When The Market Cannot Do it All!
Informational Efficiency & Information Dispersion

Brice Corgnet*, Mark DeSantis** and David Porter**

Abstract
To shed new light on the informational efficiency debate, we go back to the basics by studying the impact of the distribution of private information on the informational efficiency of markets. Our findings are unequivocal: markets achieve informational efficiency when information is concentrated but do not when it is dispersed. According to our learning model, this is the case because the cognitive challenges faced by traders when inferring others’ private information from prices is lessened when information is concentrated compared to when it is dispersed. Our study stresses the crucial role of the distribution (not the amount) of information for markets prices to transmit private information. Our work suggests that the existence of information specialists, by limiting the dispersion of information, may favor informational efficiency. By contrast, the lowering costs of accessing market information as a result of new information technologies may lead to less efficient markets.

Keywords: Information aggregation, information dispersion, market efficiency, experimental asset markets, learning models.

JEL CODES: C92, G02, G14.
1. Introduction

Markets are essential to the well-functioning of our societies. Yet, debates on the efficiency of markets are still rampant. To shed light on this conundrum, we propose to study how basic features of the structure of information in markets affects informational efficiency. We start our inquiry by developing a learning model à la Corgnet, DeSantis and Porter (2015a) to assess whether the distribution of private information affects the extent to which traders can discover the true value of a financial asset. This model provides behavioral foundations for the aggregation of information in markets by positing that learning other traders’ private pieces of information is a task that requires specific cognitive skills which not all people possess (see Corgnet, DeSantis and Porter, 2015a). Learning in markets with private formation is a challenging task. Extensive simulations of the learning model suggest that the distribution of information is crucial for understanding the informational efficiency of markets. This is the case because inferring private information from market orders is more cognitively demanding when information is dispersed than when it is concentrated. It follows that informational efficiency should be higher in markets where information is concentrated than in market where it is dispersed. We test our main conjecture using market experiments pioneered in the tradition of Smith (1962) and Plott and Sunder (1982, 1988). More recently, numerous scholars (Bossaerts, 2009; Noussair and Tucker, 2014, Frydman et al. 2014) have articulated the benefits of this methodological choice which allows for controlling various aspects of the trading environment such as the distribution of information:

“The advantage of experiments is that they give researchers a large degree of control over the trading and information environment, which can make it easier to tease theories apart.”

Frydman, Barberis, Camerer, Bossaerts and Rangel (2014), p. 907

We considered two treatments which only differ in the distribution (not the amount) of information across traders. In the disperse info treatment, each of the traders in the market was privately informed of which possible value (out of three) the asset could not take. As half of the traders were given one clue (e.g., “Not the low value”) and the other half were given the other possible clue (e.g., “Not the high value”), the aggregate information available to traders in the market was complete. We contrast this with the concentrated info treatment in which one-half of the traders were given two clues (e.g., “Not the low value and not the high value”) implying that they knew the true valuation of the asset (the middle value), while the other traders were not provided with any information beyond the asset’s possible values and probabilities.
Our findings provide clear-cut support for our main conjecture. We find that prices converge to true asset valuation when information is concentrated whereas prices do not adjust to information when information is dispersed. Even though our model does not provide insights regarding the size of the effect, our experimental findings show striking differences. The difference between the two treatments is not one of degree. Informational efficiency is perfect in the concentrated info treatment whereas it is inexistent in the dispersed info treatment. Using the Plott and Sunder (1988) terminology, market prices are consistent with the rational expectation hypothesis under concentrated info whereas market prices are in line with the prior information model under dispersed info. The prior information model (Lintner, 1969) is such traders do not infer any private information of others’ traders and thus represents a situation in which markets are not informationally efficient.

A notable advantage of the experimental method is that it allows us to study the behavioral foundations of market efficiency in the spirit of Corgnet, DeSantis and Porter (2015b). In our current setup, our theoretical model implies that the informational efficiency crucially hinges on the cognitive sophistication of traders which has been identified by Corgnet, DeSantis and Porter (2015b) as reflective skills measured using the cognitive reflection test (CRT, henceforth). These skills allow traders to proficiently infer other traders’ private information from observing market orders by applying Bayes rule correctly. These skills relate to the concept of cursed traders (Eyster, Rabin and Vayanos, 2015) who are defined as those who “neglect the informational content of prices”. Our model implies that the effect of reflective skills on the informational efficiency of markets interacts with the distribution of information. This is the case because the cognitive challenge of inferring private information from market orders varies across different distributions of private information. Thus, cognitive skills appear to be especially relevant when information is perfectly dispersed which in our setting corresponds to the case in which all traders receive the same number of signals about asset valuation. This is the situation in which informational efficiency is expected to be the lowest. To assess the soundness of our behavioral model of informational efficiency we test, using psychometric data collected for each of our trader participants, not only whether reflective traders earn more than non-reflective traders but also whether reflective traders’ superior earnings depend on the distribution of private information in the market. Using test scores on the CRT, we were able to identify reflective and non-reflective traders. We were then able to show, as conjectured, that reflective traders outperformed non-reflective traders the most in the dispersed info treatment. Relatedly, we show that reflective traders in the concentrated info treatment outperform non-reflective traders only when comparing traders who were not informed about the true value. This is the case because reflective skills
are only crucial when one has to infer asset valuation from market orders. In line with our model, when perfectly informed, *reflective* traders do not outperform *non-reflective* traders.

Our findings thus suggest that markets may substantially differ in terms of informational efficiency, and that markets may not always reach informational efficiency. This goes in the direction of reconciling seemingly contradictory pieces of evidence which fuel the debate between classical and behavioral finance.¹ In doing so, our approach establishes cognitive foundations for the informational efficiency of markets that help us identify when markets are expected to aggregate information successfully.²

Our approach also sheds light on the long tradition of lab and field experiments on information aggregation which mainly focus on institutional aspects of informational efficiency (e.g. Plott, Wit and Yang, 2003). For example, the work of Plott and Sunder (1988) led to the idea that information aggregation was more easily achieved in markets in which a complete set of Arrow-Debreu securities was available (Plott, 2000). In Plott and Sunder (1988) Arrow-Debreu securities sessions, the traded asset delivered a positive dividend only if one of three possible states occurred. It follows that, even in a case in which each trader received only one clue (e.g. “Not the high value”) (what we refer to as *dispersed info*), half of the traders would know the true value of the asset (e.g. the Arrow-Debreu security associated to the high value would be worthless). Thus, Arrow-Debreu securities ultimately transform a market in which information is originally dispersed in a market in which half of the traders are insiders which is a characteristic of *concentrated info* markets. Our findings on the crucial role of information distribution on the informational efficiency of markets sheds light on Plott and Sunder (1982, 1988) findings by showing that Arrow-Debreu securities facilitate the aggregation of information as they simplify the distribution of information by transforming a *dispersed info* market into one in which information is concentrated. Our model and our empirical tests show that the *concentrated info* market crucially differs from the *dispersed info* market in terms of informational efficiency because it represents a less cognitive challenge to traders and facilitate the inference of others’ private information from publicly-available market orders.

