The Disposition Effect in the U.S. Equity Options Market

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Abstract

This paper explores the presence of the disposition effect in the U.S. equity options market using open interest to proxy for investor behavior. The disposition effect is the tendency of investors to sell winning positions when there is the potential for more gains and to hold losing positions while incurring additional losses. This analysis focuses on open interest changes for groups of equity options which are separated into quintiles by underlying asset price change. The data suggests that investors in the U.S. equity options market do exhibit tendencies of the disposition effect. Additional analysis examines the behaviors of retail and institutional investors and supports the expectation that retail investors exhibit the behaviors/traits of the disposition effect more frequently, or to a larger degree, than institutional investors.
1. Introduction

The purpose of this paper is to investigate the presence of the disposition effect in the U.S. equity options market. The disposition effect is defined as the tendency to hold on to losing holdings too long and to sell winning holdings too early, thereby missing the opportunity for gains while incurring additional losses (Barberis & Xiong, 2009; Shefrin & Statman, 1985; Szyszka & Zielonka, 2007). Documentation, which will be further explored in the next section, exists to suggest the presence of the disposition effect in the equities market. Some work has been done to support the idea that the disposition effect is present in option-like securities (Choe & Eom, 2009; Schmitz & Weber, 2012), while other researchers have indicated that trading behavior in certain situations in the options market (for example, behaviors in one trading day) tends towards the disposition effect (Coval & Shumway, 2005).

The goal of this study is to look at investor behavior over the time period January 1996 to August 2013 to evaluate whether the disposition effect is present in the U.S. equity options market. Additional topics of interest include the differentiation between retail and institutional investors in regards to the presence of the disposition effect in options trading behavior. This portion of the analysis will be done with data presented for the time period May 2005 to August 2013.

There are key differences between the equities and equity options markets that need to be considered throughout the course of this analysis. One of these differences is that equity options have a set expiration date while equities do not expire and can theoretically be owned indefinitely. This is important to consider because the behavior
of an investor might change when faced with an approaching expiration date, which could result in unique patterns of investor behavior in each market. This also makes the disposition effect slightly more difficult to measure in the equity options market since investors have a set time period in which this behavioral bias may be exhibited and investor behavior could be altered depending on time to expiration.

Another difference to consider is that when investing in equities investors are purchasing a share in the company, which is not the case with options. An investor purchasing a call option purchases the right to buy an underlying asset (ie. stocks or commodities) before the date of expiration at the price stipulated in the options contract regardless of the current market price for the underlying asset. Therefore, it is favorable for the price of the underlying asset to increase prior to the date of expiration because the investor can exercise the call option to purchase an asset at below market value and then sell it at market value to make a profit. Put options are contracts conveying the right for an investor to sell an asset before the date of expiration. This means that it is favorable for the underlying asset price to decrease before the date of expiration because an investor can purchase an underlying asset for below the initial price of the option, then sell it at the predetermined price for a profit. Throughout this analysis, price change relates to the underlying asset, not the option contract value, and open interest change relates to the number of open option positions.

Additionally, it is rare for equities to lose all market value except in the case of company bankruptcy or other extreme situations. Options, however, will often expire without market value. As time to expiration for out of the money options becomes
short, options will have reduced value and low liquidity which minimizes investor incentive to close the position. This characteristic of options is important to remember throughout the paper because it will color some of the results – the changes in open interest may not be fully explained by the disposition effect because of the consideration that investors simply hold onto options with no market value because of a lack of market interest.

Beginning with an overview of what behavioral finance and the disposition effect are will provide some context to the analysis completed in this paper. An overview of the research question, data, and approach will follow this section, progressing to results and discussion. Analysis of open interest changes as a proxy for investor behavior will demonstrate that the disposition effect does seem to be present in the U.S. equity options market. Additional insights throughout this paper include the differences in behavior which suggest that retail investors are more likely to exhibit the behaviors of the disposition effect than institutional investors, as is expected given the perception of investor sophistication for each class of investor.
2. Literature review

2.1 Introduction to traditional and behavioral finance

There are two primary schools of thought regarding investor behavior: traditional finance and behavioral finance. Traditional finance operates under the assumption that investors are rational beings, referred to as Homo Economicus, and make decisions without emotion or bias (Bloomfield, 2010; Mullainathan & Thaler, 2000). As rational beings, investors are expected to update their beliefs when new information is received, and make choices that are considered rational (Barberis & Thaler, 2003). On the other hand, behavioral finance incorporates the typical irrational, biased, and emotional human behavior that impacts the decisions of investors. Barberis and Thaler (2003) define behavioral finance theory as encompassing investors who either do not update their beliefs to accommodate new information, or whose choices are unacceptable in terms of Subjected Utility Theory.

In 1998, Fama argued that behavioral finance theory should not be accepted because there is no single test to prove that biases do significantly impact investors, unlike in traditional financial theory which allows for predictions based on utility theory. In order for Fama and other traditionalists to accept the theory of behavioral finance, all aspects of it must be able to be proven wrong – and to do so requires a theory that is simple, unified, and refutable (Bloomfield, 2010; Fama, 1998). Behavioralists argue that while there is not yet a unified testing method, it is clear through some of the decisions made that investors are not acting in a rational frame of mind and therefore do not fit the Homo Economicus model (Bloomfield, 2010). Barberis and Thaler
(2003) argue that neither traditional nor behavioral finance fully encompass the complexities of an investor’s choice, but that a substantially better theory can be generated from the combination of the two schools of thought.

2.2 Behavioral finance

Theories of behavioral finance help to explain why investors trade, how portfolios are chosen, how portfolios are impacted by the decisions, and why returns vary between equities for reasons other than risk (Subrahmanyam, 2007). As mentioned above, behavioral finance is a multi-faceted field of study. There is likely no way to completely merge all biases and behaviors together into one simple and testable theory. However, retail components of behavioral finance have been thoroughly studied. Examples of these components include prospect theory, the representativeness heuristic, an availability bias, and others (Howard & Yazdipour, 2010; Chen, et al, 2007). Heuristics are essentially “rules of thumb” which allow an individual to process and judge a situation quickly, but will result in biases and errors in judgment, while availability bias refers to the saliency of information – recent information is more salient and therefore more likely to impact an investment decision (Ritter, 2003; Howard & Yazdipour, 2010).

Examples of heuristics which are prevalent throughout literature include overconfidence, regret aversion, familiarity, and anchoring (Baker & Nofsinger, 2010; Ritter, 2003). Emotions and the framing of decisions are not heuristics, but do play an important role in investment decisions (Baker & Nofsinger, 2010; Ritter, 2003).

Overconfidence is composed of two main parts: the mis-calibration (ie estimating a
discoverable fact, or estimating quantities that are not yet known), and the better-than-average effect (which causes people to consider themselves better than they are, both in terms of skills and analysis) (Glaser & Weber, 2010). This overconfidence can prompt investors to believe that they must be right about a holding, refusing to sell it when it is down on the grounds that it will soon see a significant increase. Regret aversion is a fairly straightforward concept; investors feel regret for a previous decision and may seek to preemptively reduce that regret by taking fewer risks in the future (Dowling & Lucey, 2010). This can lead to asset allocation focused on less-risky assets, a lack of diversification, or selling stocks before the position becomes a loss in the portfolio. Anchoring is the adjustment of a perception around a fixed starting point, which may or may not be appropriate for the situation (Schwartz, 2010). For investors this starting point is typically the purchase price and the performance of a stock relative to that price often impacts investment decisions. Familiarity bias is the tendency to forego the potential for more upside from stocks in “unknown territory” for the comfort and peace of mind associated in investing in assets which are familiar, though potentially more risky (Foad, 2010). This can lead to a lack of portfolio diversification and curb portfolio returns, while also potentially increasing the risk of the portfolio (Foad, 2010). Emotions and framing also play a role in investment decisions – with emotions from outside events or biases regarding companies (ie idealizing one company and ignoring its faults) influencing investment actions, and the framing of decisions resulting in a situation appearing more favorable or negative than it is in reality (Schwartz, 2010; Taffler & Tuckett, 2010). These are only a
handful of the behavioral biases and heuristics which can impact the investor in the course of making an investment decision, which is a large part of the reason why no “one theory” has been derived – there are simply too many variables to include.

An additional area of consideration is the impact of investor sophistication and trading experience on behavioral biases. Do more seasoned investors manage to avoid the traps of behavioral biases or are they set in their ways and exacerbating the problem? Feng and Seasholes (2005) investigated this and found that investors with trading sophistication or trading experience were not able to avoid behavioral biases (specifically the disposition effect), though the presence of both factors did significantly limit the effects of those biases. This study was completed through the analysis of equity securities, and the results are likely to carry over into the options market. There, too, investors may be more susceptible to making irrational decisions based on emotions or biases without trading sophistication and experience.

These are only a few of the components which comprise behavioral financial theory. It is easy to see that Fama was correct in saying that there is no unified, central theory which can easily test for all aspects of the behavioral biases that may be affecting investors, thus making it difficult to fully accept the theory – there are simply too many variables in human behavior (Bloomfield, 2010; Fama, 1998). However, there is a compelling case for each of these behavioral biases – all of the studies cited have numerous sources which provide significant results regarding the impact of biases and heuristics on traders. Therefore, though there is no unified theory, behavioral finance makes sense for judging the investment decisions of individuals and is an area in
which more study can be completed. Additionally, a large portion of the research completed is in the equities market, so the exploration of behavioral finance in other markets could be beneficial in increasing the understanding of investor irrationality.

