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# Informed traders' performance and the information environment: Evidence from experimental asset markets

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ABSTRACT

We report the results of 18 experimental markets designed to investigate the effect of the information environment on informed traders' performance. In our experiment, traders bid to acquire costly, imperfect information on asset value and then take part in a double-auction asset market. We posit that the nature of the information environment, distinguished by the cost of information, affects traders' ability to prosper. Using the inverse relationship between cost of information and number of informed traders, we study whether traders can properly determine the value of the information under enriched and impoverished environments. In our experiment, the enriched environment includes a significant number of informed traders, whereas the impoverished environment has few informed traders. We find that traders in an impoverished environment pay too much for information and, once informed, they do not transact enough to recover the cost of information acquisition. Traders who compete for information that confers a larger information advantage are worse off than those who compete in an environment in which information is more widely available.



## 1. Introduction

Traders devote considerable resources, including time and effort, to gather and evaluate information on asset value. The decision to engage in costly information acquisition is far from simple. Traders must discern the usefulness of private information, requiring them to anticipate the actions of others and assess the extent to which asset price is informative (e.g., Diamond, 1985; Grossman & Stiglitz, 1980; Hauser, Huber, & Kaempff, 2015; Verrecchia, 1982a). Because uncertainties abound, traders face substantial difficulty gauging the expected benefit of being informed.

Experimental findings are mixed as to whether informed traders are able to recover the cost of information acquisition (e.g., Ackert, Church, & Shehata, 1997; Copeland & Friedman, 1992; Huber, Angerer, & Kirchler, 2011; Huber, Kirchler, & Sutter, 2008; Sunder, 1992; Tucker, 1997). Comparisons between studies are complicated because features vary across experimental markets. An important and unexamined feature is the nature of the information environment, representing the cost of information acquisition. According to the theory developed in Grossman and Stiglitz (1980), the higher the cost of information, the smaller the equilibrium percentage of individuals who are informed. In an efficient market, the incremental value generated from using information equals the cost of the information, so that the value of information is a decreasing function of the number of traders informed in the market. We posit that the nature of the information environment, impoverished versus enriched, has a marked effect on traders' ability to properly assess the expected benefits of private information.

When the environment is impoverished, information is costly to come by. Information acquisition is effortful and challenging and, thus, occurs infrequently. Under such conditions, traders believe that purchasing information will allow them to make sizable profits because the high cost will discourage others from information acquisition. We argue that informed traders focus excessively on self, causing them to overestimate their ability to capitalize on an informational advantage while ignoring potential difficulties in executing beneficial trades (e.g., Hales, 2009; Langer, 1975; MacDonald & Ross, 1999; Otten & van der Pligt, 1996; Weinstein,

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1980). The heightened self-focus propels them to overspend on information acquisition and, further, to be preoccupied with protecting their advantage. As a result, informed traders constrain their activity to inhibit information revelation (Caskey, Hughes, & Liu, 2015; Kyle, 1984, 1985; Rustichini, Satterthwaite, & Williams, 1994; Wang, 1998), but so much so that it negatively affects their ability to recover the high cost of information acquisition and degrades their performance.

In contrast, when the environment is enriched, information is less costly, so that many traders become informed. With more widely available information, competitive pressures make it challenging to earn informational rents (e.g., Foster & Viswanathan, 1993; Holden & Subrahmanyam, 1992). Informed traders must transact aggressively to exploit their advantage (e.g., Bloomfield & O'Hara, 1999; Tucker, 1997). Such behavior, in turn, speeds information dissemination, undercutting their advantage (Foster & Viswanathan, 1996; Rustichini et al., 1994). Therefore, in an enriched environment, informed traders are more likely to focus on the market and other traders rather than on self, resulting in more accurate estimation of their ability to use information.

We conduct 18 experimental markets to investigate the effect of the information environment on informed traders' ability to properly assess the value of the information and, in turn, their performance. In our experimental sessions, traders vie to acquire costly, imperfect information on asset value and then take part in a double-auction asset market. We vary the number of informed traders across experimental markets, representing different information environments. We refer to the environment as impoverished when markets have few informed traders and as enriched when markets have many informed traders. In an impoverished environment few traders are informed, which reflects the higher value of information and captures the feature of this information environment in which information acquisition is more demanding and costly. By comparison, in an enriched environment, the opposite holds. The nature of the information environment is important because it impacts the potential benefit of information acquisition. That is, informed traders have more (less) to gain when the environment is impoverished (enriched) (e.g., Diamond, 1985; Maffett, 2012; Naranjo, 2013; Verrecchia, 1982a; Zhang, 2001). Other studies vary the number of informed traders and endow traders exogenously with costless, private information, and, thus, they ignore the cost of private information (e.g., Ackert & Church, 1998; Ackert, Church, & Zhang, 2002; Bossaerts, Frydman, & Ledyard, 2014; Schnitzlein, 2002). This line of research begs the question of whether traders can properly evaluate the benefit of information acquisition. The issue is important because it has significant implications for the production of private information as well as regulatory calls to promote transparent disclosures, particularly in impoverished environments.

The research issue naturally lends itself to a laboratory study. With an experimental economics approach, we are able to regulate the flow and content of private information, creating different information environments; to observe the cost of information acquisition as determined endogenously, reflecting traders' readiness to expend resources; and to identify informed and uninformed traders, tracking their market activity and performance. Archival researchers have used institutional ownership to proxy for the proportion of better-informed traders (e.g., Ali, Klasa, & Li, 2008; Utama & Cready, 1997), but this proxy is comingled with relative search costs and other features of firms' information environment (e.g., the availability of pre-disclosure information and returns expectations). An important and missing feature of prior work is allowing traders to determine *endogenously* who becomes informed and what amount to spend (e.g., Libby, Bloomfield, & Nelson, 2002, p. 791). Our experimental approach allows us to assess directly whether it pays to acquire information, isolating the underlying information environment.

Our results indicate that informed traders fare poorly when the information environment is impoverished, with their performance being inferior to that of uninformed traders. We offer evidence that when the environment is impoverished, informed traders misjudge their ability to exploit an informational advantage and overspend to acquire private information. Further, they do not transact enough to recoup the cost of information acquisition, even under the naïve assumption that information is *not* disseminated. Along these lines, a stream of theoretical research suggests that information acquisition per se creates a deadweight loss (e.g., Diamond, 1985; Hirshleifer, 1971; Verrecchia, 1982b). Consistent with this research, our experimental markets provide little evidence that investment in information is welfare-improving in our environment.

Our findings have implications for the disclosure of value-relevant information. Public disclosures (mandatory or voluntary) can be particularly beneficial when the information environment is impoverished, including policy directives that promote transparent disclosures. When the environment is impoverished, information is costly to obtain, and traders' behavior can negatively affect their economic well-being if traders overspend on information. Regulatory initiatives that encourage transparent disclosures increase the availability of useful information. Such initiatives restrain traders' tendency to overspend on information acquisition, enhance information flows, and facilitate pricing and allocative efficiencies. Therefore, traders are better able to allocate scarce resources in a manner that is welfare-improving.

Our findings also have implications for the extant literature on winner's curse, which documents overspending: auction winners frequently overpay to acquire an item (e.g., Kagel & Levin, 2011; Kagel, 1995; Thaler, 1988). Charness and Levin (2009) suggest that it is important to examine how winner's curse is affected by individuals' experience and institutional variations, including how individuals behave in market settings. Our finding that traders overpay to acquire private information is analogous to winner's curse. Our results indicate overspending when one *or* two participants acquire private information. Indeed, overspending is even more pronounced in markets with two informed traders. Importantly, overspending persists over time: that is, as traders accumulate experience with the institutional setting. Our market participants appear to have difficulty assessing future prospects – *how* they will use private information to earn informational rents. Relatedly, Charness and Levin (2009, 228) assert that winner's curse arises because individuals "fail to recognize that a future contingency is relevant to their current decisions." We surmise that individuals' cognitive frailties underlie difficulties incorporating future events in decision making, which hinder performance.

In addition to examining the impact of the information environment on performance, we examine whether traders are able to undo bias relating to asset value in the information they purchase. We include a bias manipulation in our design because much previous research documents that financial analysts' 6- to 12-month ahead earnings forecasts are overly optimistic, on average (e.g., Barefield & Comiskey, 1975; O'Brien, 1988; Richardson, Teoh, & Wysocki, 2004). In one-half of our markets, traders compete to acquire information that provides an unbiased estimate of asset value, and in the other half the information is systematically biased upward. Our findings indicate few differences between bias treatments, suggesting that informed traders are able to adjust for systematic bias.

The remainder of this paper is organized as follows. In section 2, we provide a framework to assess the performance of informed traders in light of the information environment. In section 3, we describe the experimental method. In section 4, we present the

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experimental results. Lastly, we offer concluding remarks and discuss our findings.