A strand of the information aggregation literature focuses on the role of institutional aspects in understanding the informational efficiency of markets such as the existence and competition between market makers (Cason, 2000; Krahnen and Weber, 1999, 2001) or the presence of futures markets (Friedman, Harrison and Salmon, 1984). These institutional aspects were found to facilitate information

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¹ See for example the dialogue between Eugen Fama and Richard Thaler: [http://review.chicagobooth.edu/economics/2016/video/are-markets-efficient](http://review.chicagobooth.edu/economics/2016/video/are-markets-efficient)

² Our approach can be referred to as falling into the field of “cognitive finance” (Corgnet et al. 2015a) as it aims at identifying the cognitive underpinnings of the well-functioning of markets.
aggregation. More closely related to our paper, some works have extended the original experiments of Plott and Sunder (1982) to different structures of information including sequential information release (Copeland and Friedman, 1987; Barner, Feri and Plott, 2005) which was generally found to hamper informational efficiency. Also, asset markets in which traders make sequential decisions and in which traders’ decision times are random have been found to generate information cascades in which some private information fails to be transmitted to prices (Nöth and Weber, 2003). Other works have focused on the presence of manipulators that could distort prices and hamper informational efficiency of the market (Hanson, Oprea and Porter, 2006; Veiga and Vorsatz, 2010). Hanson, Oprea and Porter (2006) incentivize manipulators to distort market prices but find that they were not ultimately affecting informational efficiency. Veiga and Vorsatz (2009, 2010) use computerized market manipulators and show that they can distort asset prices.

Importantly, the complexity of the informational structure has also been found to affect the informational efficiency of markets. Plott, Wit and Yang (2003) find that information aggregation is less pronounced in settings in which pooling all private traders’ information does not unveil the value of the asset with certainty. In addition to aggregate uncertainty, Camerer and Weigelt (1991) show that the nature of the private signals plays an important role in the informational efficiency of markets. The authors show that private information may fail to aggregate in cases in which traders do not know with certainty whether half the market is composed of insiders. O’Brien and Srivastava (1991) also find that asset prices do not converge to fundamentals in an environment with multiple assets in which asset valuation can depend on previous realization of dividends.

Our work directly connects to these papers by developing a behavioral model that accounts for the crucial role of market complexity in explaining the informational efficiency of asset prices. We also extend previous research by directly comparing the informational efficiency of two market environments that differ in one simple dimension (the distribution of information).

Our work stresses that market complexity, whether it arises from the complexity of signals, the number of assets, the dynamics of trading or the distribution of information, is a crucial ingredient to understand the informational efficiency of markets.

At a theoretical level, our work relates to the research agenda initiated by Guesnerie (2000) regarding the study of coordination of beliefs in markets. Applied to financial markets, this literature studies the relationship between information revelation and the precision of private signals (Desgranges and Guesnerie, 2005). This analysis suggests that revelation of information is most likely when information is
precise than when it is not, in line with our model conjecture that concentrated info markets will be more informationally efficient than disperse info markets. Their rationale is that rational expectations cannot be obtained from an eductive learning process if too much information is transmitted into prices relatively to the precision of private signals. This is the case because, as prices reflect a large amount of private information, traders will primarily condition their bidding strategy on prices thus ultimately disregarding their own private information.

2. Model

2.1. Setup

In our learning model, traders vary regarding their capacity to infer information from prices, which we refer to as reflective capacity. Our markers are thus populated by both reflective and non-reflective traders. Reflective traders can perfectly infer others’ private information from market orders by applying Bayes rule whereas non-reflective traders learn nothing from prices.

Let \( \alpha \) represent the proportion of reflective (REF) traders and \( (1 - \alpha) \) the proportion of non-reflective traders in the market. One-half of our traders are informed of the asset’s true value and the other half are uninformed. Moreover, we assume that half of the informed (uninformed) traders are reflective while the other half is not. These proportions of informed reflective and non-reflective traders are assumed to be common information in the model.

We consider that prices occur as a result of a continuous flow of bids and asks posted by traders (see Appendix C).\(^3\) At the beginning of each period, a trader (selected at random) either accepts the current best bid or ask or posts a new bid/ask (or both) to the market. Then, another trader is selected at random to either accept the current best bid or ask or improve the spread. In line with our experimental design, the bid (ask) of the newly selected trader will replace the current bid (ask) if and only if it improves the current spread.\(^4\) Traders (selected at random) continue to post bid-ask spreads to the market until a trade occurs. A trade occurs if a newly selected trader’s belief of the asset’s value is greater than the current best ask or if the trader’s belief is less than the current best bid. If a trade occurs, then the price, \( p \), is set at the

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\(^3\) We do not model the role of a market maker (or a specialist) as is commonly the case in the mark microstructure literature so as to mimic our experimental design. Our design uses a decentralized auction mechanism in which all traders have the same portfolio and the same level of private information.

\(^4\) Note, however, that the bid-ask spread is only updated when the newly selected trader has enough cash (shares) to cover the bid (ask) position.
current best bid (or ask). Note that the sequence of market orders is not random. Depending on their current information and depending on whether they are reflective traders or not, traders may be more or less likely to trade given a bid-ask spread. What is entirely random is which of many traders with the same information and the same level of reflection will trade at a given bid-ask spread.

The bid-ask spread is determined as a function of the trader’s belief regarding the true asset value. Specifically, the bid (ask) is a randomly drawn integer from a uniform distribution on the interval $[b_c, \mu_{n,X}]$ ($[\mu_{n,X}, a_c]$), where $\mu_{n,X}$ denotes the belief of the true value of the asset for the reflective (non-reflective) trader ($Y = R$ or $Y = NR$, respectively) who is informed (uninformed) ($X = I$ or $X = u$, respectively), $b_c$ ($a_c$) represents the current best bid (ask), and $n$ corresponds to the market event. Note that the interval [1,600] corresponds to the range of permissible values in the experiment. Moreover, similar to our experimental market design we implement a strict improvement rule in which a trader’s ask must be greater than his or her bid similar to our experiment. For a non-reflective trader, the bid and ask are randomly drawn from a uniform distribution on the interval [1,600].

**Updating rules**

After each transaction, the reflective traders update their beliefs of the true value of the asset by applying Bayes’ rule to infer other traders’ information from market prices. Non-reflective traders do not update their beliefs. All traders submit orders based upon their belief of the asset’s true value (bids below and asks above).

To understand the mechanics of the model, consider the following illustrative example. Suppose that the true value of the asset is 50 and that all traders are reflective. Informed traders, whether reflective or non-reflective, know this true value, while uninformed traders’ belief of the asset’s value is 223.5 ($0.35 \times 50 + 0.45 \times 240 + 0.20 \times 490$), i.e. $\mu_{0,I} = 50$, $\mu_{0,I} = 240$ or $\mu_{0,I} = 490$ and $\mu_{0,u} = 223.5$. Let us

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5 The book is not cleared after each transaction. However, each time a trader is randomly selected, any of the trader’s outstanding bids and asks that are not consistent with the trader’s current belief of the asset’s value are removed from the book. For example, suppose the trader had a belief of 223.5 and submitted a bid of 200 and an ask of 250. Suppose the trader subsequently updates his belief to 185. The next time this trader is randomly selected to act, then his bid of 200 will be canceled.

6 A market event corresponds to either a transaction or an improvement to the bid-ask spread.

7 Reflective traders do not update their beliefs if a trade fails to occur in a given period. This is a simplifying assumption because reflective traders could learn others’ information from the absence of a trade.

8 Our framework can be extended by considering the general case in which non-reflective traders are able to update their beliefs. For example, suppose traders are reflective-type $\eta$ if they need to observe $\eta$ prices consistent with a certain value of the asset before updating their belief accordingly. This extension of our model would relate to recent works stressing the prominent role of inattention in financial decisions (e.g., Agnew, Balduzzi, and Sunden, 2003; Andersen et al. 2015).

