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Daily income target effects: Evidence from a large sample of professional commodities traders

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Abstract

We provide evidence of rational reference-dependent preferences in the proprietary trading of professional traders. We find increased trading effort and risk taking by traders following morning losses. Further analysis provides no evidence of a deterioration in trading performance subsequent to losses, as neither risk-adjusted performance nor trade execution appear to be negatively affected by prior losses. The evidence supports the existence of rational reference-dependent preferences in the form of trader daily income targets: these professional traders exhibit increased work effort subsequent to abnormal morning losses. The evidence is inconsistent with the alternative explanation of costly loss aversion.

JEL classification: D03; D53; G10

Keywords: Daily income targets; Reference dependence; Loss aversion

1. Introduction

Self-employed professional traders often operate in an arena where their presence, their attention span, and their effort are all personal decisions at any given time. They may choose to participate in trading or not, and may arbitrarily or strategically take days or afternoons off. The purchase or lease of a membership on an exchange by a professional trader implies a daily fixed cost of trading, in addition to the variable costs such as fees and effort. We investigate whether previous evidence of the relationship of professional trader

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activity to prior outcomes might be explained by daily income targeting, along the lines of Camerer et al. (1997). We find that, rather than costly irrationality, such as that associated with loss aversion (e.g., Coval and Shumway, 2005), observed afternoon behavior (increased effort and risk taking) is consistent with rational reference-dependent preferences.

Numerous studies provide evidence of loss aversion among experimental subjects and retail investors.[1] Indeed, the phenomenon may reflect evolved adaptations for general decision making and may also be shared with other species. A recent study (Chen et al., 2006) provides evidence of loss aversion in Capuchin monkeys, suggesting that observed human loss aversion behavior may be a vestigial heuristic, of unknown origin, which affects the behavior of a typical trader endemically and negatively if unchecked by conscious discipline. Further evidence shows that the behavior may apparently be altered physiologically. Shiv et al. (2005) find that experimental subjects with a particular brain damage that impairs emotional responses related to gains and losses made more money in experiments than did unimpaired subjects, where by design the gamble had positive expected earnings. Lo et al. (2005) also link trading success to emotional discipline, finding that the day traders in their sample who exhibit more intense emotional responses also exhibit significantly worse trading performance.

It is important to recognize that successful trading does not necessarily require the elimination of emotional reactions or "behavioral traits" (such as loss aversion). For example, Bénebou and Tirole (2004) model the development of self-control, and show that more self-confident individuals are likely to develop the most self-control, which suggests that overconfident traders could be the most disciplined. Thus, successful traders may exhibit various "behavioral traits" without endangering their livelihood. But traders have significant financial incentives to minimize *costly* impacts of "suboptimal" behavioral traits such as loss aversion, and professional traders are likely to develop self-control mechanisms that dampen costly effects. Consistent with the idea of emotional regulation, Locke and Mann (2005) find that trader-level empirical proxies for trading discipline (indicative of predetermined trade exit points) are predictive for future risk-adjusted performance. Adding to the evidence that professional traders develop mental discipline with regard to losses, Alevy et al. (2007) compare student to professional traders in experiments, and find that only the students appear sub-optimally responsive to the gain/loss domain.

However, the evidence on trader reaction to losses is mixed. Haigh and List (2005) compare students to professional traders in an experimental setting designed to test for evidence of myopic loss aversion, and find that professionals fare worse than students. Perhaps, as Lo and Repin (2002) point out, in certain situations traders may behave differently while trading with "play money" in an experiment than when trading with their own capital at risk.[2] However, consistent with Haigh and List (2005), the findings of Coval and Shumway (2005) challenge the idea that professional traders either develop or have an inherent disciplined trading approach with regard to losses. Coval and Shumway (2005) examine the trading records of professional futures traders engaged in their main

[1]Hirshleifer (2001) provides a broad summary.

[2]Haigh and List (2005) address the "play money" issue, and set up their experiment so that traders had opportunity to make around \$30−\$40 for a half hour, which their discussions with CBOT officials suggested was typical of expected wages on the floor.

occupation—trading for proprietary accounts in a futures market. They find evidence that traders with cumulative morning losses increase risk taking in the afternoon, and perhaps most interestingly, that those morning-losers exacerbate the noise in afternoon market prices with excessively aggressive trading. The findings of Coval and Shumway (2005) and Haigh and List (2005) offer a challenge to the notion that professional traders dampen the emotions that lead to costly behaviors.

While both Coval and Shumway (2005) and Locke and Mann (2005) rely on rich transactions-level data for professional futures traders, the papers arrive at differing conclusions regarding the rationality of trader behavior. The distinction between the particular methods and findings in Locke and Mann (2005) and Coval and Shumway (2005) are important. Locke and Mann (2005) examine whether traders are more reluctant to close out losses than gains on a trade-by-trade basis, where each trade is continuously marked to market to keep a running measure of the trade's paper loss or gain. Thus, similar to Odean (1998), Locke and Mann (2005) test directly for the disposition effect as described by Shefrin and Statman (1985), the financial adaptation of Kahneman and Tversky's (1979) prospect theory. The disposition effect results from decision makers having constantly shifting "S-shaped" utility functions around recent gains and losses, i.e., immediate wealth changes, rather than the traditional aggregate wealth level. As a consequence, gains and losses are predicted to affect contemporaneous decisions asymmetrically in that traders are more likely to dispose of winning positions than losing positions.

Rather than analyzing contemporaneous effects, Coval and Shumway (2005) examine the effect of cumulative profitability on subsequent behavior. In their formulation, an aversion to potential losses leads to costly afternoon behaviors when traders find themselves with morning losses. In effect, Coval and Shumway (2005) seek evidence of costly trader irrationality when faced with the prospect of losing money for the day. They find that traders with morning losses execute more afternoon trades, that the increased trading is poorly executed, and that the traders with morning losses take on abnormally higher amounts of risk in the afternoon.

