost function is $C(\pi_1, \pi_2) = \frac{1}{5} \left[\left(\pi_1 - \frac{1}{2} \right)^3 + \left(\pi_2 - \frac{1}{2} \right)^3 \right]$.

market, the increase in the size of pessimistic buyers is higher than the decrease in the size of optimistic buyers. Hence, the seller's market share increases. When r is not very large, the benefit from specialization dominates; hence investment increases. The seller benefits from specialization. Then the second effect, the decrease in the value of information for all buyers, becomes larger and the investment decreases. Figure (3) shows the optimal menu when I have a cubic cost function. The respective investments and profits are shown in Figure (4).

4 Duopoly Competition

Next, I analyze the case of duopoly competition. A continuum types buyers with measure 1 buys information products to improve their decision making. Two sellers compete with the investment level and the highest quality experiments they choose. There are two stages in this model. In the first stage, each seller $k \in \{1, 2\}$ chooses an investment level

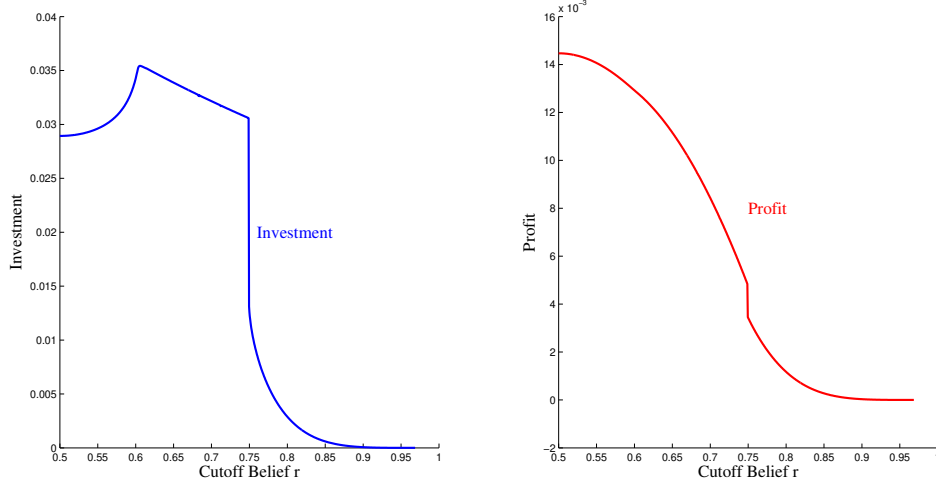


Figure 4: Monopoly Seller's Investment and Profit for Different Cutoff Belief r

Note: Buyers' types follow a uniform distribution. Here shows how the total investment and profit of the monopoly seller change as the cutoff belief r increases from $\frac{1}{2}$. Investment first increases due to the benefit from specialization and then decreases as a reason for a decrease in the value of information. However, the monopoly seller's profit decreases. It shows that the seller can extract the most consumer surplus when the distribution is symmetric on two sides of the cutoff belief.

I_k and the most informative experiment E_k . After observing two sellers' choices, buyers choose which firm to go to. In the second stage, each seller chooses a menu of experiments they provide and the prices after buyers arrive. The buyers then choose to purchase an experiment from the menu or exit the market with no additional information.

The timing is as follows:

- (i) Each seller chooses an investment I_k and the most informative experiment E_k ;
- (ii) The state ω is realized while unobserved. Buyers receive private information and type θ is realized;
- (iii) Every buyer chooses which seller to go to;
- (iv) The seller posts a menu $\mathcal{M}_k$. Each buyer chooses a product E from the menu and pay t_E ;
- (v) Every buyer observes a signal in the experiment purchased and chooses an action.

Note that I assume that each buyer can only visit one seller. Once a buyer selects a seller, he cannot buy product from the other seller. Therefore, sellers will post the revenue-

maximizing menus and charge monopoly prices in the second stage. The competition between sellers lies in their choices of investment and the highest quality experiments, which essentially determine their market share and, hence, their profits in the second stage.

Single-homing is common in information markets: credit rating subscriptions, consulting engagements, and enterprise AI contracts typically involve a primary provider, because the cost of reconciling conflicting signals across vendors exceeds the benefit. Under multi-homing, buyers could combine a high- π_1 experiment from one seller with a high- π_2 experiment from another. Yet the investment-incentive channel would persist, since each seller's market share, and hence its incentive to invest, is still diluted by competition.

Formally, Each seller first chooses investment I_k and her most informative experiment E_k . Then design a menu based on her belief about the distribution of buyers who choose to visit her. Suppose seller k holds a belief G_k about the measure of coming buyers, where $G_k(\theta) \leq G(\theta)$. The seller's strategy is $\sigma_k = (I_k, E_k, \mathcal{M}_k(I_k, E_k))$. Each buyer first selects a seller and then chooses a product from the menu. Note the strategy of selecting a seller as $K(\theta) \in \Delta\{1, 2\}$ and choosing an experiment $E(\theta, \mathcal{M}_{K(\theta)})$ from menu $\mathcal{M}_{K(\theta)}$. Then the strategy of buyer θ is $\sigma_\theta = (K(\theta), E(\theta, \mathcal{M}_{K(\theta)}))$.

Definition 1. We focus on pure strategy *Perfect Bayesian Equilibrium* $\Sigma^* = (\sigma_k^*, \sigma_\theta^*)_{k, \theta}$, which satisfies:

- (a) Given a seller's belief $G_k^*(\theta)$, the investment I_k^* and her most informative experiment E_k^* maximize her profit, the menu she provides $\mathcal{M}_k^*$ is the revenue-maximizing menu under $G_k^*(\theta)$ and E_k^* ;
- (b) Given sellers' choices of menus $\mathcal{M}_1^*$ and $\mathcal{M}_2^*$, each buyer's choice of seller $K^*(\theta)$ and his choice of experiment $E^*(\theta, \mathcal{M}_{K(\theta)})$ maximize the utility of buyer θ ;
- (c) Each seller's belief about the types of buyers visiting to her is consistent with buyers' choices, $G_k^*(\theta) = \int_0^\theta 1_{\{K(\theta)=k\}} dG(x), \forall \theta, k$.

4.1 Splitting Equilibrium

We focus on a class of equilibrium where buyers split their choices about sellers according to a common threshold. We call this type of equilibrium as *splitting equilibrium*.

The splitting structure arises from the monotonicity of buyer preferences: the further a buyer's belief is below r , the stronger his preference for high π_2 , and vice versa. If two sellers differentiate along signal dimensions, the buyer population sorts at a single threshold. The sorting is self-reinforcing, since a seller attracting mostly pessimistic buyers optimally specializes in high π_2 , which further reinforces their choice.