9 As the true value of the asset is assumed to be 50, there are no informed traders who believe the value is 240 or 490. However, this fact is not known by the uninformed reflective traders who must therefore act as if these traders do exist.
consider traders with the clue “Not 240”.¹⁰ Suppose the first randomly selected trader submits a bid of 200 and an ask of 360 (see Figure 1 Panel A). Uninformed traders know the bid could not be submitted by a trader who knows the value is 50. Moreover, these uninformed traders also know the ask could not have been submitted by a trader who knows the value is 490. Based upon the model’s Bayesian updating rules (see Appendix C), the uninformed reflective trader updates his belief to 202.6 (see Figure 1 Panel B).

Next suppose the bid of 200 is accepted. Only traders who believe the asset’s true value is 50 would be willing to sell at a price of 200. Thus, the uninformed reflective traders learn that the asset’s value is 50 (see Figure 1 Panel D).

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¹⁰ The updating rules for other traders and other possible asset values are similar. Refer to Appendix C for more details.
2.2. Conjectures

Conducting simulations for each case (dispersed info and concentrated info), we were able to derive the following conjectures (see Appendix C for details). Our first conjecture states that the dispersion of private information will make the revelation of information through prices more difficult. In our model, this means dispersed information is a more challenging inference problem. Also, for a non-reflective trader, being informed about the actual valuation of the asset is the only way to know what the asset is worth.

Conjecture 1. Our model predicts lesser informational efficiency in the dispersed info case than in the case of concentrated info.

Relatedly, our simulations indicate that reflective traders, on average, learn the true value of the asset after approximately 1 transaction or 4 market events (bid, ask, or trade) in the concentrated info treatment. However, in the dispersed info treatment the reflective traders require approximately 6 transactions (or 12 market events) to learn the asset’s value. This suggests that the number of transactions should be lower in the concentrated info treatment as uninformed reflective traders quickly become informed. Thus, information is dispersed rapidly eliminating the need for further trades.

Conjecture 2. Our model predicts larger transaction volumes in the dispersed info case than in the case of concentrated info.

At the individual level, our model has clear implications regarding the relative performance of reflective and non-reflective traders. Our simulations show that earnings are higher for reflective than for non-reflective traders in both the dispersed info and the concentrated info cases. More subtly, our simulations show that the difference in earnings across these two categories of traders should be less pronounced for the case of concentrated info.

Conjecture 3. Our model predicts that reflective traders will earn more than non-reflective traders for both the dispersed info case and the concentrated info case.

The last implication of our model is crucial to test the soundness of our setup. It states that the relative performance of reflective traders compared to non-reflective traders in the concentrated info case depends on whether we consider traders who are informed of the true value of the asset. In particular, reflective traders and non-reflective traders are shown to obtain similar earnings when both know the true value of
the asset. *Reflective* traders obtain superior earnings only when comparing traders who are not informed of the true value of the asset. This implication of the model follows directly from our assumption that cognitive reflection boosts performance because it allows traders to infer others’ private information from market orders. It follows that *reflective* skills are only worthwhile if traders do not hold complete information about the value of the asset.

**Conjecture 4.** In the *concentrated info* case, our model predicts that *reflective* traders will earn more than *non-reflective* traders only when comparing traders who do not start the market knowing the value of the asset.

### 3. Experimental Design

Our study uses the design of Plott and Sunder (1988) and, in particular, their parameterization of *Market 9* (Treatment C). This design introduces an experimental asset which can only assume three possible values: 50, 240 or 490 francs (each franc was worth $0.001) with probabilities 35%, 45% and 20%, respectively. We use a computerized version of the continuous double auction trading mechanism.\(^\text{11}\) We made this choice purposefully as computerized continuous double auction trading mechanisms are widely used in actual stock market exchanges (Parsons et al. 2008). We conduct two treatments which only vary in the distribution (not the amount) of information across traders. In the *disperse info* treatment, each of the twelve traders in the market is privately informed of which possible value the asset could not take. As half of the traders were given one clue (e.g., “Not 50”) and the other half were given the other possible clue (e.g., “Not 240”), the aggregate information available to traders in the market was complete. We contrast this with the *concentrated info* treatment in which one-half of the traders were given two clues (e.g. “Not 50” and “Not 240”) and were thus informed of the true value of the asset (“490”), while the other traders were not provided with any information beyond the asset’s possible values and probabilities. This treatment closely follows the design of Plott and Sunder (1982) who study how private information held by insiders is transmitted into prices. Note that in both

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\(^\text{11}\) In continuous double auctions, traders can submit, at any time, offers to buy or sell the asset. Traders can also accept current market orders to buy or sell an asset.
treatments the quantity of information, as measured by the number of clues released to traders, is the same.\footnote{Indeed, in the information aggregation design each participant receives a clue (12 clues in total). In the dissemination setting each of six informed trader receives two clues (e.g., if the true value is 240, then this trader receives the clue “Not 50” as well as the clue “Not 490”).}

We recruited a total of 238 individuals from a subject pool of more than 1,500 individuals at a major Western US University.\footnote{All experiments in this paper were funded by the Economic Science Institute and the Argyros School of Business and Economics.} We conducted a total of 10 sessions per treatment with 12 (or 11) traders in each.\footnote{Two sessions were run with 11 participants instead of 12 in the \textit{concentrated info} treatment.} Traders were endowed with 1,200 francs in cash and 4 shares of the asset. Each session consisted of 17 markets with independent draws for the value of the asset.

Before each session started, subjects completed a 10-minute training quiz regarding the random device (a spinning wheel) that was then used during the experiment to draw the actual value of the asset (either 50, 240 or 490 francs) at the end of each of the 17 markets. This training follows Plott and Sunder (1982, 1988) experimental procedure. This training (see online Appendix O1, Instructions Part 1) consisted of having subjects predict the outcome of the spinning wheel over 10 trials. Each correct prediction was rewarded 25 cents, and each incorrect answer incurred a 10 cent penalty. Average earnings (including a $7 show-up fee) for the two hours and a half experiments were equal to $48.0.

All of the subjects who participated in our experiments were invited after the original study to complete a one-hour survey as part of the laboratory policy to collect individual information about subjects who are registered in the pool (See Appendix B for descriptions).\footnote{At the end of each session, subjects also completed a series of tests and a demographic survey for a total of 25 (15) minutes in the \textit{dispersed (concentrated) info} treatment. All of these tasks were computerized. Subjects were paid a flat fee of $3 to complete the tests. As is common practice in the literature, no pay-for-performance was used for the tests. We included a financial literacy test (see Appendix B). In the \textit{dispersed info} treatment, we also included a self-monitoring scale which was not included in the \textit{concentrated info} treatment.}

4. Results

We test our four conjectures sequentially, starting with an analysis of informational efficiency at the market level and then focusing on an individual-level analysis of trader earnings.

4.1. Market Analysis: informational efficiency

Our primary measure to assess the informational efficiency of a market is the mean absolute deviation between the price and the value predicted by two benchmark models: rational expectations and prior information (see e.g. Plott and Sunder, 1982, 1988; Copeland and Friedman, 1987). The rational
expectations benchmark corresponds to full informational efficiency in which case prices are equal to the true value of the asset.

Rational expectations (RE)

Under rational expectations, all subjects trade as if they knew the private information of the other traders in the market. Regardless of the treatment (dispersed or concentrated info), the pooled information of all traders identifies the value of the asset with certainty. It follows that, under RE, price predictions are equal to the actual value of the asset. Moreover, in this scenario trades can only occur in equilibrium at a price equal to the value of the asset.

