Do Arbitrageurs Amplify Economic Shocks?

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Abstract: We test the hypothesis that arbitrageurs amplify fundamental shocks in the context of short arbitrage in equity markets. The ability of speculators to hold on to short positions depends on asset values: shorts are often reduced (increased) following good (bad) news about a stock. As a result, the prices of highly shorted stocks are excessively sensitive to economic shocks. Using monthly short interest data we find evidence consistent with this destabilizing mechanism. (1) The price of a highly shorted stock is more sensitive to earnings news than a stock with little short interest. (2) The change in short interest around announcements (proxied by share turnover) is more sensitive to earnings surprises for highly shorted stocks. (3) For highly shorted stocks, returns to shorting are higher following better earnings news. We further confirm this hypothesis using two quasi-experiments: these effects are more pronounced for NASDAQ stocks (which are easier to short) than NYSE stocks and these effects have become more pronounced over time for small stocks with the rise of hedge funds.

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I. Introduction

In this paper, we examine whether arbitrageurs amplify exogenous economic shocks in asset markets. This issue is related to a large literature dating back to Friedman (1953) on the role of speculators in affecting asset price dynamics. A number of theories indicate that asset prices are excessively sensitive to economic news when arbitrage is limited in various ways by leverage constraints or agency problems arising from delegated money management.[1] For example, suppose hedge funds subject to leverage constraints have positions in a stock and there is a negative earnings surprise about the stock that causes the price to fall. They are then forced to cut back on their positions and the stock price will move more with the news than an otherwise similar stock without any hedge funds. The key amplifying mechanism is that the ability of arbitrageurs to maintain their positions is tied to asset values, which imparts an upward tilt to asset demand schedules.[2]

This amplification mechanism is believed by many to be a key ingredient behind recent financial crises. For instance, the market turmoil of 1998 is widely blamed on the forced selling of the large hedge fund Long Term Capital Asset Management. The turmoil in the Summer of 2007 is attributed to the forced selling of many multi-strategy quantitative funds. And throughout the crisis since the collapse of Lehman Brothers, many astute market observed have pointed to the forced unwinding of highly levered trades for the collapse of and extreme volatility in financial markets. *Reuters Newswire* reports (October 24, 2008): "The manager of the world's biggest bond fund said on Friday that forced liquidations, based on margin calls, are driving stocks lower, and not fear. Bill Gross, chief investment officer of Pacific Investment Management Co. or Pimco, said on CNBC television that margin calls were driving the selling that has resulted in a long-term deleveraging of assets not seen since the 1930s." Echoing this theme, Jim Rogers in an interview with the *Financial Times* (November 17th, 2008) said: "A forced liquidation like we are now experiencing has occurred only 8 or 9 times in the past 150 years." Interestingly, despite the wide attribution of the importance of this amplification mechanism in financial markets, there is relatively little systematic evidence on whether fundamental shocks are amplified by such speculative activity. As such, an understanding of the

[1] A few examples include Delong, Shleifer, Summers and Waldmann (1990), Shleifer and Vishny (1997), Kyle and Xiong (2001), and Gromb and Vayanos (2002).

[2] This leverage mechanism has been pointed out in a number of other settings including stocks (Garbade (1982)), corporate asset sales (Shleifer and Vishny (1992)), land (Kashyap, Scharfstein and Weil (1990)), Kiyotaki and Moore (1997)) and housing (Stein (1995)).

effects of speculators on asset price dynamics has never been more important from both academic and public policy perspectives.

We tackle this issue in the context of short arbitrage in equity markets. There are several reasons why short selling in equity markets is an ideal setting to study this issue. First, we can measure the magnitude of arbitrage activity (on the short side) in different stocks. There are plentiful panel data on the magnitude of short selling and most of it is undertaken by professional speculators such as hedge funds as opposed to retail investors. This stands in contrast to the difficulty of measuring levered long speculative positions in equities. Second, in practice, the ability of arbitrageurs to hold on to short positions depends on asset values: shorts are often reduced (increased) following good (bad) news about a stock for a variety of reasons. Most notably, short sales tend to be highly levered transactions that require having enough funds in the margin account. Third, there is substantial anecdotal evidence in support of this amplification mechanism in the context of short arbitrage.

Indeed, the financial press often speaks of “short covering” (the cutting down of short positions through the purchase of shares) causing excess volatility in markets. A case in point is the internet stock eBay which reported significantly better earnings than expected in the summer of 2005. Its stock price soared the same day. The press pointed to short covering as a likely source of the price movement (see Nassar (2005)). More recently, on October 28, 2008, hedge funds shorting Volkswagen the car maker were forced to short cover when news came out that Porsche had bought up much of VW's remaining free float. Shares in the German car maker, which started trading at €420 a share hit an intraday high of €1,005.01, valuing the company at €296.06-billion euros ($370.4-billion) based on ordinary stock, more than that of world number one company Exxon Mobil Corp's $343-billion market value at Monday's closing price. Analysts said VW will come down with a bang once the hedge funds finish buying all the shares they need to cover their speculative positions.

To capture this amplification mechanism caused by short-covering, we begin by developing a simple three date model of asset price dynamics in which arbitrageurs have a profitable opportunity to short an over-priced stock subject to positive sentiment.[3] The key

[3] Our short-selling set-up is consistent with empirical studies on the source of short seller profits. Dechow et.al. (2001) and D’avolio (2003) argue that the source of profits for short sellers is that they short mis-priced stocks: short sells increase with price-to-earnings stocks and short sellers cover as the mis-pricing corrects, *i.e.* as price converges towards earnings.

ingredient is that the ability of arbitrageurs to hold on to short positions depends on asset values (*i.e.* the past performance of these positions). There is also an earnings announcement which may affect the sentiment in the stock. The sensitivity of the stock price to earnings news is simply the regression coefficient of the stock return around the earnings announcement date on the earnings surprise (or the difference between the earnings and the consensus forecast scaled by previous price). We derive three key predictions, which we test using monthly data on short sales in U.S. equities from the period of 1993 to 2007.

The first prediction is that price sensitivity to earnings news is higher for a stock with positive short selling (*i.e.* arbitrage presence) than for a stock with no short selling (*i.e.* no arbitrageurs). We define a highly shorted stock as one in the top 33% of the short ratio (short interest to shares outstanding) distribution for that quarter and a stock with no short selling as one in the bottom 33% of short ratio distribution for that quarter. Our sample drops out the firms in the middle of short ratio distribution because stocks may have a small amount of short interest due to hedging trades. Only those with substantial short ratios are likely subject to genuine valuation motivated arbitrage activity.

We test this prediction by running a pooled regression of cumulative abnormal returns around (quarterly) earnings announcement dates (from 7 days before to one day after) on a high earnings surprise dummy variable (equal to one if stock is in the top 33% of the earnings surprise distribution for that quarter and zero otherwise), a dummy variable for whether a stock is highly shorted before the earnings date and the highly shorted dummy interacted with the high earnings surprise dummy. The coefficient for the interaction then tells us the difference in the sensitivity of stock price to news between highly shorted stocks and stocks with little short interest.

In estimating this relationship, we naturally worry about unobserved heterogeneity, *e.g.* highly shorted stocks may be more in the "media spotlight" than other stocks and hence their prices respond more to news. To deal with this issue, we take great care to estimate this regression specification (and indeed all the other specifications below) in a variety of ways such as controlling for a number of stock characteristics (*e.g.* interacting news with stock characteristics such as firm size, institutional ownership), using stock fixed effects and using industry by quarter effects (to capture potentially time-varying spotlight effects). Regardless of how we estimate this relationship, we find that the price of a highly shorted stock is more sensitive to earnings news than a stock with little shorting. For stocks with little short interest, having a high earnings surprise leads to a higher cumulative abnormal return of about 4.5 percentage points (or 450 basis points). In contrast, for highly shorted stocks, the comparable figure is conservatively around 5.64 percentage points. The difference of 114 basis points (about 25% larger for highly shorted stocks) is economically and statistically significant. We verify that this relationship (as well as all the other ones established below) is robust to a variety of different specification checks such as ways of measuring abnormal returns and earnings surprises. Importantly, we can simultaneously test several other predictions that do not follow from an unobserved heterogeneity story but do from our amplification hypothesis.

