The Journal of Prediction Markets 2014 Vol 8 No 3 pp 34-56

THE POWER OF PRIORS: HOW CONFIRMATION BIAS IMPACTS MARKET PRICES

Michael Cipriano
Johnson College of Business and Economics
University of South Carolina – Upstate

Thomas S Gruca
Henry B. Tippie School of Business
University of Iowa

ABSTRACT

One form of confirmation bias is the tendency for people to ignore information that is inconsistent with their current beliefs. While confirmation bias is the subject of both analytical models and experiments in accounting and finance, its effect on market prices has not been studied due to limitations associated with traditional financial markets. In eleven real-money movie box office prediction markets, confirmation bias was induced in all traders via the explanation effect, i.e. a requirement to submit a box office forecast and an explanation prior to trading. When all traders are subject to confirmation bias, market prices do not accurately reflect new, value-relevant information. However, in comparable a set of seven real-money movie prediction markets that included both traders who have not been subject to explanation requirement and those who have, we find efficient incorporation of new information into market prices. This study extends our knowledge of the conditions under which individual trader biases affect market prices and provides potential insights into open questions about forecasting errors among financial analysts.

Key Words: Prediction markets, confirmation bias, explanation effect, market efficiency, behavioral finance

1 INTRODUCTION

The behavioral finance literature suggests that individual level biases affect the judgments of investors and that these biases can ultimately lead to irrational market prices (e.g. Odean, 1998; Barberis and Thaler, 2001). Proponents of market efficiency counter that the biases exhibited by individuals are eliminated in the market place (e.g., Camerer, 1987; Fama, 1998; Rubenstein, 2001). The few experimental tests of this assertion (e.g., Camerer, 1987; Ganguly, Kagel and Moser, 1994; Kluger and Wyatt, 2004; Tuttle, Coller and Burton, 1997; Teschner, Wagenschwanz and Weinhardt,

2012) have generated mixed results leaving open the question of under what conditions do individual level biases affect market prices.

Since information processing is a key aspect of financial markets (e.g., Lucas, 1972; Grossman, 1981; Daniel, Hirshleifer, and Subrahmanyam, 1998; Plott, 2000; Pouget, Sauvagnat and Villenueve, 2014), any biases in the way market participants or intermediaries (i.e., equity research analysts, financial statement auditors, etc.) incorporate new information into their beliefs and behavior is of great interest in the fields of accounting and finance. One of the most widely studied psychological biases in human information processing is confirmation bias, which is the tendency of individuals to put too much weight on information that confirms their prior views and too little weight on disconfirming information (e.g., Lord, Lepper, Ross, 1979; Evans, 1989; Nickerson, 1998, Shefrin, 2007; Hart, Albarracın, Eagly, Brechan, Lindberg, Merrill, 2009). While the prior views of investors regarding particular securities in traditional markets are typically unobservable, equity research analysts do provide forecasts of companies' future performance with detailed explanations of their rationale behind the forecasts to the public. Subsequently, these analysts revise their forecasts as new information becomes available. Analysts do not typically invest in the securities they follow, but investors do consider analyst forecasts and forecast revisions in their trading decisions (i.e., Liu, 2003; Hughes, Liu and Su, 2008). Thus, if confirmation bias is impacting the forecast revision process of analysts, it could also be impacting market prices set by traders relying on analyst forecasts.

In this paper, we study the effect of confirmation bias on market prices in a set of eighteen real money movie box office prediction markets. In eleven of these markets, all participants played the dual role of 1) analyst, by submitting a detailed written forecast of the movie's box office receipts as well as explanations to support their forecast, and 2) investors, by trading securities whose value is derived from the movie's box office receipts. Numerous psychological studies of the "explanation effect" (e.g., Anderson, Lepper, Ross, 1980; Koehler, 1991; Hammersley, Kadous, Magro, 1997) suggest that the written forecast explanation task will induce confirmation bias in these traders. While we do not require these traders to report revised forecasts during their market participation, we are able to indirectly measure their revised beliefs through the security prices they set in those markets. In other words, rather than measuring traders' forecast revisions, we measure the aggregate results of traders' behavior – market prices – that theoretically reveal all traders' updated forecasts. As such, we are able to measure the potential impact of confirmation bias on market prices by measuring the collective behavior of participants playing the roles of both analyst and investor.

Using a real-money prediction market for this study provides important advantages. First, studying the impact of confirmation bias on prices in

naturally occurring market settings is difficult with traditional archival research techniques because investors' prior beliefs are typically unknown. Consequently, most financial research in this area consists of experiments wherein a participant's initial beliefs about the ultimate value of a financial security are randomly assigned by the researcher (e.g., Eames, Glover & Kennedy, 2006; Hales, 2007; Han & Tan, 2010; Thayer, 2011) rather than being based on a subject's own information processing as they often are in the sociology and psychology literatures (e.g., Ross, Lepper, Strack & Steinmetz, 1977; Sherman, 1980; Sherman, Skov, Hervitz & Stock, 1981; Tetlock, 1985; Koehler, 1991; Ditto, Munro, Apanovitch, Scepansky & Lockhart, 1998). Similar to Hammersley, et al. (1997), we induce confirmation bias by measuring subjects' initial beliefs via a written explanation. We believe that this element of external validity in our design is important because prior beliefs outside of the laboratory arise due to individuals' background and information processing, not random assignment.

Second, we measure how confirmation bias impacts the behavior of those who might be subject to it. While numerous studies in psychology examine how changes in beliefs are affected by the explanation effect (i.e., Anderson and Wright, 1988; Hammersley, et al., 1997; Hammersley, 2011), there are no studies in which individual or collective behavior is measured as a function of both participants' initial beliefs and information received subsequent to initial belief formation and explanation. Ultimately, behavior of individuals in markets is what most market research attempts to understand irrespective of what market participants claim to believe. In the face of new information received subsequent to initial belief formation and explanation, we believe that behavior (i.e., buying and selling securities at various prices) is a more relevant measure of the impact of confirmation bias than merely asking subjects their updated beliefs (i.e., revised forecasts).

Third, because traders are participating in a real-money prediction market, there is an appropriate level of financial incentives. In controlled experiments, researchers induce confirmation bias regarding news about a financial security via endowment (i.e., Hales, 2007). However, without the financial incentives associated with market participation, it is unclear whether the effects of confirmation bias on individuals will ultimately impact market prices.

In eleven of the movie prediction markets, all traders are asked to provide a written forecast of the 4 week box office performance of a soon-to-be-released movie. The traders then participate in a real-money futures market where the values of the contracts being traded are tied to the 4 week box office performance of a given movie. This creates a unique market setting that contains both an appropriate level of financial stakes and traders whose prior beliefs are measured in a manner that induces confirmation bias. We measure the ability of traders to accurately revise their initial forecasts in a very powerful manner – by measuring the changes in contract prices after new, highly relevant information is revealed to the market.

