Pinning in the S&P 500 Futures

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Abstract
We document that S&P 500 futures finish in the proximity of the closest strike price more often on days when serial options on S&P 500 futures expire than on other days. The effect is driven by the interplay of market makers' rebalancing of delta hedges due to the time-decay of the hedges as well as in response to reselling (and early exercise) of in-the-money options by individual investors. Consistent with limits to arbitrage, we find that the effect is asymmetric and stronger above the strike price. In line with increased options activity, pinning becomes more pronounced in recent years.

Key words: Pinning, Futures, Options, Option Expiration, Hedging
JEL classification: G12, G13

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From first principles, we would expect stock prices to be uniformly distributed on any small interval - there should not be any attraction to one particular stock price or another. However, pinning exactly describes such tendency of stock prices to finish at the expiration date of an option more frequently near a strike price. This is a fascinating feature as it involves effects across two markets: the options market and the market for the underlying.

Pinning is well-documented for individual stocks, see the instances described in Anders (1982), Krishnan and Nelken (2001), or Augen (2009, pp. 26). However, only Ni, Pearson, and Poteshman (2005) engage in a large sample and comprehensive study of stock option pinning and provide statistical evidence of its existence. In their paper, the main driving force for pinning is the market maker’s adjustment of the delta hedge due to the time-decay of the hedges, according to Avellaneda and Lipkin (2003), and stock price manipulation of proprietary traders.

In this paper, we take the analysis to the aggregate level and analyze the behavior of S&P 500 futures (henceforth futures) on expiration days of options on S&P 500 futures (henceforth SP options). Since SP options expire on a monthly cycle and futures expire on a quarterly cycle, we primarily focus on serial expiration months (all months excluding the quarterly cycle) as those days provide us with a unique laboratory of cases when SP options expire and the underlying future continues to trade for an additional month or two. It is exactly this feature that enables the future to pin to the nearest strike price.

As futures are highly liquid (average daily turnover in 2009 are 27,384 contracts), it is hard to imagine that futures could be subject to manipulation and we will provide evidence to this effect. Further, as opposed to individual stocks, where likely delta hedgers (market makers) tend to hold long option positions, market makers are typically short the options on the S&P 500 index (henceforth SPX options) (Garleanu, Pedersen, and Poteshman, 2009). We will argue that this fact extends to the very similar market for SP options. Given such short position of the market maker in the SP options, the time decay of the delta hedge should

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1 The fact that pinning occurs only on expiration dates is different from clustering which is the tendency of prices to be quotes on particular round values. Such clustering is independent of a day being an expiration day or not. See Schwarz, Van Ness, and Van Ness (2004) for a recent account of clustering in S&P 500 futures trade prices.
then lead, according to the model of Avellaneda and Lipkin (2003), to anti-pinning in the S&P 500 futures and not to pinning.

[Insert Figure 1 about here]

Surprisingly however, we find evidence of pinning in the serial expirations of closest to maturity S&P 500 futures and not of the predicted anti-pinning. We document this behavior in Figure 1 where we depict the percentage of future settlement prices finishing within $0.25 of the closest strike price. Since the option strike prices are spaced $5 apart, we expect 10% to finish close to the strike price. However, from August 1987 until November 2009 we see in Figure 1, Panel A that this frequency is elevated on expiration days as opposed to the five preceding or following days. Panel B documents that this effect is even stronger from January 1998 until November 2009. Below we show that these values are also significantly different from the expected 10% value.

In additional tests, we find that pinning is especially pronounced from above the strike price. Intuitively, this asymmetry is due to limits to arbitrage: pinning from above is more difficult to arbitrage away as it involves buying the depressed future. In turn, one would need to sell (short) the S&P 500 basket which is difficult. Thus, the transaction costs on the related arbitrage are large and we can have periods of time where the future price is pinned from above.

Given that the observed pinning is seemingly at odds with the, according to Ni, Pearson, and Poteshman (2005), main story for pinning due to Avellaneda and Lipkin (2003) we explore in detail other potential explanations for pinning. Anders (1982) suggests that last minute sales of in-the-money option by individual investors lead to pinning as the market maker needs to adjust the hedge afterwards. By the same token, pinning can also arise because of early exercise of options. We test the competing three mechanisms via logistic regressions which explain pinning and anti-pinning based on option volume, open interest, and early option exercise. To the best of our knowledge, we are not aware of any other study using early options exercise data.
Our regressions confirm that the time decay of the delta hedge of Avellaneda and Lipkin (2003) indeed leads to anti-pinning, but the effects of the other two mechanisms are overcompensating. Further, the results confirm that manipulation is an unlikely explanation for the documented pinning. Robustness checks find these results stable with regard to changes in the methodology.

To corroborate that the documented pinning is indeed related to options expirations, we show that there is no pinning in second to maturity futures, on which there exist no expiring SP options. Also, there is no pinning in the first to maturity futures on the quarterly expirations when SP options and futures expire simultaneously in the value of the S&P 500 index. This is understandable since the S&P 500 basket is much harder to move through trading than the future. For the same reason, there is no pinning in the S&P 500 index itself due to expiration of SPX options on the S&P 500 index nor in the exchanged traded fund on the S&P 500 (SPDR) due to expiration of its SPY options.