The second prediction is that the change in the short interest ratio of a stock should be negatively correlated with the earnings surprise (*i.e.* a positive earnings surprise should lead to a fall in this ratio). That is, we are verifying the key mechanism behind the amplification effect. Ideally, we want to measure the sensitivity of changes in daily short interest to unexpected earnings announcements. Unfortunately, we can only observe short interest at a monthly frequency (during the middle of months whereas earnings announcements tend to occur at the end of months). Such monthly changes are too coarse to pick up the short covering effect around earnings dates. Therefore, we use a stock's turnover as a proxy for changes in short interest.

The prediction we test is that turnover is more sensitive to the absolute value of unexpected earnings (*i.e.* either good or bad news) for highly shorted stocks than for other stocks. Consistent with our model, we find that, for stocks with little short interest, having high unexpected earnings increases turnover by about 0.21 percentage points. For highly shorted stocks, the comparable figure is conservatively around 0.67 percentage points. This is also an economically and statistically significant difference.[4]

Our third and perhaps most important prediction is that arbitrageurs are forced to get out of short positions that turn out to be profitable. This means that for highly short stocks, short positions after the event date should be more profitable after better earnings news forces short covering. We find that for stocks that are un-shorted, good news leads to higher subsequent returns (from 2 days after to 180 days after the announcement) to holding the stock---about 358 basis points This is consistent with the well documented post earnings announcement drift (see, *e.g.*, Bernard and Thomas (1989, 1990)). However, for highly shorted stocks, good news leads

[4] These findings control for level differences in turnover between highly-shorted stocks and other stocks. Consistent with our model, highly-shorted stocks have higher turnover than other stocks. However, this could also be consistent with other asset pricing models without our effects (see, e.g., Scheinkman and Xiong (2003)).

to negative excess returns of -72 basis points. In other words, short positions are more profitable after good earnings news for these stocks.. This difference is economically and statistically significant.

It is this third prediction that cuts strongly against a number of alternative stories. For instance, one possible reason for price being more sensitive to news for highly shorted stocks is that shorts are informed bets that there are going to be negative earnings surprises. As a result, good news means these bets are wrong and price naturally reacts more to good news. If this alternative explanation is correct, then one would not expect to find an over-reaction on the event date that translates into short positions being more profitable about good news. This post announcement return finding strongly cuts against a number of alternative explanations for our first two findings.

Finally, to better identify our amplification mechanism, we consider two quasi-experiments. First, the findings documented above ought to be stronger for NASDAQ stocks than NYSE stocks because it is easier to short NASDAQ stocks than NYSE stocks for regulatory reasons. Indeed, we find that short interest ratios are substantially higher for NASDAQ stocks all else equal. Moreover, all the aforementioned effects are stronger for NASDAQ stocks than NYSE stocks. We can think of this exercise as a triple difference estimate of our economic effects compared to our baseline double difference estimates above. Interestingly, the magnitudes of our triple-difference estimates are comparable to the double-difference estimates above and also statistically significant.

Our second, and more striking, quasi-experiment builds on the work of Hanson and Sunderam (2007) who document a striking increase in short ratio concentrated among small stocks since 2000. They argue that this is due to the rise of hedge funds. If our hypothesis is correct, then we expect to find that the destabilizing effects documented above ought to have increased among small stocks since 2000 and to not find any such difference for large stocks which did not witness such growth. We find that this is indeed the case.

Our contribution is to show that arbitrageurs amplify exogenous fundamental shocks because their ability to hold on to positions depends on asset values. We are agnostic as to the cause of why short arbitrageurs, for instance, cut their positions following good news. We have naturally framed this short covering in terms of leverage, risk management or more general agency issues. But it could very well be due to other factors such as behavioral biases which lead arbitrageurs to cut their losses.

There is a growing literature testing the implications of limits to arbitrage models. Most closely related to ours is Savor and Gamboa-Cavazos (2005), who find that short sellers cover their positions after suffering losses and increase them after experiencing gains (measured using past returns), that this relationship is very strong for positions established due to perceived overvaluation and that expected returns do not explain the documented short seller behavior. Similarly, Lamont and Stein (2004) document a negative correlation between past index returns and the aggregate short interest ratio. The main innovation of our paper relative to these and other empirical papers in the literature more generally is that we show that arbitrage activity directly influences asset prices through at least one channel: the amplification of fundamental shocks.[6] The important point is that this paper is a first in directly showing the economic mechanism that leads to destabilizing speculation in asset markets.

Our paper is also closely related to empirical papers looking at the relationship between leverage and asset prices. Most notably, Lamont and Stein (1999) test a similar hypothesis as ours but in the context of the housing market. Their principal finding is that in cities where a greater fraction of homeowners are highly leveraged, house prices react more sensitively to city-specific shocks such as changes in per capita income. In contrast to their very interesting paper, our setting provides a tighter test of the amplification-of-fundamental-shocks hypothesis for a few reasons. First, we have more and better ways to ruling out alternative explanations. Second, the horizon in which earnings shocks affect stock prices is a bit more straightforward than when per capita income shocks affect housing prices; *i.e.* we can do an event study around earnings announcements. And third, we have better data to more precisely measure our various predictions.

Our paper proceeds as follows. We present a simple model to derive the main predictions in section II. The data is presented in section III and the empirical findings in section IV. We conclude in section V. All proofs are in the Appendix.

II. Model

[6] Other recent examples related to testing limits of arbitrage models include Brunnermeier and Nagel (2004) who examine the holdings of certain hedge funds during the Internet bubble and Gabaix, Krishnamurthy and Vigneron (2005) who argue that prices of mortgage-backed securities are determined by specialized arbitrageurs.

There is a single asset (the stock) available in unit net supply. There are three dates, numbered 0, 1, and 2. At date 2, the asset is liquidated with payoff v, which may take on the value $\bar{v}$ or $\underline{v}$ with equal chance. At date 1, the value of v is announced to all. We denote the price at time t by p_t.

There are two sets of agents in the economy: noise traders and risk neutral rational speculators (*e.g.* hedge funds). The noise traders over-estimate the fundamental payoff by an amount $S > 0$ at time 0. This sentiment (optimism) may widen or narrow to $S(v)$ at time 1 (depending on the nature of the earnings announcement) and disappears completely by time 2. More formally, we assume that aggregate noise trader demands time 0 and 1 are given by (in share terms)

$$Q_0^N = \frac{E_0[v] + S}{p_0} = \frac{\frac{1}{2}\bar{v} + \frac{1}{2}\underline{v} + S}{p_0} \tag{1}$$

and

$$Q_1^N = \frac{E_1[v] + S(v)}{p_1} = \frac{v + S(v)}{p_1} \tag{2}$$

respectively.

Arbitrageurs undertake short positions to partially counteract the noise traders, but we assume their resources in the two periods, given by F_0 and $F_1(v)$, are insufficient to bring prices to fundamental value. For simplicity, initial aggregate speculator demand is given by

$$Q_0^S = -\frac{F_0}{p_0} \tag{3}$$

where $F_0 < S$. (In the Appendix, we solve the more general model in which arbitrageurs can determine how much of their resources ($D_0 \leq F_0$) to invest at time 0. The remainder is invested in cash and yields a zero net return as a safeguard against running out of funds at time 1.) At time 1, all uncertainty has been resolved and speculators take the maximum possible short position, yielding a demand of

$$Q_1^S = -\frac{F_1}{p_1} \tag{4}$$

provided $F_1(v) \le S(v)$. Due to the unit net supply assumption, the short demand of speculators in this model is also the short ratio, or the ratio of shares shorted to total shares outstanding.

We also make the following assumption regarding the time evolution of the arbitrageurs' resources

$$F_1(v) = F_0 + aF_0\left(1 - \frac{p_1(v)}{p_0}\right), \tag{5}$$

where $a > 1$. If the arbitrageurs do not short at time 0, then $F_1(v) = F_0$. But since they are assumed to short an amount F_0, their capital at time 1 depends on the return of shorting, $\left(1 - \frac{p_1(v)}{p_0}\right)$, between time 0 and 1. How sensitive their resources are at time 1 to asset values or past returns (*i.e.* their ability to hold on to shorts) is given by the parameter a. We are agnostic as to the source of why $a > 1$. Most naturally, it reflects the fact that short sellers tend to be levered. Also plausibly, it may be an internal risk management control or imposed on the speculators by outside investors, (see, *e.g.*, Shleifer and Vishny (1997)). For instance, one interpretation is that there are loss-limits at the position level or related value-at-risk (VAR) considerations and when a short position suffers a loss, the position is dramatically cut back. (Plentiful anecdotal evidence (cited in the Introduction) seems to bear this assumption out.)