In this paper, we test two hypotheses. First, in markets populated exclusively by traders who have submitted written forecasts and supporting justifications, we expect that security prices will not fully reflect new information as a result of all traders exhibiting behavior consistent with confirmation bias (Pouget, et al., 2014). Consistent with our first hypothesis, we find that prices in these markets do reveal traders' significant under-weighting of a value-relevant, public information signal.

In seven additional markets, traders who were required to provide initial forecasts are joined by (presumptively) unbiased traders who are not subjected to that requirement. Our second hypothesis is that security prices will fully reflect new information in markets with a mixture of traders with induced confirmation bias and unbiased traders (Forsythe, Nelson, Neumann & Wright, 1992; Pouget, et al., 2014). Consistent with our second hypothesis, we find prices in these seven markets reveal traders' complete weighting of a value-relevant, public information signal.

The rest of the paper proceeds as follows: Section 2 presents background literature on confirmation bias, how the explanation effect can induce confirmation bias and the effect of confirmation bias on market prices. Section 3 provides background information on our markets, our measures and our information signal. Section 4 focuses on the model we used to test our hypotheses. In Section 5, we present our results. Section 6 concludes with a discussion of our findings and directions for future research.

2 RELATED RESEARCH

2.1 CONFIRMATION BIAS

Confirmation bias is one of the best known and most often studied decision making biases (see Evans, 1989, Nickerson, 1998, Hart, et al., 2009 and/or Pouget, et al., 2014 for extensive reviews of the confirmation bias literature). It is generally defined as "the seeking out or interpreting of evidence in ways that are partial to existing beliefs." (Nickerson, 1998, p. 175). In general, the two primary sources of confirmation bias in human cognition are 1) meaning change and/or 2) biased assimilation (Bodenhausen, 1988; Nickerson, 1998). On the one hand, meaning change is the human tendency to interpret information in a manner that makes it support prior beliefs whether or not it does. On the other hand, biased assimilation refers to the tendency to give more attention and more weight to information that corroborates prior beliefs and less attention and less weight to information that contradicts those prior beliefs. It is this latter source of confirmation bias – biased assimilation – which we expect to affect traders in our study who forecast a future event, justify that forecast in writing and then trade in a prediction market where new, value-relevant information is made public.

The effects of confirmation bias have been incorporated into a number of financial models including Daniel, et al. (1998) and Rabin and Schrag (1999). In a market model set forth in Daniel, et al. (1998), trader overconfidence is the source of the biased assimilation form of confirmation bias. By modeling the weight placed on a privately-generated signal in assessing an asset's value as a function of an individual's confidence, Daniel, et al. (1998) show that the biased individual incorrectly perceives his initial private information to be more precise than subsequently received public information. This leads the individual to overweigh his initial private information and underweight value-relevant, public information in estimating an asset's value unless it confirms his private information. As a result, security prices in asset markets populated with this type of biased trader are predicted to not reflect the rational incorporation of new information over time.

Rabin and Schrag (1999) directly model the effects of the meaning change form of confirmation bias. In their model, an economic agent subject to confirmation bias interprets information signals as being confirmatory of his initial beliefs whether or not they actually are confirmatory. Depending on the extent of the bias, it can be difficult or even impossible for the agent to change his initial beliefs even in the face of a significant number of highly disconfirming information signals. The relevance and strength of the information signals becomes almost irrelevant in their model because the agent interprets information in a manner that supports his initial beliefs or ignores it completely.

2.2 USING THE EXPLANATION EFFECT TO INDUCE CONFIRMATION BIAS

Individuals who develop written explanations are more likely to persist in their beliefs in the face of disconfirming evidence than those who have not developed a written explanation (Anderson, et al., 1980). The impact that a written explanation has on an individual's future beliefs and behaviors is known as the "explanation effect." In the case of an individual forecasting a future outcome (e.g., future earnings, future movie box office receipts, winner of an election, etc.), the explanation effect generates a causal mental representation from available information (Hammersley, et al., 1997; Anderson, et al., 1980).

In studies of causal representation, information that is more consistent with a subject's initial written explanations receives more weight in subsequent assessments of the likelihood that the forecasted event will happen while inconsistent information will either receive less weight or be completely ignored (e.g. Ditto, et al,, 1998; Lord, et al., 1979). Thus, one of the consequences of eliciting a written explanation from individuals is confirmation bias, specifically biased assimilation that results in the under-

weighting of information that is received after an initial explanation task when that new information is inconsistent with the initial explanation.

It is important to note for this study that confirmation bias can affect more than beliefs. It can also alter future behavior in a manner that ignores information received subsequent to the creation of the initial written explanation (e.g. Sherman, 1980; Sherman, et al., 1981). In these studies, Sherman and his colleagues show that the written predictions that subjects make of their future behavior actually influences their eventual future behaviors. While a considerable amount of the confirmation bias research literature focuses solely on the measurement of beliefs, Sherman (1980) and Sherman, et al. (1981) measure the impact that the written predictions themselves have on future behavior. The implication of their work for this study is that the written forecasts our subjects generate should impact not only their forecasts, but also their trading behavior.

2.3 THE EFFECTS OF CONFIRMATION BIAS ON MARKET PRICES

Pouget, et al. (2014) model financial market participants in a manner that is similar to Rabin and Schrag (1999). They extend Rabin and Schrag (1999) to analytically examine how the extent of confirmation bias influences trader beliefs as reflected by market prices. As in Rabin and Schrug (1999), they model each information signal as being either positive or negative relative to initial beliefs. One of their primary results is that markets including traders with confirmation bias misprice securities due to the degree to which biased traders' interpretation of information signals are irrationally conditioned on their prior beliefs. In other words, traders' biased beliefs results in behavior – as measured by security prices -- that does not reflect full incorporation of value-relevant, new information when it does not confirm their priors. Based on Pouget, et al. (2014), we can predict how traders in markets populated exclusively by those who submitted a written forecast will react to new information.

Due to the explanation effect, we expect that the act of creating and justifying a written forecast will induce confirmation bias in these traders. Based on prior experimental research on confirmation bias and its effects on behavior, all of these traders with confirmation bias will not give sufficient weight to new information in updating their forecasts of the outcome of the market. Furthermore, they are unlikely to trade in a manner consistent with rational expectations. This leads to our first hypothesis:

> Hypothesis 1: *In markets including only traders subject to confirmation bias, prices will reflect significant under-reaction to information received subsequent to initial belief formation.*

In the Pouget, et al. (2014) model, they postulate that traders subject to the confirmation bias will eventually be joined in the market by rational traders who are not subject to the bias. These rational traders will fully incorporate public information. Thus, Pouget, et al. (2014) predict that the unbiased traders will drive prices to be efficient in markets that include a mix of both biased and rational traders. This is consistent with some of the behavioral finance literature that shows the impact of individual psychological biases on market prices can be mitigated by the presence of unbiased traders (e.g. Ganguly, et al., 1994; Camerer, 1987; Camerer, 1992; Kluger and Wyatt, 2004). It is also consistent with prior research on the efficiency of prediction markets (i.e., Forsythe, Rietz and Ross, 1999).