When the distribution of types is symmetric, there is an equilibrium where two sellers split the market. Those pessimistic buyers all go to one seller, who specializes in generating more accurate good news, i.e. higher π_2 . The optimistic buyers select the other seller who specializes in generating more accurate bad news. I can check this is indeed an equilibrium. (a) If all pessimistic buyers visit the same seller, say seller 1, she will specialize in providing experiments with a higher π_2 . (b) The cutoff buyer $\theta = r$ is indifferent with two sellers, while for any pessimistic buyer $\theta < r$, he strictly prefers the experiment provided by seller 1. (c) There is market segmentation and both sellers have correct beliefs.

Proposition 3. *Suppose the cutoff type $r = \frac{1}{2}$, the density function $g(\cdot)$ and the cost function are symmetric. There exists a Perfect Bayesian Equilibrium where $I_1^* = I_2^*$, buyers with belief $\theta \leq \frac{1}{2}$ visit seller 1 and buyers with belief $\theta > \frac{1}{2}$ visit seller 2. Both sellers provide only one informative experiment in the menu. The experiments of two sellers, $E^{*1} = (\pi_1^{*1}, \pi_2^{*1})$ and $E^{*2} = (\pi_1^{*2}, \pi_2^{*2})$, are symmetric. And I have $\pi_1^{*1} \leq \pi_1^{*2}$.*

The formal proof is in Appendix. Note that in this equilibrium each seller only serves buyers with beliefs at one side of r , i.e., either $\theta \leq r$ or $\theta \geq r$. There the one-sided condition in Corollary (1) is satisfied. As long as I have function forms of $g(\cdot)$ and $C(\pi_1, \pi_2)$, I can solve the optimal experiment provided by duopoly by applying Corollary (2).

This specialization result is consistent with patterns observed in several markets. In credit ratings, agencies differ in their emphasis on default-risk sensitivity versus creditworthiness confirmation, and split ratings across agencies are common (Becker and Milbourn, 2011). In ESG ratings, competing providers specialize along different assessment dimensions, producing cross-provider correlations of only 0.54 (Berg, Kölbel, and Rigobon, 2022). In the LLM market, no single model dominates all evaluation categories; leadership rotates across coding, reasoning, and scientific knowledge.⁸

When the cost function is linear, I have the following bang-bang solution, where sellers either provide fully informative experiments or uninformed experiments.

Example 2. Suppose the cutoff type $r = \frac{1}{2}$, $G(\cdot)$ is uniform distribution and cost function is $C(\pi_1, \pi_2) = c \cdot (\pi_1 + \pi_2 - 1)$, (i) if $c < \frac{1}{32}$, I have $E_1^* = E_2^* = (1, 1)$; (ii) if $c \geq \frac{1}{32}$, I have $E_1^* = (0, 1)$ and $E_2^* = (1, 0)$.

Compare the above equilibrium in duopoly competition with the optimal investment of monopoly case in Example 1. I can see that when the marginal cost is in a moderate

⁸Berg, Kölbel, and Rigobon (2022) contrast the ESG correlation of 0.54 with 0.99 for the more concentrated credit rating market, consistent with the model's prediction that competition induces greater signal-dimension differentiation. For LLM benchmark comparisons, see the LMSYS Chatbot Arena (<https://lmarena.ai>).

range $c \in (\frac{1}{32}, \frac{1}{16}]$, monopoly seller will make an investment and provide a partial informative experiment. However, the duopoly sellers make no investment and provide no information. To see more insights, I can work on a quadratic cost function $C(\pi_1, \pi_2) = c \cdot (\pi_1 + \pi_2 - 1)^2$ with $c \leq \frac{27}{256}$. When the marginal cost $c = \frac{1}{16}$. The monopoly seller provides experiment $(0.38, 1)$ (or $(1, 0.38)$), and the duopoly sellers provide $(0.25, 1)$ and $(1, 0.25)$ respectively.

Moreover, the splitting equilibrium exists in more general settings. Since two sides of the buyers have the opposite preferences over π_1 and π_2 . Once two sellers choose to differentiate their experiments by specialising in generating different signals, each buyer will visit the seller specializing in his favourite signal. As long as the difference in profit between the two sides buyers is not too large, the splitting equilibrium exists.

Uniqueness. Splitting equilibrium may not be unique. Consider two sellers with different investments. Suppose the high investments specializing in π_2 and low-belief buyers come to her. She can attract some high-belief buyers with moderate belief since the value of the high investment seller's product is higher, although they have the opposite preferences. Then the threshold in the splitting equilibrium is no longer the cutoff belief r . The new threshold θ^* should make the buyer with belief $\theta = \theta^*$ indifferent between buying from two sellers. I will give more detailed illustration in section 4.3.

Although the equilibrium may not be unique, I show that the above equilibrium maximizes two sellers' joint profit.

Proposition 4. *Suppose the cutoff type $r = \frac{1}{2}$, the density function $g(\cdot)$ and the cost function are symmetric. If two sellers split the market with a threshold belief θ , then the joint profit is maximized at $\theta = \frac{1}{2}$.*

Proposition 4 shows that the symmetric splitting equilibrium is not only a Nash equilibrium but also the joint-profit-maximizing arrangement among all splitting equilibria. At $\theta = \frac{1}{2}$, each seller serves an equal share of buyers and can fully exploit the gains from signal-dimension specialization. Any asymmetric split shifts the threshold away from r , forcing one seller to serve a disproportionately large and heterogeneous submarket while the other serves a smaller one; neither can specialize as efficiently, and their combined profit falls. This means that the competitive equilibrium already achieves the sellers' collectively preferred market division, leaving no scope for further coordination to improve joint profits within the class of splitting equilibria. Yet, as the next result shows, this "best possible" duopoly outcome still produces less informative experiments than monopoly.

4.2 Monopoly versus Duopoly

We are interested in the comparison between monopoly and duopoly. The following theorem is the main results that duopoly competition leads to a less informative outcome.

Theorem 1. *If the cutoff belief is $\frac{1}{2}$, the type of buyers follows a symmetric distribution, the cost function is symmetric, separable and the marginal cost is increasing, then the monopoly seller provides more informative experiments and serves more buyers than the case of the duopoly.*

Proof. Given the most informative experiment (π_1, π_2) , assume the monopoly seller's maximized revenue is $R^M(\pi_1, \pi_2)$ and the profit maximizing solution is (m, m) . Assume The duopoly seller who serves low belief buyers has revenue function $R^D(\pi_1, \pi_2)$, note as seller 1. Seller 1's profit maximizing solution is (d_1, d_2) . Seller 1 specializes in generating higher π_2 , therefore $d_1 < d_2$. So I only need to show that $d_2 < m$ when $m < 1$.