Based on a literature review, the paper develops the hypotheses in Section I. Section II introduces the econometric methodology of testing for pinning and documenting the driving mechanisms. All data are presented in Section III. Results for different option classes follow in Section IV while robustness checks are presented in Section V. Section VI concludes.

I. Literature and Hypotheses

We motivate our study by evidence that pinning exists in the near to maturity futures on serial expiration days of SP options. Next, we turn to possible reasons as to why such pinning might occur. Since many arguments relate to the delta hedging of the market maker, we now argue that the market maker tends to be short at-the-money straddles (positions of sold calls and puts in roughly equal number) and that only the market maker delta hedges.

We know that the market maker in the S&P 500 index options is short gamma, thus selling mainly straddles (see Table 1 in Garleanu, Pedersen, and Poteshman 2009). Unfortunately, such proprietary data is unobtainable for the futures options market. However, we argue that market maker positions are likely to be rather similar since the two
markets are closely related. The correlation between the S&P 500 index and the shortest to maturity future in the period from 1983 to 2009 is 0.9999. Further, trading activity in the SPX options market and the SP options market are highly related. Correlations of near-the-money open interest and volume between the two markets during the last 5 days leading up to expiration Friday are 0.86 and 0.79, respectively. This leads us to assume that the market maker in the SP option market holds similar positions as in the SPX options market, i.e. the market maker is largely short at-the-money straddles in SP options.

With respect to delta hedging, we argue that only market makers delta hedge as they are faced with large aggregate positions which they take on from trading with many (small) individual investors. Individual investors do not normally hedge their smaller positions since they would often be constraint by transaction costs and financial know-how in hedging. Ni, Pearson, and Poteshman (2005) argue along similar lines. Moreover, they report that institutional trading in the index options market does only amount to a rather small fraction of total volume. Consistent with this claim, Savickas and Wilson (2003) report that approximately 70% of all option trades (equity and index) in 1995 are due to trades between public customers and market makers. We argue that we can follow their example by ignoring the effect of institutional traders in the similar market for futures options. Next, we detail all the explored pinning mechanisms.

The simplest mechanism is the change of delta hedging sold straddle (i.e. short gamma) positions as the underlying future moves. In Figure 2 we can see that a sold straddle with the future being above the strike price has a negative delta of almost -1, which is hedged with almost a long future. As the future falls, the straddle gains delta, thus the hedge needs to lose delta by selling futures in the falling market. The reverse mechanism operates in increasing markets. This effect amplifies the movement of the underlying in the presence of movement in the underlying future which leads to higher volatility; see Pearson, Poteshman, and White (2007). However, this mechanism does not lead to pinning as postulated by Krishnan and Nelken (2001) because the hedging pressure does not revert at the strike price of the straddle; it merely amplifies the movement of the underlying future.

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2 We define near-the-money as options with moneyness between 0.95 and 1.05. We calculate correlations for all the expirations in the period from January 1990 to December 2009.
I.A Delta Hedging and Time Decay Effect (Avellaneda and Lipkin, 2003)

Avellaneda and Lipkin (2003) argue that the time decay of delta-hedges of long option positions leads to pinning.\(^3\) Alas, given that the market maker typically holds a sold straddle position, their mechanism leads in that case to anti-pinning. As we can see in Figure 3, initially at \(t_0\), the hedge around the strike price of the straddle is zero or almost zero. However, as expiration comes very close and the future goes slightly above the strike price, the delta of the position moves from almost zero to almost \(-1\), thus, the hedge involves buying the future in up-markets. A similar mechanism establishes the predicted anti-pinning for the case where the future is below the strike price.

The main hypothesis related to Avellaneda and Lipkin (2003) is (we express all hypotheses in terms of pinning; anti-pinning being then a lessening of pinning):

**Hypothesis AL-1:** *At-the-money (ATM) open interest is negatively related to pinning.* The larger the ATM open interest on expiration Friday,\(^4\) the larger is the sold straddle position that the market maker needs to hedge. Thus, the higher the open interest, the weaker the pinning, or the stronger the anti-pinning effect.

As we will see later, we use end-of-day options data in this study. As end-of-day open interest on expiration Friday is theoretically zero, we use open interest on the Thursday before expiration Friday. We follow here Ni, Pearson, and Poteshman (2005). However, as

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\(^4\) Options on S&P 500 futures typically expire on the third Friday of the month. Occasionally, due to holidays, the expiration falls on the Thursday before the third Friday of the month. In our sample, this happens three times. As reported in the Robustness Section, omitting these days does not change the results.
options are actively traded during expiration Friday, Thursday open interest does not reflect exactly Friday open interest.

Thus, we complement the main hypothesis with two additional hypotheses related to option trading activity on expiration Friday: option volume and option early exercise.

**Hypothesis AL-2:** *ATM option volume is positively related to pinning.* ATM option volume on expiration Friday is partly related to the closing of open positions which will expire at day end. Thus, it is reasonable to presume that while some option volume will open new positions, the net effect is to close positions. Assuming reasonably stable proportions, larger volume should then lead to more closures of positions, thus reducing open interest and the hedging need of the market maker. As a result, there should be less anti-pinning and more pinning.