These studies lead to our second hypothesis:

Hypothesis 2: *In markets including both traders subject to confirmation bias and unbiased traders, prices will efficiently reflect information received subsequent to initial belief formation.*

3 MARKET OVERVIEW

The setting for our study is a real money prediction market in which participants trade securities whose value is tied to a future event. This market started operations in 1988 and is operated by the faculty of a large Midwestern university. As a market for research and teaching purposes, it has received two "no action" letters from the Division of Trading and Markets of the Commodity Futures Trading Commission. Since its inception, this market has accurately forecasted a large number of national, local and international elections relative to both the pre-election polls and actual election outcomes (Forsythe, et al., 1992; Berg, Nelson and Rietz 2008).

All trading in this market is conducted via an anonymous, computerized double auction which accepts both market and limit orders. All limit orders (bids/asks) are queued by price and submission times. The best bid and ask prices are available to traders as are past daily average prices and transaction levels. An individual's investment in the market is limited to $500 and no short selling is allowed.[1] In addition, no transaction fees are charged to traders.

Traders may acquire securities from the market in a bundle consisting of one of each of the securities in the market. A complete bundle of securities may be purchased from or sold to the exchange at any time for $1, the

[1] A trader may simulate a "short-sale" of a single security or set of securities by buying a $1 bundle and selling securities from that bundle that are expected to fall in price. After the expected fall in price, the securities may be purchased from other traders and the entire bundle sold back to the exchange for $1.

guaranteed liquidation value of the bundle. Therefore, the supply of securities in the market expands and shrinks as traders desire without contaminating the individual prices as set by the traders.

3.1 MOVIE BOX OFFICE MARKETS

The markets of interest in this study are focused on predicting the domestic box office performance of a particular movie in its first 4 weeks of release. In each market, a bundle of four to 8 securities was offered. Each security is associated with a mutually exclusive and collectively exhaustive range of box office receipts within the specified four-week period. At the end of the market, only one of the securities pays off $1 while the others expire worthless. Consequently, the bundle of securities is a set of outcome-spanning Arrow-Debreu securities. For example, in a market conducted in late 2007, there were 5 securities associated with the movie *Beowulf*. They are presented in Table 1. The prices of these securities represent the market's collective estimate of the probability that the given movie's box office receipts will fall within the relevant range after the first 4 weeks of release in theaters.

Table 1:Security Definitions for *Beowulf* (2007) Movie Box Office Market

Security	Definition
BEOW060L	$1.00 if *Beowulf*'s official box office receipts for the 11/16/07-12/13/07 period are lower than or equal to $60 million; zero otherwise.
BEOW070L	$1.00 if Beowulf's official box office receipts for the 11/16/07-12/13/07 period are greater than $60 million and lower than or equal to $70 million; zero otherwise.
BEOW080L	$1.00 if Beowulf's official box office receipts for the 11/16/07-12/13/07 period are greater than $70 million and lower than or equal to $80 million; zero otherwise.
BEOW090L	$1.00 if Beowulf's official box office receipts for the 11/16/07-12/13/07 period are greater than $80 million and lower than or equal to $90 million; zero otherwise.
BEOW090H	$1.00 if Beowulf's official box office receipts for the 11/16/07-12/13/07 period are greater than $90 million; zero otherwise.

Table 2: Movie Box Office Market Descriptions

MOVIE	Date Market Began Trading	Date Movie Opened	Number of Securities - (Type of Market)	Number of Traders/ Forecasters
Lost in Space	3/27/1998	4/3/1998	4 - (open)	81/ 44
Mercury Rising	3/27/1998	4/3/1998	4 - (open)	81/ 44
Enemy of the State	11/9/1998	11/20/1998	4 - (closed)	88/ 88
I Still Know What You Did Last Summer	11/9/1998	11/13/1998	5 - (closed)	88/ 88
Sleepy Hollow	11/5/1999	11/19/1999	5 - (open)	345/ 106
The World is not Enough	11/5/1999	11/19/1999	5 - (open)	311/ 106
The 6th Day	11/3/2000	11/17/2000	4 - (closed)	91/ 91
How the Grinch Stole Christmas	11/3/2000	11/17/2000	4 - (closed)	91/ 91
Monsters, Inc.	10/19/2001	11/2/2001	5 - (open)	285/ 34
Harry Potter and the Sorcerer's Stone	11/2/2001	11/16/2001	6 - (open)	380/ 111
Die Another Day	11/8/2002	11/22/2002	5 - (open)	183/ 86
The Cat in the Hat	11/7/2003	11/21/2003	8 - (closed)	84/ 84
The Sponge Bob Square Pants Movie	11/5/2004	11/19/2004	6 - (closed)	58/ 58
Happy Feet	11/3/2006	11/17/2006	5 - (closed)	106/ 106
The Fountain	11/3/2006	11/22/2006	5 - (closed)	106/ 106
300	2/23/2007	3/10/2007	5 - (closed)	58/ 58
Beowulf	11/2/2007	11/16/2007	5 - (closed)	61/ 61
Twilight	11/3/2008	11/21/2008	6 - (closed)	63/ 63

Trading in all movie markets began from 4-19 days before the opening of the movie in theaters. Traders could access the market 24-hours a day through the Internet. Trading continued for four weeks after the opening of the movie.

The securities were liquidated after official four-week box office data became available. We are focusing on a set of 18 movie box office markets organized between 1998 and 2008. An overview of these markets is provided in Table 2.

3.2 TRADERS

Participation in these markets is limited to traders with an academic affiliation (including students, staff and faculty). There are two distinct types of markets being compared in this study. The first is denoted as a "closed" market. These are markets in which every trader was required to submit a point forecast of the 4-week box office performance for each movie supported by a 2-4 page justification of the forecast. An example of the forecasting instructions is available in the appendix.

In exchange for their forecasts and accompanying written justifications, the traders were provided a $5 or $10 trading account (They could add more funds up to the $500 market limit). These traders were asked to execute at least two trades while the market was open (buying or selling a bundle of securities is considered a trade).

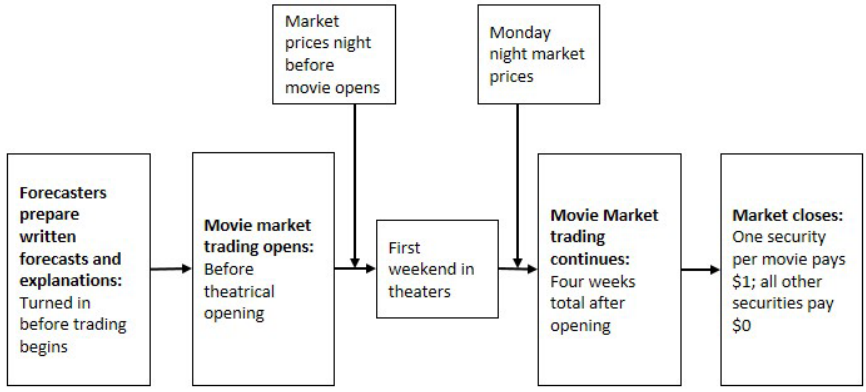
The second type of market is denoted as an "open" market since market participation was open to all traders with an academic affiliation. Therefore, these markets consisted of a subset of traders who had provided a written forecast (and justification) before trading commenced and a subset of traders who did not participate in the forecasting experience. We refer to this latter group of traders in the open markets as "rational" or "unbiased" traders because they are not subject to the confirmation bias we induced by requiring forecasters to prepare, justify and submit a written forecast prior to trading. There are seven open markets in our study.