Now I consider constrained problem for seller 1, such that she has to choose $\pi_1 = \pi_2$. Then the pricing strategy of seller 1 is the same as monopoly seller for buyers with low belief $\theta < r$. Therefore I have $R^M(\pi, \pi) = 2R^D(\pi, \pi)$.

Note the separable and symmetric cost function as $C(\pi_1) + C(\pi_2)$. Then I know (m, m) maximized monopoly seller's profit $R^M(\pi_1, \pi_2) - C(\pi_1) - C(\pi_2)$. Therefore m is also the solution of the constraint maximization problem $\max_{\pi} [R^M(\pi, \pi) - 2C(\pi)]$. Thus I have

$$m \in \operatorname{argmax}_{\pi} R^M(\pi, \pi) - 2C(\pi) = 2R^D(\pi, \pi) - 2C(\pi)$$

Since $m < 1$, I have that for all $\pi > m$, $\frac{dR^D(\pi, \pi)}{d\pi} \big|_{\pi} < C'(\pi)$. The monopoly seller does not choose a higher π because of the marginal revenue is lower than the marginal cost.

On the other hand, seller 1's optimal choice (d_1, d_2) maximized $R^D(\pi_1, \pi_2) - C(\pi_1) - C(\pi_2)$. Then I have

$$C'(d_2) = \frac{\partial R^D}{\partial \pi_2}(d_1, d_2) < \frac{\partial R^D}{\partial \pi_2}(d_2, d_2) < \frac{\partial R^D}{\partial \pi_2}(d_2, d_2) + \frac{\partial R^D}{\partial \pi_1}(d_2, d_2) = \frac{dR^D(\pi, \pi)}{d\pi} \big|_{\pi=d_2}$$

The first inequality is because $\frac{\partial R^D}{\partial \pi_2}(\pi_1, \pi_2)$ is increasing in π_1 . The second inequality is due to the positive marginal revenue of π_1 . The proof of these two properties is left in appendix. Then I have $m > d_2 > d_1$. The monopoly seller provides more informative experiments than the duopoly sellers. $\square$

Therefore, competition leads to a less informative outcome. The result holds for a broad class of distributions of types and cost functions. It can be interpreted in three parts. First, the nature of the generation and production of information products has

the feature of almost zero marginal cost. Therefore from the viewpoint of maximizing social surplus, it is less efficient to have more than one unity to make investment. Second, duopoly sellers have less incentive to invest since they have less market share than the monopoly. Although duopoly sellers benefit from specialization when facing buyers with more aligned preferences. I show the benefit is not large enough to out-weight the loss in market share, compared with monopoly. Third, the distortions in the market become severe in the case of duopoly. Not only duopoly sellers provide less informative experiments, they also serves to less buyers.

Empirically, [Becker and Milbourn \(2011\)](#) document that increased competition among credit rating agencies, driven by Fitch's market-share expansion, reduced the informational content of ratings, a pattern consistent with the mechanism in Theorem 1.

Welfare Comparison. Theorem 1 establishes that monopoly provides more informative experiments. A natural question is whether this informativeness advantage translates into welfare gains. When buyers' types follow a uniform distribution, the answer is unambiguously yes: monopoly dominates duopoly in total surplus, consumer surplus, and producer surplus simultaneously.

Corollary 4. *Suppose the conditions of Theorem 1 hold and $G(\cdot)$ is a uniform distribution. Then:*

- (i) *Consumer surplus is higher under monopoly: $CS^M > CS^D$;*
- (ii) *Total welfare is higher under monopoly: $W^M > W^D$;*
- (iii) *Producer surplus is higher under monopoly: $PS^M > PS^D$.*

The proof is in the appendix. The result that monopoly generates higher *consumer* surplus is especially striking: competition reduces buyers' welfare despite potentially lowering prices, because the quality degradation is so severe. Under uniform distribution, consumer surplus equals exactly one-third of total buyer value regardless of experiment quality. Since the monopolist's higher investment generates proportionally more value, consumers are better off even though they face a monopoly price. This unambiguous welfare ranking strengthens the policy implications of Theorem 1: in information markets with the cost structure described, market concentration enhances welfare under every standard criterion.

4.3 Asymmetric Distributions

Next, I check the splitting equilibrium when the distributions on the two sides of cutoff belief r become asymmetric. I carry out the analysis by changing r with a uniform distri-

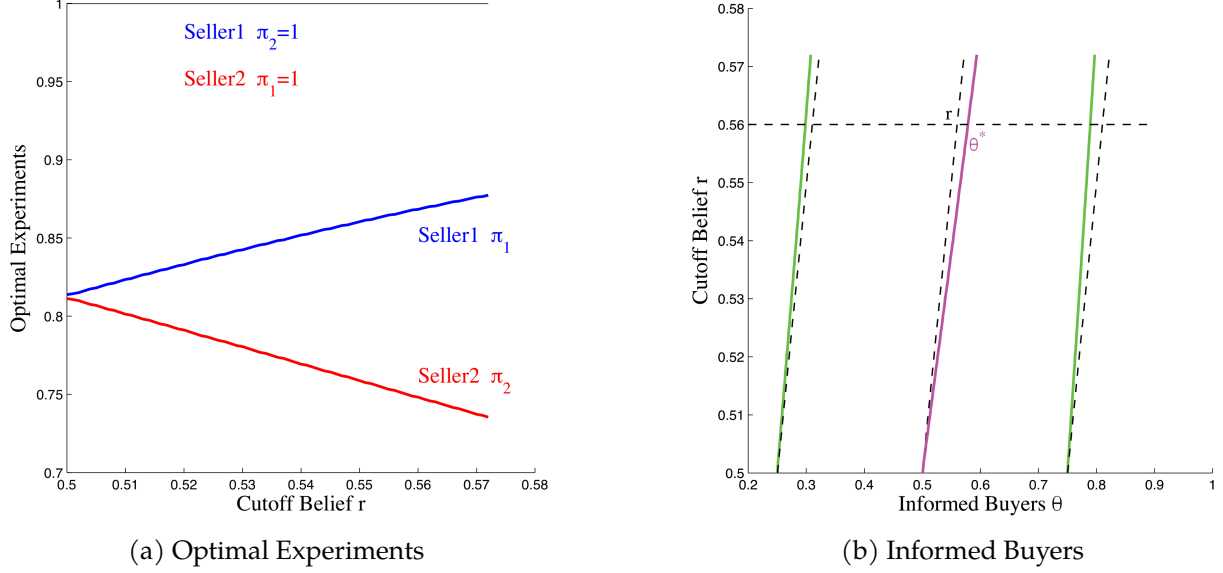


Figure 5: Oligopoly Sellers for Different Cutoff Belief r

Note: Panel (a) shows how the optimal experiments chosen by duopoly sellers change as the cutoff belief r increases from $\frac{1}{2}$. Seller 1 serves buyers with low belief. Panel (b) shows how the measure of informed buyers changes. For any given r , seller 1 serves the buyers with belief between the left green line and the purple line. Seller 2 serves the buyers with belief between the purple line and the right green line. The middle dashed line indicates $\theta = r$. The three dashed lines are parallel. Seller 1 has a larger market share as r increases. Cost function is $C(\pi_1, \pi_2) = \frac{1}{20} \left[\left(\pi_1 - \frac{1}{2} \right)^2 + \left(\pi_2 - \frac{1}{2} \right)^2 \right]$.

bution of buyers' types.