2.3 Behavioral finance and prospect theory

A major breakthrough in the field of behavioral finance occurred with the derivation of the prospect theory formula (Kahneman & Tversky, 1974). Prospect theory incorporates several irrational behaviors to evaluate the most likely real-world result of a situation, as opposed to the previously employed expected utility theory, which does not take psychological effects under consideration (Bloomfield, 2010). Studies performed regarding prospect theory (e.g.; Barberis & Xiong, 2009; Ben-David & Hirshleifer, 2012; Li & Yang, 2013) indicate that people are more willing to accept an assured cash gain of minimal value as opposed to a second, riskier option of accepting no gains or higher gains based upon the results of a coin flip.

Derived by Kahneman and Tversky in 1974, prospect theory “theorizes how an individual or group of individuals behaves, on average, in a world of uncertainty” and the retail evaluations of payoff prospects in risky behaviors (Altman, 2010). This theorization takes into account a variety of heuristics, cognitive illusions, and biases, which come together to complete the picture of the general behavior of the irrational investor. Beyond that, prospect theory also takes into consideration the manner in which alternatives are “framed” to be more or less appealing in absence of deeper thought (Howard & Yazdipour, 2010). This can be applied to the topic of discussion
later in the paper regarding an investor’s choice to take a profit or take a loss on an investment.

Prospect theory assumes, unlike standard economic utility theory, that decisions are reference-dependent and that investors will frame their decisions based upon unrelated or insignificantly-correlated facts (Altman, 2010). Among the concepts included within prospect theory are loss-aversion, the disposition effect, and biases such as the overconfidence bias. The prospect theory model has also been shown to demonstrate a diminishing sensitivity as shown by the tendency of investors to be “risk-averse for gains and risk-seeking for losses” (Li & Yang, 2013).

2.4 The disposition effect

In 1985, Shefrin and Statman coined the phrase, “the disposition effect.” Their paper describes the disposition effect as “the tendency to sell winners too early and ride losers too long” and other papers have provided evidence of the disposition effect in investor behavior (Barberis & Xiong, 2009; Shefrin & Statman, 1985; Szyszka & Zielonka, 2007). The disposition effect essentially states that investors are reluctant to realize losses in their portfolio and therefore hold onto stocks that are losing value beyond the point at which a rational investor would sell. The opposite holds true for winning stocks: investors who are impacted by the disposition effect will liquidate positions that have accumulated value because they are risk-averse in the event of positive gains (Henderson 2012, Hens & Vlcek 2011). This suggests that people are more willing to accept an assured cash gain of minimal value, eliminating the risk of liquidating the holding and realizing negative returns in the future. Berry and Fogel
(2006) indicate that this is related to a tendency of investors to avoid the realization of a loss for emotional reasons. A review of previous literature also indicates that investors who are impacted by the disposition effect end up paying more in capital gains taxes than they would had they invested in a more rational manner (Kaustia, 2010). A market wide impact of the disposition effect is that it can impact trade volume and superficially inflate or deflate market price of an asset, making it difficult to accurately and effectively advise clients or invest wisely (Kaustia, 2010).

As mentioned in the discussion about prospect theory, investors have a tendency to make decisions based upon a pre-determined reference. Shefrin and Statman (1985) posit that an investor is unlikely to change a reference point due to the idea of mental accounting. This causes the investor to ignore possible interaction between holdings and make a choice based purely upon a holdings’ relational position to the reference point, which is often the purchase price of the asset (Shefrin & Statman, 1985). Shefrin and Statman also cite ideas put forth by Gross, which suggest that investors hold onto losing stocks in order to avoid a tangible effect of them being wrong – because they still believe that they were right in choosing the holding (Shefrin & Statman, 1985). The above-stated investor tendencies contribute to the disposition effect, and influence investors to sell profitable stocks at disadvantageous times (either for lost potential profit or tax expenses) while holding on to losing stocks longer than they should, if aiming for a highly profitable portfolio. Prospect Theory also plays a role in the disposition effect – the diminishing sensitivity feature of the function makes
investors risk-averse and likely to sell a holding after a gain, and risk-seeking in the event of a loss, prompting investors to hold the asset (Li & Yang, 2013).

The disposition effect has a tangible impact on the profitability of investment portfolios. When foregoing potential additional gains through the sale of “winning” stocks, there is an opportunity cost that many investors do not necessarily consider when making the trade, as they have become risk averse in the area of gains (Coval & Shumway, 2005). Additionally, investors become risk-seeking in the area of losses, assuming that any additional losses are less significant than any potential recovery the stock might make which encourages the investor to keep the holding until at least the breakeven point (Henderson, 2012; Kyle, Ou-Yang & Xiong, 2006; Xing, Zhang & Zhao, 2008). There is a tangible cost to holding onto a losing position longer than the rational investor would, as the portfolio loses paper value and the funds currently invested in the losing stock could be invested elsewhere to find gains.

Since Shefrin and Statman’s 1985 study, a substantial amount of research has been done on the disposition effect to test if it really does impact investors. Perhaps the most notable of these studies was done in 1998 by Terrence Odean, and involved the analysis of tens of thousands of accounts of investors who trade in the equities markets. Odean’s study showed that the disposition effect is highly prevalent, and results in losses for the investor (Odean, 1998). Oddly enough, this effect is reversed in December due to tax implications, as highlighted in several studies (Odean, 1998; Schmitz & Weber, 2012).
2.5 Evidence and rebuttals of prospect theory-driven disposition effect

Kyle, Ou-Yang, and Xiong (2006) looked at prospect theory, the disposition effect, and Sharpe ratios to determine that an agent is likely to hold a position that is losing money, with the intent to liquidate at the breakeven point – indicating that agents are risk averse near the reference point. This follows the previous research done on prospect theory, risk aversion, and the disposition effect, as mentioned above. When completing similar research, Henderson found that in the case that the Sharpe ratio is sufficiently low, an investor will liquidate a position and incur those losses (Henderson, 2012). However, as stated by Fama, these theories still cannot be put together into one cohesive, testable theory or formula.

2.6 The options market

Multiple papers have demonstrated that options markets lead the stock market (Anthony, 1988; Easley, O’Hara & Srinivas 1998). However, there is a lack of information regarding the disposition effect in the options market. This is in contrast to the equities market, for which there is significant research. The high risk associated with the options market means that investors have opportunities for large returns and significant losses. It is therefore important to understand how behavioral biases and heuristics affect the retail investor in this market. Do these concepts work as predictors in the options market? Do they function in the same manner as in equities? Is investor profitability negatively impacted in the short term as a result of these biases? These are important questions that have yet to be fully explored in the options market.
Studies on option-like securities show that the disposition effect is present for the retail investor during trade (Choe & Eom, 2009; Schmitz & Weber, 2012). Schmitz and Weber (2012) study bank-issued warrants traded in the German markets, while Choe and Eom (2009) focus on stock index futures in Korea. With the similarities in call-put strategies, timing, and derivative natures, it stands to reason that options may react in the same way. However, this research is limited to non-options securities, and is from foreign markets.

Choe and Eom (2009) also find that the disposition effect is more present in the behaviors of investors in long-term futures than in short-term futures, and Stein (1989) finds that “longer term options overreact relative to shorter term ones.” In studying the disposition effect in the options market, it is important to consider that open interest tends to increase as time to expiration shortens due to this investor preference. These changes in investor behavior could be confused with tendencies of the disposition effect, which will also be measured by open interest change, and it is important to try and separate the causes of the behavior. As such, investor behavior immediately prior to the date of expiration will not be considered as relating to the disposition effect.

This paper will consider equity options and U.S. traders to measure the impact of the disposition effect as it could provide information on investment strategies to investors in that market.
2.7 Proposal – Studying the disposition effect in the options market

The purpose of this study is to look into the disposition effect and its impact on short term investor profitability in the options market. When looking at the equities market, it can be determined that the disposition effect is present and negatively impacts investor profitability (Odean, 1998). As stated above, it has been concluded that the options market leads the equities market. Therefore, utilizing methods similar to those used in Odean’s 1998 study on the disposition effect in the stock market and Choe and Eom’s 2009 study on the disposition effect in the futures market should provide a comprehensive view on the impact of the disposition effect in the options market. By combining these two methodologies, a compelling analysis of the presence of the disposition effect in the options market can be completed. A potential addition to this study would be an analysis on the impact of investor sophistication and trading experience on reducing the disposition effect in the options market and what that means for investor profits. As mentioned above, investors with less experience and trading sophistication are more likely to be impacted by the disposition effect (Feng & Seasholes, 2005). The motivations behind options investments have also been explored, and it has been observed that investors in the options market tend to be investing for the purpose of gambling as opposed to hedging equities positions (Bauer et al, 2009; Meyer et al, 2014).

The study addresses a gap in the knowledge base regarding the disposition effect, specifically how it relates to the options market, implying a conceptual significance associated with the study. This paper seeks to alleviate that lack of research by
determining if traders in the options market are impacted by the disposition effect.