Based on this mixed evidence regarding professional trader loss aversion, we re-examine loss-related trader behavior in the context of the broader literature investigating reference-dependent preferences, which includes research on intertemporal labor supply by workers with flexible daily schedules, such as the flexibility enjoyed by futures traders. In particular, Camerer et al. (1997), Farber (2005, 2008), and Crawford and Meng (2008) document a negative relationship between early-day incomes and subsequent hours worked by New York City cab drivers. Kőszegi and Rabin (2006) formalize the concept of an endogenous daily income target, and provide the following insight:

> Intuitively, if a driver earns less money than she expected early in the day, she will be more willing to work later, so as to mitigate the losses from falling short of her target (Kőszegi and Rabin, 2006, p. 1153).

Income targets imply an increased effort by cab drivers who have had unsuccessful mornings in order to reach a reference point, or desired income level. In related work, Doran (2009) provides evidence linking changes in anticipated cab driver income to changes in reference points. Self-employed futures traders face the same general time constraints as cab drivers. These futures traders are free to come and go from the trading arena, free to bid or offer at anytime (or not) and thus should be free to reveal to the econometrician the effects of accumulated profits on subsequent behavior. While Crawford and Meng (2008) model drivers as having targets for hours worked as well as income targets, we focus on income targets only, given that daily futures trading sessions are relatively brief (4–6 h).

We examine afternoon proprietary trading by professional futures traders conditional on morning income. Our results confirm the preliminary finding of Coval and Shumway (2005): Traders take on more risk and execute a higher number of bad trades (buying high and selling low) in the afternoon after they have accrued unusual morning losses. However, we also find that traders with morning losses trade more in the afternoon. Thus, consistent with the notion of daily income targets, traders with morning losses increase their effort in the afternoon. While we find strong evidence that morning losers execute a greater number of "bad" trades, the evidence on the proportion of "bad" trades executed by morning losers is inconclusive. These results suggest that trading strategies are unaffected by morning income, and that instead it is effort that changes. Further, the traders in our sample exhibit no reduction in risk-adjusted performance for afternoons subsequent to morning losses. Consistent with the existence of daily income targets, traders in our sample appear to work harder in the afternoon after morning losses, but reveal no evidence of costly loss aversion. There is no evidence that morning losses lead these professional traders to influence market prices in an irrational or harmful fashion.

The remainder of the paper is structured as follows: Section 2 describes the data and methods. Section 3 presents our results, and Section 4 concludes.

2. Data and methods

We use transactions data for 1995 from the Chicago Mercantile Exchange, generously supplied by the Commodity Futures Trading Commission (CFTC). We examine traders in the two most active currencies (Deutsche marks and Swiss francs) and the two most active non-financial commodities (live cattle and pork bellies). Our basic data set contains the trading of all members and leaseholders in these four contracts. Members may execute trades as an agent or for their personal account, with specialization in one or the other the norm. Traders executing trades for a personal account tend to trade at a high frequency and the activity resembles market making, although trading strategies are generally unconstrained. The guarantor for the trader may have particular intraday limits for the trader based on the trader's capital.[3] Following Locke and Mann (2005), we select all traders that execute at least five proprietary trades on at least 10 different days during the 1995 calendar year in a contract, and have at least one positive and negative morning in the year, resulting in an overall sample of 287 traders.[4] The selected traders were responsible for 99% of the personal account volume traded in these contracts during this period.[5]

[3]During our sample period, all trading was in open outcry in the pit, with manual recording of trades. As such, the personal trading records were reconciled at the end of the day. Our discussions with traders provide anecdotal evidence that traders continuously track their intraday profitability and risk exposure.

[4]For our analysis, we use the trading by the trader in the contract for which they are most active during the year. For example, a few traders may have traded pork bellies and cattle on different days during the year, but we limit our analysis to one of these contracts, the one in which the trader was most active.

[5]The excluded traders (responsible for around 1% of personal account volume) are either transient traders in our commodities or, more likely, absorbing trades into a personal account in order to offset brokerage error trades (e.g., the trader bought when the customer wanted to sell).

We divide each trading day into two intervals of equal duration. For the two currencies, the first half is from 7:00 am (the open) to 10:29 am, with the second from 10:30 am to 2:00 pm (the close). For the bellies and cattle, the first half is from 9:00 am (the open) to 10:59 am, the second half from 11:00 am to 1:00 pm (the close). To enhance our exposition, we describe the first half of the day using the term "morning" and the second half using the term "afternoon."

The CFTC data provide trades sequenced to the minute. Futures traders may buy or sell freely, agreeing in principal to take or make delivery of some commodity at a certain time in the future for this fixed price. For each minute of the trading day we note the quantity of contracts executed by each trader for a proprietary account and the associated prices. For each trading day, we calculate morning income for each trader by marking each proprietary trade to market at the final price of the morning period.[6] Traders are assumed to evaluate their income at the close of the morning interval by calculating income from offset trading, and adding to that the mark-to-market value of existing positions, using the end-of-morning price. This is the income that we use to separate our trader days into those for whom morning income is positive, versus those for whom morning income is negative.

We calculate certain market statistics by minute, such as the weighted average price ("market price"), as well as a ranking of all prices. We identify situations where traders execute "worst-price" trades, or trades that moved the market price. Coval and Shumway (2005) refer to such trades as price setting. Based on the ranking of prices in a minute, a trader executes a price setting-trade when buying at the highest or selling at the lowest price in a minute.[7] Sometimes a trader executes multiple trades in the same minute, which we are unable to sequence. If a trader buys contracts at two different prices during a minute, we consolidate the trades and use the quantity-weighted mean price as the trader's buy price for that minute. We treat sales analogously so that, for each minute, we track each trader's buy volume and mean purchase price, as well as the trader's sell volume and mean sales price.