3.3 MARKET TIMELINE

The timeline of the market is provided in Figure 1. The first step in the market timeline is the submission of the traders' forecasts. This step pertains only to those traders. All other steps are common to all market participants. Once the forecasts are submitted, the movie box office market opens. Trading in the markets began before the opening of the movie in theaters. Once the movie opened in theaters, trading continued for four weeks.

Nielsen/EDI (now owned by Rentrak) tracked movie box office performance following each weekend on a weekly basis. Daily estimates are also available at other web sites, e.g., the-numbers.com. After the final 4-week receipts are available in print (through Variety), the markets are liquidated. This entails exchanging $1 for each winning security held by a trader. Nothing is paid for losing securities.

Figure 1: Movie Box Office Market Time Line



3.4 PUBLIC INFORMATION AVAILABLE TO INVESTORS

A movie's performance in the first weekend of release is an important determinant of its overall performance (e.g., Krider & Weinberg, 1998; Pennock, Nielsen, & Giles, 2001). Most movies have their largest box office receipts in the first weekend, followed by a sharp drop-off in subsequent weeks. Therefore, when trying to predict the four-week box office performance of a given movie, traders should pay particular attention to its performance over the first weekend.

There is a well-known relationship between the opening week-end performance of a movie and its total receipts over a 4-weekend time period. A large scale movie prediction game - the Hollywood Stock Exchange (HSX.com) - suggests that the four-week total is close to 2.9 times the opening weekend (Pennock, Nielsen, & Giles, 2001; Elberse, 2007; Elberse & Anand, 2007).[2]

To evaluate how well the first weekend box office results can forecast the four-week total, we collected a sample of 417 movies released between 1999 and 2001 from www.hollywoodstockjournal.org (on 6/11/2007). We compared two forecasts of the four-week box office total. The first is based on the HSX price on Friday night of the first weekend the movie is in theaters. Comparing this figure with the actual 4-week total, the mean absolute percentage error (MAPE) is 56%. Our second forecast was generated by

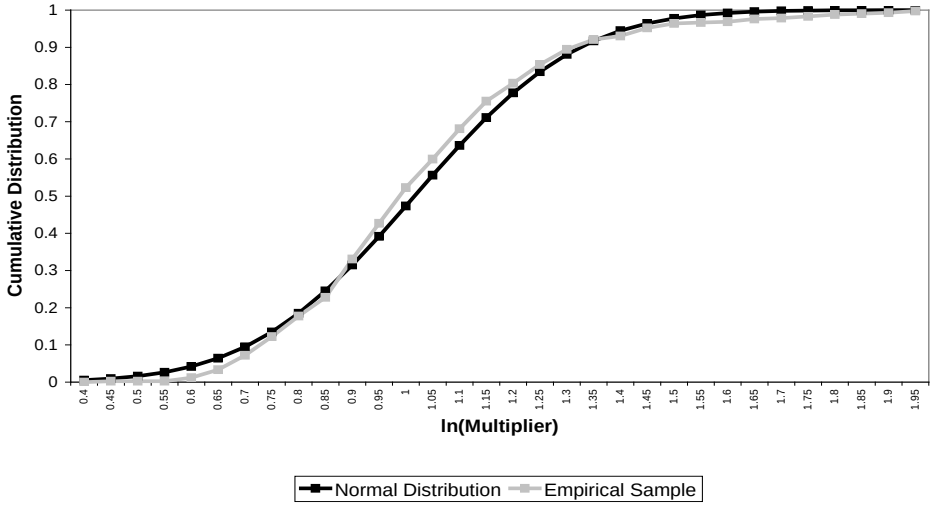
[2] This ratio is used to adjust prices of HSX securities on Monday after a trading halt on the opening Friday of wide release (> 500 screens) in theaters. The HSX trading halt is intended to reduce the impact of traders with insider information on the market's prices.

multiplying the first weekend box office total by 2.9. The MAPE for this forecast was only 20%, a substantial reduction.

Therefore, once a trader observes the opening weekend performance of a movie, the multiplier of 2.9 provides a relatively accurate point estimate of the four-week total. For example, the 2007 movie *Beowulf* made $27.5 million in its first weekend. Using the 2.9 multiplier, a trader would forecast a four-week total of $79.75 million. This is very close to the actual four-week total of $77.9 million, an absolute percentage error of 2.3%.

While the movie multiplier provides an accurate point estimate of the four-week total, the actual multiplier does vary. Using the same sample of 417 movies released between 1999 and 2001, we found that the average ratio between the first weekend box office performance and the four-weekend total was 2.85, very similar to the 2.9 ratio used by HSX.com. The standard deviation of the multipliers is 0.78. The multipliers in our sample have a distribution that does not significantly deviate from a log-normal distribution (Kolomogrov-Smirnov $D = 1.161$, $p < 0.135$) with a mean of 1.016 and a standard deviation of 0.241. We plotted the cumulative distribution of actual multipliers ($\log_e$ transformed) against a normal distribution in Figure 2.

Figure 2: Movie Multiplier Distribution (n = 417)



This plot shows that the distribution of the multipliers (using the loge transformation) is well-characterized by a normal distribution.

Using this empirical distribution of movie multipliers, we can determine the expected security prices given the first weekend box office performance of a particular movie. For example, in the 2007 *Beowulf* market, the upper bound

of the BEOW060L security is $60 million. Given first weekend box office receipts of $27.5 million, the likelihood of the four-week total being less than $60 million is the same as the probability that the multiplier is less than 2.18 ($60/$27.5 = 2.18). Given the ($\log_e$) mean and standard deviation of the distribution of multipliers, the corresponding Z-score is (2.180 - 1.016) / (0.241) = -0.98. The cumulative standard normal distribution at this point is 0.163. This suggests that the probability that the actual multiplier will be less than 2.18 is 16.3%. This corresponds to the probability that *Beowulf* will make less than $60 million in its first four weeks given its actual opening weekend take of $27.5 million. Therefore, given the first weekend box office results, the expected value of the BEOW060L security is $0.163.

The well-behaved relationship between the first weekend box office results and the four-week total provide a very good benchmark to evaluate security prices (and changes in prices) we observe in the movie box office markets. We will assess how well prices incorporate this public information about the ultimate value of the securities after the first weekend results are available to traders.