## 2. Framework

When it comes to an information acquisition decision, traders face a daunting task. They must evaluate whether to acquire firm-specific information in light of the information environment. The cost of acquiring information regarding a firm's performance is affected by the firm's size, coverage in the business press, voluntary disclosures, and institutional holdings (e.g., Drake, Roulstone, & Thornock, 2015). Furthermore, the usefulness of firm-specific information is affected by financial reporting quality, including the readability and opacity of disclosures (e.g., Bloomfield, 2002; Bushman, Piotroski, & Smith, 2004; Maffett, 2012). We maintain that the nature of the information environment has a marked effect on traders' information search and evaluation.[1] We refer to the environment with less costly access to information as enriched, and with more costly access to information as impoverished.

In an impoverished environment, as compared to an enriched environment, it is more costly to acquire information and, further, to decipher the implications of the information for asset value (cf. Coslor, 2016). When the environment is impoverished, press releases and business news coverage are infrequent (Bushee, Core, Guay, & Hamm, 2010); regulatory filings are stark, supplying just enough information to satisfy minimum reporting requirements (Botosan, 1997; Lang & Lundholm, 1993); the quality of accounting information is low, with weak linkages to fundamental value (Bushman et al., 2004; Maffett, 2012); and disclosures are dense and opaque (Bloomfield, 2002; Li, 2008). Under such conditions, information acquisition is time consuming and costly. Since the high cost deters many traders from acquiring information, the benefit of becoming informed is potentially substantial. By contrast, when the environment is enriched, the reverse holds. If information is easy to access and understandable, informed traders are commonplace (many in number). The expected benefit associated with acquiring information is diminished, as compared to an impoverished environment. Regardless of the environment, when all traders are rational and can consistently anticipate market behavior, the cost of information equals the value of the information (Grossman & Stiglitz, 1980). With fewer informed traders, those who acquire information have more opportunity to complete profitable transactions. Thus, the value of information is a decreasing function of the number of informed traders. Since the cost of acquiring information should equal to the value of the information, in equilibrium, there are fewer informed traders in an impoverished environment, relative to an enriched environment.

Therefore, to measure individual participants' assessments of information value in different information environments, we vary the number of informed traders (one, two, and four) between experimental sessions. For markets with one or two informed traders, the environment is impoverished: a small number of participants acquire information. We include these two experimental conditions to assess the sensitivity of our results to an impoverished environment with a monopolistic advantaged trader versus two competing traders (e.g., Ackert, Church, & Zhang, 2004; Foster & Viswanathan, 1993; Holden & Subrahmanyam, 1992; Kyle, 1985). For markets with four informed traders, the information environment is enriched: a relatively large number of participants acquire information. Indeed, in our design, at least one-half of the market participants acquire information in this experimental condition. The experimental design allows us to examine the effect of the information environment on informed traders' performance, including their assessment of information value as measured by their willingness to expend resources on information acquisition as well as their trading activity. Below, we develop our research hypotheses.

### 2.1. The impact of the environment on informed traders' profit

Traders contemplate the expected benefit of acquiring private information and, if informed, the best way to execute profitable transactions. Gains from private information are realized through transactions facilitated by private information. To appropriately assess information value, traders consider how others behave in the market. This is a highly complex task, so that traders may not rationally evaluate the benefits of information acquisition. For example, Hales (2009, 231) conjectures that informed traders construct egocentrically myopic mental models of the trading environment, highlighting self and the potential benefits of private information as a means to improve economic position. In assessing future prospects, individuals dwell on self, as opposed to others, because mental representations of self are more detailed and readily accessible than representations of others (Camerer & Lovallo, 1999; Eiser, Pahl, & Prins, 2001; Higgins & Bargh, 1987). The self-focus leads to overstating own ability (Otten & van der Pligt, 1996), bringing about unrealistic optimism (Buehler, Griffin, & Ross, 1994; Langer, 1975; MacDonald & Ross, 1999; Weinstein, 1980). Excessive self-focus, in turn, causes traders to overestimate the benefits of private information. We proffer that the nature of the information environment directly affects traders' performance, as measured by net profit. When the environment is impoverished, few traders are informed, making them atypical, underscoring individuality and distinctiveness. By comparison, when the environment is enriched, many traders are informed. The informed traders are more realistic about their ability to use information to generate profit because they cannot ignore the presence of other informed traders who compete to earn informational rents.

We posit that traders in an impoverished information environment are likely to underperform because they over-estimate the profit they can earn with private information, as compared to traders in an enriched information environment. Our first hypothesis is as follows.

**H1.** *Informed traders' profit, net of information cost, is lower in an impoverished information environment, as compared to an enriched environment.*

After testing Hypothesis 1, we delve deeper into the performance of informed traders. As we detail in our discussion of the experimental results, we find that informed traders underperform. There are two possible explanations for this poor performance. First, as we posit in hypothesis 2, informed traders may fare worse in an impoverished environment because the cost of information is excessive. Second, as we posit in hypothesis 3, informed traders may not complete enough trades to recover the cost of information. Either, or a combination of both, may result in a net loss from information acquisition.

[1] The Securities and Exchange Commission (SEC) requires filing companies to provide financial information in an interactive format (e.g., XBRL), facilitating search (Hodge, Kennedy, & Maines, 2004), though market participants do not always capitalize on publicly available information. For example, SEC comment letters are useful in assessing firm value; however, such information is accessed infrequently (e.g., Dechow, Lawrence, & Ryans, 2016; Ryans, 2016). A multitude of services aggregate firm-specific information to aid information acquisition (e.g., Bloomberg and Reuters financial services, Yahoo!Finance, Google Finance, MarketWatch.com, TheStreet.com, etc.), and specialized sources supply information at a cost (e.g., financial analysts). Finally, Internet message boards facilitate information exchange (e.g., RagingBull, MotleyFool, HotCopper, and SiliconInvestor).

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### 2.2. The impact of the environment on the realized value and cost of information

Traders *should* expend resources on information acquisition up to the point that the expected benefit equals the cost. Determining the expected benefit is a difficult task. Previous studies suggest that individuals often overspend to become informed. Bricker and DeBruine (1993) provide evidence that individuals acquire private information, even when it is not beneficial to do so based on the expected returns of investment strategies. Kraemer, Noth, and Weber (2006) find that about one-half of their participants overestimate their ability to use private information, leading to non-rational information purchases (relatedly see Bloomfield & Luft, 2006). Gabaix, Laibson, Moloche, and Weinberg (2006) offer evidence that traders' cost-benefit calculations are myopic when deciding on information acquisition. Charness and Levin (2009) provide evidence that overspending occurs because individuals do not adequately take into account future events, negatively impacting their ability to prosper. For our purposes, individuals have difficulty anticipating the behavior of other traders *and* understanding how their own actions affect information dissemination. These shortcomings lead to overspending on private information.

In deciding how much to spend on information acquisition, traders envision profit-making opportunities. The allure of personal gains made by the exploitation of an informational advantage is enticing. The attractiveness is magnified to the extent that traders focus on self in assessing future prospects. Uniqueness bolsters self-focus in an impoverished information environment, encouraging traders to overspend on information. Therefore, we posit that informed traders are too optimistic about their abilities to use information to generate profit so they overspend on information acquisition, particularly when the environment is impoverished. As a result, the value realized from information use is lower than the cost incurred to acquire information. Our second hypothesis is as follows.

**H2.** *Informed traders are more likely to overspend on information acquisition in an impoverished information environment, as compared to an enriched environment.*

### 2.3. The impact of the environment on the activity of informed traders

If informed traders are to prosper, they must be able to use the information to recoup the cost of acquisition. One reason that traders overestimate the value of information is that they are too optimistic about their ability to use information to generate profit in the market. Once informed, informed traders face two conflicting incentives in deciding whether to transact (Wang, 1998, p. 323). On one hand, informed traders do not want to miss out on profit-making opportunities. On the other hand, they want to limit their activity in order to conceal private information so that the value of information is maintained. Limiting activity may not reduce profit opportunities if the profit from each of the reduced number of transactions is larger. We posit that the nature of the information environment affects the tradeoff between the two incentives.

In an impoverished environment, informed traders seek to profit from the information they acquired. They strategically trade to constrain the dissemination of private information in the market because competitive pressures are dulled with fewer informed (Kyle, 1984, 1985, 1989). Informed traders are willing to incur opportunity costs, potentially forgoing transactions, to safeguard their informational advantage. By limiting activity, they avoid the anticipated regret of losing their informational advantage (e.g., Baron & Ritov, 1994; Nicolle & Riggs, 2013; Nicolle, Fleming, Bach, Driver, & Dolan, 2011; Wong & Kwong, 2007). Constraining trade, however, potentially undercuts informed traders' ability to recover the cost of information acquisition.

When the information environment is enriched, on the other hand, competitive pressures loom large. Informed traders are acutely aware that such pressures weaken their informational advantage. Now informed traders must actively vie for informational rents (Holden & Subrahmanyam, 1992). They are more aggressive in the market and, in turn, more conspicuous (e.g., Bloomfield & O'Hara, 1999; Tucker, 1997). They must transact quickly because first movers potentially capture the bulk of informational rents. Competitive pressures, ultimately, push informed traders into a rat race to exploit their informational advantage (Foster & Viswanathan, 1996, p. 1438). They are forced to transact aggressively to avoid the anticipated regret of failing to recoup the cost of information acquisition (Nicolle & Riggs, 2013; Wong & Kwong, 2007).