The prior information model corresponds to the case in which no aggregation of information occurs because traders do not use prices to infer others’ private signals.

Prior information (PI)

In this model traders do not infer other traders’ information from market prices but apply Bayes’ rule to compute the expected value of the asset given their own information (Lintner, 1969). That is, subjects base their trades solely on the information received at the beginning of the market and fail to reflect on asset prices to uncover other traders’ information. As a result, PS considers the PI asset price prediction to equal the expected value of the trader with the most positive prior information (i.e., the trader whose prior information about the asset leads to the highest expected value across traders).

We calculate the mean absolute deviation of asset prices with respect to model $j$ as follows:

$$\text{average}_i | p_i - m_j |$$

where $i$ represents a transaction, $p_i$ corresponds to the transaction price, and $m_j$ is the predicted price based upon the appropriate model.$^{16}$

Figure 2 illustrates the sharp difference in asset prices across treatments regardless of the market. In the dispersed info treatment, prices do not come close to the true value of the asset whereas prices are rapidly converging to the true value of the asset in the concentrated info treatment.

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$^{16}$ Note that the prior information (PI) model predicts the asset’s price to be equal to the true value (and, hence, consistent with the RE price prediction) when the true value is 240 or 490. However, when the asset’s true value is 50, the PI model predicts a price of 223.5. This may explain why the p-value assessing differences in mean absolute deviation between RE and PI models fails to reach significance.
Figure 2. Average price per minute over the 10 sessions for each of the seventeen markets (*dispersed info* treatment in dashed blue, *concentrated info* treatment in green). The average price per market period is listed at the top of each subfigure, and the true value of the asset is denoted at the bottom of each subfigure. The value of the asset in a given period is also indicated by a solid horizontal line and the PI model predicted value is indicated by a dashed line (*dispersed info*) or a dotted line (*concentrated info*).

It is not surprising that the mean absolute deviation with respect to the true value of the asset is significantly higher on average in the *dispersed info* compared to the *concentrated info* treatment whether we consider the first or the last market for each possible value of the asset or the first or last three transactions for each market (all p-values < 0.05, Wilcoxon Rank Sum Tests, WRT henceforth).\(^\text{17}\)

In addition, the mean absolute deviation calculated with respect to the true value of the asset is lower than when calculated with respect to PI when considering the *concentrated info* treatment for the last three markets or for the last three transactions of each market (see Appendix D, Table D.1). The opposite is true when considering the first three markets or the first three transactions of each market. This shows that private information is being transmitted to prices over the course of a market. It also shows that markets become more informationally efficient over the course of the experiment. For the case of *dispersed info*, the PI model exhibits a lower mean absolute deviation than the RE model

\(^{17}\) The first (last) three markets for each asset value correspond to Markets 1, 2 and 5 (14, 15 and 17).
regardless of the markets and transactions which are being considered (see Appendix D, Table D.1). This stresses that prices do not incorporate private information over the course of a market period and that the market ability to capture private information does not improve over the course of an entire experimental session.

In addition to prices, our model allows us to derive conjectures with respect to asset allocations. It predicts that under dispersed info, traders who hold the most positive clue will be net purchasers of the asset whereas those who hold the most negative clues will be net sellers. Regarding concentrated info, it predicts that informed traders will be net purchasers (sellers) when the value of the asset is high (low). We provide support for these conjectures for both treatments. In the dispersed info treatment, those traders with the most positive clue are indeed net purchasers of shares whereas those with the most negative clue are net sellers (see Appendix D, Table D.2, first column where the positive clue dummy is positive). In the concentrated info treatment, we also support our conjecture that informed traders accumulate shares when the true value of the asset is high whereas being net sellers when it is low (see Appendix D, Table D.2, second column where the interaction term between the informed dummy and the asset value is positive). Interestingly, as traders become experienced and as markets achieve higher levels of informational efficiency, the difference in holdings between informed and uninformed traders shrinks (see Appendix D, Table D.3, column 1). This is consistent with the fact that in informationally efficient markets informed traders are less at a disadvantage than in less efficient markets. Actually, in the first market (of each possible asset value) informed traders in the concentrated info treatment earn 16.7% more than uninformed traders while earning only 6.4% more in the last market (of each asset value). We show that the differences in earnings between informed and uninformed traders decrease over time (see Appendix D, Table D.3, column 2).

We also report supporting evidence for our second conjecture regarding trading volumes across treatments. The individual market figures in Appendix A show that, not only are prices closer to the true value of the asset in the concentrated info treatment but volumes of transactions are also lower. On average, we observe 5.409 transactions in the dispersed info treatment compared to 4.493 in the concentrated info treatment. This 17.8% difference is statistically significant (p-value < 0.0001, WRT).

4.2. Individual Analysis: on the behavioral foundations of informational efficiency

To test Conjecture 3, we make use of the empirical definition for reflective and non-reflective traders proposed by Corgnet, DeSantis and Porter (2015a). We define reflective (non-reflective) traders as those who score in the top quartile in terms of CRT scores. As conjectured, reflective traders earn more than
non-reflective traders for both treatments. However, the difference in earnings is larger for the dispersed info treatment than for the concentrated info treatment (see Figure 3). The difference in earnings is statistically significant for the dispersed info treatment (p-value = 0.095, WRT) but not for the concentrated info treatment (p-value = 0.610, WRT).

Figure 3. Total earnings (in USD) across treatments for non-reflective and reflective traders.

The lack of significance difference in earnings in the concentrated info treatment for reflective and non-reflective traders is likely due to the fact that, in half of the cases, non-reflective traders are endowed with complete information thus never being at an informational disadvantage with respect to reflective traders. According to Conjecture 4, the difference between these two groups of traders in the concentrated info treatment should only arise when comparing traders who did not receive clues about the true value of the asset. To test Conjecture 4, we have to conduct our statistical analysis at the period level so as to account for the fact that a given trader may have or may not have received clues about the true value of the asset, depending on the period. We thus conduct a regression analysis of market earnings as a function of cognitive reflection and other individual characteristics such as IQ scores (using Raven test) and financial literacy scores (Fernandes, Lynch and Netemeyer, 2014).
### Table 1. Panel regression of trader earnings as a function of cognitive reflection and information held by traders

<table>
<thead>
<tr>
<th>Market earnings (in $)</th>
<th>Informed traders</th>
<th>Uninformed traders</th>
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<tbody>
<tr>
<td>Sample:</td>
<td></td>
<td></td>
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<tr>
<td>All CRT levels [1]</td>
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<td></td>
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<td>CRT score</td>
<td>12.623 (15.593)</td>
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<td>CRT Top 25% Dummy (^{18})</td>
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<td>Raven score</td>
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<td>Financial literacy score</td>
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<td>100.148 (88.262)</td>
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<tr>
<td>Intercept</td>
<td>1,949.496****</td>
<td>1,836.211********</td>
</tr>
<tr>
<td></td>
<td>(260.839)</td>
<td>(419.233)</td>
</tr>
<tr>
<td>Observations</td>
<td>978</td>
<td>448</td>
</tr>
<tr>
<td>Prob &gt; χ²</td>
<td>0.135</td>
<td>0.651</td>
</tr>
<tr>
<td>R²</td>
<td>0.00772</td>
<td>0.0150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00439</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