4 MARKET PRICE UPDATE MODEL

We model the market prices in response to new information using the following simple price update model:

$$P_{j,t} = P_{j,t-1} + wS_{j,t} \quad (1)$$

where $P_{i,t}$ is the price of security j at time t, $P_{j,t-1}$ is the price of security j at time t-1, w is the adjustment weight for new information, $S_{j,t}$ is signal provided by the new information about the value of security j in time t.[3]

For the initial price ($P_{j,t-1}$), we use the actual price of the individual security at midnight on the night before the movie opened in theaters. For the updated price ($P_{j,t}$), we use the security price at midnight on Monday following the first weekend. While the official first-weekend results are available during the day on Monday, we measure the price at midnight to allow traders time to react to the official box office results.

We define the signal ($S_{j,t}$) as the difference between the pre-opening ($P_{j,t-1}$) and the expected price ($E_{j,t}$) based on the first weekend box office results, i.e., $S_{j,t} = (E_{j,t} - P_{j,t-1})$. For example, the actual price of the BEOW060L security the night before the movie opened in theaters ($P_{1,t-1}$) was $0.0085. As noted in

[3] This is a much simpler asset pricing model than Rabin and Schrag (1999) and Pouget, et al. (2014), but it embraces their assumption that market price evolves as a result of initial beliefs being established and then updated as a result of traders receiving, weighing and incorporating new information into the beliefs about an asset's true value.

the previous section, based on the first weekend box office performance and the movie multiplier, the expected security price after the first weekend ($E_{1,t}$) is \$0.163. The signal ($S_{1,t}$) from the first weekend's results is positive (0.1545 = 0.163 - 0.0085), indicating that the security was underpriced prior to the movie's opening given the performance of the movie on its first weekend.

Using prices before and after the first weekend of each movie and the historical movie multiplier, we can estimate the sensitivity of prices ($P_{j,t}$) to the signal ($S_{j,t} = E_{j,t} - P_{j,t-1}$) through the estimation of a weight parameter (w) by carrying the above substitutions through Equation (1) and moving the initial price ($P_{j,t-1}$) to the left hand side as follows:

$$P_{j,t} - P_{j,t-1} = w(E_{j,t} - P_{j,t-1}) \quad (2)$$

The weight parameter estimate (w) measures the sensitivity of post-weekend prices to the information signal of first weekend box office receipts and the movie multiplier relative to prices prior to the weekend as follows:

$$w = (P_{j,t} - P_{j,t-1}) / (E_{j,t} - P_{j,t-1}) \quad (3)$$

An estimate of w equal to 1 implies efficient incorporation of that information signal. In the above example, if the actual price of the BEOW060L security on Monday ($P_{1,t}$) is \$0.163, then the price change ($P_{1,t} - P_{1,t-1}$) is \$0.1545 which is the exact amount of change in price expected ($E_{1,t} - P_{1,t-1}$). However, if w is estimated to be less than 1 due to $P_{1,t}$ being less than \$0.163 (i.e., \$0.10) the implication is that traders under-reacted to the new information.

We illustrate the construction of our dependent and independent variables across all securities in a market using the data from the 2000 market for *The 6th Day*. A total of four securities were offered: SIX50L which is bounded above at a 4 week box office total of \$50 million, SIX70L which pays \$1 if the movie made more than \$50 million and less than \$70 million, SIX90L which pays \$1 if the movie made more than \$70 million and less than \$90 million and SIX90H which pays \$1 in the event the movie made more than \$90 million in its first 4 weeks of wide release (between 11/17/2000 and 12/15/2000). All markets were constructed in a similar manner.

Continuing with *The 6th Day* example, the prices of these securities at midnight on Thursday ($P_{j,t-1}$) before the movie opened in theaters (in black) and at midnight on Monday after the movie opened in theaters ($P_{j,t}$ in grey) are presented in Figure 3.

The first weekend's box office total was \$13.02 million. Applying the parameters of the log-normal distribution of movie multipliers to the first weekend's receipts, we computed the expected prices ($E_{j,t}$) of each of the security. These prices are indicated by white bars (with dots). The resulting

dependent and independent variables for each security in *The 6th Day* market are presented in Figure 4.

Figure 3: Security Price Changes in Movie Box Office Market for *The 6th Day*

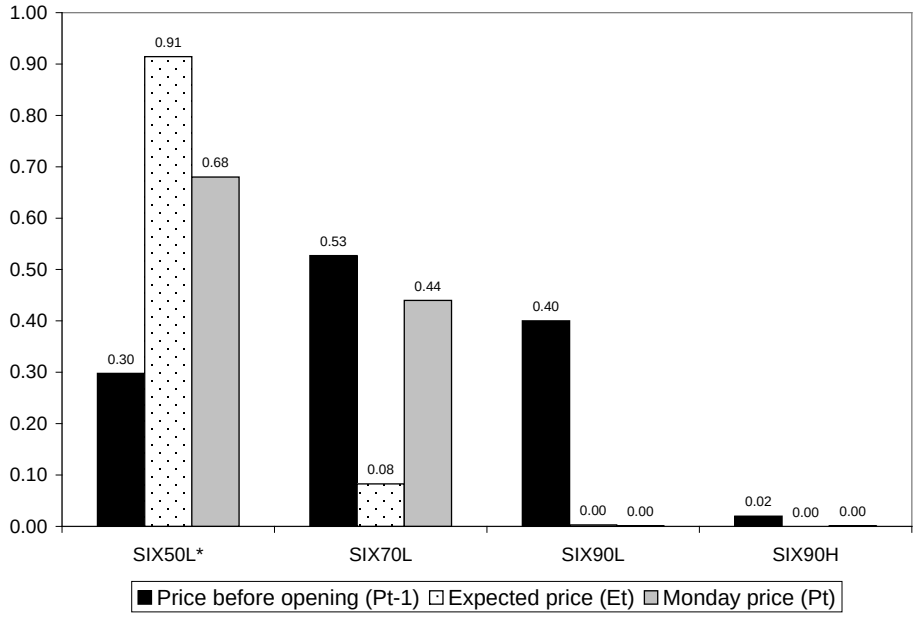
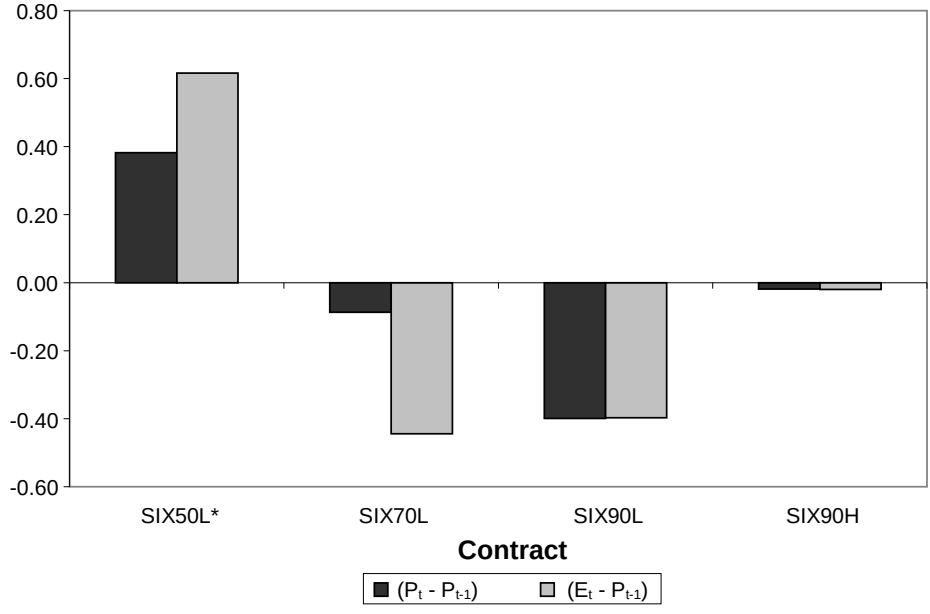