Suppose the cutoff belief r is larger than $\frac{1}{2}$. Then, the seller serves the low-belief buyers, say Seller 1, who has a higher benefit from specialization. Therefore she will increase the investment. Then, the experiment provided by Seller 1 is more attractive even for some buyers with belief $\theta > r$, while θ is near r . Then seller 1 can steal additional buyers from seller 2's market share. I show that there exists a new threshold $\theta^* > r$. Buyers splitting according to threshold θ^* is an equilibrium.

Proposition 5. *For any $r \in (0, 1)$ and $r \neq \frac{1}{2}$, buyers' types follow a uniform distribution $G(\cdot)$, cost function is symmetric. If $r > \frac{1}{2}$, there exists a splitting equilibrium with threshold $\theta^* > r$ such that buyers on the two sides of θ^* go to different sellers. The seller 1 serves buyers $\theta < \theta^*$ chooses $\pi_1^1 \leq \pi_2^1$, and the seller serves buyers $\theta > \theta^*$ chooses $\pi_1^{*2} \geq \pi_2^{*2}$. Seller 1 has a larger market share.*

Figure 5 gives an illustration of the equilibrium of duopoly as r increases from $\frac{1}{2}$. Note that the optimal experiment of monopoly is $(1, 1)$, which is more informative than duopoly

sellers. Each duopoly seller specializes in generating one perfectly informative signal. While r increases, seller 1 increases her investment. For buyers with belief θ slightly higher than r , seller 1’s experiment is more valuable. So the new threshold θ^* of splitting equilibrium lies on the right side of r .

Proposition 5 has several implications. First, even with symmetric costs and technology, the equilibrium can be asymmetric: the seller serving the larger (pessimistic) side of the market invests more, earns higher profits, and “steals” marginal buyers from the rival. This resonates with empirical patterns where the dominant information provider in a market is the one catering to the majority’s risk concern. For instance, during periods of heightened default risk in credit markets, the rating agency most trusted for downgrade accuracy gains disproportionate influence. In the LLM market, if most enterprise users are cautious about reliability (pessimistic priors), the provider that excels at flagging uncertainty attracts a larger share than its share of optimistic users alone would predict.

Second, the threshold $\theta^* > r$ means that some buyers whose beliefs favor the rival’s signal dimension nonetheless choose the dominant seller, because her higher investment makes the overall product more valuable. This implies that investment advantages compound market-share advantages, a feedback loop that can sustain persistent asymmetry across competing information providers.

5 Discussion

5.1 Testable Predictions

The model generates predictions that distinguish it from standard models of product-market competition.

1. *Concentration and information quality.* In information markets with high fixed costs and low marginal costs, greater market concentration is associated with higher information quality. The credit rating evidence of [Becker and Milbourn \(2011\)](#) supports this prediction.
2. *Signal-dimension specialization.* Competing information providers differentiate by specializing in different signal types rather than offering identical products. This can be tested by decomposing accuracy into distinct dimensions, e.g., sensitivity versus specificity in diagnostics, or performance across benchmark categories for LLMs.
3. *Buyer sorting across providers.* Buyers with different prior beliefs sort to different providers. In the LLM market, this sorting is evident: Claude captures 42% of the code-generation market among developers, while ChatGPT dominates consumer use at roughly

75% market share; in enterprise settings with regulated industries, Anthropic leads with 32% versus OpenAI’s 25%.⁹ These patterns are consistent with heterogeneous users selecting providers whose signal strengths align with their prior beliefs about reliability in specific domains.

5.2 Data Markets and Information Product Specialization

The splitting equilibrium implies that competing information sellers endogenously differentiate along signal dimensions, even when they have access to the same investment technology. This implication helps explain specialization patterns observed across several markets.

In financial data markets, catastrophe risk indices (e.g., AIR Worldwide, RMS) specialize in detecting negative shocks, corresponding to high π_2 , while growth-oriented analytics platforms specialize in identifying positive signals (earnings surprises, technology adoption), corresponding to high π_1 . In credit scoring, products designed to identify likely defaulters serve cautious lenders, while products designed to identify reliable borrowers serve lenders seeking portfolio expansion.

In medical diagnostics, the well-established distinction between ruling-in tests (high specificity) and ruling-out tests (high sensitivity) illustrates the signal-dimension tradeoff central to the model.¹⁰ Physicians with different priors about a patient’s condition prefer different test types, just as buyers in the model sort to different sellers. My framework offers a market-competition mechanism for why complementary test designs, rather than uniformly accurate ones, may coexist in equilibrium.

5.3 Statistical Errors and the Information Quality Tradeoff

The model’s signal accuracies (π_1, π_2) map directly to classical hypothesis testing: π_2 is specificity (one minus the Type I error rate) and π_1 is sensitivity/power (one minus the Type II error rate). The Neyman-Pearson framework and the ROC curve characterize the technical frontier between these two errors; my model adds to this by showing how market structure determines where on this frontier an information provider operates.

Under a monopoly, the seller invests to reduce both error types jointly. Under a duopoly, each seller specializes in reducing one error type for the buyer segment that values it most. The contribution of my framework is to connect the classical sensitivity-

⁹See Menlo Ventures, “2025 Mid-Year LLM Market Update,” 2025.

¹⁰In clinical practice, this is captured by the SpPIn criterion (Specific test, Positive result, rules In) and SnNOut criterion (Sensitive test, Negative result, rules Out); see [Boyko \(1994\)](#) for a formal analysis.

specificity tradeoff to market incentives: the same statistical constraint has different welfare consequences depending on whether information is provided by a monopolist or by competing sellers.