Determining a more effective trading strategy through the minimization of the disposition effect may have the consequence of increasing retail investor profitability and thereby increasing their participation in the market.
3. Research Questions, Data, and Approach to Analysis

The primary question that will be explored throughout this paper is whether investors in the U.S equity options market demonstrate the disposition effect. Secondary to that question, this paper explores differentiation between behaviors of retail investors and institutional investors. It is hypothesized that investors in the U.S. equity options market will demonstrate behaviors in line with the disposition effect, and that retail investors are more likely to do so, or will do so to a more significant degree, than institutional investors.

Information for individual equity options, obtained from OptionMetrics, is utilized to perform the analysis for the initial question of whether or not investors are exhibiting behaviors that suggest the presence of the disposition effect. This data is combined with data from the Center for Research in Security Prices (CRSP) to determine the moneyness of individual options in addition to providing return data for underlying assets. Combining the data sets allows for the separation of options into quintiles by underlying asset price gain/loss percentage to track open interest changes for each quintile, providing insights as to whether investors are closing winning positions (as evidenced by a decreasing upward slope, a plateau, or a negative slope) or holding onto positions after losses. Open interest measures the number of open positions for the option and in the case where open interest is increasing, it can be supposed that investors are opening positions and/or neglecting to close positions which have been opened, with the reverse being true as well. With this supposition, it can be inferred that groups of options which see increasing open interest when losing money are held
by investors that are reluctant to realize losses by not exiting positions and that new positions being opened may be the result of gambling or risk-seeking behavior. These fluctuations in open interest change can have other contributing factors which influence investor behavior in conjunction with the disposition effect and which will be further explored in the results and discussion section.

Information from another data source, the International Securities Exchange Open/Close Trade Profile dataset, has been added to provide additional insights as to whether retail investors are more prone to the disposition effect than institutional investors. This would be demonstrated by differences of behavior when looking at open interest changes for options in each category of moneyness for different types of investors. Differences in open interest changes could indicate that retail investors tend to keep losing positions open more frequently than an institutional investor, or close winning positions more frequently than the institutional investor. This is a reasonable assumption to make because the institutional investor would likely be more regimented in trading policy, and safeguards put into place by institutions to prevent high losses could force these traders to close losing positions earlier than a retail investor might. Adding this dimension to the paper allows for the demonstration that in the U.S. equity options market, retail investors are more highly impacted by the disposition effect than institutional investors, a theory that has been explored in the equities market.

As mentioned above, the data is divided into quintiles or terciles by price change of the underlying asset to more easily delineate the “winning” options as compared to the
“losing” options with open interest changes tracked through to the date of expiration.

In the case of call options, an increase in the underlying asset price is beneficial since investors in calls are purchasing the right to buy an asset at a set price. If the underlying asset price increases, the option can be purchased below market value and be sold at market value to ensure a profitable transaction. The opposite is true for put options as investors are purchasing the right to sell the asset at a set price and would prefer to sell the underlying asset for a higher price than the current market value. Therefore, a winning option for calls would be in High Quintile which demonstrates the largest increase in underlying asset value, while the opposite is true for put options.

Graphs included in this paper will show options with 180 days to expiration, tracking open interest changes as the dates to expiration approach. This time range allows for a more detailed look at how open interest changes over time and also allows investors more time to close or maintain positions.

Analysis of the institutional and retail investor results incorporate the ratio of institutional investors to retail investors, which are separated into terciles labelled Low, Mid, and High. Institutional and retail investors are identified within the International Securities Exchange Open/Close Trade Profile dataset. Institutional investors are defined as investors that initiate trades with more than 200 contracts, with individuals trading less than that amount. In the case where this ratio is in the Low Tercile, there are relatively more retail investors, while the High Tercile has relatively more institutional investors.
4. **Results and Discussion**

Several methods of exploring the data have been utilized, all of which are described below. Except in cases where retail vs. institutional considerations are raised, the data is collected from January 1996 to August 2013. The cases which explore the differences between retail and institutional investors consist of samples from the years between May 2005 and August 2013.

![Graph](image)

**Figure 1: Open interest changes for all call options**

$\text{OI}_p/\text{OI}_{180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. ATM calls are defined as calls within 5 percent of current underlying asset price, ITM calls are between 5 and 10 percent in the money, and OTM calls are between 5 and 10 percent out of the money.
Open interest increases for all call moneyness types until it drops significantly at approximately 10 days to expiration for each. ITM open interest increases at the slowest rate while OTM increases at the fastest rate. This increase in open interest suggests that investors are opening options contracts at a faster rate than investors are closing the contracts. This could indicate a tendency to hold onto losing options, especially since the open interest for OTM call options increases faster than ITM or ATM. An OTM call option which experiences a decrease in underlying asset price has lost more value than an ITM or ATM call option might in that scenario because ATM/ITM options may not become OTM as a result of that decrease, but OTM calls will be driven further out of the money. The lower rate of change in ITM open interest suggests that investors are closing out of “winning” options contracts, depicting a potential tendency to the disposition effect. However, the presence of the disposition effect based upon this figure can only be speculated. Until price change variables are included, the presence of the disposition effect cannot be determined. It is worthwhile, however, to consider the disposition effect here given that the three call option moneyness groups can be compared to one another. This shows the difference in general behavior for investors in each call moneyness classification in terms of open interest changes over time.

Another explanation for the increase in open interest for all three types of option moneyness is that investors prefer shorter term options to longer term options and therefore open positions later in the options’ lifetime than when there are 180 days to expiration. Additionally, OTM options tend to have more associated risk since any
decrease in underlying asset prices makes the options even further OTM and reduces
value to a further degree than an ITM or ATM call option which experiences a
decrease in underlying asset price. As mentioned earlier in this report, investors
sometimes get involved in the options market as a means of gambling. Given the
higher level of risk associated with OTM calls as opposed to ATM or ITM, an
increase in open interest which suggests higher levels of investor involvement could
be indicative of this gambling behavior. As the least risky option type, ITM options
see the smallest increase in open interest over the time period, which suggests that
investors are avoiding the option type which does not provide as significant of a
gambling opportunity as either OTM or ATM call options.

The expectation when separating options by moneyness types and then into price
change quintiles would be to see positive open interest changes for each quintile in
each option moneyness with a drop in open interest as the option nears expiration.
This is partially explained by the fact that investors would prefer shorter term options
or are investing in the option as it gets closer to expiration, thereby increasing open
interest. The drop in open interest as expiration approaches can be explained by
investors closing positions in order to avoid fulfilling the contract.

ATM calls are not considered highly risky options. While more risky than ITM
options, ATM call options are less risky than OTM options. As such, less gambling
activity might be expected in ATM options than OTM options. Therefore, investors
will likely behave differently when comparing the different types of moneyness. These
behaviors will cause interesting shifts in the ordering of the price change quintiles
when looking from the lowest increase in open interest to the greatest, and will be explored in the following figures.

**Figure 2: Open interest changes for call at-the-money (ATM) options by price change quintile**

ATM calls are defined as calls with the strike price within 5 percent of current underlying asset price. $O_{i}/O_{i180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignment. For calls, High Quintile presents the most favorable results for investors.

As previously mentioned, the price change quintiles are determined by changes in the underlying asset price, so an option in the High Quintile sees the most positive (or least negative) return when compared to other quintiles. As shown in Figure 2, the High Quintile demonstrates the slowest increase in open interest of any of the price
change quintiles. Investors could be avoiding an entrance into positions with options in this group due to the perception that there is little additional value to be gained from the investment. This would account for a stagnation in growth of open interest. However, this would not account for the decrease in open interest beginning at approximately 75 days to expiration. This notable decrease in open interest would be explained by the closing of positions. Since these positions are considered “winning” options, investors are likely closing out of these positions to take profits, which suggests the presence of the disposition effect in investor behavior. Quintile 4 follows a similar trajectory to High Quintile, but with higher levels of open interest. This suggests similar behavior to investors with options in the High Quintile, but also suggests that investors may open more positions as the date of expiration approaches than in High Quintile. Investors likely see more opportunities for continued value gain in Quintile 4 options when compared to High Quintile, but still exhibit behaviors typical of the disposition effect.

The lowest-earning 20 percent (Low Quintile) of call ATM options are in the middle of the five price change groups in terms of open interest changes over time. This could indicate that investors are still willing to enter positions in these options, to a point, which could indicate some gambling tendency as these are options that will likely be OTM given the average losses incurred. However, the stagnation of open interest change prior to a sharp drop off at the end of the time period suggests that while investors are hesitant to close positions, there may also be a “point of no return” at which investors exit losing positions. This could also suggest that investors merely
hold onto the positions because there is little to no market value in the market, and merely close the position at or near expiration to avoid fulfilling the obligation.

Quintiles 2 and 3, which have the second and third lowest returns, respectively, demonstrate the largest increase in open interest over time. Quintile 2 has a negative average price change, while Quintile 3 has a slightly positive average price change, but both remain slightly OTM (as seen in Table 1). The opening of positions in these options could indicate some risk-taking behavior by investors and would account for the large increases in open interest. Given that Quintile 2 saw a negative price change, these investors are also holding onto losing positions until immediately before the date of expiration which could indicate tendencies of the disposition effect.
Figure 3: Open interest changes for call out-of-the-money (OTM) options by price change quintile

OTM calls are defined as calls between 5 and 10 percent out-of-the-money. OI$_p$/OI$_{180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignment. For calls, High Quintile presents the most favorable results for investors.