In sum, we expect the information environment to impact informed traders' activity in the market. We posit that informed traders are less likely to complete sufficient transactions to recoup the cost of information acquisition when the environment is impoverished. Our third hypothesis is as follows.

**H3.** *Informed traders are less likely to transact enough to recover the cost of information acquisition in an impoverished information environment, as compared to an enriched environment.*

## 3. Experimental method

### 3.1. Overview

We conduct 18 experimental markets. Each market consists of a series of periods, and each period includes two phases. The first phase is a sealed-bid uniform-price auction, where participants compete to acquire imperfect information on asset value. The second phase is a double-auction market, where participants trade shares of an asset that pays a liquidating dividend at period end. As we discussed earlier, we manipulate the number of traders who acquire imperfect information on asset value between experimental markets. We conduct six markets with one informed trader, six markets with two informed traders, and six markets with four informed traders. Markets with one and two informed traders represent an impoverished information environment, and markets with four informed traders represent an enriched information environment.

In addition to our manipulation of the information environment, we vary the quality of private information. Previous research indicates that traders adjust their behavior for bias in information, as long as the bias is not too large (Ackert et al., 1997; Ackert, Church, & Zhang, 2008).[2] To examine whether traders in our environment adjust for bias, we systematically alter the quality of information within each set of six markets that vary the number of informed traders (i.e., one, two, and four informed). In one-half of the markets, private information is an unbiased estimate of asset value and in the other one-half it is a moderately biased estimate (a constant added to the unbiased estimate). Extensive analyses indicate very few differences between markets with unbiased and biased imperfect information. Further, statistical inferences

[2] Ackert et al. (2008) report that traders have difficulty adjusting for a large bias, which in their study is one-third of expected asset value. In contrast, as in our design, when the bias is moderate (one-fifth or less of asset value), traders are able to adjust.

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reported throughout the paper are unaffected if we control for the biasedness of the imperfect information (i.e., biasedness and interactions involving this variable are not statistically significant in any analysis). Our results indicate that traders adjust assessments of the value of information for bias, consistent with the results reported by Ackert et al. (1997) and Ackert et al. (2008). To facilitate exposition, we do not report the results of markets with unbiased versus biased information separately.

### 3.2. Participants

We recruited 139 students from a Canadian university to participate in our experimental markets. Students are third and fourth-year undergraduates, primarily in business and economics. Thirteen experimental markets include eight participants, and five include seven participants.[3] Students earn from $12.30 to $66.65 Canadian dollars, with an average of $35.81, for participating approximately 2 h.

### 3.3. Procedures

At the beginning of each session, participants receive a hard copy of the instructions and follow along as an experimenter reads the instructions aloud. Talking between participants is not permitted during the experiment, and one of the researchers as well as an experimental assistant are present in all markets to ensure that such communication does not occur.

Each market consists of 12 periods, and participants are not informed beforehand of the number of periods. During each period, participants trade certificates having a one-period life. A liquidating dividend is received for each certificate held at period end: the liquidating dividend is synonymous with asset value. Participants are instructed that the period-end dividend is determined by drawing from a discrete, bell-shaped distribution (refer to Fig. 1). The period-end dividend ranges from $300 to $2,700, in $100 increments, with a mean of $1500. The dividend draws were conducted prior to administering the experimental sessions, and the same sequence is used across markets. The use of a pre-selected sequence enhances comparability of markets conducted under similar as well as different experimental conditions. The pre-selected sequence also can be used in future research as a means to compare data from an earlier study (Cason & Friedman, 1996, p. 1310, note 4).

At the beginning of each period (phase one), participants submit a sealed bid indicating the price at which they are willing to acquire an estimate of the period-end dividend. Participants are instructed that the process of generating the estimate is unique and constant across periods. To allow them to assess the usefulness of the estimate, a history collected over 10 practice periods is provided. The history includes the estimate, period-end dividend, and the difference. We determine an estimate of asset value as follows. First, we ascertain the period-end dividend by drawing from the discrete, bell-shaped distribution described above (refer to Fig. 1). Then, we add an error term that can take values [−200, −100, 0, +100, +200], with probabilities of 0.14, 0.23, 0.26, 0.23, and 0.14, respectively. Accordingly, the estimate may be the period-end dividend or one of its four nearest neighbors.[4] The discrete distribution used to generate the error term is not disclosed to participants. Table 1 summarizes the estimate of asset value per period and the period-end dividend used in our experimental markets.

An auction determines the participant(s) acquiring the estimate of asset value and the number of auction winners varies across markets. In six markets, one participant acquires the estimate of asset value at the second-highest bid (second-price auction). In another six markets, two participants acquire the estimate at the third-highest bid (third-price auction). In the remaining six markets, four participants acquire the estimate at the fifth-highest bid (fifth-price auction). The information environment is impoverished with one or two informed traders and enriched with four informed traders. After conducting the sealed-bid uniform-price auction, the experimenter publicly announces the cost of information acquisition. Similar auction procedures (i.e., where price is set equal to the $n$+1 highest bid) have been used elsewhere (e.g., Ackert et al., 1997; Copeland & Friedman, 1992; Sunder, 1992). With this auction

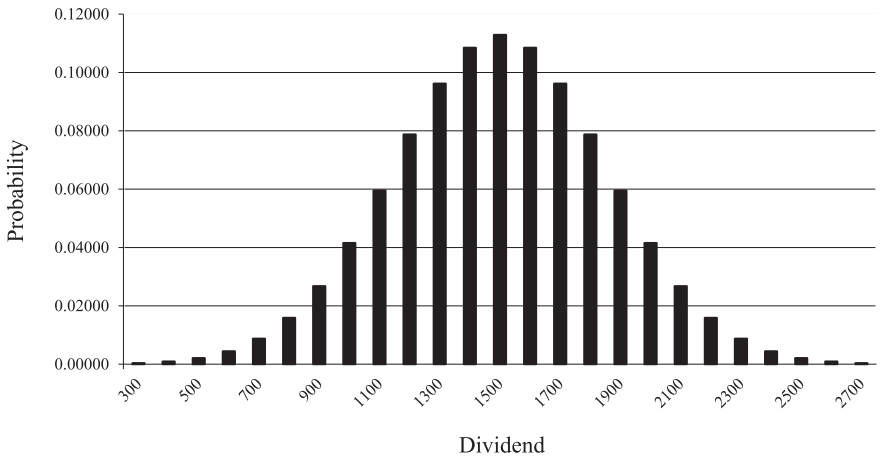


**Fig. 1. Distribution used to Determine Period-End Liquidating Dividend.**
*Notes*: The discrete distribution, depicted above, was included in the experimental materials and used to determine period-end liquidating dividend (asset value). The draws were conducted prior to administering the experimental sessions, and the same sequence was used across our experimental markets.

[3] We attempted to recruit eight participants for each market, but because of no shows, some markets include only seven participants. Of the five markets with seven participants, three include one informed trader, and two include four informed traders.

[4] The observed period-end dividend draws range from $800 to $2400. Thus, the four nearest neighbors always include two values above the dividend and two below it.

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**Table 1**
Private information and period-end liquidating dividend.

| Period | Estimate of Asset Value | Period-End Dividend |
|---|---|---|
| 1 | 1900 | 1700 |
| 2 | 1600 | 1600 |
| 3 | 800 | 1000 |
| 4 | 2400 | 2400 |
| 5 | 1100 | 1200 |
| 6 | 1600 | 1500 |
| 7 | 1000 | 1000 |
| 8 | 1900 | 1800 |
| 9 | 1400 | 1300 |
| 10 | 800 | 1000 |
| 11 | 1900 | 1900 |
| 12 | 1200 | 1300 |

*Notes:* Asset value per period takes one of 25 values, ranging from $300 to $2700 in increments of $100, with a mean of $1500. The estimate of asset value is determined based on the period-end dividend plus an error term. The error term takes values [−200, −100, 0, +100, +200], with probabilities of 0.14, 0.23, 0.26, 0.23, and 0.14, respectively.

mechanism, the dominant strategy is for individuals to reveal their true valuations, and bids are independent of risk preferences and expectations about others' bidding behavior (Davis & Holt, 1993, pp. 277–280).

Next, we conduct an experimental asset market, where participants buy and sell certificates (phase two). Each period, participants are endowed with two certificates and $50,000. Participants learn whether they have to pay a tax on their dividend earnings, but there is no tax on capital gains. The tax rate on dividend earnings is either zero or 20 percent. The instructions indicate that the tax rates differ across traders as well as periods. At the beginning of each period, three or four participants are assigned each tax rate, and across the 12 periods each participant is assigned each rate the same number of times. We introduce different tax rates to create incentives to trade. Certificates are worth more to participants with a zero tax rate on dividend earnings than those with a 20 percent tax rate. Accordingly, participants with a zero tax rate have incentives to buy certificates, and those with a 20 percent tax rate have incentives to sell. The use of different tax rates is comparable to varying traders' state-dependent dividend preferences (see Plott & Sunder, 1982, p. 665).