We now solve for the asset prices. Date 2 represents the long-run in which price reverts to fundamental value, *i.e.* by no arbitrage, $p_2 = v$. Since aggregate demand in each period must equal the unit supply, *i.e.*

$$Q_t^S + Q_t^N = 1, \tag{6}$$

price at time 0 is

$$p_0 = \frac{1}{2}\overline{v} + \frac{1}{2}\underline{v} + S - F_0. \tag{7}$$

Equating supply and demand at time 1 and then substituting from equation (5), we get

$$p_1(v) = \frac{v + S(v) - F_0(1+a)}{1 - a\dfrac{F_0}{p_0}}. \tag{8}$$

Finally, we introduce an important variable for our empirical work. This variable, the sensitivity of stock price to earnings news (or often called the earnings response coefficient) denoted by β, is:

$$\beta(v) = \frac{\dfrac{\Delta p}{p_0}}{\dfrac{\Delta v}{p_0}} = \frac{p_1 - p_0}{v - E[v]} \tag{9}$$

The earnings response coefficient is the percent change in price divided by the percent change in the value of the stock (scaled by price). It represents the responsiveness of price to innovations in fundamental value. Higher values of β denote higher sensitivity of prices to news. Alternatively, we can also scale the earnings innovations by the expectation of earnings. The theoretical results are similar and so we stay with the definition in equation (9) since it is the one most often used in papers that measure the sensitivity of price to earnings news.

The following three propositions are the key predictions of the model that we test. For all three propositions, we are assuming there is not enough capital to bring prices close to fundamental value.

Proposition 1*: The sensitivity of stock price to earnings news, β, is greater for shorted stocks than for un-shorted stocks.*

The key amplifying mechanism is that the ability of arbitrageurs to maintain their positions is tied to asset values. The effect is similar to that of leverage constraints for long positions.[7]

The second proposition is that the change in the short interest ratio of a stock should be negatively correlated with the earnings surprise (*i.e.* a positive earnings surprise should lead to a drop in the short ratio). Unfortunately, our monthly short interest data is too coarse to capture this short covering effect around earnings announcements, particularly in light of the findings in

[7] Though this model is very stylized, it is possible to perform some back of the envelope calculations to gauge the differential in sensitivity of price to news between highly shorted compared to un-shorted stocks (the details of these calculations are available upon request from the authors). The upshot is that the results are sensitive to the unobservable parameter *a* (the amplification parameter) and the differential sensitivity can vary between being 10% to 30% greater for highly shorted stocks (assuming a mean short ratio of 8%) depending on what one assume about this parameter. Our empirical estimates fall comfortably within this wide range of calibration magnitudes.

Diether, Lee and Werner (2005). Due to the inability to measure daily short covering, we show that this short covering effect translates into turnover being more sensitive to unexpected earnings for highly shorted stocks than un-shorted stocks.

Proposition 2*: For shorted stocks, the change in short ratio is inversely related to the earnings surprise. Share turnover around earnings announcements is more sensitive to (the absolute value) unexpected earnings for highly shorted stocks than for un-shorted stocks.*

It is the latter implication of this proposition that we focus on in our empirical work, *i.e.* we can only test that turnover is more sensitive to (absolute value of) unexpected earnings news for shorted stocks.

Finally, the premise of the amplification mechanism is that arbitrageurs are forced to get out of profitable short positions. Proposition 3 formalizes this premise by allowing sentiment to rise even after good news so that the short position remains profitable. This is a modeling device meant to capture the fact that short positions may be fundamentally profitable but arbitrageurs may have difficulty hanging on to short positions if their ability to do so depends on asset values. In a more dynamic set-up with multiple earnings dates, we could also accomplish the same result by introducing transitory earnings shocks.

Proposition 3: *If sentiment increases proportionally with unexpected earnings news, then for highly shorted stocks, the expected return to shorting is higher after a good earnings surprise.*

We test Proposition 3 by comparing subsequent stock returns after earnings announcements for highly shorted stocks to un-shorted stocks. The only caveat in testing Proposition 3 is that there is the well-documented post earnings announcement drift in the data, *i.e.* stocks with good (bad) news) continue to drift in the direction of the news after the announcement (see, *e.g.*, Bernard and Thomas (1989, 1990)). We do not model post earnings announcement drift in this paper, though we could by assuming a degree of under-reaction to news as in Barberis, Shleifer and Vishny (1998) or Hong and Stein (1999). As such, we need to account for this in testing this proposition. So, another way of posing this proposition is that there should be less drift in highly shorted stocks compared to other stocks.

III. Data

Our data on monthly short interest, available for the period of January 1993 to 2007, are obtained from Bloomberg. We use short interest to construct short ratios for each month. Each month's short interest data represents positions that closed on the first business day on or after the 15th of the month. Hence we approximate the short ratio by dividing total short interest positions by shares outstanding (from CRSP) on or closest to the 12th day of each month. We focus on extremes---highly shorted stocks (top 33% of the short ratio distribution in that quarter) compared to little shorted stocks (bottom 33% of the short ratio distribution in that quarter). Our comparison analysis drops out the firms in the middle of the short ratio distribution. Stocks in this range could be shorted for valuation reasons or for hedging reasons (see, *e.g.*, Chen, Hong and Stein (2001), Asquith, Pathak and Ritter (2006)). This extreme comparison is the cleanest way of identifying our effect. More specifically, we define *HISR* as a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise. The top 33% cut-off is chosen because among this sub-group there is a relatively high short ratio (about 7.42% on average). The bottom 33% is to make sure there is no shorting whatsoever in these stocks (the mean in this sub-group is 0.59%). (Our results are robust to using other cut-offs.)

We combine these data with information from three other databases. First, quarterly earnings consensus estimates and actual initial (*i.e.* unadjusted) releases are collected from the I/B/E/S summary files. In practice, researchers have a few different ways of calculating unexpected earnings (*UE*). *UE* is the difference between the actual quarterly earnings according to I/B/E/S and the consensus forecast provided by I/B/E/S in the last month before the announcement date scaled by either past price, previous earnings or the consensus forecast (see, *e.g.*, Conrad, Cornell and Landsman (2002), Kothari (2001)). Different studies scale *UE* differently, typically by either past price or previous earnings and less frequently by the consensus forecast. Our results are fairly similar across these different measures. We follow convention and scale *UE* by past price (our results of *UE* is scaled by previous earnings is omitted for brevity and available from the authors.) We define *UEHIGH* as a dummy variable equal to one if a stock's earnings surprise is in the top 33% of the distribution for that quarter and zero otherwise.

Second, data on daily holding period returns, prices, trading volume and shares outstanding are obtained from the Center for Research in Securities Prices (CRSP). Using these data, we calculate cumulative abnormal returns around earnings announcement dates as follows. Each stock is assigned to a size-valuation category by assigning them each year first to size deciles based on their market capitalization at the start of the year and then to valuation deciles based on the ratio of market capitalization to last year's book equity. In this way we create one hundred different size-valuation categories. We use the entire sample to calculate the loadings of these one hundred portfolios using the Sharpe (1964) CAPM and the Fama and French (1993) three-factor model.

In addition to a simple return net of the risk-free, we then calculate daily abnormal returns for each stock using one of these two models. For each year, each stock inherits the loadings of its size-valuation category (determined at the beginning of the year) with which its abnormal return is calculated. Abnormal returns are then cumulated from five trading days before until one day after the earnings release date (*CAR*). We also calculate cumulative post-announcement returns (*POSTCAR*) using days +2 to +180 relative to earnings release. Both *CAR* and *POSTCAR* are abnormal returns relative to the Fama and French (1993) model. We have worked with various permutations of the timing in calculating these event day returns and the results are all similar. We use the two definitions here since they are again standards in event studies. Using the CRSP database, we also calculate daily share turnover (using trading volume and shares outstanding) and then take the average of daily share turnover from day -7 to day +1 surrounding the earnings announcement (*AVGTURN*). The timing is set to match that of the *CAR*.

Third, the following annual accounting variables are obtained from the CRSP/COMPUSTAT merged Industrial Annual data file: book equity (data item 60), convertible securities (data item 39), earnings per share (data item 57) and fiscal-year-end closing price (data item 199). The price-to-earnings valuation ratio is calculated as the lagged price as of 21 days before earnings release divided by the previous year's annual EPS.[9]

[9] We have also performed a number of other robustness checks using the different valuation ratios. We calculate an alternative P/E ratio as previous year's fiscal-year-end closing price in the numerator and current release of earnings from I/B/E/S in the denominator (assuming earnings are greater than 0, otherwise, we keep these observations in the database but create a dummy variable for non-positive earnings firms). Other valuation ratios used for further robustness checks are market-to-book, market-to-assets and market-to-sales, all generated similarly using 21 day lagged prices and previous year's accounting numbers.