As mentioned in the analysis of Figure 2, investors will behave differently when investing in options of different moneyness. OTM call options would be considered more risky than ATM calls because the investor is opening a position with the need for underlying asset price to increase significantly in order for the option to be ITM, while ATM options do not need as large of an increase in underlying asset price in order to
become ITM. As a result, more gambling behavior could be expected from investors in OTM options when compared to ATM options.

For OTM calls, Low Quintile sees the smallest increase in open interest change, followed by High Quintile, Quintile 2, and Quintile 3. Quintile 4 has the largest increase in open interest over the time period.

This change in order of the quintiles in terms of open interest change between OTM and ATM calls results from additional losses incurred on OTM options as compared to ATM options. While an ATM option that loses underlying asset value may become OTM, an OTM option that loses underlying asset value becomes significantly OTM. At this point, investors may keep positions open and neglect to exercise the options prior to the date of expiration because the options no longer have any value. Having essentially reached the point of no return at which no new investors will open positions and committed investors see no reason to execute the position given how little value remains for the option, there is little transaction activity.

High Quintile is the most similar to Low Quintile in terms of open interest change, with a decrease starting around 30 days to expiration instead of the relative plateau demonstrated by Low Quintile. This behavior indicates that investors are closing out of positions, or exercising options, as opposed to holding onto the position to generate more profit. This is one aspect of the disposition effect: the sale of winning positions as opposed to the holding of winning positions to gain more profit. Given the expiration component present for options, it would make sense that there be a drop in
open interest prior to expiration as investors exercise the options. However, the early decrease in open interest with at least thirty days left before expiration suggests that investors are closing out of these positions early and missing out on potential gains that could be seen over the course of the remaining days to expiration.

Quintiles 2, 3, and 4 all see open interest increase over the course of the 180 days, with the quintiles showing open interest increases in numerical order. Quintile 2 is the price change quintile with the most similar open interest changes to High and Low Quintiles. This quintile has the second lowest underlying asset value change and does have a negative median price change, as seen in Table 1. While investors open positions in options within this price change quintile at a higher rate than both High and Low Quintiles, the disparity between the open interest changes of this quintile and Quintiles 3 and 4 demonstrate that investors consider this a more risky investment.

The dips in open interest change in the last thirty days before expiration could be explained by investors closing out of these positions to minimize losses (perhaps having reached the point at which investors are willing to accept loss), and retain some market value for these options. Sharp increases in open interest could indicate gambling activity in the last few days of the option’s time to expiration.

Quintiles 3 and 4 see a larger increase in open interest than the other quintiles, which suggests that investors are opening these positions throughout the life of the option. There are some dips in open interest change which could relate to investors closing out of winning positions (price change for both quintiles is slightly positive), with
investors then opening positions in the last few days as a means of gambling on additional returns.

**Figure 4: Open interest changes for call in-the-money (ITM) options by price change quintile**

ITM calls are defined as calls between 5 and 10 percent in-the-money. $\text{OI}_{p}/\text{OI}_{180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignation. For calls, High Quintile presents the most favorable results for investors.

As mentioned previously, ITM is the least risky moneyness type since the call option strike prices are already above the underlying asset price and therefore have value for the investor at time of purchase. Therefore, investor behavior in these options can be expected to differ from that displayed in the cases of ATM and OTM calls.
The lowest two quintiles of price change (which indicate a loss or comparatively insignificant gain compared to the market) see the largest increase in open interest as compared to any other quintile despite having the lowest underlying asset value change. However, given the decrease in underlying asset value, these options have lost value relative to the starting point which suggests that investors in these options are neglecting to close losing positions or are instead investing in options that are slightly ITM in the hopes that the value will increase again prior to the date of expiration. If investors are not closing these losing positions, then this could suggest the presence of the disposition effect. Additionally, there is a significant separation in open interest change with approximately 30 days to expiration, where Quintile 2 sees a surge in open interest. This could suggest that investors are gambling on these positions in the hopes that the positions might regain some of the previous value.

High Quintile and Quintile 4 both see the lowest rate of increase in open interest change, with decreases in open interest starting as early as 50 days to expiration and decreasing open interest to below 100 percent of initial open interest levels by the date of expiration. This suggests that investors are not opening positions because there is little additional value to be gained that would incite a gambler to invest in the option. The option is now so far ITM that the purchase price is more expensive, leading to proportionally smaller gains than a less expensive ITM option. Additionally, the decreases suggest that investors are closing winning positions a significant amount of time before the date to expiration which suggests that investors are exhibiting behaviors of the disposition effect.
Quintile 3 demonstrates increases in open interest at a greater rate than High Quintile and Quintile 4, but a slower rate than Low Quintile and Quintile 2. This is to be expected given that the quintile has comparatively average performance with slightly positive changes in underlying asset price, as seen in Table 1. At around 20 days to expiration, open interest begins to decline. Because this is so far from the date of expiration, it can be supposed that these investors are closing out of winning positions early and missing out on potential profits, thus exhibiting the disposition effect.

<table>
<thead>
<tr>
<th>Price Change &amp; Moneyness: Calls</th>
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<tbody>
<tr>
<td></td>
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<tr>
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<td>High Quintile</td>
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<tr>
<td>Price Change Moneyness</td>
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<td></td>
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</table>

Table 1: Price and moneyness changes for call options

This table quantifies the median price change and moneyness of each quintile for each call option moneyness. ATM calls are defined as calls within 5 percent of the strike price, ITM calls are between 5 and 10 percent in the money, and OTM calls are between 5 and 10 percent out of the money. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignment. For calls, High Quintile presents the most favorable results for investors.
Looking at ATM call options, Figure 2 shows that the Low Quintile is in the middle of the five groups in terms of open interest changes, while Quintiles 2 and 3 show increases in open interest. Given that there is a tendency to close options if investors feel that the option is losing too much money, or to avoid investing in options that are significantly OTM, this is not completely unexpected. Additionally, there is the consideration that investors are not opening positions in the options within this quintile because the positions are no longer seen as viable investments or are considered riskier due to underlying asset price decreases driving the options closer to OTM. Because there is a negative price change for Quintile 2 and a slightly positive price change for Quintile 3, it is reasonable to see the open interest numbers increase significantly for these options if the disposition effect is present as there are investors opening positions with these options, as well as holding onto the positions even after suffering a loss. Both Quintile 4 and High Quintile see positive changes in price, and have decreasing open interest. This suggests that investors are closing out of positions with these options while there is not significant purchasing activity.

For OTM calls, the Low Quintile sees the most marked decline in open interest, which can be explained by the fact that the negative price change for these options is moving these positions so far out of the money that many investors would consider the options a complete loss and close the position, in addition to investors not opening positions with these options. High Quintile has a slightly larger increase in open interest than Low Quintile but it drops off more in the last 12 days to expiration. This could be
explained by investors closing positions that have gained money, with the median for the quintile’s price change being positive and nearly three times that of Quintile 4.

The quintiles for ITM calls that have the most noticeable increases in open interest are Low Quintile and Quintile 2, which have the most negative price change as seen in Table 1. This can be explained by investors keeping positions open while incurring additional losses or opening positions that are losing money. High Quintile and Quintile 4, which Table 1 shows with positive price changes, have the slowest increases in open interest and decline at around 75 days to expiration. This suggests that investors are closing out of winning positions long before the date of expiration, again demonstrating a tendency towards the disposition effect.

Specifically looking at call options, the analysis of open interest change over time while taking into consideration underlying asset change suggests that the disposition effect is present in investor behavior. However, there is speculation that investors in put options are generally more sophisticated investors, which could diminish the presence of indicators of the disposition effect. The next portion of this paper will look into an analysis of the same types of data as the previous, but in regards to put options to determine if investors in put options exhibit the same tendency towards the disposition effect.
Figure 5: Open interest changes for all put options

$\frac{OIp}{OI_{180}}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. ATM puts are defined as puts within 5 percent of current underlying asset price, ITM puts are between 5 and 10 percent in the money, and OTM puts are between 5 and 10 percent out of the money.

The increase in open interest is less pronounced for put options as compared to call options, which can potentially be linked to the tendency of options investors to gamble with call options, while using put options as a mode of hedging. This could indicate that the put option positions are being opened by a more experienced investor that would tend to be less susceptible to the disposition effect. ITM put options have the slowest growth in open interest, which also drops off earlier than the other options. This suggests that while investors are perhaps less susceptible to the disposition effect,
it still does impact investment decisions. OTM and ATM options trend very similarly in terms of open interest change, though neither increases to the same extent as the call option counterparts. This suggests that investors also display a tendency towards the disposition effect with put options.

However, it cannot be determined from this figure whether or not the disposition effect is present in investor behavior as price change has not been incorporated. The presence of this graph in the paper is to depict the differences in investor behavior with regards to ATM, ITM, and OTM puts.

Incorporating the gambling theory mentioned in regards to Figure 1, it can be inferred from Figure 5 that investors regard ATM and OTM puts as nearly equal in terms of gambling opportunities. This is due to the fact that put ATM and put OTM open interest changes are extremely similar through the course of the 180 days, which suggests that investors in both types of moneyness exhibit similar behavioral tendencies, perhaps including the disposition effect. Looking at ITM puts, there is a significantly smaller increase in open interest over the time period which suggests that investors do not view that type of option as a viable gambling opportunity and close the positions as the time to expiration approaches, perhaps to reap the profits gained with the position.