The asset markets are organized as oral double auctions.[5] Such markets potentially produce less noise than computerized double auctions, most notably when participants do not have prior experience with the protocol or mechanics of the market organization. Williams (1980) provides evidence that, with inexperienced participants, computerized double auctions produce greater variability in transaction prices, which slows convergence to the equilibrium price, as compared to oral double auctions. Because imperfect information is already noisy, we choose to use an oral double auction in an attempt to minimize other noise associated with the market organization.[6]

Each period, traders are free to make verbal offers to buy or sell one certificate at a designated price, and all offers are publicly announced and recorded. Outstanding offers stand until accepted or replaced by a better bid or ask price, and we do not allow short sales. Each market period lasts 4 min. At period end, participants are asked to record a prediction of the liquidating dividend, which may shed light on information transmission and participants' ability to generate trading profit (e.g., Chewning, Coller, & Tuttle, 2004). Subsequently, the dividend is announced, and the same dividend is received for all certificates held by a participant.

Period-end cash balances are computed as follows. The number of certificates on hand is multiplied by the dividend per certificate to determine dividend earnings. This amount is converted to an after-tax figure by multiplying by one minus the tax rate. Participants add the after-tax dividend earnings to their cash balance and then subtract the initial endowment of $50,000. The net amount represents participants' experimental earnings for the period.[7] Endowments are reinitialized at the beginning of the next period. At the end of 12 periods, participants complete a post-experiment questionnaire, which elicits demographic information.

## 4. Results

Experimental participants make decisions over 12 periods that affect their profitability, including deciding how much to spend on private information, posting offers to buy and sell certificates, and transacting certificates. In all analyses reported below, we omit periods 1–3. We do so because, in the initial periods, trader behavior and market outcomes sometimes are irregular and extreme.[8] The first three periods provide a basis for participants to familiarize themselves with the procedures and the mechanics of our experimental markets. Detailed analyses and results are presented below to test our hypotheses.

### 4.1. Informed traders' profit

Our first hypothesis posits that informed traders' profit, net of information cost, is less when the information environment is impoverished than when it is enriched. Panel A of Fig. 2 presents informed traders' net profit normalized by the dividend on a period-by-period basis averaged across markets under the same experimental treatment. We normalize net profit because traders' profits, collectively, are increasing in the period-end dividend, which varies from period to period. The data suggest that after period 4, informed traders generally earn less profit in an impoverished environment as compared to an enriched environment. Notice that we observe much smaller differences between conditions for uninformed traders, as Panel B of Fig. 2 suggests. We also present informed and uninformed traders' profit on a period-by-period basis in Panel C of Fig. 2. In this figure, we average the uninformed traders' profit across all markets and experimental conditions and separate the profits for informed traders by information condition, i.e., impoverished and enriched condition. We observe that informed traders in the impoverished condition perform very differently from other traders.

To provide further insight into trader profit across conditions simple averages of normalized net profit by market are reported in Panel A of Table 2. Consistent with the pattern illustrated in Fig. 2,

[5] Although oral auction markets are being replaced by computerized trading, open-outcry markets can still be found, such as those at the Chicago Board of Trade. For example, Polansek (2013) reports that through June of 2013, open-outcry trading comprised 59 percent of corn options volume, representing 7,008,644 options contracts. The London Metal Exchange also recently decided to keep its open-outcry trading floor (Rice, 2014; "Lords of the Ring," 2016). In addition, while the trading pits at the New York Mercantile Exchange have gone silent, the *Wall Street Journal* recently reported that the Chicago Mercantile Exchange plans to retain open-outcry trading for its very popular financial contracts (Osipovich, 2016/2017).

[6] DeJong, Forsythe, Lundholm, and Watts (1992) report that computerized and oral double-auction markets result in similar prices and allocations; however, trading volume is higher in computerized markets.

[7] At the conclusion of the session, participants' experimental earnings, cumulated over 12 periods, are multiplied by 0.001 to determine their cash payment.

[8] In some markets, the cost of information acquisition is markedly higher in periods 1–3 than in the remaining periods (e.g., two or more times higher). Likewise, several transaction prices are excessive in periods 1–3 (e.g., more than three standard deviations from the mean).

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profit for informed traders is typically lower in markets with an impoverished information environment. However, the profit of uniformed traders does not seem to vary much across information treatments.

To formally test H1, we perform the basic ANOVA. The dependent variable is informed traders' average profit per period for the six experiment markets within each treatment, net of information cost, normalized by the period-end dividend ($\pi^I$). Informed traders' average net profit is the normalized net profit for the informed per period for each session, averaged across periods 4–12. In Panel B of Table 2 the independent variable is the number of informed traders per market, $N^I$, which takes the values one, two, or four. Panel C reports the results of a similar analysis in which the independent variable, *Impoverished*, is an indicator variable taking the value of 1 if the information environment is impoverished and 0 otherwise.

The results in Panel B of Table 2 show that $N^I$ is statistically significant at $p = 0.017$ indicating that the number of informed traders has a significant impact on informed traders' net profit. Similarly, the results presented in Panel C of Table 2 indicate that the information condition has a significant effect on the ability of informed traders to prosper. In this ANOVA the independent variable, *Impoversished*, is significant at $p = 0.033$. The results presented in Table 2 provide support for Hypothesis 1, suggesting that the net profit of informed traders differs across information environments.

We perform additional analysis to further assess H1 (results not tabulated). First, as a robustness test, we perform a linear mixed-model analysis using maximum likelihood estimation (see Greene, 1997, Ch. 14). The approach expands the general linear model by allowing the data to exhibit correlated and non-constant variability. The dependent variable is informed traders' average profit per period, net of information cost, normalized by the period-end dividend ($\pi^I$). We find that informed traders earn less in an impoverished environment than an enriched environment, as predicted by H1. Notably, when the environment is impoverished, informed traders generate less profit in markets with two as opposed to one informed trader. This result likely occurs because, in markets with two informed traders, advantaged traders must compete with one another to exploit their informational advantage.

To provide additional insight into the robustness of our findings, we consider the possibility that the characteristics of informed traders differ in an impoverished versus enriched environment, which potentially could inflate the cost of information acquisition, degrading their performance. If so, our findings might be attributable to informed traders' characteristics rather than the information environment per se. To address this issue, we compute an alternative measure of informed traders' profit. We determine informed traders' average gross profit per period and then subtract the *median sealed bid* to acquire private information. The median bid represents the central tendency of traders' willingness to expend resources on information acquisition. As long as traders are randomly distributed across our markets, the median bid provides a measure that is independent of traders' characteristics. We repeat the preceding analysis, subtracting the median sealed bid per period to compute an alternative dependent variable. Specifically, we determine informed traders' gross profit on a period-by-period basis, subtract the median sealed bid, and then take the average per period, normalizing by the period-end dividend (denoted $\pi^{I^*}$). The results (not tabulated) are very similar to those reported previously. Most notably, $N^I$ is statistically significant at $p < 0.001$ ($F = 20.52$). The estimated marginal mean profits are 1.50, 1.22, and 1.71 in markets with one, two, and four informed traders, respectively, which are significantly different from one another at $p \leq 0.025$. The results provide compelling evidence that the information environment, rather than individuals' characteristics, affects informed traders' performance. We find that informed traders do worse in an impoverished environment than an enriched environment, consistent with H1.

Finally, we repeat the analyses described above using uninformed traders' average normalized profit per period as the dependent variable (denoted $\pi^U$). Notably, $N^I$ is not significant ($p = 0.971$). The performance of uninformed traders does not vary significantly across information environments.

In sum, the information environment affects informed traders' profit, but not uninformed traders' profit. We find that informed traders are *worse off* when the environment is impoverished as compared to enriched, as predicted by H1. As we discussed above, there are two possible explanations for the observed poor performance. Informed traders may fare worse in an impoverished environment because the cost of information is excessive or because they do not complete enough trades to recover the cost of information, or both.

### 4.2. Realized value and cost of information

Our second hypothesis posits that informed traders are more likely to overspend on information when the information environment is impoverished than when it is enriched. We begin by compiling descriptive evidence of the cost of information acquisition on a period-by-period basis, averaged across markets in the same experimental condition. As shown in Panel A of Fig. 3, the average cost is noticeably higher in markets with an impoverished environment than an enriched environment: the differences often are in the neighborhood of three to six times higher. The cost pattern suggests that private information is more valuable when the environment is impoverished as compared to enriched. Nonetheless, the magnitude of the differences are striking, let alone the sheer amount expended when the environment is impoverished. The mean cost of information acquisition over periods 4–12 is 1,122, 1,276, and 256 in markets with one, two, and four informed traders, respectively. Traders expend substantially more on information acquisition when the environment is impoverished as compared to enriched.