Finally, firm market capitalization is obtained from CRSP. Monthly return volatility is calculated using daily return data from CRSP. A measure of analyst disagreement, or the dispersion of analyst forecasts (calculated as in Diether, Malloy and Scherbina (2002)), is obtained from I/B/E/S.

The sample includes stocks that are listed on the NYSE or NASDAQ. Observations are dropped if the dependent variable is missing or the controls are missing. The summary statistics for these variables are presented in Table 1. The key statistic is that the mean of the short ratio distribution is about 3.39% and its standard deviation is 4.77%. For stocks in the top 33% of the short ratio distribution, the mean is 7.42% as we mentioned earlier. For stocks in the bottom 33% of the short ratio distribution, the mean is 0.59%. The statistics for the other variables are similar to those reported in other papers.

IV. Empirical Findings

A. Sensitivity of Price to Earnings News

We begin by testing Proposition 1. We want to measure how the sensitivity of price to earnings news varies by whether a stock is actively shorted or not. We first measure the overall effect of unexpected earnings shocks on returns: *i.e.* the price to earnings sensitivity for the typical firm in our sample. This will provide us with a benchmark. To this end, we estimate the following specification:

$$\begin{aligned} CAR_{i,t} = \alpha &+ \beta_1 UEHIGH_{i,t} + \beta_2 HISR_{i,t} + SIZE\,dummies_{i,t} + P/E\,dummies_{i,t} \\ &+ DISAGREEMENT\,dummies_{i,t} \\ &+ CONVDEBT\,dummies_{i,t} + VOLATILITY\,dummies_{i,t} \\ &+ INDUSTRY\,dummies_{i} + QUARTER\,dummies_{t} + \varepsilon_{i,t} \end{aligned} \tag{10}$$

Our sample only includes firms in the top 33% and bottom 33% of the short ratio distribution in any given quarter. The left-hand side (LHS) variable is *CAR* (cumulative abnormal return from day -7 to +1). The right-hand side (RHS) variable of interest is *UEHIGH* which equals one if a firm’s earnings surprise in the top 33% of the earnings surprise distribution for that quarter and zero otherwise. The other RHS variables include *HISR* (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise), *SIZE* (market cap divided into 25 dummies by quarter), *P/E* (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), *DISAGREEMENT* (the dispersion in analyst forecasts divided into 25 dummies by quarter), *CONVDEBT* (convertible debt divided into 25 dummies by quarter), *VOLATILITY* (return volatility of firms in the previous month calculated using daily returns divided into 25 dummies by quarter), *INDUSTRY* dummies (SIC at the 2 digit level) and *QUARTER* dummies. We will explain the rationales behind each of these control variables as we build on this specification to test our predictions below.[10]

The result for this specification is reported in column 1 of Table 2. As expected, the coefficient on *UEHIGH* is positive and statistically different than zero. The coefficient implies that moving up one decile of unexpected earnings is associated with a 5.08 percentage point increase in the return of the stock (*CAR*). This number is in line with other studies of the sensitivity of stock price to earnings surprises mentioned earlier. The coefficient on *HISR* is negative and statistically significant consistent with some studies on short interest and stock returns (see, e.g., Asquith, Pathak and Ritter (2005), Boehmer, Jones and Zhang (2008)), who point out that highly shorted stocks under-perform other stocks.

We then estimate the following model, which is the same as the previous one except for the addition of the interaction of *UEHIGH* and *HISR*:

$$\begin{aligned} CAR_{i,t} = {} & \alpha + \beta_1 UEHIGH_{i,t} + \beta_2 HISR_{i,t} + \beta_3 UEHIGH_{i,t} \times HISR_{i,t} + SIZE\ dummies_{i,t} \\ & + P/E\ dummies_{i,t} + DISAGREEMENT\ dummies_{i,t} \\ & + CONVDEBT\ dummies_{i,t} + VOLATILITY\ dummies_{i,t} \\ & + INDUSTRY\ dummies_{i} + QUARTER\ dummies_{t} + \varepsilon_{i,t} \end{aligned} \tag{11}$$

The coefficient of interest is β_3, which measures the differential sensitivity of high short ratio stocks to unexpected earnings compared to other stocks. The result is reported in column 2. The estimates show that the sensitivity to high unexpected earnings shocks is greater for high short ratio stocks. β_1 suggests that for a low short ratio stock, having a high *UE* is associated with a 4.51 percentage point increase in *CAR*. β_3 is 1.13 and statistically significant from zero

[10] We have also included the age of the firm in all of our cross-sectional regressions as a control and find similar results.

with a t-statistic of nearly 6. So having a high *UE* increases *CAR* by 1.13 percentage points more for a high short ratio stock than a low short ratio stock. β_3 suggests that the sensitivity of high short ratio stocks to unexpected earnings is about 1.13/4.51 = 25% greater than for low short ratio stocks.

This regression specification controls for a number of stock characteristics, but these controls do not allow for the sensitivity of price to news to vary by these stock characteristics. To remedy this, we estimate the following model, which is the same as the previous one except for the addition of the interactions of *UEHIGH* with the other firm characteristics:

$$\begin{aligned}
CAR_{i,t} = {} & \alpha + \beta_1 UEHIGH_{i,t} + \beta_2 HISR_{i,t} + \beta_3 UEHIGH_{i,t} \times HISR_{i,t} + SIZE\ dummies_{i,t} \\
& + SIZE\ dummies_{i,t} \times UEHIGH_{i,t} + P/E\ dummies_{i,t} + P/E\ dummies_{i,t} \times UEHIGH_{i,t} \\
& + DISAGREEMENT\ dummies + DISAGREEMENT\ dummies \times UEHIGH_{i,t} \\
& + CONVDEBT\ dummies_{i,t} + CONVDEBT\ dummies_{i,t} \times UEHIGH_{i,t} \\
& + VOLATILITY\ dummies_{i,t} + VOLATILiTY\ dummies_{i,t} \times UEHIGH_{i,t} \\
& + INDUSTRY\ dummies_i + QUARTER\ dummies_t + \varepsilon_{i,t}
\end{aligned} \qquad (12)$$

The coefficient of interest again is β_3, which measures the differential sensitivity of high short ratio shocks to unexpected earnings shocks than other stocks. We include the additional interactions of *UEHIGH* with the other control variables because price sensitivity to news might vary by the different characteristics. For instance, the price of a high price-to-earnings stock is likely to have a different sensitivity to earnings news than a low one. Similarly, the price of a large capitalization stock might respond more to news than the price of a small capitalization stock if the investors in large stocks are more likely to be institutions and institutions pay closer attention to news compared to individuals. We also add interactions of *UEHIGH* and *DISAGREEMENT* because highly shorted stocks may simply have more analyst dispersion and the price of high divergence of opinion stocks may react more to news. The logic for institutional ownership and past volatility are similar. For convertible debt, short interest might be driven by hedging trades associated with the purchase of convertible securities. Because we want to measure short interest related to speculative trades as precisely as possible, we include convertible debt by *UEHIGH* interactions.

The results from this estimation are presented in column 3. β_3 is positive and statistically significant (1.19 with a t-statistic of 5.6). The estimate shows that the sensitivity to *UE* is greater for high short ratio stocks; for these stocks, the increase in *CAR* is 1.19 percentage points more for having a high *UE*, similar to what we obtained in column 2. In contrast to the estimates in column (2), note that we cannot obtain a unique estimate of β_1 in this specification because of all of the other interactions with *UEHIGH*. As a result, we cannot perform the same economic significance calculations as in column (2). Hence, one can think of the estimate in column (3) as providing a robustness check.

In columns 4-6, we re-estimate the specifications in columns 1-3, except that we now include stock fixed effects (*i.e.* we only use a stock's time series variations in short ratio and price sensitivity to news to estimate the relationship between these two variables of interest). The logic of this estimation is that we are worried that even with all of our elaborate controls, there might still be fixed differences across stocks for which we have not yet accounted (*e.g.* some stocks are more in the spotlight in some un-measurable manner and these stocks attract both more shorts and react more to earnings surprises). We obtain similar estimates to our previous specification. The coefficient in front of *UEHIGH* in column 4 is 5.16 instead of 5.08 from column 1. In column 5, the coefficient in front interaction *of UEHIGH* and *HISR* is 1.33, similar to the estimate of 1.13 in column 2. Interacting *UEHIGH* with the other stock characteristics in column 6 does not significantly affect our estimate of β_3.