\(**\) p<0.001, \(*\) p<0.01, \(*\) p<0.05, \(\ast\) p<0.1

5. Conclusions

The informational efficiency of markets continues to be a subject of heated debate. Our approach builds on prior experimental designs to develop an asset market environment in which the distribution of information can be controlled for. This allows us to study the relationship between the distribution of information and the informational efficiency of markets. To that end, we derived conjectures based on a behavioral learning model which posits that specific cognitive skills (assessed using the CRT) are necessary for people to infer others’ private information. This behavioral model stresses that extracting private information from market order is indeed a cognitive challenge. However, this cognitive challenge substantially varies according to the distribution of private information in the market. We show, for example, that information extraction and thus informational efficiency is more likely when information is \(\text{concentrated}\) than when it is \(\text{dispersed}\). We confirm these conjectures by comparing informational efficiency of experimental asset markets in a treatment in which all traders had the same quantity of information and in a treatment in which half of the traders where fully informed while the

---

\(^{18}\) This dummy takes value one if a trader’s CRT score is in the top 25% of participants.
other half did not receive any private pieces of information. All private information was revealed in the *concentrated info* treatment. By contrast, in the *dispersed info* treatment prices remained mostly flat thus not revealing any private information. Because we also collected data on our traders’ cognitive skills we were also able to test precise implications of our model regarding the interaction between traders’ private information and their cognitive skills. We confirmed the soundness of our model by showing, for example, that reflective skills (measured using the CRT) were most relevant when private information was scant as is the case of all traders in the *dispersed info* treatment or as is the case of uninformed traders in the *concentrated info* treatment.

Our findings help reconcile different views regarding the informational efficiency of markets by showing that the extent of the transmission of private information to asset prices crucially hinges on the distribution of information in the market. So, markets cannot do it all in the sense that they cannot always achieve strong-form efficiency (Fama, 1970). Our work hints at directly testable implications. In the same markets, stocks for which information is more concentrated in the hands of specialists are more likely to achieve strong-form efficiency than markets in which this is not the case. This observation also implies that the recent decrease in the cost of information following the revolution in the technologies of information may actually hamper informational efficiency. If the concentration of information facilitates informational efficiency, then markets will become less efficient as information becomes more evenly distributed in the population of traders.

6. References


**Appendix A: Market Figures**

The average price per market period is listed at the top of each subfigure, and the true value of the asset is denoted at the bottom of each subfigure. Each transaction is denoted by a red dot. The rational expectations value is indicated by a horizontal line, and the prior information value is indicated by a dashed line.
Figure 1.1. Information Aggregation Session 1.

Figure 1.2. Information Aggregation Session 2.

Figure 1.3. Information Aggregation Session 3.

Figure 1.4. Information Aggregation Session 4.
Figure 1.5. Information Aggregation Session 5.

Figure 1.6. Information Aggregation Session 6.

Figure 1.7. Information Aggregation Session 7.

Figure 1.8. Information Aggregation Session 8.
Figure 1.9. Information Aggregation Session 9.

Figure 1.10. Information Aggregation Session 10.
Figure 1.11. Information Dissemination Session 1.

Figure 1.12. Information Dissemination Session 2.

Figure 1.13. Information Dissemination Session 3.

Figure 1.14. Information Dissemination Session 4.
Figure 1.19. Information Dissemination Session 9.

Figure 1.20. Information Dissemination Session 10.
Appendix B. Surveys

Follow-up survey tests

*Extended cognitive reflection test (CRT):*

Taken from Frederick (2005):

1. A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost? ____ cents
   
   [Correct answer: 5 cents; intuitive answer: 10 cents]

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? ____ minutes
   
   [Correct answer: 5 minutes; intuitive answer: 100 minutes]

3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ____ days
   
   [Correct answer: 47 days; intuitive answer: 24 days]

Taken from Toplack et al. (2014):

4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together? _____ days
   
   [Correct answer: 4 days; intuitive answer: 9]

5. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class? ______ students
   
   [Correct answer: 29 students; intuitive answer: 30]

6. A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90. How much has he made? _____ dollars
   
   [Correct answer: $20; intuitive answer: $10]

7. Simon decided to invest $8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has: a. broken even in the stock market, b. is ahead of where he began, c. has lost money
   
   [Correct answer: c; intuitive response: b]
Raven Test

We utilized the Raven progressive matrices test (Raven, 1941) as a general measure of intelligence (Mackintosh, 2011). Specifically, we utilized the odd number of the last three series of matrices (Jaeggi et al. 2010). The duration of the test was 10 minutes. The number of matrices correctly solved in the Raven test is a conventional measure of cognitive ability. Measures of general intelligence are commonly related to working memory capacity, which refers to the short-term holding and manipulation of information (Conway, Kane and Engle, 2003).

The following is an example of a Raven question:

![Raven Test Question](image)

**Figure B.1:** Example of a Raven Test question
End of experiment survey

Financial literacy

The scale was taken from Fernandes, Lynch and Netemeyer (2014).

1) Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, would you be able to buy:
   - more than today with the money in this account
   - exactly the same as today with the money in this account
   - less than today with the money in this account
   - Don’t know
   - Refuse to answer

2) Do you think that the following statement is true or false? “Bonds are normally riskier than stocks.”
   - True
   - False
   - Don’t know
   - Refuse to answer

3) Considering a long time period (for example 10 or 20 years), which asset described below normally gives the highest return?
   - savings accounts
   - stocks
   - bonds
   - Don’t know
   - Refuse to answer

4) Normally, which asset described below displays the highest fluctuations over time?
   - savings accounts
   - stocks
   - bonds
   - Don’t know
   - Refuse to answer
5) When an investor spreads his money among different assets, does the risk of losing a lot of money:

- increase
- decrease
- stay the same
- Don’t know
- Refuse to answer

6) Do you think that the following statement is true or false? “If you were to invest $1000 in a stock mutual fund, it would be possible to have less than $1000 when you withdraw your money.”

- True
- False
- Don’t know
- Refuse to answer

7) Do you think that the following statement is true or false? “A stock mutual fund combines the money of many investors to buy a variety of stocks.”

- True
- False
- Don’t know
- Refuse to answer

8) Do you think that the following statement is true or false? “After age 70 ½, you have to withdraw at least some money from your 401(k) plan or IRA.”

- True
- False
- It depends on the type of IRA and/or 401(k) plan
- Don’t know
- Refuse to answer

9) Do you think that the following statement is true or false? “A 15-year mortgage typically requires higher monthly payments than a 30-year mortgage, but the total interest paid over the life of the loan will be less.”
Suppose you had $100 in a savings account and the interest rate is 20% per year and you never withdraw money or interest payments. After 5 years, how much would you have on this account in total?

- More than $200
- Exactly $200
- Less than $200
- Don’t know
- Refuse to answer

11) Which of the following statements is correct?

- Once one invests in a mutual fund, one cannot withdraw the money in the first year
- Mutual funds can invest in several assets, for example invest in both stocks and bonds
- Mutual funds pay a guaranteed rate of return which depends on their past performance
- None of the above
- Don’t know
- Refuse to answer

12) Which of the following statements is correct? If somebody buys a bond of firm B:

- He owns a part of firm B
- He has lent money to firm B
- He is liable for firm B’s debts
- None of the above
- Don’t know
- Refuse to answer

13) Suppose you owe $3,000 on your credit card. You pay a minimum payment of $30 each month. At an Annual Percentage Rate of 12% (or 1% per month), how many years would it take to eliminate your credit card debt if you made no additional new charges?
Appendix C. Model conjectures

<< Add detailed description of model >>

**Preliminary Simulation Results**

We assume the proportion of *reflective* traders as well as the proportion of *informed reflective (non-reflective)* traders in the market is common information. For each value of alpha (proportion of *reflective* traders) we conduct 10,000 simulations. The following tables provide support for conjectures 1, 3, and 4. We utilize a stopping criterion of 30 transactions though the results are robust to alternate criteria (e.g., 5 transactions).