We also compute the median sealed bid to acquire private information on a period-by-period basis. The median bid provides insight into whether the information environment in itself affects traders' propensity to devote resources to information acquisition: that is, the degree to which market participants, as a whole, value private information. Panel B of Fig. 3 depicts the median bid per period averaged across markets in the same experimental condition. As shown, the median bid is consistently higher when the environment is impoverished as compared to enriched. Controlling for period and including periods 4–12, the estimated marginal means are 799, 1,057, and 278 in markets with one, two, and four informed traders, respectively. Pairwise comparisons indicate that the median bid is significantly higher in markets with one or two informed traders than in markets with four informed traders, $p < 0.001$.

Panel A of Table 3 presents the average normalized profit of informed and uninformed traders across the two information environments. On average, informed traders make higher gross profits and lower net profits than the uninformed. To formally test H2, we perform an ANOVA on the impact of acquiring information on the net profit of the informed traders using the uninformed traders as a reference, but first we present the ANOVA for normalized gross profit in Panel B of Table 3. The variable *Informed*, which equals 1 if a trader is informed and zero otherwise, is statistically significant at $p < 0.01$, suggesting that traders who acquire information earn statistically higher gross profits. The variable *Impoverished*, which equals 1 if the information environment is impoverished and zero otherwise, is not statistically significant. However, the interaction of *Informed* and *Impoverished* is

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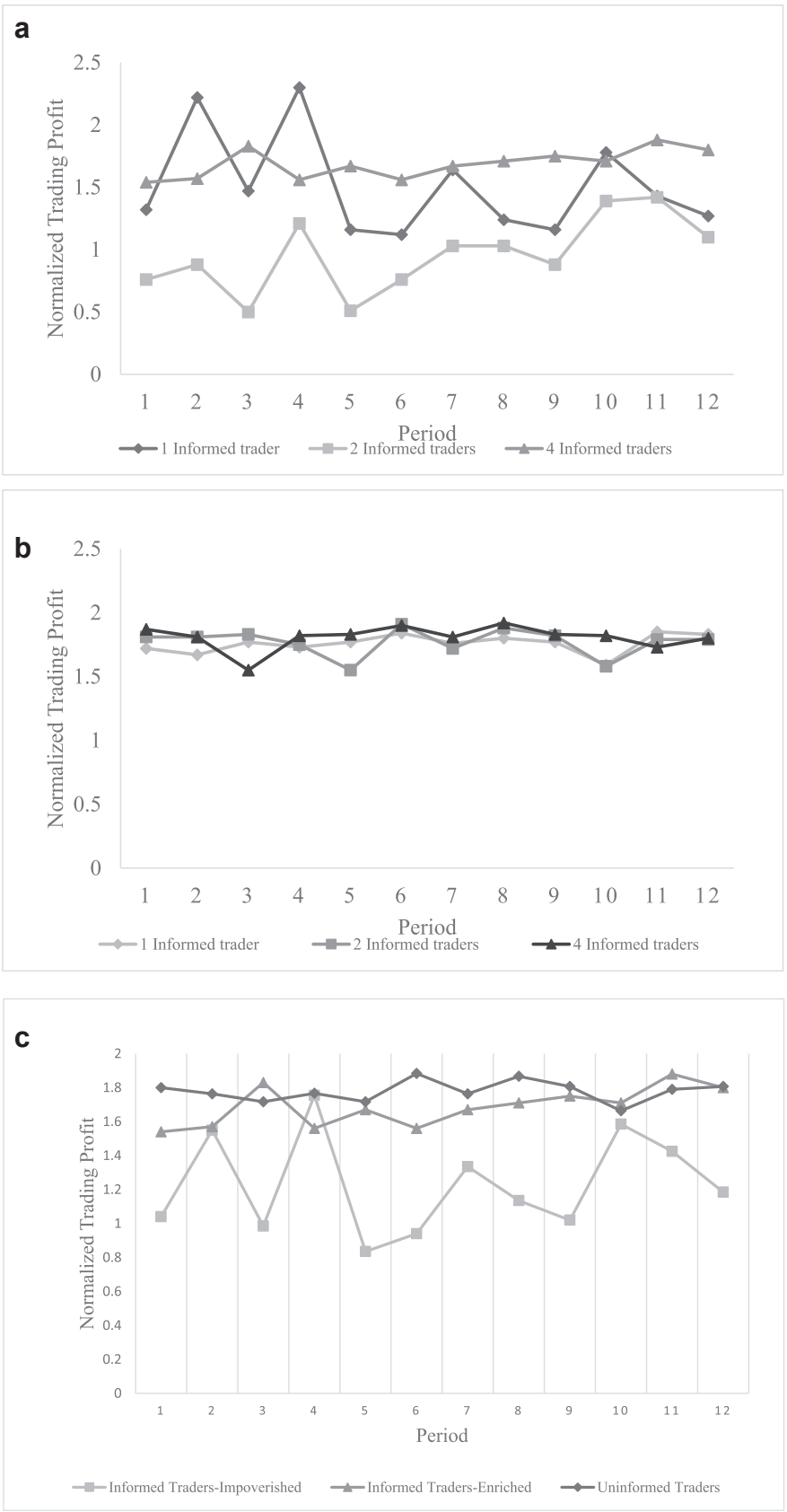


**Fig. 2. Traders' Profit**.
Panel A: Informed Traders' Normalized Net Profit.
Panel B: Uninformed Traders' Normalized Net Profit.
Panel C: Informed and Uninformed Traders' Normalized Net Profit.

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**Table 2**
Tests of informed traders' profit across information environments.

Panel A: Average Normalized Net Profit by Session

| Number of Informed Traders ($N^I$) | Market | Net Profit | |
|---|---|---|---|
| | | Informed | Uninformed |
| 1 | 1 | 1.588 | 1.766 |
| | 2 | 1.036 | 1.798 |
| | 3 | 1.641 | 1.739 |
| | 4 | 1.840 | 1.794 |
| | 5 | 0.839 | 1.760 |
| | 6 | 1.813 | 1.788 |
| 2 | 7 | 0.434 | 1.682 |
| | 8 | 1.741 | 1.812 |
| | 9 | 0.857 | 1.759 |
| | 10 | 1.299 | 1.735 |
| | 11 | 0.898 | 1.808 |
| | 12 | 0.941 | 1.738 |
| 4 | 13 | 1.908 | 1.854 |
| | 14 | 1.724 | 1.749 |
| | 15 | 1.604 | 1.929 |
| | 16 | 1.675 | 1.841 |
| | 17 | 1.606 | 1.816 |
| | 18 | 1.697 | 1.831 |

Panel B: Impact of the Number of Informed on the Profit of Informed Traders

| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
|---|---|---|---|---|---|
| | | 18 | 0.359 | 0.420 | 0.342 |
| | | *df* | *MS* | *F-statistic* | *P-value* |
| Model | 1.398 | 2 | 0.699 | 5.42 | 0.017 |
| $N^I$ | 1.398 | 2 | 0.699 | 5.42 | 0.017 |
| Residua | 1.932 | 15 | 0.129 | | |
| Total | 3.330 | 17 | 0.196 | | |

Panel C: Impact of Information Environment on the Profit of Informed Traders

| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
|---|---|---|---|---|---|
| | | 18 | 0.394 | 0.253 | 0.207 |
| | | df | MS | F-statistic | P-value |
| Model | 0.844 | 1 | 0.844 | 5.45 | 0.033 |
| Impoverished | 0.844 | 1 | 0.844 | 5.43 | 0.033 |
| Residual | 2.486 | 16 | 0.155 | | |
| Total | 3.330 | 17 | 0.196 | | |

Notes: Panel A reports the average normalized net profit for informed and uninformed traders for each session, averaged across periods 4–12. Panels B and C of the table show the results of ANOVAs where the dependent variable is the mean profit in each session, excluding the first three trading periods. In Panel B the independent variable is $N^I$, a variable indicating the number of informed traders (1, 2, or 4). In Panel C the independent variable is *Impoverished*, an indicator variable taking the value of 1 if the information environment is impoverished (1 or 2 traders informed) and 0 otherwise.

statistically significant at $p = 0.0132$, suggesting that the impact of information acquisition on gross profit differs across the two information environments, which is consistent with the theoretical prediction that the value of information is higher when fewer traders are informed.

The ANOVA results for normalized net profit are presented in Panel C of Table 3. Information acquisition, as reflected in the variable *Informed*, is statistically significant at $p < 0.01$, suggesting that informed traders are worse off than those who do not acquire information. As Panel A of Table 3 shows, the net profit of the informed is lower than that of the uniformed. The ANOVA results indicate that the incremental profit generated by an information advantage is significantly lower than the cost of acquiring the information. Further, the interaction of *Informed* and *Impoverished* is significant at $p = 0.06$, suggesting that the total detrimental effect of information acquisition on net profit is higher in the impoverished environment. These results suggest that informed traders spend more on information than the value of the information, especially in the impoverished environment.

We perform additional analysis to further assess H2 (results not tabulated). First, as a robustness test, we compare informed traders' net profit to that of uninformed traders, $\pi^I - \pi^U$. The estimated marginal means are −0.227, −0.364, and −0.037 in markets with one, two, and four informed traders, respectively, and the means are significantly different from one another, $p < 0.015$. Similar to our earlier finding, informed traders fare worse in markets with two as opposed to one informed trader. Importantly, informed traders' performance is weakened when the environment is impoverished as compared to enriched, lending support for H2.