In columns 7-9, rather than including stock fixed effects, we include quarter by industry effects to account for potential time varying effects that might spuriously be generating our findings in columns 1 through 3. For instance, maybe the spotlight effect changes over time (some stocks are in the spotlight more at certain times). If this spotlight effect is not specific to a stock but is common across all stocks in the same industry, then our quarter by industry effects will control for any spurious relationship generated by such a process. Again, the estimates are remarkably similar to columns 1-3. In column 7, the coefficient in front of *UEHIGH* is now 5.15 instead of 5.08 in column 1. In column 8, the coefficient in front of $UEHIGH \times HISR$ is now 1.11 instead of 1.13. And the coefficient in front of $UEHIGH \times HISR$ in column 9 is now 1.12 instead of 1.19. All these estimates are again statistically and economically significant.

In sum, the findings in Table 2 firmly establish the first prediction of our arbitrage hypothesis and strongly cut against the alternative of unobserved heterogeneity. We take an "everything but the kitchen sink" approach in this table. Below, we consider an alternative of instrumental variables estimation to deal with omitted variable bias. But an even better way to support our arbitrage story is to test our model's additional implications that do not arise naturally out of an omitted variable bias story. We consider tests of these implications next.

B. Sensitivity of Turnover to Earnings News

The results presented in this section test Proposition 2. We want to measure how the sensitivity of turnover to earnings news varies by whether a stock is actively shorted or not. Our analysis proceeds in a manner similar to that of Table 2. The results are presented in Table 3; it is the equivalent of Table 2 except that the LHS variable is *AVGTURN*, the average (from day -7 to +1 around the earnings announcement) turnover of the stock minus the average turnover of the stocks in the exchange the stock is part of during the quarter of the observation, and *UEHIGH* is replaced by *ABSUEHIGH*, which is a dummy variable equal to one if the absolute value of the earnings surprise is in the top 33% of the *ABSUE* distribution for that quarter. The reason we use *ABSUEHIGH* instead of *UEHIGH* is that either good or bad earnings news will lead to turnover according to our model.

Columns 1 through 9 of Table 3 are analogous to those in Table 2. Column 1 shows that higher absolute *UE* increases turnover. Having high absolute UE increases turnover by about 0.44 percentage points (about 16% of a SD of turnover). Column 2 shows that this sensitivity is greater for highly shorted stocks. β_3 is positive and statistically significant (0.46 with a t-statistic of nearly 5). For low short ratio stocks, the sensitivity of turnover for having ABSUEHIGH is 0.21 percentage points. In contrast, the sensitivity for highly shorted stocks is 0.67 (0.21+0.46) percentage points, which is about 3 times bigger than the magnitude for low-short-ratio stocks. Column 3, which adds as controls interactions of *ABSUEHIGH* with other stock characteristics, confirms the results of column 2. Note that these findings control for level differences in turnover between highly shorted stocks and other stocks. Consistent with our model, highly shorted stocks (*HISR*) have higher turnover than other stocks; however, this could also be consistent with other asset pricing models without our effects. So, our findings are not driven by these level differences. Rather, we are measuring differences in sensitivities to absolute earnings surprises.

In columns 4-6, we present the results using stock fixed effects. Column (4) shows that the effect of being high UE increases turnover by 0.17 percentages points. Column (5) indicates that for little shorted stocks, having a high UE raises turnover by 0.02 percentage points. β_3 from column 5 is positive and statistically significant but is smaller than in column 3 (now 0.29 with a t-statistic of about 7). The economic effect, however, is still quite large; for highly shorted stocks, the sensitivity of turnover to absolute earnings surprise is about 14 times larger than for little shorted stocks. In other words, the economic effect is even larger when we estimate with stock fixed effects. The results using quarter by industry effects (presented in columns 7-9) are similar to columns (1)-(3). In sum, the results are consistent with the second prediction of our model. This finding suggests that any alternative story for our first finding regarding highly shorted stocks have a greater sensitivity to news should now also explain why turnover in highly shorted stocks is also more sensitive to news.

C. Subsequent Stock Returns and Earnings News

Perhaps an even more distinctive implication of our theory is Proposition 3. We want to measure how returns after the earnings announcement date differ between highly shorted stocks and un-shorted stocks. In essence, we want to verify that if the *CAR* results are due to the short covering mechanism we propose, then we should see returns to shorting being higher after a good earnings announcement. As we explained in the theory section, the only caveat in testing Proposition 3 is that there is the well-documented post earnings announcement drift in the data, *i.e.* stocks with good (bad) news) continue to drift in the direction of the news after the announcement. The post earnings announcement drift is outside the scope of our model.

Our analysis proceeds in a manner similar to that of Table 2. The results are presented in Table 4. In other words, Table 4 is the equivalent of Table 2 except that the LHS variable is *POSTCAR* (from 2 days after to 180 days after the announcement) instead *CAR*. Columns 1-3 show the standard OLS results. Column 1 suggests that being high *UE* raises *POSTCAR* by about 1.42 percentage points. This is consistent with the well documented post earnings announcement drift. Column 2 shows that for little shorted stocks, the effect of being high UE raises POSTCAR by 3.58 percentage points. However, the effect of being high UE for highly shorted stocks is much lower. β_3 is negative and statistically significant (-4.30 percentage points with a t-statistic of 7). So the overall effect of being high UE for highly shorted stocks is the sum of -4.30 and 3.58 or -0.72 percentage points. So for highly shorted stocks, being high UE actually leads to negative returns of about minus 72 basis points. In other words, for highly shorted stocks, one wants to short sell rather than buy good news stocks. The result in column 3 using more elaborate controls confirms the one in column 2. Notice here that the coefficient β_3 is smaller at -3.65 but is still statistically significant.

In columns 4-6, we present the results using stock fixed effects. β_3 from column 5 is negative and statistically significant and similar in magnitude to column 2 (-3.81 with a t-statistic of over 5). The results using quarter by industry effects (presented in columns 7-9) are slightly similar to columns (1)-(3). In sum, the results are consistent with the third prediction of our model.

D. Alternative Explanations

We now consider a number of alternative explanations for these three sets of findings. There are two closely related alternatives that can explain our main finding regarding high short ratio stocks having higher price sensitivity to news. The first is that high short ratio stocks proxy for stocks with high divergence of opinion. Hence, earnings news leads to more price discovery. We try to control for this alternative using explicit proxies for divergence of opinion such as analyst forecast disagreement and other controls such as stock fixed effects. But one might still argue that high short ratio is itself the best proxy. This alternative, however, does not naturally generate a predicted reversal associated with the price reaction. For high short ratio stocks, good news leads to a bigger price move up and subsequent reversal captured by the fact that shorting profitability after the event date increases with better news. A price discovery story would naturally imply that certain groups were right and certain groups were wrong and the bets are resolved through the earnings news, saying nothing about future returns associated with the news.

A closely related variant of this divergence of opinion story is that funds which short are informed and are betting that there is bad news about the company (see, e.g., Boehmer, Jones and Zhang (2008)). That is, high short interest predicts a negative earnings surprise. When the news is good, this means that the informed short-sellers happen to be wrong. As before, price adjusts appropriately but with no implications for *POSTCAR*.

Again, we cannot rule out every alternative explanation of our results, but we feel that our three sets of findings do cut strongly against a number of reasonable alternatives, particularly when one takes into account the stock fixed effects and quarter by industry effects specifications.

E. Quasi-Experiment 1: NASDAQ versus NYSE

Though we are comfortable with the OLS estimates, it is worthwhile to think of additional ways to better identify our amplification mechanism. We can exploit differences in short selling regulations across stock exchanges to make the following prediction: our effects above should be stronger for NASDAQ stocks which are easier to short than NYSE stocks. Short selling regulations are much more lax for stocks listed on NASDAQ than on the NYSE. Before 1994, there were not even any short selling regulations for NASDAQ stocks. It is generally thought that NASDAQ introduced some degree of regulation to compete with NYSE for firm listings because companies typically do not like to have their stocks shorted. The two exchanges also use somewhat different price tests (NYSE uses the tick test which is generally thought to be more stringent than the bid test used by NASDAQ).