The decreases in open interest seen for all types of moneyness beginning at 30 days could indicate that investors are closing positions prior to the date of expiration to realize profits from those positions. However, this can only be speculated without the
addition of price change information which will be included in the discussion of the next portion of the analysis.

**Figure 6: Open interest changes for put at-the-money (ATM) options by price change quintile**

ATM puts are defined as puts within 5 percent of current underlying asset price. $\text{OI}_p/\text{OI}_{180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignment. For puts, Low Quintile presents the most favorable results for investors.

As has been mentioned previously, investors in put options are anticipating a decrease in underlying asset price, which means that Low Quintile is the most favorable in terms of return. Therefore, the order of the quintiles in terms of increases in open interest for ATM puts would be expected to be nearly the reverse of that for ATM
calls. This is nearly demonstrated here, with the High and Low Quintiles switching placements when comparing Figures 2 and 6, and with Quintile 2 taking the place of Quintile 4 in Figure 6.

Additionally, it is expected that investors choosing ATM put options will exhibit less gambling behavior than investors choosing OTM put options, but more gambling behavior when compared to investors choosing ITM put options. This behavior can be seen when open interest increases over the course of the option’s time to expiration. While some of this behavior can potentially be attributed to the disposition effect, with investors holding on to losing options, some can also be attributed to the gambling tendencies of investors.

As with the High Quintile in the call ATM results (Figure 2), the Low Quintile for ATM puts has the slowest increase in open interest, beginning a decline at around 75 days to expiration. This early decrease in the open interest level suggests that investors are closing out of profitable positions and therefore exhibiting tendencies of the disposition effect.

Quintile 2, which has the second lowest underlying asset price change, demonstrates the second lowest increase in open interest with a faster drop in open interest than other quintiles. The underlying asset price change is negative (as can be seen in Table 2), and therefore favorable, so a decrease in open interest 30 days prior to the expiration of the option could indicate a tendency towards the disposition effect.
High Quintile follows a very similar open interest change trend to Quintile 2. The primary difference is at the 30 day mark, which is the point at which investors begin to sell off the options in Quintile 2. High Quintile represents the least favorable result for investors, and experiences a continued increase in open interest until approximately 15 days to expiration. At this time there is a plateau, which indicates that investors may have been gambling on an increase in value to the option caused by a price drop in the underlying asset. The plateau suggests that this gambling behavior stops with approximately two weeks until expiration. A general lack of decreasing open interest throughout the entire time period could suggest the presence of the disposition effect since investors are not closing this losing position. However this could also be explained by the fact that these investors may not be able to sell the options as there is little to no remaining market value.

Quintiles 3 and 4 see the largest increases in open interest change, though the order of these two quintiles is switched from the expectations gained from an analysis of ATM calls. This difference could be accounted for by the supposition that investors in put options are more sophisticated than those investing in call options, which lowers the tendency of investors to exhibit behaviors of the disposition effect. However, the changes in open interest are so similar between the two groups, which was also the case in ATM calls, that this difference in open interest changes may be inconsequential.

Looking ahead to Table 2, both Quintile 3 and Quintile 4 have positive underlying asset price changes, with Quintile 4 demonstrating the largest positive price change.
This could explain the plateau in the open interest change for this quintile in the last two weeks – investors are not gambling on the positions to the same degree as with Quintile 3 which sees an increase in open interest for a longer period of time. In both cases, investors could be holding onto the positions which are losing value, while new investors are gambling on the position in the hopes that it loses value and becomes closer to ITM.

![Diagram](Figure 7: Open interest changes for put out-of-the-money (OTM) options by price change quintile)

OTM puts are defined as puts within between 5 and 10 percent out-of-the-money. $\text{OI}_p/\text{OI}_{180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignation. For puts, Low Quintile presents the most favorable results for investors.
As is the case with OTM calls, investors choosing OTM puts may be demonstrating a tendency towards gambling or risk-taking behavior. This is due to the fact that OTM options begin out of the money and while there is the potential for the options to become ATM or even ITM options, any decrease in underlying asset value will drive the option even further out of the money, diminishing the value of the option. As a result, it is considered riskier to invest in OTM puts. This gambling behavior is demonstrated in the changes of open interest over the 180 days.

High Quintile, which includes puts with the least favorable underlying asset price changes, demonstrates the slowest-growing open interest. Additionally, the increase in open interest change appears to stagnate with approximately 30 days to expiration. This suggests that investors may not be opening positions because the options are now too far out of the money to be considered worth the risk of investment. In addition, it would suggest that investors are not closing positions, which could indicate that the options are no longer of any market value and investors still holding the position are not exercising it for that reason.

Low Quintile, which includes the options with the most favorable results, demonstrates a significant drop-off earlier than the other quintiles, at approximately 30 days to expiration. Because investors in this options group are closing positions at a faster rate than positions are being opened, there is an indication of sell-off behavior. Given that investors still have approximately 30 days in which more value could be gained from these options that have already performed well, it would seem as though investors in this category are closing winning positions earlier than expiration and
losing out on potential gains. This could indicate a susceptibility to the disposition effect.

Quintiles 2 and 3 see the largest increase in open interest as compared to the other quintiles. As seen in Table 2, options in Quintile 2 have an average decrease in underlying asset price and Quintile 3 has a slightly positive average underlying asset price change. Given that these positions are not as favorable as the results in Low Quintile, investors are not as averse to opening positions – there is still value to be gained from these OTM positions. These positions would be a better gambling opportunity than options further OTM as there a better chance of the option getting closer to ATM. Given that the options are still OTM, a position would be less expensive than the near ATM options that may be present in Low Quintile, and the potential payout percentage could be higher. Therefore, more investors would open positions in these categories as opposed to the winning options, explaining the higher rate of increase in open interest changes for Quintiles 2 and 3. The open interest change peaks at approximately 20 days to expiration indicating the point at which investors begin to close positions. While the decrease in open interest change is not to the same degree as that of Low Quintile, it does indicate a sell-off by investors in favorable positions prior to the date of expiration which could indicate a tendency towards the disposition effect.

Quintile 4 sees a slightly higher rate of increase in open interest change than High Quintile, but does not increase in open interest levels at the same rate of Quintiles 2 and 3. This could indicate that investors see this option as more of a gamble than
Quintiles 2 and 3 and are therefore engaging in risk-seeking behavior. The fact that the risk-seeking behavior of Quintile 4 does not increase open interest to the same levels of Quintiles 2 and 3 could indicate increased investor sophistication in the puts option market. Continued increases in open interest levels could indicate that some investors do not close positions which have lost market value, while others continue to invest as a method of gambling.

![PITM](image)

**Figure 8: Open interest changes for put in-the-money (ITM) options by price change quintile**

ITM puts are defined as puts within between 5 and 10 percent in-the-money. $O_{I}/O_{I180}$ refers to the percentage of current open interest as compared to open interest at 180 days to expiration. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignation. For puts, Low Quintile presents the most favorable results for investors.
As can be seen in Table 2, Low Quintile and Quintile 2 have negative median price changes, while all other quintiles experience positive median price changes. Again, puts are benefitted by negative price changes and Low Quintile and Quintile 2 demonstrate the most favorable results in this data set. As can be seen in Figure 8, both quintiles increase in open interest until approximately day 75, at which point each option group begins a decrease in open interest that continues until the date of expiration. Since each option group presents favorable results this suggests that investors are closing out of winning positions with a significant duration left prior to the date of expiration and are forfeiting potential value increases, which is a behavior of the disposition effect.

Quintile 3 increases in open interest at a quicker rate than Low Quintile or Quintile 2 which is expected given that the median underlying asset price change, as seen in Table 2, is not as favorable for this group of options. The increase in open interest indicates that investors might be willing to take some risk on this group of options which is not performing to the same level as the other two groups. However, this group of options does begin to see a decrease in open interest beginning at around 20 days to expiration which indicates that investors are selling out of these options relatively early in order to maximize the remaining market value and are forfeiting the potential gains for the time period.

Open interest for High Quintile increases at a still greater rate, which indicates gambling behavior of investors given that these options are seeing the least favorable underlying asset price change of the group. However, it does not have the highest level
of open interest change and the rate of increase plateaus at approximately 20 days to expiration, which indicates that investors are neither opening nor closing positions. This suggests that this group of options is no longer an attractive gambling opportunity and that investors are not selling positions because there is no market value to make selling a viable option. This could indicate the presence of the disposition effect because investors have held onto these positions until there is no market value remaining, and are therefore holding onto losing options far past useful life and incurring additional losses in the process.

Quintile 4 sees the greatest increase in open interest change of any quintile and, as with High Quintile, this could indicate higher levels of gambling behavior on the part of these investors. There appears to be a sell-off at approximately 20 days to expiration, which could indicate the sale of losing options. However, there is an immediate increase in open interest after that day, which suggests additional gambling behavior by the investors. This could suggest the presence of significant gambling behavior on the part of the investors.
### Price Change & Moneyness: Puts

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<th>Moneyness</th>
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Table 2: Price and moneyness changes for put options

This table quantifies the median price change and moneyness of each quintile for each put option moneyness. ATM puts are defined as puts within 5 percent of current underlying asset price, ITM puts are between 5 and 10 percent in the money, and OTM puts are between 5 and 10 percent out of the money. Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignation. For puts, Low Quintile presents the most favorable results for investors.