6 Conclusion

In this paper, I provide a framework for analyzing information provision with costly production. Buyers in the model hold heterogeneous prior beliefs and purchase statistical experiments from sellers who invest to improve accuracy. Under monopoly, a single seller serves all buyers with a jointly informative experiment. Under duopoly, sellers specialize along different signal dimensions, and buyers sort to the seller whose signal is most valuable given their prior. Equilibrium investments and profits can be asymmetric, driven by the skewed distribution of buyers' beliefs. The main finding is that, under a general class of cost functions, competition leads to a less informed outcome: aggregate information available to the market declines when a second seller enters. This result applies broadly to markets where information is costly to produce, including credit ratings, ESG assessments, financial data provision, and artificial intelligence.

The framework carries implications for competition policy and data policy in information markets. Standard antitrust reasoning presumes that entry benefits consumers, yet my analysis identifies a countervailing force: when information production requires costly investment, competition dissipates resources through specialization and duplication rather than improving overall quality. This suggests that policies promoting entry into information markets, such as encouraging additional credit rating agencies or competing AI providers, may not deliver the expected welfare gains. For data policy, the model highlights that the value of proprietary data depends on market structure: a monopolist's data feeds a comprehensive experiment, whereas competitors' data feeds partial, specialized signals. Regulations governing data access and portability should therefore account for how market structure shapes the translation of data into useful information.

Several directions for future work remain. Extending the model to N sellers would clarify how the welfare loss from competition scales with the number of entrants. Dynamic models of investment and entry could address how information quality evolves as markets mature. Finally, the model's testable predictions on specialization and buyer sorting invite empirical investigation using data from credit rating markets, AI model usage, and other information industries.

Appendix

Proof of Lemma 1:

First, I show that an experiment that has a positive value is equivalent to that it is responsive.

For any experiment E , note $U_1(\theta) = (1-r)\theta\pi_1 - r(1-\theta)(1-\pi_2)$ and $U_2(\theta) = (1-r)\theta(1-\pi_1) - r(1-\theta)\pi_2$, notice that $U_1 + U_2 = \theta(1-r) - (1-\theta)r$. Then I can rewrite equation (4) as

$$V(E, \theta) = \max\{U_1, 0\} + \max\{U_2, 0\} - \max\{U_1 + U_2, 0\}. \quad (\text{A1})$$

It's obvious that $V(E, \theta) \geq 0$. Now consider the case that $V(E, \theta) > 0$.

When $\theta \leq r$, then $U_1 + U_2 \leq 0$. Therefore $V(E, \theta) = \max\{U_1, 0\} + \max\{U_2, 0\} > 0$. That means there must be one positive value in U_1 and U_2 . Hence the other one must be negative. Since $U_2(\theta)$ is increasing in θ , then $U_2(\theta) \leq U_2(r) = r(1-r)(1-\pi_1-\pi_2) \leq 0$. Therefore $U_1 > 0$ and $U_2 < 0$.

When $\theta \geq \theta^*$, since $U_1 + U_2 \geq 0$, then $V(E, \theta) = \max\{U_1, 0\} + \max\{U_2, 0\} - U_1 + U_2$, which means there must be one negative value in U_1 and U_2 . Hence the other one must be positive. Since $U_1(\theta)$ is increasing in θ , then $U_1(\theta) \geq U_1(r) = r(1-r)(\pi_1 + \pi_2 - 1) \geq 0$. Therefore $U_1 > 0$ and $U_2 < 0$.

Therefore, all buyers will follow the recommendation actions, i.e., choose action a_1 under signal s_1 and choose action a_2 under signal s_2 .

The necessity is straightforward. If $U_1 > 0$ and $U_2 < 0$, I must have $V(E, \theta) > 0$ whenever $\theta \leq r$ or $\theta \geq r$.

Next, I show that I can focus on the responsive menu.

Without loss of generality, let type θ chooses the same action a_1 after each signal in $E(\theta) = (\pi_1(\theta), \pi_2(\theta))$. Replace $E(\theta)$ with $E_1 = (1, 0)$. Basically, we increase the probability of sending signal s_1 in both states to one. Therefore E_1 gives the same outcome distribution as $E(\theta)$ for θ . Then $V(E_1, \theta) = V(E(\theta), \theta)$. Since E_1 is a garbling of $E(\theta)$. By Blackwell's theorem, $V(E_1, \theta') \leq V(E(\theta), \theta')$ for all θ' . Therefore, the change will not affect all other types' IC constraints.

□

Proof of Lemma 2:

For any experiment $E = (\pi_1, \pi_2)$ in the optimal menu $\mathcal{M}$, if $\pi_1 < \pi_1^*$ or $\pi_2 < \pi_2^*$. Let $\delta = \min \{u_1(\pi_1^* - \pi_1), -u_2(\pi_2^* - \pi_2)\}$, and $\epsilon_1 = \frac{\delta}{u_1}$, $\epsilon_2 = \frac{\delta}{-u_2}$. Construct a new experiment E' where $\pi'_1 = \pi_1 + \epsilon_1$ and $\pi'_2 = \pi_2 + \epsilon_2$. Then $\pi'_1 \leq \pi_1^*$ and $\pi'_2 \leq \pi_2^*$, and there must be one hold with equality by construction. Furthermore $V(E', \theta) - V(E, \theta) = \theta(\pi'_1 - \pi_1)u_1 + (1 - \theta)(\pi'_2 - \pi_2)(-u_2) = \delta$ is independent of buyer's type. So the seller can replace (E, t_E) with $(E', t_E + \delta)$ without changing all buyers' constraints and increasing her revenue.

□

Proof for Proposition 1:

We generalize the approach used in the proof of Proposition 4 and 5 in [Bergemann, Bonatti, and Smolin \(2018\)](#). Basically one can think BBS as a special case when $(\pi_1^*, \pi_2^*) = (1, 1)$ and here I generalize it for any (π_1^*, π_2^*) . This proof works for non-congruent beliefs, where $F(r) \notin \{0, 1\}$. For congruent belief the solution is easier and I have it as part of the proof for Theorem 1.

Step 1. Claim that a menu is implementable and responsive if and only if: (i) $q(\theta) \in Q(\theta)$ is increasing and (ii) $\int_{\theta_1}^{\theta_2} q(\theta) = \theta_2 - r$.

Necessity.