As time passes, existing trader positions can be characterized by their unrealized trading gains or losses. We track each trader's unrealized revenues by marking the trader's positions to market each minute. We calculate the cost basis for an accumulated position using the average prices associated with the trades that were executed to build the position. If the market price is higher (lower) than a long (short) position's average cost, then at that minute the position has an unrealized gain, or a positive mark-to-market. A positive mark-to-market indicates that at that time, the position could probably be closed for a gain; a negative mark-to-market indicates that the position would probably be closed at a loss at that time.

We use the minimum mark to market for a trader during an afternoon as a measure of ex post risk, or revealed risk, since this is approximately the largest risk (maximum potential loss) to which the trader was actually exposed during that afternoon. As the traders in our sample operate in a liquid market in which a position are short lived and can typically be easily closed within seconds, our ex post risk measure captures trader realized

[6] Coval and Shumway (2005) perform this operation in an equivalent two-step procedure, first calculating the income on all trades, i.e., sales prices times quantities minus buy prices times quantities, and then marking the imbalance to market. In addition, Coval and Shumway (2005) and Locke and Mann (2005) both follow the typical assumption that traders begin each day with no trades left over from previous days.

[7] The data used by Coval and Shumway (2005) identify intra-minute trade sequences, which they use to identify trades that set a new high price or low price compared to the previous price.

willingness to be exposed to losses. In addition to our ex post risk measure, we also use ex ante risk measures. Following the approach described by Coval and Shumway (2005), we measure "Total Ex Ante Risk" as the cumulative sum of minute-by-minute products of trader absolute positions multiplied by a measure of instantaneous risk. Instantaneous risk is a rolling 60-min exponentially decaying moving average of absolute log price changes.

Table 1
Descriptive statistics.

	Morning trading		Afternoon trading	
	Mean	Median	Mean	Median
Frank	($N = 11{,}374$)		($N = 9{,}976$)	
Income	635.38	387.50	524.38	200.00
Volume	166.36	102.00	98.19	54.00
Trades	46.79	38.00	29.23	20.00
Trade Size	3.45	2.66	3.14	2.44
Exposure	2253.41	613.34	1985.90	469.79
Total Ex Ante Risk	NA	NA	258.54	76.31
Maximum Position	18.10	10.00	15.58	9.00
Mark	($N = 14{,}029$)		($N = 12{,}351$)	
Income	620.03	275.00	489.34	162.50
Volume	211.22	120.00	111.39	57.00
Trades	48.89	39.00	28.31	20.00
Trade Size	4.13	3.18	3.78	2.81
Exposure	1725.07	441.05	1458.39	311.55
Total Ex Ante Risk	NA	NA	229.22	57.01
Maximum Position	20.70	120.00	16.69	10.00
Bellies	($N = 5{,}369$)		($N = 4{,}922$)	
Income	533.35	250.00	334.39	140.00
Volume	46.66	33.00	36.08	24.00
Trades	22.62	19.00	18.39	14.00
Trade Size	2.07	1.69	1.91	1.56
Exposure	810.07	320.00	1044.59	279.67
Total Ex Ante Risk	NA	NA	337.88	150.76
Maximum Position	10.69	7.00	9.36	6.00
Cattle	($N = 12{,}531$)		($N = 11{,}186$)	
Income	334.92	110.00	261.71	70.00
Volume	113.38	43.00	87.21	34.00
Trades	27.95	14.00	23.26	12.00
Trade Size	3.72	3.00	3.40	2.71
Exposure	830.41	251.43	1711.81	220.00
Total Ex Ante Risk	NA	NA	260.12	108.69
Maximum Position	21.05	11.00	18.87	10.00

For each trader we calculate morning and afternoon trade statistics each day. The number of observations indicates trader mornings or trader afternoons in each commodity. Income is marked-to-mark trading, separated into morning and afternoons; Volume is the total number of contracts traded; Trades is the number of executions; Trade Size is contracts per trade; Exposure is the worst mark-to-market; Total Ex Ante Risk is the sum across minutes of position times the forecast log absolute price change ($\times$ 1000). The forecast log absolute price change is a 60-min moving average, which we do not calculate prior to the open, hence there are no statistics on this for the morning. Maximum Position is the absolute value of the number of contracts long or short.

"Total Ex Ante Risk" measures aggregate trader afternoon exposure to immediate volatility. We also use the maximum number of contracts, either long or short, that a trader holds during an afternoon as an alternative measure of ex ante risk. A buy followed by a sell leaves the trader with no position. On the other hand, a succession of buys or sells leads to an accumulated long or short position, and we measure this ex ante exposure to price changes as the maximum absolute afternoon position, or "Maximum Position." In addition to measures of profitability, risk, and trade execution, we also calculate and report the number of trades and total contract volume for each trader.

Table 1 provides descriptive statistics for the morning and afternoon daily activity of the traders in our sample, broken out by commodity. The unit of observation is a trader-day. The variables (calculated separately for morning and afternoon) are: Income, trader income in dollars; Volume, the number of contracts traded; Trades, the number of transactions; Trade Size, the number of contracts in a transaction; Exposure, the maximum potential (mark-to-market) loss; Total Ex Ante Risk, described above; and Maximum Position, the largest, in absolute value, of the number of contracts long or short at any point in time.

Table 1 shows that mornings are generally more active than afternoons, and that more traders are active in the morning than in the afternoon. For example, there are 11,374 morning trader-days for the franc, but only 9,976 afternoon observations. Similar ratios appear for the other contracts. Thus, some traders appear to leave work early, or fail to return from lunch, perhaps shifting to back office affairs. On average, traders in the afternoon execute fewer trades and trade in smaller sizes than in the morning, thus trade lower total volume, and in turn earn lower afternoon incomes. For each of the four commodities, mean and median trades, trade size, volume, and income are substantially lower in the afternoon than in the morning. Although average trader volume and income are lower in the afternoon, risk-taking does not appear to decline. Two of the risk measures, ex ante (Maximum Position) and ex post (Exposure) indicate that the average trader takes as much risk in the afternoon as the morning. The Total Ex Ante Risk measure requires a forecast of the absolute price change, which we will use for afternoon risk measures, but cannot be calculated for the first hour of trading, thus we present only the afternoon measures.