This price-test difference aside, the NASDAQ regulations that were introduced and those currently in use are substantially weaker than those of the NYSE. First, NASDAQ exempts its market-makers from short selling regulations. Second, trades originating from Electronic Communications Networks (ECNs) are also exempt. This means that 30% of NASDAQ short sale trades are not even subject to a bid test, whereas all NYSE trades are subject to a tick test (see, e.g., Jickling (2005), O'Hara and Angstadt (2004)).

Therefore, we expect to find that short interest ratios are substantially higher for NASDAQ stocks all else equal. In particular, we see whether being listed on NASDAQ increases the likelihood that the stock is in the top 33% of the short ratio distribution using the following regression:

$$\begin{aligned} HISR_{i,t} = \alpha + \beta_1 NASDAQ_{i,t} &+ SIZE\ dummies_{i,t} + P/E\ dummies_{i,t} \\ &+ DISAGREEMENT\ dummies_{i,t} \\ &+ CONVDEBT\ dummies_{i,t} + VOLATILITY\ dummies_{i,t} \\ &+ INDUSTRY\ dummies_{i} + QUARTER\ dummies_{t} + \varepsilon_{i,t} \end{aligned} . \tag{13}$$

The coefficient of interest is β_1, which measures how being listed on NASDAQ affects the probability that the stock is in the top 33% of the short ratio distribution. (We have also run this as a probit or logit and obtained similar results). The result is presented in Table 5; being a NASDAQ stock increases the probability that a stock is in the top 33% of the short ratio distribution by about 9 percentage points. The t-statistic of the coefficient is 9.6.

In Table 6, we then look to see whether our estimates established in Tables 2-4 are stronger among NASDAQ stocks than NYSE stocks. To this end, we adopt the same specifications as in Tables 2-4 (column (2)) except that we include additional explanatory variables including an indicator for NASDAQ, UEHIGHxNASDAQ, HISRxNASDAQ and the main variable of interest, UEHIGHxHISRxNASDAQ. Column (1) reports the results for CAR. Notice the coefficient is 0.14 with a t-statistics of a little over 2. In other words, the higher sensitivity of CAR to UE for HISR stocks compared to other stocks is larger among NASDAQ stocks than NYSE stocks. The coefficient is 0.8 with t-statistic of 2. Column (2) reports the results for AVGTURN. The AVGTURN coefficient is 0.53 with a t-stat of about 3.5. Column (3) reports the results for POSTCAR. The POSTCAR coefficient is -3.97 with a t-stat of about 6. In sum, the results in Table 6 support the implications of our model.

F. Quai-Experiment 2: Rise of Hedge Funds

Our second, and more striking, quasi-experiment builds on the work of Hanson and Sunderam (2007) who document a striking increase since 2000 in short ratio concentrated among small stocks, NYSE deciles 1-5. They argue that this is in large part due to the rise of hedge funds. Notably, Hedge Fund Research reports that assets managed by long-short equity hedge funds, which are among the most sophisticated arbitrageurs, grew from $133 billion in 2000 to $409 billion at the end of 2006. Hanson and Sunderam further report that by some estimates, hedge funds account for 85% of short positions in the US equity market. As a result, the percentage of US equity market capitalization sold short nearly doubled from 1.7% in 2000 to 3.0% at in 2007. Most interestingly to us is that this growth has been concentrated in small stocks.

In Figure 1, we verify Hanson and Sunderam's finding by plotting the average short ratio within two groups: the small stocks, which is defined as NYSE deciles 1-5, and large stocks, which is defined as NYSE deciles 8-10. We exclude deciles 6-7 since these stocks are in between in the sense that they experienced some moderate growth in short ratios. We want to get a clean test across these two groups. Indeed, we see from Figure 1 that large stocks' short ratio has not increased by much over our sample. It starts at 1% in 1993 and increases to around 2% in 1998 and since then it has fluctuated between 2% and 3% in the remaining sample period. In contrast, we see a very steep increase in the short ratio among small stocks from around 2% in 2000 to a high of 9% in 2007.

If our hypothesis is correct, then we expect to find that the destabilizing price and turnover effects documented above ought to have increased among small stocks since 2000 and to not find any such difference for large stocks which did not witness such growth. We find that this is indeed the case in Table 7. We estimate an augmented version of our baseline specification in Tables 2-4 separately for small and large stocks. We take the specification from column (2) and augment the independent variables with an indicator AFTER1999, UEHIGHxAFTER1999 and UEHIGHxHISRxAFTER1999. The coefficient of interest is in front of UEHIGHxHISRxAFTER1999. This coefficient tells us whether our effects have been stronger after 1999. Indeed, we find that the magnitudes of the coefficients are remarkably close to our baseline estimates, though the statistical significance is naturally limited because of the reduced sub-sample.

G. Robustness Checks and Additional Analyses

Finally, we present a number of robustness checks. Table 8 presents the *CAR* and *POSTCAR* regressions using the CAPM and returns net of the risk-free instead of the three-factor adjusted returns we use previously. There is no important difference between the results using these different adjustments. These robustness checks increase our confidence in concluding that the bulk of the findings support our model.

According to our model, these differential sensitivities are symmetric with regard to very good versus very bad earnings surprises: because all arbitrageurs are initial financially constrained, shorts are reduced following good news but importantly, they are also increased following bad news. However, one could imagine that cutting back of shorts following bad news is more likely than the increase in shorts following good news in reality. If shorts are often reduced (but are less likely to increase) following good (bad) news about a stock, then the above differential sensitivities should largely be driven by very good news as opposed to very bad news. We have tried examining this issue. We find some evidence suggestive of such asymmetries but our estimates are not precise. In contrast to our earlier results which are easy t obtain and robust to different specifications, the asymmetry results depend much more in specifications. As such, we point out that our findings are inconclusive on this dimension.

V. Conclusion

We develop a simple model to examine whether arbitrageurs amplify fundamental shocks in the context of short arbitrage in equity markets. The key amplifying mechanism is that the ability of arbitrageurs to hold on to short positions depends on asset values: shorts are often cut (increased) following good (bad) news about a stock. As a result, the prices of highly shorted stocks are excessively sensitive to fundamental shocks.

Consistent with this model, we find that, controlling for a host of other stock characteristics, the price of a highly shorted stock is more sensitive to earnings news than a stock with little short interest. Moreover, using daily share turnover as a proxy for short covering, we document that short interest changes in the predicted direction in response to earnings news. For highly shorted stocks, returns to shorting are actually somewhat higher following good earnings news. Finally, these differential sensitivities are more pronounced for NASDAQ stocks which are easier to short than NYSE stocks. These findings are broadly consistent with theories which emphasize the limits of arbitrage in affecting asset price dynamics.

As we suggested in the introduction, understanding the potentially destabilizing effects of speculators on asset markets is of paramount importance in light of the rise of hedge funds in the last decade. There are a number of avenues for further research to clarify the various channels through which speculators might destabilize markets. Along the same lines as this paper, if better daily data on short trades becomes available, we can more directly verify the short covering effect around earnings announcements as opposed to simply using share turnover. We can also use options data as opposed to short interest data to measure levered long or short positions in stocks and perform a similar set of analyses as in this paper. We plan to pursue these avenues in future research.

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Appendix

In this appendix we relax our earlier assumption that speculators put all their resources, F_0, at risk in the stock market immediately, and instead assume that they choose some amount, $D_0 \leq F_0$ to put at risk (the remainder is invested in cash and yields a zero net return). The speculators may want to put some money aside in case the stock becomes an even better short trade after the earnings announcement. To complete the model, we set up the speculators' incentives and solve their optimization problem. We set the problem up in terms of speculators maximizing wealth at the liquidation date. Since speculators are fully invested at time 1, profits from time 0 to 1 are already factored into this maximization. Hence speculators maximize the expectation of $R(D_0) = F_1(D_0)\left(2 - \frac{v}{p_1(D_0)}\right)$ with respect to D_0:

$$\max_{D_0} E[R] = \max_{D_0} \frac{1}{2} F_1(\bar{v})\left(2 - \frac{\bar{v}}{p_1(\bar{v})}\right) + \frac{1}{2} F_1(\underline{v})\left(2 - \frac{\underline{v}}{p_1(\underline{v})}\right) \tag{A1}$$

Taking the first derivative with respect to D_0 above and substituting F_1 from (5) gives us the following FOC:

$$\frac{1}{2}\left(1 - \frac{p_1(\bar{v})}{p_0}\right)\left(2 - \frac{\bar{v}}{p_1(\bar{v})}\right) + \frac{1}{2}\left(1 - \frac{p_1(\underline{v})}{p_0}\right)\left(2 - \frac{\underline{v}}{p_1(\underline{v})}\right) \geq 0 \tag{A2}$$

If the FOC is strictly greater than 0 then $D_0 = F_0$. For $D_0 < F_0$ to be optimal the FOC must be equal to 0. Each term in (A2) represents the incremental gross return following either a positive or a negative fundamental value announcement, accounting for the returns accumulated at both period 1 and period 2. The optimization condition (A2) and the price equations define the equilibrium of this model.