Consider a responsive menu $\mathcal{M} = \{q(\theta), t(\theta)\}_\theta$. For any experiment $q(\theta)$, only those obedient type θ' of $q(\theta)$ have an incentive to mimic type θ . Therefore I can focus on those experiment q and types θ' such that $V(q, \theta') > 0$. For these cases we write the value of information in equation (8) as

$$V(q, \theta) = \theta q + 1_{\{q \neq 0\}} \cdot [\min \{q_0 - q, 0\} - (1 - \pi_2^*)r] - \max \{\theta - r, 0\} \quad (\text{A2})$$

Consider any two types θ^1, θ^2 with $\theta^1 < \theta^2$ and any responsive experiments q^1 for type θ^1 and q^2 for type θ^2 . Since the menu is implementable, the IC constraints implies $V(q^2, \theta^2) - t^2 \geq V(q^1, \theta^2) - t^1$ and $V(q^1, \theta^1) - t^1 \geq V(q^2, \theta^1) - t^2$. Therefore I have

$$V(q^2, \theta^2) - V(q^1, \theta^2) \geq t^2 - t^1 \geq V(q^2, \theta^1) - V(q^1, \theta^1)$$

The strict single crossing property of $V(q, \theta)$ implies that $q^2 \geq q^1$. Thus $q(\theta)$ is increasing. The value of experiment $V(q, \theta)$ is differentiable in θ on $[\theta_1, r]$ and $[r, \theta_2]$ respectively. For any q , the value of the experiment is also continuous in θ . Therefore the rent function

$V(\theta)$ of the optimal menu is also continuous by the Maximum Theorem. Then I have

$$V(r) = V(\theta_1) + \int_{\theta_1}^r V_\theta(q, \theta) d\theta = V(\theta_2) - \int_r^{\theta_2} V_\theta(q, \theta) d\theta.$$

Because the two types θ_1 and θ_2 have zero value on all experiments, I have $V(\theta_1) = V(\theta_2) = 0$. Therefore $\int_{\theta_1}^r V_\theta(q, \theta) d\theta + \int_r^{\theta_2} V_\theta(q, \theta) d\theta = 0$. Apply envelope theorem to equation (A2) and I have $\int_{\theta_1}^r q d\theta + \int_r^{\theta_2} (q - 1) d\theta = 0$. Thus I obtain:

$$\int_{\theta_1}^{\theta_2} q d\theta = \theta_2 - r.$$

Sufficiency.

If $q(\theta)$ satisfies the two conditions. Construct the following prices:

$$t(\theta) = \begin{cases} \theta q(\theta) + 1_{\{q \neq 0\}} \cdot [\min \{q_0 - q(\theta), 0\} - (1 - \pi_2^*) r] - \int_{\theta_1}^{\theta} q(x) dx & \text{if } \theta \leq r \\ \theta q(\theta) + 1_{\{q \neq 0\}} \cdot [\min \{q_0 - q(\theta), 0\} - (1 - \pi_2^*) r] + \int_{\theta}^{\theta_2} (q(x) - 1) dx - (\theta - r) & \text{if } \theta > r \end{cases} \quad (\text{A3})$$

With $\int_{\theta_1}^{\theta_2} q(\theta) = \theta_2 - r$ I can simplify the price function as

$$t(\theta) = \theta q(\theta) + 1_{\{q \neq 0\}} \cdot [\min \{q_0 - q(\theta), 0\} - (1 - \pi_2^*) r] - \int_{\theta_1}^{\theta} q(x) dx \quad \forall \theta \in [\theta_1, \theta_2]. \quad (\text{A4})$$

For any type θ , the net value from reporting θ' is

$$V(q(\theta'), \theta) - t(\theta') = q(\theta')(\theta - \theta') + \int_{\theta_1}^{\theta'} q(x) dx - \max \{\theta - r, 0\}$$

Since $q(\cdot)$ is increasing on $[\theta_1, \theta_2]$, the net value reaches its maximal at $\theta' = \theta$. Then the menu including $\{q(\theta), t(\theta)\}_\theta$ is implementable and incentive compatible.

Furthermore, Figure A1 gives an illustration of the constraints on $q(\theta)$ for responsive experiments.

Step 2. At most, two informative experiments in the optimal menu.

First I write down the seller's optimization problem formally. With the price function (A4) I can derive the seller's expected revenue

$$\int_{\theta_1}^{\theta_2} t(\theta) dF(\theta) = \int_{\theta_1}^{\theta_2} \{[\theta f(\theta) + F(\theta)] q(\theta) + 1_{\{q \neq 0\}} \cdot [\min \{q_0 - q(\theta), 0\} - (1 - \pi_2^*) r] f(\theta)\} d\theta$$

The linearity of the value of information implies that the optimal menu is a step func-

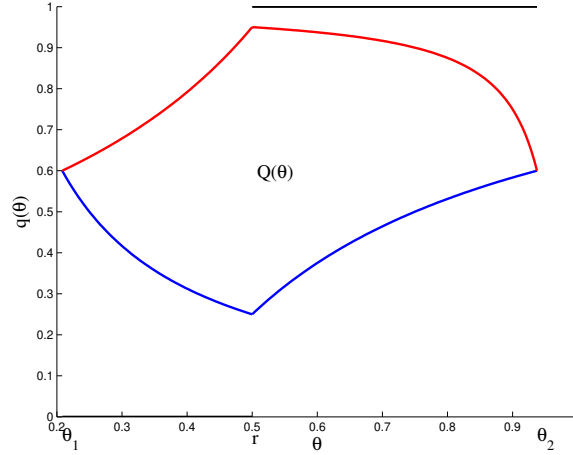


Figure A1: Constraint Set $Q(\theta)$ on Responsive Experiments
($r = 0.5$, $\pi_1^* = 0.95$, $\pi_2^* = 0.75$, which gives $\theta_1 = 0.24$, $\theta_2 = 0.93$, and $q_0 = 0.625$.)

tion. To apply the Fundamental Theorem of Linear Programming to this maximization problem, I need first discretize the buyers type into finite grids $[\theta_1, \theta + \epsilon]$, $[\theta + 2\epsilon, \theta + 3\epsilon]$, ..., $[\theta_2 - \epsilon, \theta_2]$. Then, given the fact that the optimal menu must include the most informative experiment q_0 , I can construct a linear programming problem similar to the one in Proposition 4 of BBS. Here I omit the details.

Step 3. Characterize the optimal menu.

The seller's optimization problem has an objective function concave in q . The constraints on $q(\cdot)$ is given by the two conditions in Step 1. Lagrangian method is valid. To deal with the integral constraint, I can use the method in [Toikka \(2011\)](#). Together with BBS, I can use the ironed virtual value to solve the Lagrangian problem.