In the case of puts, it is favorable for the price change to be negative. For Low Quintile and Quintile 2, there are negative price changes in all categories. Comparing these results for ATM puts to Figure 2, it can be seen that Low Quintile experiences a decrease in open interest to below 100 percent of the initial level, suggesting that investors are closing out of favorable positions. With Quintile 3 and 4 experiencing
the largest growth in open interest, it can be supposed that investors are holding onto these losing positions. This is in contrast to High Quintile, in which losses appear to prompt investors to sell, but at a slower rate than either of the two “winning” quintiles.

For OTM puts this pattern changes slightly. Low Quintile does still see the quickest decline in open interest which suggests that investors are closing out of these winning positions. High Quintile has a similar level of open interest, though the level is steadier. The decline in open interest for Low Quintile suggests the closing of positions while a steady level for High Quintile suggests that investors are not closing positions that have been opened, indicating investor tendencies towards the disposition effect.

Similar trends in the ITM put options charts and table can be observed, which again suggest the presence of the disposition effect in this sample of investors.

Linking the initial figures to price change and moneyness changes for each quintile helps make it clear that investor behaviors are likely motivated by the disposition effect. The combined insights show where gains or losses in underlying asset value can influence open interest changes, demonstrating investor behaviors.
Implied volatility change by price change quintiles

<table>
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<tr>
<th></th>
<th>IV Change (%)</th>
<th>Call IV Change (%)</th>
<th>Put IV Change (%)</th>
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<td>High – Low</td>
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Table 3: Measuring implied volatility changes for each price change quintile

Change in implied volatility is the average of 1-day implied volatility changes for each category (by option type and quintile levels). Low Quintile refers to the 20 percent of the sample with the lowest underlying asset price change, while High Quintile refers to the 20 percent of the sample with the highest underlying asset price change. Quintiles 2, 3, and 4 represent the remaining groupings of 20 percent with increasing return levels in accordance with the numerical assignation. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation.

Overall, there is an increase in implied volatility for Low Quintile and Quintile 2 with decreases in the remaining three price change quintiles. Generally, the relationship between price change and implied volatility change is expected to be inverse. An increase in implied volatility due to decreased price could indicate that investors are opening more positions, while a decrease in implied volatility could indicate the closing of positions. If this holds true, then investors are opening more positions or neglecting to close open positions in the two lowest price change quintiles but closing the positions in the highest gaining three quintiles. This suggests that the disposition effect is present. Given that the difference between the High Quintile implied volatility change and the Low Quintile implied volatility change is significant for all options and
calls, but not puts, it appears that calls drive the disposition effect when looking at implied volatility. This is consistent with the assumption that less sophisticated options investors tend to trade with call options and tend to demonstrate the disposition effect more frequently than more sophisticated investors.

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<th>Test Statistic</th>
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**Table 4: Results of a difference between proportions test to compare institutional and retail investors**

This test is a two-proportion t-test and is used to determine if the difference between two proportions is statistically significant. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional, while investors with trades of fewer than 200 contracts are considered retail.

Performing a difference between proportions test shows that the relatively higher frequency with which retail investors invest in calls as compared to institutional investors is statistically significant. This supports early supposition that less sophisticated/non-institutional investors have a tendency to invest in call options. It also supports the theory put forth in the literature review that those who invest in puts tend to be more sophisticated investors.
Table 5: Ratio of investment in all option moneyness classifications for institutional and retail investors

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<tr>
<th></th>
<th>Calls</th>
<th></th>
<th>Puts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ATM</td>
<td>ITM</td>
<td>OTM</td>
<td>ATM</td>
</tr>
<tr>
<td>Institutional</td>
<td>0.551</td>
<td>0.081</td>
<td>0.368</td>
<td>0.536</td>
</tr>
<tr>
<td>Retail</td>
<td>0.507</td>
<td>0.113</td>
<td>0.380</td>
<td>0.502</td>
</tr>
</tbody>
</table>

ATM calls/puts are defined as calls/puts within 5 percent of current underlying asset price, ITM calls/puts are between 5 and 10 percent in the money, and OTM calls/puts are between 5 and 10 percent out of the money. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional, while investors with trades of fewer than 200 contracts are considered retail.

This table provides some insights into the purchasing behaviors of institutional and retail investors for both call and put options. For both institutional and retail investors and both types of options, ATM is the preferred investment with OTM purchased somewhat less frequently. The proportion of investment in ATM versus OTM is higher in both categories for institutional investors as opposed to retail investors, which may indicate more risk-seeking behavior on the part of the retail investor.
Regression results: Calls

Regression 1 (Dependent variable: Open interest change)

<table>
<thead>
<tr>
<th>Price Change</th>
<th>ATM</th>
<th>Significance</th>
<th>ITM</th>
<th>Significance</th>
<th>OTM</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-0.021</td>
<td>***</td>
<td>-0.031</td>
<td>***</td>
<td>0.012</td>
<td>*</td>
</tr>
<tr>
<td>Low</td>
<td>-0.504</td>
<td>*</td>
<td>-0.720</td>
<td>**</td>
<td>0.173</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>-0.180</td>
<td></td>
<td>0.073</td>
<td></td>
<td>0.239</td>
<td></td>
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<tr>
<td>High</td>
<td>-0.331</td>
<td></td>
<td>1.719</td>
<td>***</td>
<td>0.492</td>
<td></td>
</tr>
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</table>

Regression 2 (Dependent variable: Implied volatility)

<table>
<thead>
<tr>
<th>Price Change</th>
<th>ATM</th>
<th>Significance</th>
<th>ITM</th>
<th>Significance</th>
<th>OTM</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-0.211</td>
<td>***</td>
<td>0.003</td>
<td></td>
<td>-0.372</td>
<td>***</td>
</tr>
<tr>
<td>Low</td>
<td>0.350</td>
<td>***</td>
<td>0.962</td>
<td>***</td>
<td>0.271</td>
<td>***</td>
</tr>
<tr>
<td>Mid</td>
<td>0.371</td>
<td>***</td>
<td>0.398</td>
<td>***</td>
<td>0.509</td>
<td>***</td>
</tr>
<tr>
<td>High</td>
<td>0.401</td>
<td>***</td>
<td>0.378</td>
<td>***</td>
<td>0.323</td>
<td>***</td>
</tr>
</tbody>
</table>

Regression 3 (Dependent variable: Implied volatility with open interest change)

<table>
<thead>
<tr>
<th>Price Change</th>
<th>ATM</th>
<th>Significance</th>
<th>ITM</th>
<th>Significance</th>
<th>OTM</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-0.213</td>
<td>***</td>
<td>-0.004</td>
<td></td>
<td>-0.372</td>
<td>***</td>
</tr>
<tr>
<td>Low</td>
<td>0.350</td>
<td>***</td>
<td>0.965</td>
<td>***</td>
<td>0.272</td>
<td>***</td>
</tr>
<tr>
<td>Mid</td>
<td>0.372</td>
<td>***</td>
<td>0.399</td>
<td>***</td>
<td>0.508</td>
<td>***</td>
</tr>
<tr>
<td>High</td>
<td>0.401</td>
<td>***</td>
<td>0.384</td>
<td>***</td>
<td>0.323</td>
<td>***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open Interest Change</th>
<th>ATM</th>
<th>Significance</th>
<th>ITM</th>
<th>Significance</th>
<th>OTM</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-0.002</td>
<td>***</td>
<td>-0.003</td>
<td>***</td>
<td>-0.001</td>
<td>***</td>
</tr>
<tr>
<td>Low</td>
<td>0.000</td>
<td></td>
<td>-0.002</td>
<td>***</td>
<td>0.001</td>
<td>***</td>
</tr>
<tr>
<td>Mid</td>
<td>-0.004</td>
<td>***</td>
<td>-0.005</td>
<td>***</td>
<td>-0.001</td>
<td>**</td>
</tr>
<tr>
<td>High</td>
<td>0.000</td>
<td></td>
<td>-0.003</td>
<td>***</td>
<td>0.001</td>
<td>***</td>
</tr>
</tbody>
</table>

Table 6: Regression results for call options by moneyness classification

This table presents the results of a two-sample t-test. ATM calls are defined as calls within 5 percent of the strike price, ITM calls are between 5 and 10 percent in the money, and OTM calls are between 5 and 10 percent out of the money. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional investors, while investors with trades of fewer than 200 contracts are considered retail. This paper looks at relative open positions between the two groups, institutional/retail, for each option then divides the sample of options into terciles to compare behaviors. Open positions are calculated by subtracting open buys from close sells for institutional investors, divided by the same calculation for retail investors. Low Tercile consists of options with the lowest ratio of institutional to retail traders, while High Tercile contains options with the highest ratio of institutional to retail traders. Mid Tercile represents the middle third of the sample when exploring this ratio.
The relationship between price change and open interest change is significant when looking at all classifications of the institutional/retail investor ratio. However, it is only significant for instances of high retail investors for ATM and ITM calls. In Low Tercile for both ATM and ITM calls, there is an inverse relationship between open interest change and price changes, which suggests that investors in those options categories are closing positions when value is gained.