We will make use of the following rearrangement of terms for the earnings-response-coefficient for the proofs below

$$\beta(v) = k\left(1 + \frac{S(v) - S - (F_0 - D_0)}{v - E[v]}\right), \tag{A3}$$

where $k = \left(1 - a\frac{D_0}{p_0}\right)^{-1} \geq 1$ and $k > 1$ for stocks with nonzero initial short ratio $\frac{D_0}{p_0} > 0$. All the propositions below assume that there is not enough capital to bring prices close to fundamental value.

Proof of Proposition 1: Note that the definition for β can be written as

$$\beta(v) = \frac{p_1 - p_0}{v - E[v]} \tag{A4}$$

We will assume that sentiment S and $S(v)$ are raised uniformly for the shorted stock (for which $0 < D_0 < D^*$, where D^* is defined below) over the un-shorted stock ($D_0 = 0$) so that $S(v) - S$ does not change.

In order for the proposition to hold, speculators must be subject to capital constraints, *i.e.* $a > 0$. When $a = 0$, the initial decision regarding D_0 is made independently of the wealth maximization problem of period 1. Hence D_0 will be chosen equal to F_0 in order to maximize period 1 profits. Along with the fact that $k = \left(1 - a\frac{D_0}{p_0}\right)^{-1} = 1$, this implies that (A3) for $a = 0$ can be simplified to

$$\beta(v) = \left(1 + \frac{S(v) - S}{v - E[v]}\right). \tag{A5}$$

Since $S(v) - S$, and v are the same for the shorted and un-shorted stock, all terms in (A5) are equal, and so the betas are equal.

Now return to the case of $a > 0$. First, we demonstrate that the partial derivative of β with respect to D_0 at the point $D_0 = F_0 = 0$ is greater than zero. Hence β is increasing for small D_0. From (A3), β consists of the product of two positive terms, k and $\left(1 + \frac{S(v) - S - (F_0 - D_0)}{v - E[v]}\right)$. It is straightforward to show that $\frac{\partial k}{\partial D_0} > 0$ at $D_0 = 0$. To prove that $\frac{\partial \beta}{\partial D_0} > 0$, it is only necessary to show that the derivative of the second term is nonnegative. Since the first order condition is continuous in D_0 and is positive for $D_0 = 0$, it must be the case that $D_0 = F_0$ even for small $D_0 > 0$. Hence $\frac{\partial F_0}{\partial D_0} = 1$, and the derivative of the second term is zero.

So far we have shown that β is larger for positive short interest stocks so long as D_0 is small. Since $\frac{\partial k}{\partial D_0}$ is always positive, changes in the sign of $\frac{\partial}{\partial D_0}\beta$ must come from changes in $\frac{\partial F_0}{\partial D_0}$. From the first order condition, we notice that as D_0 and F_0 increase, there will eventually come a point where $\frac{\partial F_0}{\partial D_0} < 1$, and at this point $\frac{\partial}{\partial D_0}\beta$ decreases and may eventually turn negative (we will see momentarily that it must turn negative). From all the equations involved, notice that this is the only possible source of change in the sign of $\frac{\partial}{\partial D_0}\beta$. Finally, consider what happens for very large D_0 and F_0. In such a case, price equals fundamental value and $\beta = 1$. Hence there must exist D^*, and so too F^*, such that the proposition holds whenever initial capital is below F^*.

Proof of Proposition 2: Intuitively, a positive (negative) earnings shock and resultant increase (decrease) in price cuts into (adds to) the speculator's selling power, implying a lower (higher) short ratio in the following period. A speculator subject to collateral constraints and/or performance based fund flow would also lose (gain) some collateral, inducing him to reduce (expand) his short position further. Now examine this statement algebraically. The initial short ratio is $\frac{D_0}{p_0}$ and the post-announcement short ratio is $\frac{F_1}{p_1}$. Consider the effect of positive news, $v - E[v] > 0$. The change in price, $p_1 - p_0$, is $v + S(v) - F_1 - (E[v] + S - D_0)$. This expression is the sum of the change in fundamental value, $v - E[v]$, and the change in unarbitraged sentiment, $S(v) - F_1 - (S - D_0)$. So long as the positive earnings news does not perversely cause the un-arbitraged sentiment to decrease, both terms are positive and the change in price is proportional to the earnings surprise. Now provided there is not enough capital to bring prices close to fundamental value in the sense of Proposition 1, D_0 is near F_0 , and $F_1 < D_0$. Therefore the short ratio changes inversely with the earnings surprise.

To show the statement regarding share turnover, note that the only traders in our model are noise traders and speculators. Hence aggregate share turnover is proportional to the (absolute value of) change in demand of either type of trader. As we've seen above, the speculator's demand is equal to the current short ratio, so turnover is exactly equal to the (absolute) change in short ratio.

Proof of Proposition 3: The expected return to shorting in our model is the ratio of price to fundamental value. Before and after a positive earnings surprise, this ratio is $\frac{p_0}{E[v]}$ and $\frac{p_1(\bar{v})}{\bar{v}}$, respectively. Of course, for $\bar{v} = E[v]$ (*i.e.* no earnings news), the expected return to shorting does not change. Hence our proposition is equivalent to $\frac{dp_1(\bar{v})}{d\bar{v}} > 1$. Our assumption that sentiment increases proportionally with unexpected earnings news is interpreted as $S'(\bar{v}) > 0$. From (8), $\frac{dp_1(\bar{v})}{d\bar{v}} = k(1 + S'(v))$. To prove the proposition, note that $k > 1$ for highly shorted stocks.

Table 1: Summary Statistics

	Mean	25th percentile	Median	75th percentile
	(1)	(2)	(3)	(4)
Short Ratio (% of shares outstanding)	3.39 [4.77]	.56	1.69	4.25
AVGTURN (mean turnover (%) from day -7 to +1)	1.00 [2.63]	.19	.46	1.03
CAR (cumulative abnormal return (%) from day -7 to +1)	.34 [10.18]	-4.24	.10	4.76
POSTCAR (cumulative abnormal return from day +2 to +180)	.08 [38.39]	-19.20	-.41	14.77
Unexpected Earnings (as a % of previous price)	-.13 [1.99]	-.09	.01	.12
Market Capitalization (millions of dollars)	3670 [15,622]	239	606	1886
Price/Earnings (if positive)	40.8 [160.5]	14.0	19.3	29.9
Analyst Disagreement	.17 [.64]	.02	.06	.13
Past Volatility	1.52 [1.39]	1.51	2.15	3.10
Convertible Debt (millions of dollars)	34.6 [176.9]	0	0	0

This table presents the summary statistics of the sample used in the regression estimations. The sample includes all stocks that are traded either on NASDAQ, AMEX or the NYSE from 1993-2007. Standard deviations are in brackets. There are 130,301 observations.

Table 2: OLS Estimates of the Sensitivity of Stock Returns to Unexpected Earnings

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Indicator for High Unexpected Earnings (UEHIGH)	5.08 (.10)	4.51 (.12)		5.16 (.12)	4.49 (.14)		5.15 (.10)	4.59 (.12)	
Indicator for High Short Ratio (HISR)	-.36 (.10)	-.90 (.14)	-.90 (.14)	-.32 (.16)	-.98 (.19)	-.97 (.20)	-.42 (.11)	-.95 (.14)	-.93 (.15)
High Unexpected Earnings $\times$ High Short Ratio (UEHIGH $\times$ HISR)		1.13 (.19)	1.19 (.21)		1.33 (.22)	1.38 (.24)		1.11 (.20)	1.12 (.22)
Stock Fixed Effects	No	No	No	Yes	Yes	Yes	No	No	No
Quarter $\times$ Industry Effects	No	No	No	No	No	No	Yes	Yes	Yes

The dependent variable is CAR. The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter. The independent variables include UEHIGH (indicator that a stock's earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. In columns (3), (6) and (9), interactions of UEHIGH and all of the other controls except the INDUSTRY and QUARTER dummies are included in the specification. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e*. the standard errors are clustered by stock.