As a final check, we compare informed traders' net profit to that of doing nothing – neither acquiring private information nor transacting. Participants are endowed with two certificates every period, so they are able to generate dividend earnings by participating passively. We start by computing the profit that accrues from doing nothing. We multiply the period-end dividend by two certificates and then take 80 percent of the product (denoted $\pi^O$). Recall that each period approximately one-half of market participants have a tax rate of 20 percent on dividend earnings. Hence, 80 percent represents an after-tax value. By including the 20 percent tax rate, the comparative basis is lowered, providing a more conservative test of overspending. Subsequently, we determine the difference between $\pi^I$ and $\pi^O$. The estimated marginal means are −0.169, −0.340, and 0.090 in markets with one, two, and four informed traders, respectively, and the means are significantly different from one another, $p < 0.01$. The findings point toward overspending in markets with an impoverished environment and are consistent with H2.

### 4.3. Informed traders' activity

Our third hypothesis posits that informed traders are less likely to complete a sufficient number of transactions to recover the cost of information when the information environment is impoverished than when it is enriched. The results described previously suggest that informed traders do not perform as well as uninformed traders, so that informed traders may pay too much for information *or* fail to realize the value of the information by conducting profitable transactions, or both. Theoretically, there is a limit on the potential incremental profit information can bring to the information holder in a given market condition. If the cost of information is higher than the potential incremental profit brought by the information, the information is over-priced. If the realized profit is lower than the potential incremental profit associated with information acquisition, informed traders do not use the information effectively in conducting transactions. Since the maximum potential incremental profit the information can bring to the information holder would be contingent on the behavior of other market participants *and* the extent of information dissemination, an unequivocal benchmark is not evident.

*Notes*: Panel A depicts informed traders' normalized profit, net of information cost, per period averaged across markets under the same experimental treatment. Panel B depicts uninformed traders' normalized profit per period averaged across markets under the same experimental treatment. Panel C depicts net profit per period averaged for informed traders in the impoverished environment, informed traders in the enriched environment, and uninformed traders across both environments. Profit each period is normalized by the dividend for the period.

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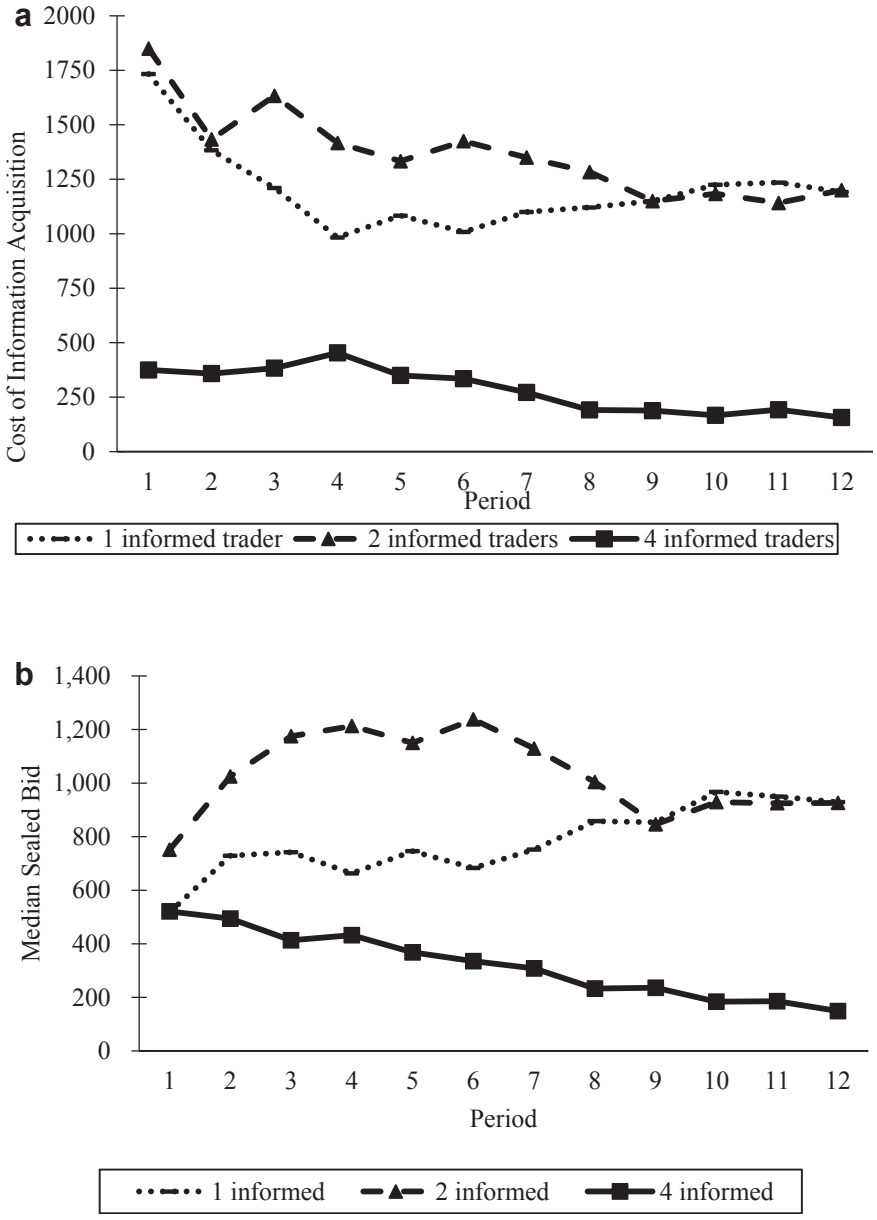


**Fig. 3. Information Cost**.
Panel A: Cost of Private Information.
Panel B: Median Bid to Acquire Private Information.
*Notes*: Panel A depicts the cost of information acquisition per period averaged across markets in the same experimental treatment. Panel B depicts the median bid per period averaged across markets in the same experimental treatment.

To provide insight into the behavior of traders, we examine whether the informed engage in sufficient transactions to cover the cost of information assuming that information is not disseminated in the market. By including observed activity, we are able to assess whether informed traders transact enough to recoup the information cost. Further, by assuming that private information is not disseminated, we allow traders to capture rents that fully exploit their informational advantage. The expected profit of one transaction with an informational advantage is determined as follows, assuming no information dissemination:

$$E(\pi) = \sum_{D>1{,}500} [(Di - \mu)*(1-\tau)*\rho i] + \sum_{D<1{,}500} [(\mu - Di)*\rho i], \quad (1)$$

where $\mu$ is the mean asset value or naïve expectation ($1500), $D_i$ represents the period-end dividend, $\rho_i$ represents the probabilities corresponding to $D_i$, and $\tau$ is the tax rate on dividend earnings (0 or 20 percent). We assume risk neutrality and that informed traders buy (sell) certificates when the unbiased estimate of asset value is above (below) the mean value. We assume that informed traders are able to transact at the naïve expectation, generating informational rents. Briefly, the first term in (1) represents the expected profit of buying one certificate, and the second term represents the expected profit of selling one certificate. Substituting in the experimental parameters, we find that $E(\pi)$ is $280 for traders with a zero tax rate and $252 for traders with a 20 percent tax rate. We use $280 in our tests because it is more conservative: that is, by increasing the expected profit per transaction, it works against a

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**Table 3**
Tests of overspending.

| Panel A: Average Normalized Net Profit for Informed and Uninformed by Condition | | | | |
|---|---|---|---|---|
| Normalized Profit | Impoverished | | Enriched | |
| | Informed | Uninformed | Informed | Uninformed |
| Gross | 2.115 | 1.765 | 1.885 | 1.837 |
| Net | 1.243 | | 1.702 | |

| Panel B: Impact of the Information Acquisition on Gross Profit | | | | | |
|---|---|---|---|---|---|
| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
| | | 36 | 0.163 | 0.483 | 0.435 |
| | | df | MS | F-statistic | P-value |
| Model | 0.794 | 3 | 0.265 | 9.97 | 0.0001 |
| Informed | 0.318 | 1 | 0.318 | 11.97 | 0.0016 |
| Impoverished | 0.050 | 1 | 0.050 | 1.88 | 0.1798 |
| Informed x Impoverished | 0.183 | 1 | 0.183 | 6.89 | 0.0132 |
| Residual | 0.850 | 32 | 0.027 | | |
| Total | 1.643 | 35 | 0.047 | | |

| Panel C: Impact of the Information Acquisition on Net Profit | | | | | |
|---|---|---|---|---|---|
| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
| | | 36 | 0.281 | 0.472 | 0.423 |
| | | df | MS | F-statistic | P-value |
| Model | 2.252 | 3 | 0.751 | 9.54 | 0.0001 |
| Informed | 0.861 | 1 | 0.861 | 10.95 | 0.0023 |
| Impoverished | 0.565 | 1 | 0.564 | 7.18 | 0.0116 |
| Informed x Impoverished | 0.300 | 1 | 0.300 | 3.81 | 0.0599 |
| Residual | 2.518 | 32 | 0.079 | | |
| Tota | 4.770 | 35 | 0.136 | | |

Notes: Panel A reports the average normalized gross and net profit for informed and uninformed traders for each information condition, averaged across periods 4–12. Panel B (C) of the table shows the results of an ANOVA where the dependent variable is the normalized gross (net) profit in each session, excluding the first three trading periods. In Panels B and C the independent variables include *Informed*, an indicator variable taking the value of 1 if informed and 0 otherwise, *Impoverished*, an indicator variable taking the value of 1 if the information environment is impoverished (1 or 2 traders informed) and 0 otherwise, and an interaction term.

finding that informed traders' activity is unnecessarily constrained, barring the recovery of cost.