Figure 4:Variables Derived from Actual and Expected Security Prices for *The 6th Day*



We followed this same estimation procedure of variables across all of our movie markets to estimate the weight parameter (w) in equation 2.

5 RESULTS

The unit of analysis is the individual security. Across the 18 markets in this study, there were 91 different securities offered to traders. We estimated the weight parameter (w) for the pooled set of markets and separately for closed and open markets using OLS with heteroskedastic-robust standard errors.

The results of our model estimation are presented in Table 3. The results of the model estimated across all securities in all markets is highly significant ($F = 74.01$ $p < 0.001$). The high level of fit ($R^2 = 0.56$) suggests that the changes in security prices are strongly influenced by the information provided by the first weekend box office performance. The intercept in the model is not significant ($p = 0.142$ for a two-tailed test). This suggests there is no general tendency for security prices to rise or fall with the release of new information about box office performance. The new information about the value of a security has a positive ($w = 0.824$) and significant ($p < 0.001$) impact on the observed changes in security prices.

Table 3: Regression Results for All Markets, Closed Markets and Open Markets

Parameters	**All Markets** [a]	**Closed Markets**[a]	**Open Markets**[a]
Constant	0.027 (0.142)	0.031 (0.172)	0.021 (0.730)
w: sensitivity to new information	0.824 (<0.001)	0.768 (<0.001)	1.089 (<0.001)
R^2	0.56	0.58	0.56
F-value	74.01 (<0.001)	59.90 (<0.001)	18.03 (<0.001)
Number of Observations	91	57	34
Hypotheses for Parameter Tests		H_0: w = 1 H_1: w ≠ 1	H_0: w = 1 H_1: w ≠ 1
t-statistic		2.34 (0.020) Reject H_0	0.31 (0.760) Fail to reject H_0

[a] p-value in parentheses.

A coefficient of 1 would indicate efficient (or 100%) incorporation of the information revealed by the signal (i.e., the first weekend box office and

multiplier) into market prices. We hypothesize that while closed markets will generate prices that reflect significant under-reaction to the information signal ($w < 1$) due to confirmation bias of all traders, the impact of conformation bias on prices will be mitigated in markets that are open to unbiased traders. Tests of our hypotheses in the subsequent sections will require both a) separate analysis of closed versus open markets and b) tests of the significance of the weight parameter w relative to 1 instead of 0.

5.1 THE IMPACT OF CONFIRMATION BIAS IN CLOSED MARKETS

There were a total of 57 securities offered in the 11 closed markets. (The parameter estimates are also presented in Table 3). The overall model is significant ($F = 59.90$, $p < 0.001$). The high level of fit ($R^2 = 0.58$) suggests that in markets in which all traders have created and submitted a written explanation, the release of interim performance data does affect prices. The intercept is not significant ($p = 0.172$). The coefficient for the influence of new information (w) is positive (0.759) and significantly different from zero ($p < 0.001$). To test Hypothesis 1, we compared the weight parameter (w) to 1. Using a 2-tailed test, we reject the null hypothesis that the coefficient is equal to 1 (t-statistic = 2.34, $p < 0.02$). Consistent with Hypothesis 1, we find that prices in a market consisting solely of traders subject to confirmation bias significantly under-react to new information.

5.2 THE IMPACT OF UNBIASED TRADERS

In Hypothesis 2, we predict that the presence of unbiased or rational traders may correct the impact of confirmation bias on market prices. We test this hypothesis in 7 additional open markets where the pool of traders includes both traders who have created and submitted a written explanation as well as traders we consider to be unbiased because they have not (to our knowledge) created a written forecast of the market outcome. There were 34 securities offered in the 7 open markets. The results of the model estimation are also presented in Table 3.

The model is significant ($F = 18.03$, $p < 0.001$) and has a high level of fit ($R^2 = 0.56$). These results imply that the observed price changes for these securities are strongly influenced by the information conveyed by the first weekend box office performance. The intercept is not significant ($p = 0.469$). The coefficient for the effect of new information on the changes in security prices (w) is positive (1.09) and significantly different from zero ($p < 0.001$).

Hypothesis 2 predicts that the presence of unbiased traders should result in price changes that neither under-react nor over-react to new information. This means the coefficient (w) should not differ significantly from 1. A two-tailed t-test fails to reject the null hypothesis that $w = 1$ (t-statistic = 0.32, $p = 0.76$). This result supports Hypothesis 2.

6 DISCUSSION AND CONCLUSIONS

The support for both of our hypotheses provides insight into how confirmation bias can be induced by having individuals provide a written forecast prior to market participation and how that bias impacts market prices. In closed markets consisting solely of biased traders, market prices reflect under-reaction to new, value-relevant information. Thus, the mere involvement of biased traders in a market does not, by itself, result in efficient information processing by traders as reflected by changes in market prices. However, in markets that are opened to traders who have not submitted a written forecast, market prices do not reflect under-reaction. These findings extend the current stream of research showing that the inclusion of rational traders in markets with irrational traders can result in efficient market prices (e.g. Ganguly, et al., 1994; Camerer, 1987; Camerer, 1992; Kluger and Wyatt, 2004).

We believe our results may provide insights into patterns of forecasting updating (or the lack thereof) observed in U.S. equity markets. Much like our biased traders, professional equity research analysts prepare and publish written forecasts of a company's future earnings that include significant explanations and justifications for their forecast. Their explanations include substantial qualitative and quantitative analysis of firm-specific, industry, and macroeconomic factors. Analysts are subject to explanation requirements while other relevant groups (i.e., individual and institutional investors) are not. In fact, only analysts publicly report their earnings forecasts, explanations of their forecasts, or subsequent revisions to them. Thus, the conditions under which the explanation effect can influence forecast revision exist in the realm of professional earnings forecasting.