Table 3: OLS Estimates of the Sensitivity of Turnover to Unexpected Earnings

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
High Absolute Unexpected Earnings (ABSUEHIGH)	.44 (.05)	.21 (.03)		.17 (.02)	.02 (.02)		.44 (.05)	.21 (.03)	
Indicator for High Short Ratio (HISR)	.81 (.04)	.65 (.03)	.65 (.02)	.41 (.03)	.32 (.02)	.32 (.04)	.81 (.05)	.65 (.03)	.65 (.03)
High Absolute Unexpected Earnings Decile $\times$ High Short Ratio (ABSUEHIGH $\times$ HISR)		.46 (.09)	.46 (.10)		.29 (.04)	.28 (.04)		.46 (.10)	.46 (.10)
Stock Fixed Effects	No	No	No	Yes	Yes	Yes	No	No	No
Quarter $\times$ Industry Effects	No	No	No	No	No	No	Yes	Yes	Yes

The dependent variable is AVGTURN. The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter. The independent variables include ABSUEDECILE (indicator that a stock's absolute earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. In columns (3), (6) and (9), interactions of ABSUEHIGH and all of the other controls except the INDUSTRY and QUARTER dummies are included in the specification. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Table 4: OLS Estimates of the Effect of Unexpected Earnings on Subsequent Stock Returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Indicator for High Unexpected Earnings (UEHIGH)	1.42 (.32)	3.58 (.41)		.74 (.34)	2.67 (.44)		1.41 (.33)	3.55 (.41)	
Indicator for High Short Ratio (HISR)	-1.71 (.39)	-.24 (.43)	-.46 (.44)	-4.43 (.63)	-3.12 (.66)	-3.37 (.66)	-1.89 (.38)	-.42 (.42)	-67 (.43)
High Unexpected Earnings $\times$ High Short Ratio (UEHIGH $\times$ HISR)		-4.30 (.66)	-3.65 (.73)		-3.81 (.69)	-3.13 (.77)		-4.27 (.65)	-3.53 (.72)
Stock Fixed Effects	No	No	No	Yes	Yes	Yes	No	No	No
Quarter $\times$ Industry Effects	No	No	No	No	No	No	Yes	Yes	Yes

The dependent variable is POSTCAR. The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter. The independent variables include UEHIGH (indicator that a stock's earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. In columns (3), (6) and (9), interactions of UEHIGH and all of the other controls except the INDUSTRY and QUARTER dummies are included in the specification. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Table 5: The Effect of being Traded on NASDAQ on the Probability of Having a High Short Ratio

Indicator for NASDAQ traded stock	.086 (.009)

The dependent variable is HISR. The independent variables include NASDAQ (a dummy equal to one if the stock is listed on NASDAQ and zero otherwise), SIZE (market cap divided into 25 dummies by quarter), P/E (the decile of a stock's earnings surprise for the quarter of the observation), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Table 6: Estimates of the Effect of Unexpected Earnings on Stock Returns, Turnover and Subsequent Stock Returns for NASDAQ versus NYSE Stocks

	CAR	AVGTURN	POSTCAR
	(1)	(2)	(3)
High Unexpected Earnings (UEHIGH or ABSUEHIGH for column (2))	3.95	.17	2.55
	(.14)	(.04)	(.44)
Indicator for High Short Ratio (HISR)	-.29	.28	-.45
	(.16)	(.03)	(.45)
Indicator for NASDAQ stock (NASDAQ)	-.30	.29	-.92
	(.17)	(.04)	(.51)
UEHIGH $\times$ HISR	.68	.16	-1.97
	(.23)	(.05)	(.66)
UEHIGH $\times$ NASDAQ	.92	.14	1.71
	(.22)	(.07)	(.76)
HISR $\times$ NASDAQ	-1.01	.64	.32
	(.25)	(.05)	(.77)
UEHIGH $\times$ HISR $\times$ NASDAQ	.80	.53	-3.97
	(.37)	(.15)	(.66)

The dependent variable is CAR in column (1). The dependent variable is AVGTURN in column (2), and the dependent variable is POSTCAR in column (3). The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter and exchange. The independent variables include UEHIGH (indicator that a stock's earnings surprise for the quarter is in the top 33% of the distribution that quarter), ABSUEHIGH (indicator that a stock's absolute earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter and exchange of the observation and zero otherwise), NASDAQ (a dummy equal to one if the stock is in NASDAQ), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), IO (institutional ownership divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Table 7: Estimates of the Effect of Unexpected Earnings on Stock Returns, Turnover and Subsequent Stock Returns for Small and Large Cap Stocks Before and After 1999

	Small Stocks			Large Stocks		
	CAR	AVGTURN	POSTCAR	CAR	AVGTURN	POSTCAR
	(1)	(2)	(3)	(4)	(5)	(6)
High Unexpected Earnings (UEHIGH or ABSUEHIGH for columns (2) and (4))	4.71 (.23)	.32 (.07)	5.18 (.92)	2.97 (.25)	.11 (.03)	1.25 (.73)
Indicator for High Short Ratio (HISR)	-.73 (.27)	.51 (.07)	1.38 (1.02)	-.16 (.28)	.15 (.04)	3.07 (.96)
Indicator for After 1999 (AFTER)	1.07 (.87)	-.13 (.13)	21.05 (5.40)	1.77 (.92)	.75 (.17)	10.04 (1.66)
UEHIGH $\times$ HISR	1.21 (.37)	.52 (.21)	-2.81 (1.53)	.76 (.41)	.58 (.19)	-.66 (1.88)
UEHIGH $\times$ AFTER	.26 (.31)	-.21 (.08)	-.59 (1.20)	.75 (.28)	.27 (.12)	-.24 (.99)
HISR $\times$ AFTER	-.98 (.36)	.45 (.08)	-4.13 (1.25)	.71 (.33)	.69 (.08)	-6.33 (1.18)
UEHIGH $\times$ HISR $\times$ AFTER	.73 (.52)	-.14 (.25)	-2.71 (1.94)	-11 (.58)	-.15 (.21)	1.41 (2.15)

The dependent variable is CAR in column (1). The dependent variable is AVGTURN in column (2), and the dependent variable is POSTCAR in column (3). The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter and exchange. Small stocks are firms with a market cap below the median and large stocks are firms with market cap above 70^{th} percentile. The independent variables include UEHIGH (the indicator that a stock's earnings surprise for the quarter is in the top 33% of the distribution that quarter), ABSUEDECILE (indicator that a stock's absolute earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter and exchange of the observation and zero otherwise), AFTER (a dummy equal to one if the observation is after 1999), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), IO (institutional ownership divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Table 8: OLS Estimates of the Effect of Unexpected Earnings on Stock Returns, Alternative Benchmarks

	CAPM		Net Risk-Free	
	CAR	POSTCAR	CAR	POSTCAR
	(1)	(2)	(3)	(4)
High Unexpected Earnings (UEHIGH)	4.51 (.12)	3.58 (.41)	4.51 (.12)	3.58 (.41)
Indicator for High Short Ratio (HISR)	-.95 (.14)	-.21 (.43)	-.90 (.14)	-.23 (.44)
High Unexpected Earnings $\times$ High Short Ratio (UEDHIGH $\times$ HISR)	1.15 (.19)	-4.30 (.67)	1.15 (.20)	-4.30 (.66)

The dependent variable in columns (1) and (3) is CAR. The dependent variable in columns (2) and (4) is POSTCAR. The sample includes all stocks in the top 33% and bottom 33% of the short ratio distribution for the quarter. The independent variables include UEHIGH (indicator that a stock's earnings surprise for the quarter is in the top 33% of the distribution that quarter), HISR (a dummy equal to one if the stock is in the top 33% of the short ratio distribution for the quarter of the observation and zero otherwise), SIZE (market cap divided into 25 dummies by quarter), P/E (price-to-earnings divided into 25 dummies by quarter and one additional dummy variable for negative earnings stocks), DISAGREEMENT (analyst disagreement divided into 25 dummies by quarter), CONVDEBT (convertible debt divided into 25 dummies by quarter), VOLATILITY (past volatility divided into 25 dummies by quarter), INDUSTRY dummies (SIC at the 2 digit level) and QUARTER dummies. Columns (1) and (2) present the estimates using the CAPM returns; columns (3) and (4) present the estimates using the returns net of the risk-free. The standard errors are adjusted by allowing for the errors to be correlated across observations of the same stock; *i.e.* the standard errors are clustered by stock.

Figure 1: Plot of Short Interest Over Time by Firm Size