□

Proof for Proposition 2:

We first give the monopoly seller's revenue function given a uniform distribution.

$$R^M(\pi_1, \pi_2, r) = \frac{r(1-r)(\pi_1 + \pi_2 - 1)}{r(1-r)(\pi_1\pi_2 + (1-\pi_1)(1-\pi_2)) + r^2\pi_2(1-\pi_2) + (1-r)^2\pi_1(1-\pi_1)}.$$

Suppose monopoly seller provide (π, π) when $r = \frac{1}{2}$. Starting from $\pi_1 = \pi_2 = \pi$, I examine the change of revenue if there is a small change of π_1 and π_2 when r is increasing from $\frac{1}{2}$. Since the cost function is symmetric, I can let $\pi_1 = \pi - \epsilon$ and $\pi_2 = \pi + \epsilon$ without changing the investment. The term $(\pi_1 + \pi_2 - 1)$ and $(\pi_1\pi_2 + (1-\pi_1)(1-\pi_2))$ do not have

a first order change. Let $K = r^2\pi_2(1 - \pi_2) + (1 - r)^2\pi_1(1 - \pi_1)$ and its change determines whether the revenue is increasing or decreasing. $\Delta K = r^2(1 - 2\pi)\epsilon - (1 - r)^2(1 - 2\pi)\epsilon = [r^2 - (1 - r)^2](1 - 2\pi)\epsilon$. If $\epsilon > 0$, I have $\Delta K < 0$. Therefore the revenue R^M is decreasing. Since I fixed the cost, then the profit is increasing. Then the monopoly seller will increase π_2 and decrease π_1 .

□

Proof for Proposition 3:

Suppose two sellers choose $I_1^* = I_2^*$ and buyers that splitting at threshold $r = \frac{1}{2}$, I show that it is buyer's best response to choose a seller according to the splitting technology. Notice that the value of information for low belief buyers ($\theta < r$) and high belief buyers ($\theta > r$) are symmetric in π_1 and π_2 . When the cost function is symmetric, suppose seller 1 chooses the most informative experiment as (π, π') , I know that $\pi < \pi'$. Since the distribution of buyers faced by seller 1 is congruent, $F_1(r) = 1$, then seller 1 only provides one item in its menu. Suppose the price is t_1 and buyer $\underline{\theta}_1$ is the lowest informed buyer from seller 1. Then $t_1 = V(\underline{\theta}_1, \pi, \pi')$. Due to symmetricity, seller 2 will provide a single item menu with price $t_2 = t_1$. Therefore for the cutoff type buyer $\theta = r$, it is indifferent from buying seller 1 and seller 2. For all other buyers, sticking to current choices is strictly better than visiting the other seller. Intuitively, because of the different preferences on two sides of the cutoff belief, the seller can specialize their investment in a way to better meet their customers' needs. Then, the buyers will split as a result. When investments are not observable, deviation is not optimal for each seller. Since $I_1^* = I_2^*$ is the optimal investment when both sellers act as a monopoly in the second stage, any deviation is not profitable.

□

Proof for Theorem 1:

Consider the duopoly seller 1 who serves buyers with belief $\theta < r = \frac{1}{2}$. Given any most informative experiment (π_1, π_2) , since the value function is strictly increasing in θ for these buyers, the seller 1 only needs to choose the buyers $\underline{\theta}$ which is the lowest type she serves. The price of the experiment is then $V(\underline{\theta}, \pi_1, \pi_2)$. Then seller 1's revenue function is

$$\begin{aligned} R^D(\pi_1, \pi_2) &= \max_{\theta} V(\theta) \cdot \left[\frac{1}{2} - G(\theta) \right] \\ &= \max_{\theta} \frac{1}{2} [\theta\pi_1 - (1 - \theta)(1 - \pi_2)] \cdot \left[\frac{1}{2} - G(\theta) \right] \end{aligned} \quad (\text{A5})$$

Apply the envelope theorem for the problem I have that $\frac{\partial R^D}{\partial \pi_2} = \frac{1}{2}(1 - \theta^*) \cdot [\frac{1}{2} - G(\theta^*)]$ and $\frac{\partial R^D}{\partial \pi_1} = \frac{1}{2}\theta^* \cdot [\frac{1}{2} - G(\theta^*)]$, where θ^* is the optimal solution. Then both $\frac{\partial R^D}{\partial \pi_2}$ and $\frac{\partial R^D}{\partial \pi_1}$ is positive, the duopoly seller's revenue is increasing in both π_1 and π_2 . To show $\frac{\partial R^D}{\partial \pi_2}$ is strictly increasing in π_1 , it is sufficient if θ^* is decreasing in π_1 , $\frac{\partial \theta^*}{\partial \pi_1} < 0$.

The first-order condition of the maximization problem is

$$(\pi_1 - \pi_2 + 1) \left[\frac{1}{2} - G(\theta^*) - g(\theta^*)\theta^* \right] = -(1 - \pi_2)g(\theta^*) \quad (\text{A6})$$

Take derivative w.r.t. π_1 , I have

$$\frac{\partial \theta^*}{\partial \pi_1} \cdot \{-g'(\theta^*)[\theta^*\pi_1 - (1 - \theta^*)(1 - \pi_2)] + 2g(\theta^*)(\pi_1 - \pi_2 + 1)\} = \frac{1}{2} - G(\theta^*) - g(\theta^*)\theta^* \quad (\text{A7})$$

From the FOC I know that $[\frac{1}{2} - G(\theta^*) - g(\theta^*)\theta^*] < 0$. Let the term on the left hand side be $LHS = -g' \cdot [\theta^*\pi_1 - (1 - \theta^*)(1 - \pi_2)] + 2g \cdot (\pi_1 - \pi_2 + 1)$, I only need to show $LHS > 0$.

Case 1, $g'(\theta^*) \geq 0$. Since $V(\theta^*) > 0$, then $\theta^*\pi_1 > (1 - \theta^*)(1 - \pi_2)$. I can rewrite LHS as

$$\begin{aligned} LHS &= \pi_1(2g - \theta^* \cdot g') + (1 - \pi_2)(g' + \theta^* \cdot g' - 2g) \\ &> (1 - \pi_2) \left[\frac{1 - \theta^*}{\theta^*} (2g - \theta^* \cdot g') + (g' + \theta^* \cdot g' - 2g) \right] \\ &= 2(1 - \pi_2) \left[\left(\frac{1}{\theta^*} - 2 \right) g + \theta^* \cdot g' \right] > 0 \end{aligned}$$

Case 2, $g'(\theta^*) < 0$. FOC gives that $(1 - \pi_2) = \frac{1}{g}(G + \theta g - \frac{1}{2})(\pi_1 - \pi_2 + 1)$. I can rewrite LHS as

$$\begin{aligned} LHS &= (\pi_1 - \pi_2 + 1)(2g - \theta^* \cdot g') + (1 - \pi_2)g' \\ &= (\pi_1 - \pi_2 + 1) \left[(2g - \theta^* \cdot g') + \frac{1}{g}(G + \theta g - \frac{1}{2}) \cdot g' \right] \\ &= \frac{1}{g}(\pi_1 - \pi_2 + 1) \left[2g^2 + \left(G - \frac{1}{2} \right) g' \right] > 0 \end{aligned}$$

Therefore I finish the proof that $\frac{\partial R^D}{\partial \pi_2}$ is strictly increasing in π_1 .