There is a significant relationship shown between price change and open interest change in Regression 1 when there is a high proportion of institutional investors for ITM calls, with the institutional investors demonstrating a more significant result than retail investors for this moneyness. Looking at the High Tercile category for ITM calls, which is both positive and highly statistically significant, it would seem that there is a direct relationship between open interest change and price change for institutional investors in this category. This would indicate that institutional investors are holding on to winning positions, contradicting the disposition effect-related tendencies of investors. It also supports the argument that institutional investors are less prone to the behavioral tendencies of the disposition effect than are retail investors. Both ATM and ITM calls demonstrate a negative and highly statistically significant relationship for all investors, which indicates that the aggregate of investors displays tendencies of the disposition effect for these categories of options.

Looking at the relationship between implied volatility change and price change in Regression 2, it appears as though this relationship is positive and highly statistically significant for each of the three terciles of institutional/retail investor ratio. This
suggests that there is not a significant difference in the impact of implied volatility change on price change for any level of investor sophistication. When looking at all call option trades, however, the relationship for ATM and OTM call options are negative and statistically significant. This results from a significant difference in sample size because a large portion of the data does not have an investor type classification and is therefore not included in the tercile data. Further study of the relationship between implied volatility change and price change is necessary given the deviation from expectations.

In Regression 3, the dependent variable is still implied volatility, but the independent variables are expanded to include both price change and open interest change. As with Regression 2, changes in sign between all investors and investor terciles for the relationship of implied volatility change to price change result from differences in sample size. Further study of the relationship between the two variables for different investor classifications is recommended. Looking at the relationship between implied volatility and open interest change, it is primarily negative and statistically significant. This is notable particularly in ITM and OTM call options, which sees this relationship for all levels of the institutional/retail investor ratio.
Table 7: Regression results for put options by moneyness classification

This table presents the results of a two-sample t-test. ATM puts are defined as puts within 5 percent of current underlying asset price, ITM puts are between 5 and 10 percent in the money, and OTM puts are between 5 and 10 percent out of the money. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional, while investors with trades of fewer than 200 contracts are considered retail. This paper looks at relative open positions between the two groups, institutional/retail, for each option then divides the sample of options into terciles to compare behaviors. Open positions are calculated by subtracting open buys from close sells for institutional investors, divided by the same calculation for retail investors. Low Tercile consists of options with the lowest ratio of institutional to retail traders, while High Tercile contains options with the highest ratio of institutional to retail traders. Mid Tercile represents the middle third of the sample when exploring this ratio.
When investigating the relationship between open interest change and price change for put options, ITM put options see a positive and highly statistically significant relationship for all three levels of the institutional/retail investor ratio. This suggests that an increase in price (which is unfavorable for put options) leads to an increase in open interest, indicating that investors are holding onto losing options while possibly purchasing new positions, supporting the presence of the disposition effect in investor behavior as well as potential gambling behavior. OTM puts, however, are negative and highly statistically significant when looking at all option traders or when there is a higher concentration of institutional investors. This suggests that a decrease in price for the option (which is favorable for put options), leads to an increase in open interest which indicates that institutional investors are keeping those positions open, contradicting the tendencies of investors exhibiting the disposition effect.

Looking at the second regression for put options, each relationship is highly statistically significant. All moneyness options show a positive relationship between the two variables for the breakdown of investments by investor type. Regression 3 is the same as Regression 2 with the additional independent variable of open interest change. The same relationships between implied volatility change and price change are observed, but with the added control of open interest change.

As is the case with Table 6, the relationship between price change and implied volatility change has opposite signs when comparing all samples to the terciles. This is again caused by a large reduction in the sample size when including the institutional/retail investor variable. Further study into the relationship of these two
variables with the tercile classifications is necessary given the deviation from expectations.
### Table 8: Regression results for all/call/put options

This table presents the results of a two-sample t-test. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional, while investors with trades of fewer than 200 contracts are considered retail. This paper looks at relative open positions between the two groups, institutional/retail, for each option then divides the sample of options into terciles to compare behaviors. Open positions are calculated by subtracting open buys from close sells for institutional investors, divided by the same calculation for retail investors. Low Tercile consists of options with the lowest ratio of institutional to retail traders, while High Tercile contains options with the highest ratio of institutional to retail traders. Mid Tercile represents the middle third of the sample when exploring this ratio.
This table looks at call and put options, as well as all options together. In Regression 1, there is a negative relationship between price change and open interest for call options, which is statistically significant for all but High Tercile. This suggests that groupings of investors which are primarily retail investors (Low Tercile) are closing call option positions which increase in price and demonstrate a favorable results. A tendency towards the disposition effect is suggested which is not present for High Tercile, supporting the supposition that retail investors are more likely to display the disposition effect than institutional investors in regards to call options. Looking at put options, there is a positive and statistically significant relationship between price change and open interest for High Tercile. This does suggest that institutional investors demonstrate the tendencies of the disposition effect for put options.

Regression 2 sees a positive and highly statistically significant relationship for all terciles, but when looking at all investors together, the relationship is negative and statistically significant. Further study into the relationship of these two variables with the tercile classifications is necessary given the deviation from expectations resulting from sample size differences in the regression.

Regression 3 shows the same overall relationship between price change and implied volatility change. There is the additional variable of open interest change added and the relationship between implied volatility change and open interest change is not consistent across investor or moneyness types. For all types of investors together, the relationship between implied volatility change and open interest change is negative and statistically significant. Variants from this behavior include the Low and High
Terciles in all categories. In each case, these relationships are positive and statistically significant. Due to the reduced sample size from the all category to the terciles, it is recommended that this relationship is further studied to determine if changes in open interest continue to impact implied volatility in this way.
## Table 9: Regression results for all options with additional considerations for price and open interest changes

This table presents the results of a two-sample t-test. CPC/PPC represent Call Price Change/Put Price Change, while COIC/POIC represent Call Open Interest Change/Put Open Interest Change. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation. The classification of institutional and retail investors is done in accordance with the ISE definitions of each group. Investors with trades of more than 200 contracts are considered institutional, while investors with trades of fewer than 200 contracts are considered retail. This paper looks at relative open positions between the two groups, institutional/retail, for each option then divides the sample of options into terciles to compare behaviors. Open positions are calculated by subtracting open buys from close sells for institutional investors, divided by the same calculation for retail investors. Low Tercile consists of options with the lowest ratio of institutional to retail traders, while High Tercile contains options with the highest ratio of institutional to retail traders. Mid Tercile represents the middle third of the sample when exploring this ratio.

<table>
<thead>
<tr>
<th></th>
<th>CPC</th>
<th>PPC</th>
<th>COIC</th>
<th>POIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td>-0.058</td>
<td>0.249</td>
<td>-0.002</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>0.008</td>
<td>0.145</td>
<td>0.000</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Mid</strong></td>
<td>-0.023</td>
<td>0.096</td>
<td>-0.003</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>-0.042</td>
<td>0.101</td>
<td>0.000</td>
<td>0.002</td>
</tr>
</tbody>
</table>

This table shows an additional regression run on all options with implied volatility change as the dependent variable, while separating out price change for calls (CPC) and puts (PPC) and open interest changes for calls (COIC) and puts (POIC). When looking at the relationship between implied volatility change and price change, the two highly statistically significant and negative results are for all types of investors and for
High Tercile. These relationships indicate that a decrease in implied volatility results in increased price. The opposite relationship is seen for PPC, with all categories presenting highly statistically significant results. This indicates the unfavorable price changes result in higher levels of implied volatility. These results are to be expected and could indicate the sale of losing positions which would contradict the presence of the disposition effect.

When looking at the results with the addition of open interest change, the statistical significance of the High Tercile CPC result decreases, though the general relationships for all categories remain the same. Looking at COIC, there is a highly statistically significant and negative relationship for all investors and the Low Tercile group. POIC demonstrates a positive and highly significant result for all groupings of investor types.
### Table 10: Changes in call open interest for price change quintiles over six 15-day periods

ATM calls are defined as calls within 5 percent of current underlying asset price, ITM calls are between 5 and 10 percent in the money, and OTM calls are between 5 and 10 percent out of the money. Low Tercile refers to the third of the sample with the lowest underlying asset price change, while High Tercile refers to the third of the sample with the highest underlying asset price change. Tercile 2 represents the middle third of option in terms of underlying asset price change. For calls, High Tercile presents the most favorable results for investors. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation.

Table 10 presents open interest changes for call options which are separated into terciles based on price change, and then separated into 15 day time periods based on time to expiration. These time ranges of 15 days are to control for changes in open interest for each price change quintile based on timing. Separating the data into time

---

### Panel A: OTM calls

<table>
<thead>
<tr>
<th></th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.091</td>
<td>0.051</td>
<td>0.151</td>
<td>0.247</td>
<td>0.244</td>
<td>-0.001</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.104</td>
<td>0.057</td>
<td>0.184</td>
<td>0.268</td>
<td>0.307</td>
<td>-0.001</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>0.124</td>
<td>0.068</td>
<td>0.224</td>
<td>0.337</td>
<td>0.402</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>0.032</td>
<td>0.016</td>
<td>0.073</td>
<td>0.090</td>
<td>0.158</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
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<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

### Panel B: ATM calls

<table>
<thead>
<tr>
<th></th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.092</td>
<td>0.056</td>
<td>0.171</td>
<td>0.293</td>
<td>0.330</td>
<td>-0.003</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.063</td>
<td>0.035</td>
<td>0.125</td>
<td>0.216</td>
<td>0.229</td>
<td>-0.008</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>0.050</td>
<td>0.028</td>
<td>0.099</td>
<td>0.185</td>
<td>0.182</td>
<td>-0.010</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>-0.042</td>
<td>-0.028</td>
<td>-0.072</td>
<td>-0.108</td>
<td>-0.149</td>
<td>-0.006</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

### Panel C: ITM calls

<table>
<thead>
<tr>
<th></th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.042</td>
<td>0.054</td>
<td>0.076</td>
<td>0.290</td>
<td>0.213</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.006</td>
<td>0.015</td>
<td>0.011</td>
<td>0.122</td>
<td>0.027</td>
<td>-0.007</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>-0.002</td>
<td>0.003</td>
<td>0.000</td>
<td>0.061</td>
<td>-0.002</td>
<td>-0.012</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>-0.044</td>
<td>-0.051</td>
<td>-0.076</td>
<td>-0.229</td>
<td>-0.216</td>
<td>-0.012</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>
periods allows for investigation into whether investor behavior changes as the date of expiration nears.