As new information becomes available, analysts may or may not revise their forecasts and publish their forecast revisions. Multiple studies suggest that analysts routinely under-react to new information in their revisions of initial earnings forecasts (i.e., Abarbanell and Bernard, 1992; Elliott, Philbrick and Wiedman, 1995; Easterwood and Nutt, 1999); Kasznik and McNichols, 2002). Elliott et al. (1995) suggest that analysts "appear prone to underweight new information and thus to under-revise their beliefs as new information is received during the year" (p. 934). However, this type of archival research does not allow the researcher to identify the causes of analysts' insufficient revision of their forecasts.

Interestingly, Liu (2003) and Hughes, et al. (2008) suggest that one reason that (sell-side) analysts do not fully incorporate new information into their revisions is because they lack the economic incentives to do so. Specifically, analysts do not have their own funds invested in the companies for which they are producing earnings forecasts. This is an interesting thought experiment which has to remain in the realm of conjecture While having analysts reduce their biases by trading in a market is consistent with traditional financial

theory on efficient markets, it is also untestable since analysts are barred from trading in companies they report on within 30 days before and 5 days after they issue an earnings forecast.

We do not claim that the traders in these prediction markets are the same as professional analysts. However, the results of this study do have implications for the stream of research on how financial analysts revise their forecasts based on new information. First, prior research on the explanation effect suggests that financial analysts will be prone to confirmation bias due to the process of forecasting earnings and justifying that forecast in writing. This psychological explanation for the often observed tendency for analysts to underweight new information is a reasonable alternative to explanations such as optimism (Easterwood and Nutt, 1999) or herding behavior (Scharfstein and Stein, 1990; Trueman, 1994).

Second, our study involves traders subject to confirmation bias that is induced by creating and justifying a forecast. Traders in these prediction markets have strong economic incentives to take advantage of all value-relevant information as they buy and sell securities. In spite of those incentives, when trading only amongst themselves, our forecasting traders do not generate market prices that fully incorporate new information. Therefore, we speculate that if the reason that financial analysts often ignore new information that is inconsistent with their prior beliefs (and current earnings forecast) due to the explanation effect, then trading in a market, even if possible, would not get rid of that bias.

As with any empirical study, there are limitations to this work derived from both its controlled and natural features. These are small-scale markets and not part of any trader's overall asset portfolio. These markets are somewhat stylized due to the trader population (primarily MBA students and other academics), the focus of the markets (movie box office predictions) and the forecasting assignment (justifying a box office prediction in writing). Also, we do not know much about the unbiased traders beyond the fact that they have an academic affiliation and invested their own money.

In this study, we extend the existing research on the effects of confirmation bias from the realms of the laboratory and the analytic model to a field setting. To our knowledge, all previous empirical research on confirmation bias focuses on the individual. We extend this stream of research by concentrating on the effect of confirmation bias on the market as a whole (as reflected in price changes). In these movie prediction markets, confirmation bias was induced in some traders via the explanation effect. When all traders are subject to confirmation bias, market prices do not accurately reflect new, value-relevant information. However, the presence of non-biased traders does lead to efficient incorporation of new information into market prices.

In conclusion, this study makes two important contributions. First, we focus on an important information processing bias – confirmation bias - that

has not been studied in a market setting. Second, we extend our understanding of the conditions under which this individual bias will affect prices in a real-money (prediction) market setting.

7 REFERENCES

J Abarbanell and V Bernard 'Test of Analysts' Overreaction/Under-reaction to Earnings Information as an Explanation for Anomalous Stock Price Behavior' *Journal of Finance* (1992) 47 1181-1207.

C A Anderson, M R Lepper and L Ross 'The perseverance of social theories: The role of explanation in the persistence of discredited information' *Journal of Personality and Social Psychology* (1980) 39 1037-1049.

U Anderson and W Wright 'Expertise and the explanation effect' *Organizational Behavior and Human Decision Processes* (1988) 42 250-269.

N Barberis and R Thaler 'A survey of behavioral finance' in G M Constantinides, M Harris and R Stulz (eds) *Handbook of the Economics of Finance* (Elsevier Science, 2001).

J E Berg, F D Nelson and T Rietz 'Prediction Market Accuracy in the Long Run' *International Journal of Forecasting* (2008) 24(2) 283-298.

G Bodenhausen 'Stereotypic biases in social decision making and memory: testing process models of stereotype use' *Journal of Personality and Social Psychology* (1988) 55 726-737.

C F Camerer 'Do biases in probability judgments matter in markets? Experimental evidence' *American Economic Review* (1987) 77 981-997.

C F Camerer 'The Rationality of Prices and Volume in Experimental Markets' *Organizational Behavior & Human Decision Processes* (1992) 51(2) 237-272.

K Daniel D Hirshleifer and A Subrahmanyam 'Investor Psychology and Security Market Under- and Overreactions' *Journal of Finance* (1998) 53(6) 1839-1886.

P H Ditto, G D Munro, A Apanovitch, J A Scepansky and L K Lockhart 'Motivated sensitivity to preference-inconsistent information' *Journal of Personality and Social Psychology* (1998) 75(1), 53-69.

M J Eames, S M Glover and J J Kennedy, J.J.'Stock Recommendations as a Source of Bias in Earnings Forecasts' *Behavioral Research in Accounting* (2006) 18 37-51.

J C Easterwood and S R Nutt 'Inefficiency in Analysts' Earnings Forecasts: Systematic Misreaction or Systematic Optimism' *Journal of Finance* (1999) 54(5) 1777-1797.

A Elberse 'The Power of Stars: Do Star Actors Drive the Success of Movies?' *Journal of Marketing* (2007) 71 102–120.

A Elberse and B Anand 'The effectiveness of pre-release advertising for motion pictures: An empirical investigation using a simulated market' *Information Economics & Policy* (2007) 19(3/4) 319-343.

J A Elliott, D R Philbrick and C I Wiedman 'Evidence from Archival Data on the Relation Between Security Analysts' Forecast Errors and Prior Forecast Revisions' *Contemporary Accounting Research* (1995) 11(2) 919-938.

J St B T Evans *Bias in human reasoning: causes and consequences* (Hillsdale, NJ, Erlbaum, 1989).

E F Fama 'Market efficiency, long-term returns, and behavioral finance' *Journal of Financial Economics* (1998) 49 283-306.

R Forsythe, F Nelson, G R Neumann and J Wright 'Anatomy of an Experimental Political Stock Market' *American Economic Review* (1992) 82 1142-1161.

R Forsythe, T Rietz and T W Ross 'Wishes, Expectations and Actions: Price Formation in Election Stock Markets' *Journal of Economic Behavior and Organization* (1999) 39 83-110.

A R Ganguly, J H Kagel and D V Moser 'The effects of biases in probability judgments on market prices' *Accounting, Organizations, and Society* (1994) 19(8) 675-700.

S J Grossman 'An introduction to the theory of rational expectations under asymmetric information' *Review of Economic Studies* (1981) 48 541–559.