In the remainder of our analysis, we normalize trader statistics by their individual annual means and standard deviations and combine normalized trader-day activity from all four contracts. Analysis segregated by market is available from the authors.

3. Trader reaction to prior losses

3.1. Measuring the effect of morning trading results on afternoon behavior

We seek evidence of a relationship between prior outcomes and subsequent trading, and an explanation if we find such a link. Our operating null hypothesis is that morning trading is not expected to have adverse subsequent effects, so that observed afternoon trader behavior depends only on contemporaneous conditions. Some subsequent behavioral effects may be within the rational realm, such as supplying an increased effort in the afternoon to meet daily income needs, when morning income falls short of those needs. On the other hand, some effects may be viewed as irrational, such as costly trading choices induced by loss aversion.

As implemented by Coval and Shumway (2005), the loss aversion hypothesis predicts that cumulative morning losses will lead traders to increase their afternoon risk-taking in a suboptimal manner, since they have been pushed into the convex region of the Kahneman and Tversky (1979) gain/loss utility function. Consistent with this aggregate interpretation of loss aversion, Coval and Shumway (2005) find evidence of increased risk-taking subsequent to cumulative losses. Further, they find that the behaviors induced by morning losses are not simply innocuous. Thus Coval and Shumway (2005) provide prima facie evidence of costly loss aversion.[8]

Alternatively, traders with morning losses may increase their afternoon effort in an attempt to achieve a desired daily income, and as a consequence, will be observed trading more frequently and/or trading in larger quantities than traders with morning gains.[9] This increased effort is dependent on morning losses, since the increased effort otherwise is assumed to be too costly. In other words, sufficient morning income obviates the need to expend extra afternoon energy and effort, both physiological (shouting and sweating) and mental (straining to keep account of the position). Traders who are behind may pick up the pace a bit, incurring perhaps some increased stress, relative to traders who are ahead and have the luxury of relaxing a bit or wandering to a Cubs game or simply heading home. The increased effort associated with attaining target income subsequent to morning losses need not imply harmful trading strategies. Thus, daily income targeting and Coval and Shumway's (2005) costly loss aversion may be considered competing views of the link between morning profitability and afternoon trading.

To distinguish between these competing hypotheses for professional traders, we compare statistics from the afternoon trading of traders with morning gains to those from traders with morning losses. All variables are normalized using the entire year of each trader's activity. We normalize variables by subtracting the trader sample mean from each variable and dividing by the trader sample standard deviation. The resulting unit of observation for each variable is standard deviations from the mean for a trader-afternoon.

Table 2 reports sample afternoon trading statistics and test results for trader-days with morning gains compared to trader-days with morning losses. There are three major column headings, "Ahead in the morning," indicating mean and median afternoon trading statistics for trader days when the trader had a profitable morning; "Behind in the morning," afternoon statistics for trader days when the trader had an unprofitable morning; and "Prob. values," where we present three two-sided probability values from tests of whether the distribution of the observed variables on afternoon trader days with profitable mornings differ from trader days with unprofitable mornings. The first is the probability from a standard t-test for the difference in means, the second is a similar probability from a winsorized t-test for the difference in means, and the third is the probability from a nonparametric Wilcoxon Z-test for the difference of the distribution of the two samples.

[8]Odean (1998) shows that the loss aversion behavior he identifies is costly: losing stocks that are retained do worse than winning stocks that are sold. On the other hand, Locke and Mann (2005) also find prima facie evidence of loss aversion; however, there are no observed costs, hence there is no conclusion of irrationality.

[9]There is at least one additional relevant hypothesis, the "house money" effect (Thaler and Johnson, 1990). Under this assumption, unexpected increases in wealth lead to increased risk-taking, since the increased wealth is considered a gift. The house money effect relies on unexpected, windfall gains, while our traders rationally expect high income variability. Thus, while on any day excessively large income may be unexpected, these traders expect such large wins on some days, rather than being shocked.

Table 2
Conditional afternoon trading differences.

	Ahead in the morning $N = 23{,}294$		Behind in the morning $N = 11{,}249$		Prob. values		
	Mean	Median	Mean	Median	t-Test	Winsorized t	Wilcoxon
Income	−0.0100	−0.0783	0.0293	−0.0576	0.0012	0.0237	0.0014
Volume	−0.0189	−0.2712	0.0709	−0.1958	<0.0001	<0.0001	<0.0001
Trades	−0.0139	−0.2055	0.0659	−0.1320	<0.0001	<0.0001	<0.0001
Trade Size	−0.0216	−0.2096	0.0433	−0.1721	<0.0001	<0.0001	<0.0001
Exposure	−0.0126	−0.2462	0.0571	−0.2237	<0.0001	<0.0001	<0.0001
Total Ex Ante Risk	−0.0292	−0.2906	0.1108	−0.2281	<0.0001	<0.0001	<0.0001
Maximum Position	−0.0334	−0.2654	0.1011	−0.1580	<0.0001	<0.0001	<0.0001

All statistics are calculated for each trader using afternoon trading. Income is calculated by marking each trade to market at the closing price for the contract that day. Volume is the total number of contracts traded. Trades is the number of executions. Trade Size is contracts per trade. Exposure is the worst marking to market for the trader across all minutes each day. Total Ex Ante Risk is the sum of minute-by-minute risk adjusted positions, where the risk-adjusted position is the absolute value of the position multiplied by the forecast absolute price change, using a rolling 60-min exponentially decaying (0.99) moving average to forecast. The afternoon mark to market is based on afternoon trading. The maximum position is the absolute value of the number of contracts long or short at each minute. Each variable is normalized for each trader using the trader's annual mean and standard deviation. The prob. values, the results of a t-test for differences in means and a Wilcoxon test are presented in the rightmost three columns. The Winsorized t-test excludes the 1% and 99% tails.