Looking at Panel A, it can be seen that each of the terciles has a positive open interest change for each time period, increasing after 45 days to expiration, except for the time period beginning 13 days before expiration. This is evidence of investor preference to purchase shorter term options, as the purchase behavior is exhibited until immediately before expiration. As seen in Figures 3-8, a drop in open interest occurs as time to expiration nears. This may indicate that it is typical behavior for an investor to close positions as the date of expiration approaches. The difference between High Tercile and Low Tercile open interest changes are positive and highly statistically significant for all time periods. In order to point towards the behavioral tendencies of the disposition effect, a negative relationship would be expected when examining the difference between High and Low Terciles. Because High Tercile has a greater increase in underlying asset price, a sell off of the asset due to the disposition effect should lead to lower levels of open interest for High Tercile than for Low Tercile.

Panel B shows the open interest changes for ATM calls. Similar to OTM calls, all terciles have positive open interest changes for each time period except for the final 13 days before expiration. The decrease in open interest for this time period could be due to investors closing positions to avoid exercise costs. One notable difference from Panel A is that the difference between the High Tercile and the Low Tercile in Panel B is negative and highly statistically significant. This is evidence of the disposition effect.
because it demonstrates that investors with options in High Tercile are selling the positions at a greater rate than investors with options in Low Tercile.

ITM calls are shown in Panel C, and show that investors in the Low Tercile and Tercile 2 have positive open interest changes for all time periods except for the final 13-5 days to expiration, again likely due to investors hoping to avoid the cost of exercising options. High Tercile, however, sees negative open interest changes for 89-76, 30-13, and 13-5 days to expiration. This suggests that investors are closing out of these winning positions, and are not necessarily following the trend seen in other options to close positions in the final few days. Additionally, the difference between the High and Low Terciles is negative and highly significant for every time period, which suggests very different investor behaviors. Given the negative values for three of the six time periods, and the fact that the positive values are at or near 0 for 75-61 and 60-46 days to expiration, it can be theorized that the disposition effect is present in the behavior of investors choosing to invest in ITM calls.
### Table 11: Changes in put open interest for price change quintiles over six 15-day time periods

ATM puts are defined as puts within 5 percent of current underlying asset price, ITM puts are between 5 and 10 percent in the money, and OTM puts are between 5 and 10 percent out of the money. Low Tercile refers to the third of the sample with the lowest underlying asset price change, while High Tercile refers to the third of the sample with the highest underlying asset price change. Tercile 2 represents the middle third of option in terms of underlying asset price change. For puts, Low Tercile presents the most favorable results for investors. Results presented with *** are those with a p-value below 1 percent and are referred to in the paper as highly statistically significant. Results presented with ** are those with a p-value between 1 percent and 5 percent and are referred to in the paper as statistically significant. Results presented with * are those with a p-value between 5 percent and 10 percent and are referred to in the paper as statistically significant. Results with a p-value greater than 10 percent are not considered statistically significant and do not have any additional notation.

Table 11 presents open interest changes for put options which are separated into

**terciles based on price change, and then separated into 15 day time periods based on**

<table>
<thead>
<tr>
<th>Panel A: OTM puts</th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.094</td>
<td>0.057</td>
<td>0.176</td>
<td>0.350</td>
<td>0.385</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.063</td>
<td>0.045</td>
<td>0.137</td>
<td>0.266</td>
<td>0.258</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>0.056</td>
<td>0.037</td>
<td>0.126</td>
<td>0.228</td>
<td>0.225</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>-0.038</td>
<td>-0.020</td>
<td>-0.050</td>
<td>-0.122</td>
<td>-0.161</td>
<td>-0.003</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: ATM puts</th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.063</td>
<td>0.048</td>
<td>0.123</td>
<td>0.265</td>
<td>0.229</td>
<td>-0.002</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.077</td>
<td>0.050</td>
<td>0.149</td>
<td>0.294</td>
<td>0.287</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>0.087</td>
<td>0.058</td>
<td>0.186</td>
<td>0.327</td>
<td>0.347</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>0.024</td>
<td>0.010</td>
<td>0.062</td>
<td>0.062</td>
<td>0.118</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C: ITM puts</th>
<th>89-76</th>
<th>75-61</th>
<th>60-46</th>
<th>45-31</th>
<th>30-13</th>
<th>13-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Tercile</strong></td>
<td>0.013</td>
<td>0.034</td>
<td>0.014</td>
<td>0.161</td>
<td>0.017</td>
<td>-0.006</td>
</tr>
<tr>
<td><strong>Tercile 2</strong></td>
<td>0.028</td>
<td>0.052</td>
<td>0.044</td>
<td>0.260</td>
<td>0.079</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>High Tercile</strong></td>
<td>0.063</td>
<td>0.074</td>
<td>0.092</td>
<td>0.358</td>
<td>0.262</td>
<td>0.014</td>
</tr>
<tr>
<td><strong>High - Low</strong></td>
<td>0.049</td>
<td>0.040</td>
<td>0.078</td>
<td>0.197</td>
<td>0.245</td>
<td>0.020</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>
time to expiration. Separating the data into time periods allows an analysis of open interest changes that are independent of time changes.

Looking at Panel A, the open interest change for each tercile in every time period is positive and the difference between High and Low Terciles is negative and highly significant. The increase in open interest beginning in the 60-46 days to expiration time frame indicates that investors may prefer shorter term options to longer term positions. Given that Low Tercile is comprised of the options with more favorable results, the expectation would be to see a positive difference between High and Low Terciles to represent the presence of the disposition effect. Therefore, this table does not present evidence of the disposition effect in OTM puts. This could be the result of the supposed higher level of sophistication of investors choosing to purchase put options.

Panel B (Panel C) shows ATM (ITM) puts, and has all positive open interest change values except for the 13-5 days to expiration category for Low Tercile. In the case of puts, Low Tercile is the favorable position and the negative open interest change could indicate a sell off of winning positions. The difference between the High and Low Terciles is positive and statistically significant, indicating that the High Tercile has higher increases in open interest than the Low Tercile, which could suggest that investors are keeping more losing positions open while closing out of winning options, therefore exhibiting the disposition effect.
5. Conclusions

Evidence is present which suggests the presence of the disposition effect in the U.S. equity options market. This paper utilizes open interest changes to proxy for investor behavior in the U.S. equity options market and explores the differences in investor behavior based on the underlying asset price change. By exploring these behaviors for each type of moneyness for both call and put options, this paper demonstrates that investors engage in behaviors which would suggest gambling tendencies in addition to behaviors which suggest the presence of the disposition effect.

As stated throughout the paper, there are a number of considerations with the options market that are not present in the equities market, so investor behavior is more difficult to specifically attribute to the disposition effect in the options market than in the equities market. However, analysis does suggest that at least some of the investor behavior can be attributed to the disposition effect, indicating that investor biases are resulting in sustained losses or missed profits. This is in line with the expectation that the investor behavior in the options market would imitate the investor behavior in the equities market. Studying individuals’ investment behavior could help investors to avoid these mistakes, just as it would in the equities market, and lead to more profitable investment decisions in this market.

Additional insights include the increased tendency of retail investors to display behaviors in line with the disposition effect when compared to institutional investors. Regressions to analyze the relationship between open interest change and price change for the three terciles of institutional/retail investors indicate that institutional investors
are less likely to exhibit behaviors common to the disposition effect, while retail investors are more likely to exhibit these behaviors. This is in line with the initial expectations developed through study of previous literature, and provides some insight into the differences in behavior between institutional and retail investors.

More study on this topic is recommended to gain further insight into the events that trigger investors to engage in this behavior, and to determine the extent to which this behavior is harming investors in terms of profits lost. Additional study into the relationship between implied volatility change and price change with additional information regarding investor classification is also recommended given the unexpected results in Tables 6, 7, and 8.

Other considerations for increased robustness of this paper include the introduction of additional controls to account for changes in moneyness for options throughout the duration of the 180 days to expiration. Option illiquidity will also be considered by integrating the bid-ask spread to determine if the reason behind investors holding onto positions is that there is no market interest in the positions. Additionally, an experiment will be implemented to determine if events such as an earnings announcement trigger behaviors that suggest the presence of the disposition effect. All of these measures will serve to provide a more definitive idea of the presence of the disposition effect. This paper demonstrates that the disposition effect could be present in the U.S. equity options market – these additional considerations will work to prove the presence of this behavior.
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