We compute the hypothetical profit, or baseline profit, by multiplying $280 and the average number of transactions per informed trader. To compute the average, we sum the total number of informed transactions per period and then divide by the number of informed traders.[9] For each market, we compute an average per period, including periods 4–12. For each period, we compare the baseline profit per period to the observed cost of information acquisition. For each experimental condition, we perform a paired *t*-test to determine whether informed traders' baseline profit differs from the cost of information acquisition. As long as the baseline profit is greater than the cost of information acquisition, informed traders have an opportunity to flourish. If the relationship reverses, though, they are doomed.

The results, summarized in Table 4, indicate that when the environment is impoverished, the baseline profit falls below the cost of information acquisition, $p < 0.01$. By comparison, when the environment is enriched, the baseline profit exceeds the cost of information acquisition, $p < 0.01$. The results provide evidence that, when the environment is impoverished, informed traders' do not transact enough to thrive, even under the naïve assumption that private information is not disseminated.[10] The findings are consistent with H3.

We repeat the analysis using a second measure of informed traders' activity. Instead of taking the average number of transactions per trader, we use the total number of transactions that involve an informed trader and re-compute baseline profit.[11] We consider whether total activity would be sufficient to recoup the cost of private information if it was concentrated in the hands of one informed trader. The results, shown parenthetically in Table 4, are similar to those above, although statistical significance is weakened in markets with two informed traders, $p = 0.086$. Notwithstanding, the findings provide additional evidence that informed traders do not engage in enough transactions to prosper when the environment is impoverished and offer further support of H3.

We maintain that informed traders do not engage sufficient transactions when the environment is impoverished, as compared to enriched, because they are more concerned about protecting their informational advantage. An alternative explanation, however, is that informed traders are less able to execute transactions

[9] A transaction is counted twice if both sides of the transaction involve an informed trader: that is, when an informed trader is the buyer as well as the seller.

[10] We also perform a mixed-model analysis, where the dependent variable is the difference between informed traders' baseline profit and the cost of information acquisition normalized by the period-end dividend. Inferences are unaffected. Most notably, $N^I$ is statistically significant at $p < 0.001$ ($F = 46.34$). The estimated marginal means are −0.429, −0.481, and 0.080 in markets with one, two, and four informed traders, respectively. The means in markets with an impoverished environment are significantly different from that in markets with an enriched environment, $p < 0.001$.

[11] For this measure, a transaction can only be counted once. An informed trader can be on one side of the transaction, as a buyer *or* seller, or on both sides of the transaction, as a buyer *and* seller. In markets with one informed trader, though, this measure is the same as the average measure – because in this case the informed trader can only be on one side of the transaction.

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**Table 4**
Tests of informed traders' activity.

| Number of Informed Traders ($N^I$) | Informed Traders' Activity | Baseline Profit | Information Cost | Difference | t-statistic |
|---|---|---|---|---|---|
| One | 2.00 | 550 | 1122 | −572 | $-6.35^{***}$ $(-6.35)^{***}$ |
| | (2.00) | (550) | | (−572) | |
| Two | 2.12 | 594 | 1276 | −682 | $-9.50^{***}$ |
| | (3.93) | (1099) | | (−177) | $(-1.75)^{*}$ |
| Four | 1.38 | 379 | 256 | 122 | $3.77^{***}$ |
| | (4.15) | (1141) | | (885) | $(12.04)^{***}$ |

*Notes*: The second, third, and fourth columns in the table include averages across six markets in the same experimental treatment, including periods 4–12. The second column, Informed Traders' Activity, includes two different measures. The topmost value represents the average number of transactions per informed trader. To compute the average, we sum the total the number of informed transactions per period and then divide by the number of informed traders. The parenthetical value represents the total number of transactions that involve an informed trader per period. The third column, Baseline Profit, represents informed traders' average profit per period assuming that private information is not disseminated and taking into account informed traders' observed activity. We determine that informed traders earn, on average, $280, per transaction, assuming that private information is not disseminated, risk neutrality, and a zero tax rate on dividend earnings. We multiply $280 by observed activity, from the second column, to compute baseline profit. The topmost value is based on the first activity measure, and the parenthetical value is based on the second activity measure. The fourth column, Information Cost, represents the average cost of information acquisition per period. The fifth column, Difference, is the baseline profit minus the average cost of information acquisition. The final column, t-statistic, is the result of a paired-t test, comparing the baseline profit to the average cost of information acquisition. One, two, and three asterisks, *, **, and ***, indicate statistical significance at 10 percent, 5 percent, and 1 percent, respectively, two-tailed.

under such conditions. Those who are uninformed may be less willing to transact because, in our impoverished environment, information disparities are evident. In this case, uninformed traders may have heightened concern about being taken advantage of. We conduct additional analysis to assess this possible explanation. We examine the number of transactions per period to test for differences in $N^I$, where the alternative explanation suggests that the volume of trade will be less in markets with an impoverished environment than an enriched environment. We find that the estimated marginal means are 4.81, 6.36, and 5.00 transactions per period in markets with one, two, and four informed traders, respectively. Indeed, pairwise comparisons indicate that trading volume is *higher* in markets with two informed traders than in markets with one or four informed traders, $p < 0.02$. Hence, the evidence does not support the alternative explanation. In sum, we find that informed traders are less likely to complete a sufficient number of transactions to recover the cost of information when the information environment is impoverished than when it is enriched, as predicted by H3.

Taken as a whole, the results reported in Tables 3 and 4 suggest that informed traders spend more on information than the value they are able to realize through trade and, further, that the realized value is lower than the potential value of the information. With the observed cost of information, even if each transaction allows informed traders to make the largest amount of profit (i.e., uninformed traders are naïve), the informed traders do not carry out sufficient transactions. In contrast, if the number of transactions observed was the result of an optimal strategy that maximizes the realized value of information in light of information dissemination, then the evidence suggests that traders overspend on information. Our evidence supports the view that the information cost is higher than the potential value of the information and the realized worth of information is lower than its potential value.

### 4.4. The impact of learning

The two information environments provide different learning opportunities to traders. In the impoverished condition, one or two participants are informed while four participants are informed in the enriched environment. Therefore, it is possible that fewer participants in the impoverished environment have sufficient opportunity to acquire information and, in turn, learn the value of information. In contrast, in the enriched environment, a larger proportion of traders acquires information multiple periods and, thus, traders have a better opportunity to learn the value of information. Consequently, it is possible that different learning opportunities influenced the results reported in previous sections.

To demonstrate the variation in traders' opportunities to acquire information, Panel A of Table 5 shows the frequency of information acquisition for markets in which 1, 2, or 4 traders are informed. For example, in markets in which a single trader acquires information, we observe that 23 out of 45 traders never acquire information. In contrast, in markets in which four traders acquire information, we observe that only 1 of 46 traders never acquires information. Thus, as might be expected, a larger proportion of traders acquires information multiple periods in the enriched environment.

To formally examine the possibility of a learning effect, we divide periods 4–12 into two time segments. This allows us to investigate whether traders behave differently across early and later trading periods. More specifically, we label the four periods from 4 to 7 as early trading periods and the periods from 8 to 12 as late. We examine the behavior of three variables across the two time segments: cost of information acquisition (previously illustrated in Panel A of Fig. 3), the median bid per period averaged across markets in the same treatment (Panel B of Fig. 3), and normalized average net profit (Fig. 2).

Panel B (C) of Table 5 presents the results of an ANOVA in which the dependent variable is the cost of information (median bid for information). The independent variables include *EarlyPd*, a dummy variable taking the value of 1 for early trading periods, 0 otherwise, *Impoverished*, an indicator variable taking the value of 1 if the information environment is impoverished and 0 otherwise, and an interaction term. Importantly, the dummy variable for early trading and its interaction with the information condition do not have a significant effect on the information cost or bid. We repeated this analysis with the independent variable $N^I$, the number of informed traders, replacing *Impoverished* and inferences are unchanged. These results fail to support a differential learning effect across information conditions.

Finally, Panel D presents the results of an ANOVA of normalized net profit. In addition to the independent variables described above, this analysis also includes *Informed*, an indicator variable taking the value of 1 if informed and 0 otherwise, as well as interaction terms. Earlier analyses illustrated the differences in performance across informed and uniformed traders, as well as differences across treatments. Once again, we observe that net profit is not significantly different across early and later trading periods. The variables that have a significant impact on net trading profit are those that were important in the main tests, including *Impoverished*, *Informed*, and their interaction.