Consistent with positive mean incomes from Table 1, these traders are generally profitable in the morning, but with a substantial number of mornings in the red. There are 23,294 trader afternoons after positive mornings, and 11,249 trader afternoons after negative mornings.[10] One interpretation of this is that every third day or so, a typical trader loses money in the morning. While losing one-third of the time might seem like a high ratio for professional trading, this losing frequency is actually lower than the findings in Locke and Mann (2005), who, using trade-by-trade data, find that an almost equal percentage of trades are winners or losers. Aggregation of a slight trade-by-trade winning advantage across a morning of trading leads to 2:1 odds of being ahead by mid-day. The number and size of trades (and thus volume) are significantly higher on days when traders lose in the morning. For all these measures, afternoon means are positive for days with morning losses and negative for days with morning gains, and the differences are significant. Normalized afternoon mean income is positive for traders with morning losses, and negative for traders with morning gains, and all three test statistics are significant at less than 5%. Traders are both more active and more profitable following mornings when they lose money.

In Table 2 we also compare afternoon ex ante and ex post risk measures for morning winners versus morning losers. "Total Ex Ante Risk" is the cumulative sum of minute-by-minute products of trader absolute positions multiplied by forecast next-minute absolute price changes, and measures cumulative trader afternoon exposure to changes in price. "Maximum Position" is the maximum absolute value (i.e., long or short) afternoon position, in contracts, a static measure of ex ante risk, as it indicates maximum potential

[10]There are also 6,080 trader mornings with positive income with no afternoon trading on that day, and 2,692 trader mornings with negative income and no afternoon trading.

sensitivity to subsequent price movements, while ignoring trader strategies. Our ex post risk measure is "Exposure," which is measured as the maximum afternoon downside exposure, or absolute value of the minimum negative mark-to-market. This risk measure incorporates realized trader strategies, as it combines the effect of a trader taking a position with the effects of subsequent price movements and subsequent trader risk mitigation (such as reducing a position in light of adverse movements).

Table 2 provides evidence that afternoon risk-taking follows the pattern of increased trading activity. All of the normalized mean risk measures are positive for afternoons when traders lose money in the morning and negative when traders win in the morning. Morning losses lead to increased afternoon activity (trades and volume), risk-taking, and income. Based on these findings, traders with morning losses exhibit, on average, more effort in the afternoon and take on higher risk. They also earn relatively higher income on afternoons after they have lost money in the morning.

3.2. *Costly loss aversion versus daily income targets*

3.2.1. *Behavioral measures*

The results reported in Table 2 are consistent with both the costly loss aversion and daily income target hypotheses, since both predict that prior losses will lead to increased activity and exposure. In order to distinguish between the loss aversion and daily income targets hypotheses, we adopt the interpretation of Coval and Shumway (2005) that if these traders are loss averse, then there must be measurable costs associated with the observed behavior. The alternative, income target hypothesis, does not imply that morning losses lead to subsequent suboptimal behavior.

Coval and Shumway (2005) identify two costly consequences of loss aversion. First, from their results they infer that traders with morning losses earn lower risk-adjusted returns in the afternoon than traders with profitable mornings. While they offer no formal test of this proposition, we pursue it as a test of rationality. Second, they observe that traders with morning losses execute more price-setting trades than traders with morning gains, and further, that those price-setting trades have abnormally bad timing. This second effect has market-wide implications, as traders with morning losses exacerbate short run volatility. We adopt these two metrics, risk-adjusted returns and price-setting trades, to distinguish between costly loss aversion and daily income targets.

3.2.2. *Afternoon risk-adjusted performance*

Under the costly loss aversion hypothesis, traders with morning losses will trade more, and have weaker risk-adjusted performance in the afternoon, compared to days with morning gains. The alternative, daily income target hypothesis, suggests that while traders with morning losses will work harder in the afternoon, there is no reason to expect the quality of their work, in this case the return on investment, to decline. We calculate the risk-adjusted performance for each trader by forming the ratio of their mean afternoon income to the mean of their afternoon risk taking, as measured in dollars. We use two different measures of afternoon dollar risk taking, based on our ex ante and ex post measures. The ex post measure of dollar risk is maximum exposure, the absolute value of the trader's greatest potential mark-to-market loss in the afternoon. The ex ante measure of dollar risk is the measure based on Coval and Shumway (2005), which sums minute-by-minute products of absolute position and forecasted absolute log price changes. We describe both measures as "RAP" (Risk-Adjusted Performance), a form of return on economic capital, and name the ex post measure Realized RAP.

The ex ante and realized RAP measures are calculated separately for two subsamples, one including afternoons when the trader is ahead in the morning and the other including afternoons when the trader is behind in the morning. In other words, for each trader we have two sets of annual risk-adjusted performance measures, one set based on afternoon trading following winning mornings and one set based on afternoon trading following losing mornings, and our test statistics are based on the cross-sectional distribution of these two performance measures. We have 266 traders with afternoon trading following both positive and negative mornings during the sample period, and we use these traders for this analysis. We test for significant differences between afternoon RAPs on days when traders win in the morning versus days when traders lose in the morning using a t-test, a winsorized t-test, and the nonparametric Wilcoxon Z.

Panel A of Table 3 shows the comparison of risk-adjusted afternoon performance on trader days with morning losses to that of trader days with morning gains. The ex ante afternoon RAP measures provide no evidence that morning profitability affects afternoon risk-adjusted performance, with no test statistic p-value smaller than 0.40. On the other hand, the mean afternoon Realized RAP is surprisingly higher (0.88 versus 0.42) for traders with losing mornings, but the medians are much closer (0.35 versus 0.29), and the p-values associated with the three test statistics are mixed.