Conjecture 1. Our model predicts lesser informational efficiency (higher mean absolute deviations) in the *dispersed info* case than in the case of *concentrated info*.

<table>
<thead>
<tr>
<th>$\alpha^R$</th>
<th>Concentrated Information</th>
<th>Dispersed Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/12</td>
<td>79.55</td>
<td>132.09</td>
</tr>
<tr>
<td>2/12</td>
<td>60.92</td>
<td>122.04</td>
</tr>
<tr>
<td>3/12</td>
<td>45.38</td>
<td>114.81</td>
</tr>
<tr>
<td>4/12</td>
<td>29.65</td>
<td>104.38</td>
</tr>
<tr>
<td>5/12</td>
<td>21.81</td>
<td>92.48</td>
</tr>
<tr>
<td>6/12</td>
<td>13.99</td>
<td>75.01</td>
</tr>
<tr>
<td>7/12</td>
<td>10.88</td>
<td>55.98</td>
</tr>
<tr>
<td>8/12</td>
<td>7.96</td>
<td>34.26</td>
</tr>
<tr>
<td>9/12</td>
<td>6.82</td>
<td>21.97</td>
</tr>
<tr>
<td>10/12</td>
<td>5.57</td>
<td>15.23</td>
</tr>
<tr>
<td>11/12</td>
<td>4.93</td>
<td>12.22</td>
</tr>
<tr>
<td>1</td>
<td>4.18</td>
<td>7.75</td>
</tr>
</tbody>
</table>
Conjecture 3. Our model predicts that reflective traders will earn more than non-reflective traders for both the dispersed info case and the concentrated info case.

Table C2. Ending wealth for reflective and non-reflective traders in both treatments.

<table>
<thead>
<tr>
<th>( \alpha^R )</th>
<th>Concentrated Information</th>
<th></th>
<th>Dispersed Information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reflective</td>
<td>Non-reflective</td>
<td>Reflective</td>
<td>Non-reflective</td>
</tr>
<tr>
<td>1/12</td>
<td>2,555.09</td>
<td>2,211.36</td>
<td>2,676.66</td>
<td>2,200.30</td>
</tr>
<tr>
<td>2/12</td>
<td>2,475.70</td>
<td>2,192.86</td>
<td>2,622.10</td>
<td>2,163.58</td>
</tr>
<tr>
<td>3/12</td>
<td>2,406.53</td>
<td>2,184.49</td>
<td>2,581.70</td>
<td>2,126.10</td>
</tr>
<tr>
<td>4/12</td>
<td>2,337.05</td>
<td>2,191.47</td>
<td>2,534.87</td>
<td>2,092.56</td>
</tr>
<tr>
<td>5/12</td>
<td>2,305.39</td>
<td>2,193.30</td>
<td>2,492.33</td>
<td>2,059.76</td>
</tr>
<tr>
<td>6/12</td>
<td>2,274.02</td>
<td>2,205.98</td>
<td>2,438.13</td>
<td>2,041.87</td>
</tr>
<tr>
<td>7/12</td>
<td>2,262.63</td>
<td>2,208.31</td>
<td>2,382.64</td>
<td>2,040.31</td>
</tr>
<tr>
<td>8/12</td>
<td>2,251.68</td>
<td>2,216.63</td>
<td>2,324.93</td>
<td>2,070.13</td>
</tr>
<tr>
<td>9/12</td>
<td>2,247.60</td>
<td>2,217.20</td>
<td>2,284.19</td>
<td>2,107.43</td>
</tr>
<tr>
<td>10/12</td>
<td>2,243.52</td>
<td>2,222.38</td>
<td>2,257.84</td>
<td>2,150.81</td>
</tr>
<tr>
<td>11/12</td>
<td>2,241.79</td>
<td>2,220.35</td>
<td>2,246.53</td>
<td>2,168.17</td>
</tr>
<tr>
<td>1</td>
<td>2,240.00</td>
<td>na</td>
<td>2,240.00</td>
<td>na</td>
</tr>
</tbody>
</table>
Conjecture 4. In the *concentrated info* case, our model predicts that *reflective* traders will earn more than *non-reflective* traders only when comparing traders who do not start the market knowing the value of the asset.

Table C3. Ending wealth for *informed (uninformed) reflective* and *non-reflective* traders.

<table>
<thead>
<tr>
<th>$\alpha^R$</th>
<th>Reflective</th>
<th>Non-reflective</th>
<th>Reflective</th>
<th>Non-reflective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/12</td>
<td>2,646.23</td>
<td>2,566.97</td>
<td>2,463.48</td>
<td>1,866.40</td>
</tr>
<tr>
<td>2/12</td>
<td>2,487.83</td>
<td>2,487.32</td>
<td>2,463.56</td>
<td>1,898.40</td>
</tr>
<tr>
<td>3/12</td>
<td>2,419.96</td>
<td>2,420.11</td>
<td>2,393.56</td>
<td>1,964.19</td>
</tr>
<tr>
<td>4/12</td>
<td>2,351.60</td>
<td>2,352.15</td>
<td>2,322.51</td>
<td>2,030.79</td>
</tr>
<tr>
<td>5/12</td>
<td>2,320.45</td>
<td>2,320.50</td>
<td>2,290.42</td>
<td>2,077.23</td>
</tr>
<tr>
<td>6/12</td>
<td>2,289.41</td>
<td>2,289.06</td>
<td>2,258.63</td>
<td>2,122.90</td>
</tr>
<tr>
<td>7/12</td>
<td>2,277.84</td>
<td>2,277.95</td>
<td>2,247.60</td>
<td>2,145.27</td>
</tr>
<tr>
<td>8/12</td>
<td>2,267.69</td>
<td>2,267.04</td>
<td>2,235.68</td>
<td>2,166.22</td>
</tr>
<tr>
<td>9/12</td>
<td>2,263.50</td>
<td>2,263.57</td>
<td>2,231.76</td>
<td>2,175.58</td>
</tr>
<tr>
<td>10/12</td>
<td>2,259.59</td>
<td>2,259.05</td>
<td>2,227.45</td>
<td>2,185.71</td>
</tr>
<tr>
<td>11/12</td>
<td>2,257.74</td>
<td>2,254.88</td>
<td>2,225.86</td>
<td>2,185.46</td>
</tr>
<tr>
<td>1</td>
<td>2,255.25</td>
<td>na</td>
<td>2,224.75</td>
<td>na</td>
</tr>
</tbody>
</table>
Appendix D. Additional analyses

Table D.1. Comparison of mean absolute deviation for model predictions of both the RE and the PI model

<table>
<thead>
<tr>
<th>Market / Transactions</th>
<th>Dispersed info</th>
<th>Concentrated info</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>PI</td>
</tr>
<tr>
<td>First three / All</td>
<td>157.551</td>
<td>76.291</td>
</tr>
<tr>
<td>Last three / All</td>
<td>51.171</td>
<td>91.711</td>
</tr>
<tr>
<td>All / First three</td>
<td>105.001</td>
<td>90.814</td>
</tr>
<tr>
<td>All / Last three</td>
<td>28.938</td>
<td>64.077</td>
</tr>
</tbody>
</table>

The relative success of the prior information model in predicting asset prices should be tempered by its inability to predict allocations or profit distributions across market subjects. Following PS, we consider the allocation predictions of each model. While the RE model predicts that subjects should not trade in these markets (except at the true value of the asset), the PI model suggests trading should occur. Moreover, these models indicate that all shares should be held by the subset of investors with the highest expected value of the asset.
Table D.2. Panel regression of net holding (shareholdings at the end of a market minus the number of endowed shares [4])