Proof for Corollary 4:

Proof. Under uniform distribution with $r = \frac{1}{2}$, the revenue of a seller serving the pessimistic submarket with experiment (π_1, π_2) at the monopoly price is $R_1^D = \frac{(\pi_1 + \pi_2 - 1)^2}{32}$, which depends on (π_1, π_2) only through the total informativeness $\sigma = \pi_1 + \pi_2 - 1$. Since

the value function is linear and the price equals half the peak value, total buyer value and consumer surplus on each side of the market take the form

$$\text{TBV}_1 = \frac{3\sigma^2}{64}, \quad \text{CS}_1 = \text{TBV}_1 - R_1^D = \frac{\sigma^2}{64}.$$

By the market-doubling identity $R^M(\pi, \pi) = 2R^D(\pi, \pi)$, these expressions scale to the full market: $\text{CS}^M = \frac{(2m-1)^2}{32}$ and $\text{CS}^D = \frac{(d_1+d_2-1)^2}{32}$. Since $2m > d_1 + d_2$ by Theorem 1, part (i) follows.

For (ii), define $W(\pi) = \frac{3(2\pi-1)^2}{32} - 2C(\pi)$. This is the total welfare when both signals have accuracy π . Monopoly welfare is $W^M = W(m)$. Duopoly welfare satisfies $W^D = \frac{3(d_1+d_2-1)^2}{32} - C(d_1) - C(d_2) \leq \frac{3(2\tilde{d}-1)^2}{32} - 2C(\tilde{d}) = W(\tilde{d})$, where $\tilde{d} = \frac{d_1+d_2}{2}$ and the inequality uses convexity of C . Since $W(\pi)$ is concave and its maximizer π^{FB} satisfies $\pi^{FB} > m > \tilde{d}$, we have $W^D \leq W(\tilde{d}) < W(m) = W^M$.

Part (iii) follows because $\text{PS} = W - \text{CS}$, and both W and CS are higher under monopoly. Alternatively, for any (π_1, π_2) , profit per seller is $\frac{\sigma^2}{32} - C(\pi_1) - C(\pi_2) \leq \frac{(2\bar{\pi}-1)^2}{32} - 2C(\bar{\pi})$ by convexity of C , where $\bar{\pi} = \frac{\pi_1+\pi_2}{2}$. The right-hand side is maximized at $\bar{\pi} = m$, so each duopoly seller's profit is bounded by the constrained maximum, which equals half of monopoly profit. $\square$

Proof for Proposition 5:

When buyers' types follow a uniform distribution. Sellers always provide a single item menu in any splitting equilibrium. When the cutoff belief r increases from $\frac{1}{2}$, I can use the argument from the proof for Proposition 2 to claim that seller 1 will increase both π_1^{*1} and π_2^{*1} . First suppose buyers still splitting according to r , then seller 1's revenue from the market when providing (π_1, π_2) is $R^1 = V(\frac{r+\theta_1}{2}, \pi_1, \pi_2) \cdot (\frac{r-\theta_1}{2})$, where θ_1 is given by Corollary 3. The function form is similar with the monopoly's revenue, so apply the same argument I can get that seller 1 will increase π_1^{*1} and π_2^{*1} . The intuition is that seller 1 has a larger market share; therefore, the investment will increase. Due to the monopoly pricing, the price increase is less than the increase in the value of the cutoff buyer. As a result, seller 1 will increase its price. On the other hand, by examining seller 2's revenue function, I can get that seller 2 will decrease both π_1^{*2} and π_2^{*2} and decrease its price. Now, the net value for the cutoff buyer from seller 1 is strictly higher than that from seller 2. Consider the buyer with type $\theta = r + \epsilon$. Although he has a different preference over two signals from low-belief buyers, the net value from Seller 1's experiment is higher than the value from Seller 2's experiment. However, due to the effect of specialization, the value function of high belief buyers for seller 1's experiment decreases faster than the value function from

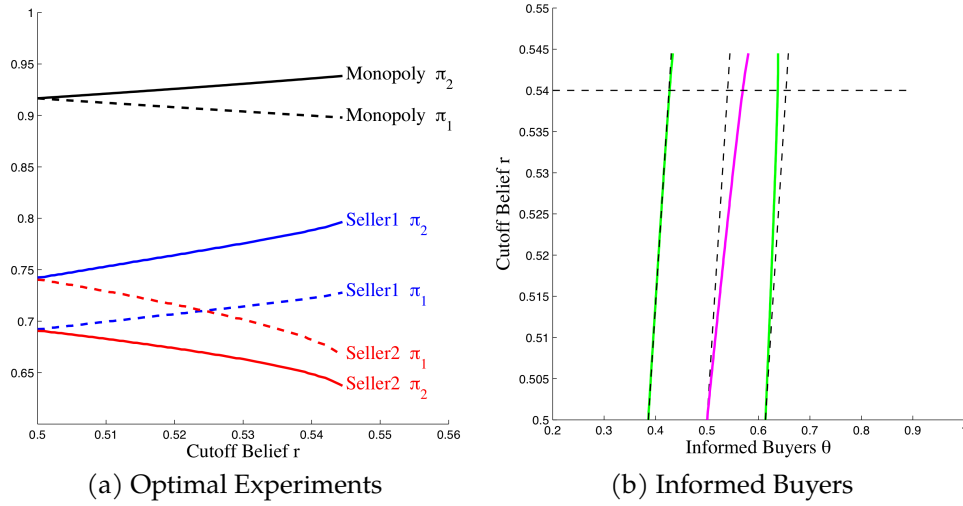


Figure A2: Duopoly Sellers for Different Cutoff Belief r

Cost function is $C(\pi_1, \pi_2) = \frac{1}{5} \left[\left(\pi_1 - \frac{1}{2} \right)^3 + \left(\pi_2 - \frac{1}{2} \right)^3 \right]$. Buyers' types follow a uniform distribution. Panel (a) shows that how the optimal experiments chosen by monopoly and duopoly sellers change as the cutoff belief r increases from $\frac{1}{2}$. Seller 1 serves buyers with low belief. Note that Seller 1 increases investment in both signals, and Seller 2 decreases investment in both signals. The optimal experiment of duopoly sellers are always less informative than that of monopoly. Panel (b) shows how the informed buyers change as the cutoff belief r increases. For any given r , seller 1 serves the buyers with belief between the left green line and the purple line. Seller 2 serves the buyers with belief between the purple line and the right green line. All other buyers get uninformative experiments.

seller 2's experiment. So by moving the threshold from r to $r + \epsilon$, we can decrease the difference of the threshold buyer's net payoff from two sellers. Then there exists a $\theta^* > r$ such that he is indifferent between two sellers.

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