The results presented in Panel A of Table 3 offer no evidence that morning losses negatively affect risk-adjusted trading performance in the afternoon. These results fail to support the costly loss aversion hypothesis, but remain consistent with the daily income target hypothesis. These findings related to risk-adjusted performance conflict with the Coval and Shumway (2005) suggestion that morning losses are associated with lower afternoon risk-adjusted performance. While Coval and Shumway interpret their results (income is flat, risk goes up) as evidence that morning losers have lower afternoon risk-adjusted performance, they do not develop any measure of risk-adjusted performance, nor do they formally test the hypothesis.[11]

Our income and risk accounting methodology follows Coval and Shumway's (2005) morning and afternoon split in the respect that income is calculated separately for morning and afternoon, closing out positions at the end of the morning by marking them to the end-of-morning prices. On some days traders may end the morning with open positions, which may generate pre-existing afternoon exposure. As a robustness check, we replicate these tests using a different risk measure defined as the maximum of the end-of-morning risk and afternoon risk, and find no qualitative difference.

3.3.3. *Afternoon price-setting trades*

We next look at the quality of the prices at which traders execute their proprietary trades in the afternoon. Under the costly loss aversion hypothesis, morning losses have a harmful effect on afternoon trading, and losses should lead to increased "bad," or "price-setting" trades. Coval and Shumway (2005) find an increase in the number of poorly executed trades in the afternoon by traders with morning losses. We find this particular result hard to interpret as a cost without further investigation. The alternative daily target income

[11]Coval and Shumway (2005) draw the inference by alluding to the separate normalized income and risk measures, rather than examining risk-adjusted returns, per se.

Table 3
Panel A: afternoon risk and return; Panel B: afternoon timing and price-setting trades.

	$N = 266$						
	Ahead in the morning		Behind in the morning		Prob.values		
	Mean	Median	Mean	Median	t-test	Winsorized t	Wilcoxon
(A)							
Realized RAP	0.382	0.295	0.855	0.350	0.115	0.019	0.067
Ex Ante RAP	0.227	0.143	0.285	0.140	0.405	0.621	0.453
(B)							
	Ahead in the morning		Behind in the morning		Prob.values		
	Mean	Median	Mean	Median	t-test	Winsorized t	Wilcoxon
	$N = 23{,}294$		$N = 11{,}249$				
Number of price-setting trades	−0.0143	−0.2088	0.0665	−0.1210	<0.0001	<0.0001	<0.0001
Proportion of price-setting trades	0.0018	−0.0437	0.0020	−0.0164	0.9813	0.0381	0.1534
Timing of non-price setting trades (raw)	4.3822	2.5000	4.2969	2.2317	0.7919	0.0587	0.0160
Timing of price-setting trades (raw)	−1.7586	−0.3472	−1.5091	−0.3969	0.1606	0.3818	0.8929
Timing of non-price setting trades (normalized)	0.1706	0.1115	0.1709	0.0986	0.8615	0.9746	0.1812
Timing of price-setting trades (normalized)	−0.1738	−0.1202	−0.1654	−0.1149	0.2573	0.1162	0.3816

(A) For each trader we calculate afternoon income, and two afternoon risks per day, (1) the absolute value of the minimum mark to market, and (2) the sum of minute-by-minute risk adjusted positions. The risk adjusted position is the absolute value of the position multiplied by the forecast absolute price change, using a rolling 60-min exponentially decaying (0.99) moving average. For both of these we form the ratio of income to risk as risk-adjusted-performance ("RAP"), calculate the mean RAP per trader conditional on morning income, using data for the full year, and then examine the distribution of mean RAP across traders. There are 266 traders out of the 287 who have both winning and losing mornings with afternoon trading sufficient to calculate both risk measures. The table presents average and median RAPs across traders, conditional on the morning profitability (positive or negative) of the trader. We test the null hypothesis that RAP is not affected by morning income. The prob. values, the results of a t-test for differences in means and a Wilcoxon test are presented in the rightmost three columns. The Winsorized t-test excludes the 1% and 99% tails. (B) Price-setting trades are those for which the trader is buying at the maximum price or selling at the minimum price each minute. The proportion of price-setting trades is the number of price-setting trades as a proportion of the total trades. The timing of a trade is difference between the price of the trade less the price in ten minutes, with timing positive when the price is higher 10 min after a buy or lower 10 min after a sale. Normalized timing standardizes each trader's timing by the trader's annual mean and standard deviation. We test the null hypothesis that the variable is not affected by morning income. The prob. values, the results of a t-test for differences in means and a Wilcoxon test are presented in the rightmost three columns. The Winsorized t-test excludes the 1% and 99% tails.

hypothesis does not predict a decline in trading skill, and thus, while there may be increased trading, we do not expect an increased propensity for poor trade execution. The general course of trading entails some probability of poor execution, and if this propensity is relatively constant for each trade, we expect to find a higher number of bad trades if traders are simply executing more trades due to increased effort. Table 2 provides strong evidence of increased afternoon effort following losing mornings.[12] Therefore, we sharpen our focus to include the rate of poor trade execution. Under this formulation, the costly loss aversion hypothesis predicts that morning losses lead to both increased trading at bad prices, as well as an increased rate of poor trade execution. The alternative daily income target hypothesis only predicts an increased number of bad trades due to increased trading.

In the first two rows of Panel B of Table 3 we present statistics comparing both the number and the rate of bad trades made by traders in the afternoon following morning losses to those following morning gains. The variables are normalized for each trader by the annual mean and standard deviation. A bad trade is a buy at the highest prevailing price, or a sale at the lowest prevailing price. The table indicates that traders with morning losses execute a significantly higher number of price-setting trades in the afternoon relative to traders with profitable mornings. The mean is positive for traders behind in the morning, and negative for traders ahead in the morning, the median is greater (less negative) for traders behind in the morning, and all three p-values are less than 0.0001. There is strong evidence of an increase in the number of price-setting trades following losing mornings.