<table>
<thead>
<tr>
<th></th>
<th>Dispersed Info</th>
<th>Concentrated Info</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive clue dummy</strong>&lt;sup&gt;19&lt;/sup&gt;</td>
<td>2.403**** (0.187)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Informed dummy</strong>&lt;sup&gt;20&lt;/sup&gt;</td>
<td>-</td>
<td>-2.215**** (0.251)</td>
</tr>
<tr>
<td>Informed dummy × Asset value</td>
<td>-</td>
<td>0.008**** (0.0007)</td>
</tr>
<tr>
<td>Asset value</td>
<td>5.720&lt;sup&gt;17&lt;/sup&gt; (0.004)</td>
<td>-0.004 (0.0007)</td>
</tr>
<tr>
<td>Gender Dummy (1 if male)</td>
<td>0.850*** (0.289)</td>
<td>0.335 (0.367)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.584**** (0.252)</td>
<td>0.634 (0.554)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>2,040</td>
<td>1,972</td>
</tr>
<tr>
<td><strong>Prob &gt; χ²</strong></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.163</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

**** p<0.001, *** p<0.01, ** p<0.05, * p<0.1

---

<sup>19</sup> This dummy takes value 1 if a trader holds the most positive clue in a market in the dispersed info treatment and 0 otherwise.

<sup>20</sup> This dummy takes value 1 if a trader is fully informed in the concentrated info treatment and 0 otherwise.
Table D.3. Panel regression of net holdings and earnings in the *concentrated* info treatment as a function of a trader’s information and market

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
<th>Earnings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Asset value)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Informed dummy</strong></td>
<td>-3.323****</td>
<td>3.270****</td>
<td>260.259****</td>
</tr>
<tr>
<td></td>
<td>(0.553)</td>
<td>(0.457)</td>
<td>(348.997)</td>
</tr>
<tr>
<td><strong>Market</strong></td>
<td>-0.075*</td>
<td>0.079***</td>
<td>4.542*</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.026)</td>
<td>(2.675)</td>
</tr>
<tr>
<td><strong>Informed dummy × Market</strong></td>
<td>0.0141**</td>
<td>0.0153****</td>
<td>-10.218***</td>
</tr>
<tr>
<td></td>
<td>(0.056)</td>
<td>(0.037)</td>
<td>(3.415)</td>
</tr>
<tr>
<td><strong>Asset value</strong></td>
<td>-</td>
<td>-</td>
<td>4.000****</td>
</tr>
<tr>
<td></td>
<td>(0.077)</td>
<td></td>
<td>(0.077)</td>
</tr>
<tr>
<td><strong>Gender Dummy (1 if male)</strong></td>
<td>0.392</td>
<td>0.089</td>
<td>38.633</td>
</tr>
<tr>
<td></td>
<td>(0.639)</td>
<td>(0.264)</td>
<td>(42.222)</td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td>0.023</td>
<td>-0.004****</td>
<td>1024.726****</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.001)</td>
<td>(70.187)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>580</td>
<td>580</td>
<td>696</td>
</tr>
<tr>
<td><strong>Prob &gt; χ²</strong></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.092</td>
<td>0.153</td>
<td>0.716</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

**** p<0.001, *** p<0.01, ** p<0.05, * p<0.1
Appendix O1. Instructions (online appendix)

Authentication
Please enter your login ID:
login: [Input Field] 
[Submit] button

Welcome!
Please enter your name below to get started:
First and Last Name: [Input Field] 
[Submit] button
Instructions Part 1

This is an experiment in the economics of market decision making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment we are going to simulate a stock market in which you will buy and sell certificates in a sequence of 57 market weeks.

At the end of each year, each certificate you hold will be worth either $0, $240, or $480. The specific amount will be determined by the spin of a wheel. The features of this spinning wheel are described below.

Instructions Part 1

Consider a wheel subdivided into 100 equal-sized pie-slices labeled with the numbers 1 through 100. Each year you spin this wheel, and the spinner (or you) is equally likely to land on any of the numbered slices. If the spinner lands on a number between 1 and 10 (including 1 and 10), it is labeled at 50 is paid. If the number landed on is between 11 and 80 (inclusive), Y is doubled at 90% of $800 is paid, and if the number landed on is between 81 and 100 (exclusive), it is doubled at 400% is paid.

On the following screen you will be asked to predict (one at a time) the outcome of the spin of the wheel. That is, you will predict whether the X, Y, or Z dividend is paid. If your individual prediction is correct, you win $10. If wrong, you lose $3.00. Once you make your prediction, click the "Spin the Wheel" button. After the spin has occurred you will be prompted to make your next prediction and the software will update your earnings.

Note: to simplify the appearance of the wheel, the wheel is subdivided into 5 wedges representing the range of values for which each dividend (X, Y, or Z) is paid.
Instructions Part 2

The type of currency used in this market is francs. All trading and earnings will be in terms of francs. Each franc is worth $0.001 to you. At the end of the experiment, your francs will be converted to dollars at this rate, and you will be paid in dollars. Notice that the more francs you earn, the more dollars you earn.

You will spend the next few minutes learning how to use your computer to trade. Talking between participants is not allowed. All communication will take place by using the computer screen in front of you. If you are found to violate this rule or disturb the experiment by inappropriate remarks or otherwise, we will ask you to leave.

Instructions Part 2 Continued

There are 12 traders in this experiment.

Your profits come from two sources: from collecting certificate earnings on all certificates you hold at the end of the year and from buying and selling certificates. During each year you are free to purchase as many certificates as you wish, provided you follow the rules below.

For each certificate you hold at the end of the year, you will be given one of the numbers of francs that will be provided in the Information section of your screen. An example is provided below. One of these three numbers is selected each year using the spinning wheel described in Part 1 of the instructions.

<table>
<thead>
<tr>
<th>Division</th>
<th>Number of Francs</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Division</td>
<td>50</td>
</tr>
<tr>
<td>Y Division</td>
<td>240</td>
</tr>
<tr>
<td>Z Division</td>
<td>400</td>
</tr>
</tbody>
</table>

Your total certificate earnings for a period are computed for you and displayed on your screen by multiplying these amounts per certificate by the number of certificates held. That is,

\[
\text{Total Certificate Earnings} = \text{Number of Certificates Held} \times \text{Earnings per Certificate}
\]

Suppose, for example, that you hold 5 certificates at the end of year 1. If for that period your earnings are 240 francs per certificate (i.e., it is the Y Division), then your total certificate earnings in the year would be 5 \times 240 = 1,200 francs.
Instructions Part 2 Continued

Sales from your certificates holdings increase your franchise and be the amount of the sale price. Similarly, purchases reduce your franchise and lower the amount of the purchase price. This you gain or lose money on the purchase and resale of certificates.

At the beginning of each year you are provided with an initial holding of certificates that is listed on your computer screen as below. You may sell those if you wish or you may hold them. For each certificate you hold at the end of the year, you receive the "earnings per certificate."

In addition, at the beginning of each year you are provided with an initial amount of franchises on hand which is also listed on your computer screen as below. You may sell them if you wish or you may hold them. At the beginning of each year, you are endowed with holdings of certificates and franchises on hand. You are free to buy and sell certificates as you wish according to the rates below. Your franchise on hand at the end of year is determined by your initial amount of franchises, earnings on certificates earned at the end of the year, and beginning and ending franchise and cash of certificates. These are your profits for the year. Your holdings of cash and shares are never carried over from year to year to the next.