J Hales 'Directional Preferences, Information Processing and Investors' Forecasts of Earnings' *Journal of Accounting Research* (2007) 45(3) 607-628.

J S Hammersley, K Kadous and A M Magro 'Cognitive and Strategic Components of the Explanation Effect' *Organizational Behavior and Human Decision Processes* (1997) 70(2) 149-158.

J S Hammersley, J.S 'A Review and Model of Auditor Judgments in Fraud-Related Planning Tasks' *Auditing: A Journal of Practice and Theory* (2011) 30(4) 101-128.

J Han and H Tan 'Investors' reactions to Management Earnings Guidance: The Joint Effect of Investment Position, News Valence and Guidance Form' *Journal of Accounting Research* (2010) 48(1) 81-103.

W Hart, D Albarracin, A Eagly, I Brechan, M Lindberg and L Merrill 'Feeling validated versus being correct: a meta-analysis of selective exposure to information' *Psychological Bulletin* (2009) 135 555-588.

J S Hughes, J Liu and W Su 'On the Relation between Predictable Market Returns and Predictable Analyst Forecast Errors' *Review of Accounting Studie*s (2008) 13 266-291.

R Kasznik and M F McNichols 'Does Meeting Earnings Expectations Matter? Evidence from Analyst Forecast Revisions and Share Prices' *Journal of Accounting Research* (2002) 40(3) 727-759.

B D Kluger and S B Wyatt 'Are Judgment Errors Reflected in Market Prices and Allocations? Experimental Evidence Based on the Monty Hall Problem' *Journal of Finance* (2004) 59(3) 969-997.

D J Koehler 'Explanation, Imagination, and Confidence in Judgment' *Psychological Bulletin* (1991) 110 499-519.

R E Krider and C B Weinberg 'Competitive dynamics and the introduction of new products: The motion picture timing game' *Journal of Marketing Research* (1998) 35 1–15.

J Liu 'Market and analysts reactions to earnings news: an efficiency comparison' (2003) UCLA Working Paper.

C G Lord, M R Lepper and L Ross 'Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence' *Journal of Personality and Social Psychology* (1979) 37 2098-2110.

R E Lucas 'Expectations and the neutrality of money' *Journal of Economic Theory* (1972) 4 103–124.

R S Nickerson 'Confirmation bias: a ubiquitous phenomenon in many guises' *Review of General Psychology* (1998) 2 175-220.

T Odean ‘Volume, volatility, price, and profits when all traders are above average’ *Journal of Finance* (1998) 53 1887-1934.

D M Pennock, F A Nielsen and C L Giles ‘Extracting Collective Probabilistic Forecasts from Web Game’ in *Proceedings of the Seventh ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (New York, 2001) pp 174-183.

C Plott ‘Markets as Information Gathering Tools’ *Southern Economic Journal* (2000) 67 1-15.

S Pouget, J Sauvagnat and S Villeneuve ‘A Mind is a Terrible Thing to Change: Confirmatory Bias in Financial Markets’ (2014) Toulouse School of Economics Working Paper.

M Rabin and J Schrag ‘First impressions matter: a model of confirmatory bias’ *Quarterly Journal of Economics* (1999) 114 37-82.

L D Ross, M R Lepper, F Strack and J Steinmetz ‘Social explanation and social expectation: Effects of real and hypothetical explanations on subjective likelihood’ *Journal of Personality and Social Psychology* (1977) 35(11) 817-829.

A Rubinstein ‘A Theorist’s View of Experiments’ *European Economic Review* (2001) 45 615-628.

D Scharfstein and J Stein ‘Herd behavior and investment’ *American Economic Review* (1990) 80 465-479.

H Shefrin *Behavioral Corporate Finance: Decisions that Create Value* (New York, McGraw-Hill Irwin, 2007)

S J Sherman ‘On the Self-Erasing Nature of Errors of Prediction’ *Journal of Personality and Social Psychology* (1980) 39 211-21.

S J Sherman, R B Skov, E E Hervitz and C B Stock ’The effects of explaining hypothetical future events: From possibility to probability to actuality and beyond’ *Journal of Experimental Social Psychology* (1981) 17 142-158.

P E Tetlock ‘Accountability: A social check on the Fundamental Attribution Error’ *Social Psychology Quarterly* (1985) 48 227-236.

J Thayer ‘Determinants of Investors’ Information Acquisition: Credibility and Confirmation’ *The Accounting Review* (2011) 86(1) 1-22.

B Trueman ‘Analyst forecasts and herding behavior’ *Review of Financial Studies* (1994) 7 97-124.

B Tuttle, M Coller and F G Burton ‘An examination of market efficiency: Information order effects in a laboratory market’ *Accounting, Organizations, and Society* (1997) 22(1) 89-103.

F Teschner, F Wagenschwanz and C Weinhardt ‘Analysis of the Disposition Effect: Asymmetry and Prediction Accuracy’ *Journal of Prediction Markets* (2012) 7(1), 27-42.

8 APPENDIX:

Movie Forecasting Assignment

In early November (the 3rd to be exact), we will open trading in two movie box office markets through the MOVIE MARKET. The value of the futures contracts in these markets will be determined by the 4 week (through December 14th) total domestic box office sales for two movies scheduled to open on November 17th. These movies are How the Grinch Stole Christmas and The Sixth Day. You can check out how the top movies in America are faring at the AC Neilsen Entertainment Data, Inc. site (entdata.com).

You will have two tasks related to these markets. First, each student will individually develop a forecast for the box office returns for these two movies based on sources available on the Internet. Second, you will have to make trades in the markets based on your forecasts. You are required to make at least one trade in each market before the movies open and at least one trade in each market after the movies open. Failure to make these trades will result in a grade of Fail for the entire assignment. There is no make up for the trade portion of this assignment.

On the Thursday, November 2nd, each student will turn in a two-three page memo which contains your forecasts for the two movies. You should discuss what information sources you used to develop the forecasts and how these sources were integrated to yield the final forecasts.

One question you might have is: How do I forecast the results for a movie that is not yet in theaters? This is a key question faced by executives in the movie industry from production companies all the way down to the owners of a neighborhood cinema. You should start by visiting the movies' web pages. Then, using box office data from the past available on the web, look at the success of similar movies. These could be movies with the same stars, directors, type of plot or even same time of release in the year. In addition to the Internet resources, back issues of Variety (Main Library) contain weekly results for the top 50 movies in the country.

In most forecasting assignments, your hard work results in either a good grade or bad grade depending on how the actual event turns out. This assignment is very different because your hard work can pay off in real money through the MOVIE MARKET futures contracts. In addition, since there is trading over time and information revealed about the movies' performance at the box office every weekend, there are opportunities to profit even if your original forecast is incorrect.

I would encourage you to try out the simulated trading via the MOVIE MARKET web site before you have to make your required trades. Unlike the simulation or practice trades, the actual trades on your account cannot be reversed.