However, when we examine the percentage of poorly executed trades, we find mixed results. The mean and median rates of ‘‘bad’’ trades are only slightly higher for traders with losing mornings. The p-values vary, with an insignificant t-test, a significant winsorized t-test, and an insignificant Wilcoxon probability of 0.1134. The clear evidence of an increased number of price-setting trades does not carry over into the rate of price-setting trades. We cannot conclude that the percentage of price-setting trades increases in afternoons following morning losses for the typical trader. Therefore, while we confirm the finding in Coval and Shumway (2005) of increased numbers of ‘‘price-setting’’ trades by traders with morning losses, our failure to find an increased rate of such trades leads us to conclude that the occurrence of ‘‘price-setting’’ trades is simply a consequence of being active in the market, and that the observed increase in these trades is a natural consequence of trading more. Thus, while inconsistent with the costly loss aversion hypothesis, the rise in the amount (but not the rate) of ‘‘price-setting’’ trades is fully consistent with daily income targets.

We have not discussed the general (ir)rationality of traders executing trades at seemingly poor prices. All traders during this time period were on the floor of the exchange in view of all other traders. Thus, poor execution due to an irrational error, or trading error, seems a little odd to begin with. Price-setting trades may be executed in anticipation of price movements, rather than simply being poorly executed market making trades. Trades executed in anticipation of short-term price movements often sacrifice good execution (resulting a seemingly ‘‘bad price’’) in order to profit from subsequent price movement, as documented by Manaster and Mann (1999). We examine the short run profitability, or timing, of every afternoon trade, conditional on whether the trade was price setting or not, as well as whether the trader had a good or bad morning. For our timing measure, we compare the executed trade price to the average market-wide price 10 min later. If a trader buys at a high price, but the price continues to rise, then that is a positively timed trade. Similarly, if a trader sells at a low price, but the price continues to fall, then that is also a

[12]Indeed, there is evidence that some supposed market makers may benefit from market timing, which may require an occasional price-setting trade. Thus, while there may appear to be an occasional poorly executed trade, it is not necessarily an irrational or stressed trade.

positively timed trade. We examine raw timing (dollars per contract) and normalized timing, adjusting each trader's timing by the trader's mean and standard deviation of timing.

The results are presented in the bottom four rows of Panel B of Table 3. We examine price setting as well as non-price-setting trades, though we are most interested in the price-setting trades. We use a t-test, winsorized t-test, and the Wilcoxon Z to test for the affects of morning losses on timing ability or costs. Regardless of morning income, price-setting trades have inferior raw timing, with negative average 10-min timing. On average, traders do not exhibit an abnormally negative timing associated with poorly executed trades. Comparing the timing of raw and normalized price-setting trades for morning losers to morning winners, all test statistics are insignificant. Above we found that there was no significant increase in the rate of poor trade execution for traders with morning losses, though we qualified the results as mixed. However, we find that when one interprets the results on the percentage of poorly executed trades, these "price-setting" trades are not abnormally costly.

3.4. Trader heterogeneity regarding costly loss aversion

The above aggregate findings, or representative trader analysis, may obscure evidence of costly loss aversion at an individual level. To examine these individual effects, we first estimate a linear relationship between morning income and the propensity for poor afternoon execution at the individual trader level, and then examine the distribution of the coefficient representing costly susceptibility to loss aversion. The general form of the regression model employed is $y_{it} = D_{1t}\alpha_{1i} + (1 - D_{1t})\alpha_{2i} + D_{2t}\beta_{1i}x_{it} + (1 - D_{2t})\beta_{2i}x_{it} + e_{it}$, where the dependent variable y_{it} is one of three measures of afternoon performance: (1) the percentage of price-setting trades by trader i on afternoon t, (2) the number of price-setting trades by trader i on afternoon t, and (3) the ratio of income to the 95th percentile of trader i's worst position on afternoon t, or the risk-adjusted performance on that afternoon. This third measure differs from the ratio used in Panel A of Table 3, since there we use the ratio of a trader's mean income and risk, and examine the cross section of this ratio. Here we require a set of observations for each trader, hence a daily risk-adjusted income is calculated. These variables are normalized by the trader's annual mean and standard deviation. The independent variable x_{it} is the standardized morning income of trader i on day t, the ratio of that morning's income to the annual standard deviation, and the error is assumed to have the usual properties. The concern is that morning losses influence afternoon behavior, so we focus on those days when morning income is negative. If some traders are consistently prone to costly loss aversion (as Coval and Shumway, 2005 implement the term), then we should find that, on average, for these traders, the more they lose in the morning, the worse will be their afternoon performance. Based on this reasoning, the estimate of β_{2i} in the model will be significantly negative for traders with noticeable, costly loss aversion.

While morning losses may lead to costly trading behaviors under the costly lost aversion hypothesis, the hypothesis does not imply that gains induce superior subsequent performance, leading to potentially asymmetrical afternoon responses to gains and losses. We allow for this possible asymmetric response by estimating three variations of the model. In the first variation, the variables D_{1t} and D_{2t} are both equal to 1 when $y_{it} > 0$, or both equal to 0 otherwise. This is a two-intercept, two-slope model, where in addition to an affect of morning losses, traders are allowed independent responses to morning gains, β_{1i}, and there is also an independent intercept for days with morning gains, α_{1i}. In the second variation, D_{1t} is set to 0 always but D_{2t} is equal to 1 when $y_{it} > 0$. In this version the marginal response to losses is independent of the marginal response to gains, but the two states share a common intercept, α_{2i}. In the third variation, both D_{1t} and D_{2t} are set to 0 always, with the result that this model imposes a common slope and intercept for trader days with gains or losses. In this last, most restrictive variation, if the trader has increasingly costly afternoon trading (e.g., more and more price-setting trades) as morning losses grow, the trader also has increasingly superior afternoon trading (in terms of fewer and fewer price-setting trades) as morning gains accumulate. We have no prior affection for any of these models, and across specifications the results are relatively consistent.

The number of observations for each trader regression is the number of days in our sample on which they trade in the morning and afternoon, and have measures for the dependent variable in the afternoon. For the 287 traders, the mean number of observations is 164 such days, and the median is 188, with a maximum of 251 days and a minimum of 10 (our original selection minimum).