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Information about Dividends

Whether the dividend you receive from the certificates you hold is the X dividend, the Y dividend, or the Z dividend is determined by the experimental at the beginning of the year by selecting a number with 30 equally spaced numbers on it. Each number is equally likely to be selected (i.e., have the same probability). If the number landed on is between 1 and 35 (inclusive), the dividend is paid. If the number landed on is between 36 and 100 (inclusive), the dividend is paid and the number landed on is between 95 and 100. If dividend is paid, the player (i) if the number is landed on, then the Y dividend will be paid. That is, each player would receive 240 for each certificate held at the end of the year. The wheel will only spin once at the beginning of each period. You will not be chosen the spin of the wheel, but you will be given a hint as to its outcome described in next page). Moreover, the outcome of the spin, that is the actual dividend for the year, will be displayed on the computer screen at the end of the year.

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Instructions Part 2 Continued

At the beginning of each year, before trading starts, the experimenter will provide half of you with two cards about which the outcome is X, Y, or Z (in each period). After the experimenter has spun the wheel and determined the outcome for the period, your cards (if any) will appear on your computer screen. It will be one of the following:

<table>
<thead>
<tr>
<th>Clear Options</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>The certificate is worth 500 francs.</td>
<td>The certificate is worth 500 francs.</td>
<td>The certificate is worth 240 francs.</td>
<td></td>
</tr>
<tr>
<td>The certificate is not worth 500 francs.</td>
<td>The certificate is not worth 500 francs.</td>
<td>The certificate is not worth 240 francs.</td>
<td></td>
</tr>
<tr>
<td>(Not X Divided / Not Z Divided)</td>
<td>(Not X Dividend / Not Y Dividend)</td>
<td>(Not Y Dividend / Not Z Dividend)</td>
<td></td>
</tr>
</tbody>
</table>

Information

Also, your card:

The certificate is worth 240 francs.

The certificate is worth 500 francs.

The certificate is not worth 500 francs.

(Not Y Dividend / Not Z Dividend)

Each certificate will be worth 50 Y (Dividend), 240 Y (Dividend), or 0 Y (Dividend) if 50, 240, or 0 Y (Dividend) is drawn, respectively.

Each period, the computer randomly selects the traders into two groups of six each. One group will receive the cards, while the other group will not receive any cards. For example, when the outcome is the Z dividend, six traders will receive the card. The certificate is not worth 500 francs. The certificate is not worth 240 francs. Each group receives the cards determined randomly by the computer. A similar procedure is followed for each year.
Instructions Part 2 Continued

The market for these certificates is organized as follows. The market will be conducted in a series of years. Each year lasts for 5 minutes. Any person may make an offer to buy one certificate at a specified price, and anyone with certificates to sell is free to accept or not accept the offer. Likewise, anyone wishing to sell a certificate is free to make an offer to sell one certificate at a specified price.

The process by which you can make offers to buy and/or offers to sell is described on the following pages.
Making Offers

To accept an existing offer from another participant, click the Buy or Sell button in the Immediate Offer section below. The Immediate Offer section shows you the best prices to buy or sell that are currently available in the market.

Suppose you want to place an offer to buy. It must be higher than the current best offer to buy, which is now $85. Say you want to buy at $90. You will have to type in $90 and click the Buy button. Please do exactly that on your screen by typing $90 in the Submit New Offer box and clicking on the Buy button.

Making Offers

Notice your $250 Offer to Buy now appears in both the Market Graph and the Offer Book.

Next, suppose you want to place an offer to sell. It must be lower than the current best offer to sell, which is now $495. Say you want to sell at $470. You will have to type in $470 and click the Sell button. Please do exactly that on your screen by typing $470 in the Submit New Offer box and clicking on the Sell button.
**Making Offers**

Notice your Offer to Sell now appears in both the Market Graph and the Offer Box.

*Next step: You have submitted new offers, click the NEXT PAGE button to proceed accepting each offer.*

<table>
<thead>
<tr>
<th>Offer</th>
<th>Buy Offer</th>
<th>Sell Offer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Accepting Offers**

To accept an existing offer from another participant, click the Buy or Sell button in the Immediate Offer section below. This section shows the best prices below, that are currently available on the market.

By clicking on the Sell button, you start at the listed price. The current best offer below is 240. If you click Sell, you will accept the offer at the price of 240 immediately. Your certificate, electronic or not, and your cash increases by 240 francs. This is reflected in the "Your holdings" box. Click the Sell button below to confirm.

<table>
<thead>
<tr>
<th>Offer</th>
<th>Buy Offer</th>
<th>Sell Offer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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45
Accepting Offers

Notice your certificate sale of 2000s shows as a black dot on the Market Graph. Also, as noted in the "Your Holdings" box, your cash increased by 2000 francs and your certificates decreased by 5.

Next, by clicking on the Buy button, you buy at the 50 franc price. The current best offer to sell is 450. If you click Buy, you buy a certificate at the price of 450 francs each. Your certificates will increase by 1, and your francs will decrease by 450. This is reflected in the "Your Holdings" box. Your francs will decrease by 450. Click the Buy button to buy to continue.

Accepting Offers

Notice your certificate purchase of 450s shows as a black dot on the Market Graph. Also, as noted in the "Your Holdings" box, your cash increased by 450 francs and your certificates increased by 5.

Now that you have accepted the new offer, click the NEXT PAGE button to continue.
Cancelling Offers

Instructions Part 3

Question 1: At the end of each period, each certificate earns a dividend of:

- A. 0
- B. 50
- C. Either 50, 240 or 490
- D. 490

Question 2: Which of the following statements is correct?

- A. All dividend values (50, 240 or 490) are equally likely
- B. 50 is more likely to occur than the other dividend values.
- C. 490 will occur an average 50% of the time.
- D. 240 is more likely to occur than the other dividend values.

Question 3: You can put a new offer to buy in the market by:

- A. Clicking on the buy button when submitting a new offer to the market
- B. Clicking on the sell button when submitting a new offer to the market
- C. Clicking on the sell button to accept an immediate offer available in the market
- D. Clicking on the buy button to accept an immediate offer available in the market

Question 4: You can accept an existing offer to sell in the market by:

- A. Clicking on the sell button when submitting a new offer to the market
- B. Clicking on the sell button when accepting an existing offer in the market
Question 4: You can accept an existing offer to sell in the market by:
A. Clicking on the buy button when submitting a new offer to the market.
B. Clicking on the sell button when submitting a new offer to the market.
C. Clicking on the buy button to accept an existing offer available in the market.
D. Clicking on the sell button to accept an existing offer available in the market.

Question 5: The experiment will consist of a total of:
A. 12 market years
B. 15 market years
C. 18 market years
D. 17 market years

Question 6: If I receive the clue "The certificate is not worth 50 francs. The certificate is not worth 100 francs," at the beginning of a given year, this means:
A. Each certificate will earn a dividend of 400 at the end of the period.
B. Each certificate will earn a dividend of 200 at the end of the period.
C. Each certificate will earn a dividend of 50 at the end of the period.
D. Each certificate will earn a dividend of 250 at the end of the period.

Question 7: Which of the following statements is correct?
A. All the traders will receive a dividend.
B. No trader will receive a dividend.
C. Each trader will receive a different dividend.
D. Half of the traders will receive a dividend, and the other half will not receive a dividend.

Quiz Completed
You have successfully completed the quiz.

The practice round will begin when everyone is ready.
Please work quietly.