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**Table 5**
Tests of learning.

Panel A: Frequency of Informed

| Frequency Informed | Number of Informed Traders ($N^I$) | | | Total |
|---|---|---|---|---|
| | 1 | 2 | 4 | |
| 0 | 23 | 12 | 1 | 36 |
| 1 | 8 | 7 | 6 | 21 |
| 2 | 5 | 6 | 6 | 17 |
| 3 | 3 | 7 | 1 | 11 |
| 4 | 1 | 4 | 4 | 9 |
| 5 | 1 | 5 | 2 | 8 |
| 6 | 0 | 1 | 2 | 3 |
| 7 | 1 | 2 | 3 | 6 |
| 8 | 1 | 1 | 3 | 5 |
| 9 | 1 | 1 | 7 | 9 |
| 10 | 0 | 0 | 4 | 4 |
| 11 | 0 | 0 | 1 | 1 |
| 12 | 1 | 2 | 6 | 9 |
| Total | 45 | 48 | 46 | 139 |

Panel B: Impact of Learning on the Cost of Private Information

| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
|---|---|---|---|---|---|
| | | 36 | 115.683 | 0.204 | 0.129 |
| | | df | MS | F-statistic | P-value |
| Model | 109392.49 | 3 | 36464.16 | 2.72 | 0.0605 |
| EarlyPd | 30446.55 | 1 | 30446.55 | 2.28 | 0.1413 |
| Impoverished | 76879.06 | 1 | 76879.06 | 5.74 | 0.0226 |
| EarlyPd x Impoverished | 10206.26 | 1 | 10206.26 | 0.76 | 0.3890 |
| Residual | 428243.73 | 32 | 13382.62 | | |
| Total | 537636.23 | 35 | 15361.04 | | |

Panel C: Impact of Learning on Median Bid to Acquire Information

| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
|---|---|---|---|---|---|
| | | 36 | 421.252 | 0.374 | 0.315 |
| | | df | MS | F-statistic | P-value |
| Model | 3394290.5 | 3 | 1131430.2 | 6.38 | 0.0016 |
| EarlyPd | 68450.0 | 1 | 68450.0 | 0.39 | 0.5389 |
| Impoverished | 3293888.9 | 1 | 3293888.9 | 18.56 | 0.0001 |
| EarlyPd x Impoverished | 65401.4 | 1 | 65401.4 | 0.37 | 0.5481 |
| Residual | 5678494.8 | 32 | 177453.0 | | |
| Total | 9072785.2 | 35 | 259222.4 | | |

Panel D: Impact of Learning on Net Profit

| Source | Partial SS | Number of observations | Root MSE | R-squared | Adjusted R-squared |
|---|---|---|---|---|---|
| | | 72 | 0.297 | 0.466 | 0.407 |
| | | df | MS | F-statistic | P-value |
| Model | 4.934 | 7 | 0.705 | 7.97 | <0.0001 |
| EarlyPd | 0.077 | 1 | 0.077 | 0.87 | 0.3531 |
| Informed | 1.630 | 1 | 1.630 | 18.43 | 0.0001 |
| Impoverished | 1.161 | 1 | 1.161 | 13.12 | 0.0006 |
| EarlyPd x Informed | 0.022 | 1 | 0.022 | 0.25 | 0.6172 |
| EarlyPd x Impoverished | 0.004 | 1 | 0.004 | 0.05 | 0.8319 |
| Informed x Impoverished | 0.845 | 1 | 0.845 | 9.56 | 0.0029 |
| EarlyPd x Informed x Impoverished | 0.001 | 1 | 0.001 | 0.01 | 0.9126 |
| Residual | 5.660 | 64 | 0.088 | | |
| Total | 10.594 | 71 | 0.149 | | |

Notes: Panel A reports the number of traders who are informed each respective time in each treatment ($N^I$). Panel B (C) of the table presents the results of an ANOVA in which the dependent variable is the cost of information (median bid for information), excluding the first three trading periods. In Panels B and C the independent variables include *EarlyPd*, a dummy variable taking the value of 1 for early trading periods, 0 otherwise, *Informed*, an indicator variable taking the value of 1 if informed and 0 otherwise, *Impoverished*, an indicator variable taking the value of 1 if the information environment is impoverished (1 or 2 traders informed) and 0 otherwise, and an interaction term. Panel D presents the results of an ANOVA of normalized net profit. In addition to the independent variables described above, this analysis also includes *Informed*, an indicator variable taking the value of 1 if informed and 0 otherwise, as well as interaction terms.

## 5. Concluding remarks

This paper reports the results of 18 experimental markets designed to investigate the effect of the information environment on informed traders' performance. Our findings suggest that, when the environment is impoverished, informed traders spend too

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much on information acquisition. Further, under such conditions, they do not transact enough to recover the cost of private information. We assert that, when the environment is impoverished, strategic motives are at the forefront of informed traders' behavior, causing them to limit their activity (e.g., Kyle, 1984, 1985, 1989; Wang, 1998). Such behavior, however, is detrimental to their well-being, eroding profit.

Our findings provide important direction for theoretical research. Our results suggest that traders overestimate the benefits of private information, which compels them to devote inordinate resources to information acquisition. Over-investment in information, in turn, can lead to sub-optimal resource allocation decisions. In our setting, traders appear to overvalue private information, especially when the environment is impoverished. But, such a finding draws into question the existence of an equilibrium that includes costly information acquisition.

In light of the observed over-investment in information, another conundrum is our finding that two competing insiders fare worse than a monopolistic advantaged trader. This result appears to be driven by overspending, which is even *more* pronounced in markets with two informed traders than one. Kyle (1989) suggests that informed traders should be able to recover the cost of private information due to imperfect competition; however, his model does not consider traders' cognitive shortcomings in evaluating the benefits of being informed (see also Charness & Levin, 2009). We encourage future study to probe this important issue.

Participants in our markets have difficulty learning to assess the benefits of private information. Informed traders' profit improves over the latter periods of our markets, but participants continue to overspend on information acquisition when the environment is impoverished. Evaluating the benefits of private information, though, is challenging to say the least. Consider that the benefits of information acquisition are not realized immediately, but rather through trading in a double-auction market. Our setting is complex in that participants vie for private information and then transact in a double-auction market. Moreover, participants' decisions in the two markets are interrelated. Hobson, Marley, Mellon, and Stevens (2015) provide experimental evidence that the effect of winner's curse persists over time in a complex environment, but not in a simple one (i.e., the effect declines over time in a simple setting). In the complex environment, participants' payoffs are contingent on a subsequent decision (an effort choice). By contrast, in their simple environment, participants' payoffs are revealed immediately. The study's findings suggest, not surprisingly, that learning is stymied in a complex environment.

Naturally-occurring markets often are complex and not necessarily conducive to learning. Yet other mechanisms may be present in markets that regulate individuals' behavior, which are absent from our setting. For example, in securities markets, economic Darwinism provides a powerful disciplinary force that can rein in overspending. In an experimental setting, however, economic Darwinism is not practical because participants typically cannot be made to bear losses. In addition, resource constraints are present in naturally-occurring settings, which diminish individuals' ability to overspend. Our participants, on the other hand, are endowed with funds that enable them to spend large amounts on private information. We implore researchers to investigate the effects of economic Darwinism, resource constraints, and other aspects of our experimental design on traders' behavior in an impoverished environment.

We acknowledge that some experimental features of our markets may impact informed traders' profit. Participants are endowed each period with two certificates, which have an expected value of $3000 or $2,400, conditioned on participants' tax rate on dividend earnings (two multiplied by the mean of the asset value distribution multiplied by the tax rate). So even if participants make *bad* decisions, their profit per period is usually nonnegative. Indeed, we note that traders' profit is nonnegative 97.7 percent of the time. Hence, informed traders' may be less cognizant of the missed opportunities of paying too much to acquire information than if they had greater potential to generate losses. Nonetheless, we would still expect to observe differences in traders' performance comparing an impoverished versus an enriched environment.

In our markets, informed traders have an incentive to sell certificates when private information indicates that the unbiased estimate of asset value is below the naïve price; however, short sales are not allowed. Because traders are only endowed with two shares, their capacity to sell certificates is limited. Notwithstanding, our analyses control for informed traders' incentives to buy or sell certificates. Restrictions on short sales are prevalent in naturally-occurring markets, and while these constraints inhibit the dissemination of information, prices are not necessarily biased (Diamond & Verrecchia, 1987).

Finally, we acknowledge that in our setting, participants' willingness to become informed is expressed solely in monetary terms. That is, participants submit a sealed bid that indicates *how much they are willing to pay* (in dollars) to become informed. Information search and acquisition, however, typically entail much more than monetary costs, most notably participants' time and effort. Participants' willingness to expend monetary versus non-monetary resources likely varies, and indeed, they may be more willing to expend non-monetary resources if the opportunity cost of their time is low. We encourage future study to explore this issue.

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