The results are summarized in Table 4, where we report distributional statistics for the estimates of β_{2i}, the point estimate of the marginal effect of additional losses on costly trader behavior. We report the results for the three model variations and three measures of

Table 4
Individual characteristics.

	Percentiles					Number significant	Percent significant (%)
	5th	25th	Median	75th	95th		
Model 1: Separate slope for positive and negative profits, and separate intercept							
Dependent variable							
Percent price-setting	−0.8837	−0.1364	0.0292	0.1823	0.1977	10	3.66
Number price-setting	−1.5629	−0.3147	−0.0679	0.1143	0.3507	36	13.19
Risk-adjusted return	−0.7522	−0.0764	0.0126	0.1102	0.2554	12	4.40
Model 2: Separate slope for positive and negative profits, common intercept							
Percent price-setting	−0.6491	−0.0996	0.0304	0.1823	0.6401	8	2.88
Number price-setting	−0.9900	−0.2828	−0.1110	0.1143	0.6766	41	14.75
Risk-adjusted return	−0.6718	−0.0668	0.0417	0.1102	0.4627	14	5.04
Model 3: No separation of gain and loss							
Percent price-setting	−0.2862	−0.0964	−0.0277	0.0471	0.0253	23	8.16
Number price-setting	−0.4164	−0.1475	−0.0176	0.0931	0.0423	34	12.06
Risk-adjusted return	−0.2231	−0.0549	−0.0042	0.0452	0.1877	6	2.13

For each trader day, when the trader is active in both the morning and afternoon, we calculate morning profits and afternoon performance measures of number of price-setting trades, percentage of price-setting trades, and risk-adjusted performance (afternoon income divided by afternoon risk). For each trader, we find the response of afternoon behavior to morning losses. Three regression models are used. The first allows for separate responses for losses and gains, and also separate intercepts. The second model allows for separate responses, but with a common intercept. The third model simply regresses the afternoon risk against morning profits. The table reports both the distribution of the parameter estimate and the distribution of the probability values associated with these parameters. The distributional statistics presented are the maximum, 95th percentile, 75th percentile, median, 25th percentile, 5th percentile, and the minimum. The rightmost two columns give the number of traders for whom the coefficient is significant, and the percentage of traders who were estimated for that specification.

costly afternoon behavior. We also report the number and percentage of traders with an estimated β_{2i}, which is significantly negative at the 5% level (two sided t-test). The number of traders with sufficient data for each specification varies slightly. Consistent with the results in Tables 2 and 3, the median responses are close to 0, and for only a few traders is the estimate of β_{2i} both negative and significantly different than zero. For the typical trader, there is no relationship between the extent of morning losses and the propensity for poor afternoon behavior. Between 34 and 41 traders (about 13% of the sample), depending on the model, significantly increase the number of price-setting trades in the afternoon in response to morning losses. Far fewer traders, between 8 and 23 (around 5% of the sample), respond to morning losses by executing a significantly higher percentage of price-setting trades. This difference between the number and percentage of price-setting trades is consistent with our prior findings. Finally, less than 5% of the traders (between 6 and 14, depending on the model) exhibit significantly reduced risk-adjusted performance in the afternoon after suffering increased morning losses. Evidence of costly loss aversion does appear for selected traders in our sample, but it is clearly not typical.

The results reported in Table 4 indicate some cross-sectional variation in our sample of the effect of morning income on afternoon behavior, and that a small fraction of traders appear to be significantly affected by their morning losses. If these are indeed indicators of harmful reference-dependent behavior (the regression coefficients), then they ought to be useful in explaining the future trading performance of these traders. We split the data into four quarterly subsamples and calculate sample correlations between quarterly estimated regression coefficients, β_{2i}, and subsequent risk-adjusted performance. We use each of the first three quarters of the year to obtain the β_{2i} s, and measure risk-adjusted performance for those same traders for each of the last three quarters. Finally, we calculate correlations for the six inter-temporal combinations (i.e., first quarter regression coefficient and second, third, and fourth quarter performance, second quarter regression coefficient and third and fourth quarter performance, and third quarter regression coefficient and fourth quarter performance).

We spare the reader a table full of insignificant correlations, though will gladly supply such upon request. Both Pearson and Spearman correlations between the regression coefficient and subsequent risk-adjusted performance are overwhelmingly insignificant for all quarterly combinations. A few correlations are significant, but some of these are in the wrong direction (poor behavior in one quarter associated with future success in subsequent quarters). We conclude that even the 5–10% of traders in our sample who are found to have poor afternoon behavior, on average, when losing money in the morning, are likely being identified only by chance.

The typical trader does not appear to be negatively affected by their morning losses. Nor does subsequent performance appear to be related to measured behavioral relationships between morning losses and afternoon behavioral metrics. Morning losses do seem to push the typical trader to increase his or her effort in the afternoon: this is evidenced by increased afternoon trading and risk-taking, perhaps attempting to achieve a desired daily income, which does increase following morning losses. However, the increased effort does not lead to a significant decline in trading performance. Further, those traders who do exhibit a significant relationship between morning income and afternoon performance are not less successful in the future. The finding of a significant relationship, prima facie evidence of irrationality, for a small percentage of traders, appears to be a chance occurrence.

4. Conclusions

In this paper we examine the impact of morning trading results on afternoon trading behavior by professional futures traders. We find increased afternoon trading and risk taking by traders with morning losses, supporting both the daily income target and loss aversion hypotheses. We find no evidence of costly loss aversion behavior, in terms of reduced trading performance or irrational prices subsequent to morning losses. Instead, we find that intertemporal trader activity is consistent with the existence of trader daily income targets, as traders do not exhibit harmful market or personal effects after incurring morning losses, despite the solid evidence of increased effort and activity associated with morning losses. Thus, the evidence is consistent with rational reference dependent preferences.

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