**Hypothesis AL-3:** *ATM early option exercise is positively related to pinning.* Early exercise of individual investors long positions would lead to reduced short positions of the market maker and thus to reduced hedging needs. This would weaken the anti-pinning and thus strengthen pinning.

**I.B Reselling of Slightly In-The-Money Options**

Anders (1982) argues that individual investors dislike long in-the-money (ITM) option positions at expiration because they expose individual investors to price risk over the weekend. This concern is relevant for the SP options since they settle with physical delivery. Thus, investors sell their ITM positions to the market maker who will then need to adjust the hedge on the typical market maker short straddle position. In Figure 4 we can appreciate what ensues as the future starts at the strike price and increases above the strike price. The short straddle changes its delta from about zero to about -0.5 and the hedge requires buying half a future.\(^5\) Now, the call is ITM and has a delta of about 0.75. The investor sells the ITM call to the market maker and the market maker's reduced short straddle position (= one short out-of-the-money (OTM) put) requires 0.75 futures less in the hedge, a net effect of -0.25 futures. Thus, the market maker sells a quarter future as the future goes above the strike

\(^5\) The delta values are not exact but simply meant to be suggestive of possible values and magnitudes.
price. The opposite story unfolds below the strike price. Note that these effects are asymmetric as downward pressure from above the strike price is due to calls being ITM, upward pressure from below the strike price being due to ITM puts.

Our hypotheses related to Anders (1982) are twofold:

**Hypothesis AN-1:** ATM call volume is positively related to pinning from above the strike price. As we argued above, volume is related to the closing of positions. Thus, ATM call volume measures investor activities as calls go ITM and will lead to directional pinning, namely, to increased pinning from above the strike price as the future is being pushed downward closer towards the strike price.

**Hypothesis AN-2:** ATM put volume is positively related to pinning from below the strike price. The mechanism is exactly the opposite of hypothesis AN-1.

### I.C Early Exercise of Slightly In-The-Money Options

The next potential explanation of pinning is due to early exercise of ITM call options and simultaneous selling of the delivered underlying future. This puts downward pressure on the price of the future and as the effect reverses for ITM put options, options exercise can explain pinning.\(^6\)

The mechanism is very similar to Anders (1982) but based on individual investors exercising their American ITM options instead of selling them as in Anders (1982). Again, this is a realistic concern as the SP options are American. Individual investors will then buy the necessary future for delivery (in case of a put) or sell the delivered future (in case of a call) right away in the market. However, the results are just the same in terms of hedging and pinning as in Anders (1982). In detail, we start again with the future starting near the strike price and increasing above the strike price. The short straddle position of the market maker

\(^6\) This behavior has been documented in Chiang (2010), albeit with a focus on underlying stock returns and without referring to pinning.
changes from a delta of zero to about -0.5 delta and the hedge requires a purchase of 0.5 futures. Furthermore, when the investor exercises the ITM call, the market maker needs to buy additional 0.5 futures for the delivery of one future, which is then sold on the market by the investor. The net effect is thus the purchase of one future (0.5 + 0.5 futures) by the market maker and the selling of one future by the investor. However, the market maker still needs to hedge the remaining OTM put leg of the original sold straddle. As the OTM put option has a delta of about 0.25, the market maker needs to sell 0.25 of the future. The total market effect is hence 0.25 sold futures (= 0.5 + 0.5 – 1 – 0.25 futures) and the mechanism creates exactly the same downward pressure as in Anders (1982).

The hypotheses related to early option exercise are twofold again:

**Hypothesis EARLY-1:** *ATM call early option exercise is positively related to pinning from above the strike price.* ATM call option exercise measures investors winding down positions as the calls go ITM and will lead to directional pinning, namely, to increased pinning from above the strike price as the future is being pushed downward closer towards the strike price.

**Hypothesis EARLY-2:** *ATM put early option exercise is positively related to pinning from below the strike price.* The mechanism is exactly the opposite of the hypothesis EARLY-1.

### I.D Manipulation of the Underlying

Observationally equivalent to the pinning mechanisms of Anders (1982) and the early exercise explanation is the market manipulation mechanism of Ni, Pearson, and Poteshman (2005). Here, sophisticated market participants with short positions (i.e. the typical market maker in the SP options) could gain from manipulating the future. Namely, pushing the future downward from above the strike price would reduce payments to individual investors with long call option positions while pushing the future upward from below the strike price would reduce payments to individual investors with long put positions. We investigate to what extent pinning can be explained by the hedging mechanisms of Anders (1982) and early exercise mechanism. Only residual pinning should then be attributable to market
manipulation and would show up as additional explanatory power of volume of future trading which we use to measure manipulation.

However, as the futures market is very large and liquid, any manipulation should be rather difficult as it would involve large unhedged trades in order to move the future sufficiently for the purpose of manipulation. Such trades would leave the market maker vulnerable to price risk over the weekend which is undesirable for the market maker. Further, the risk of detection of the manipulation will also diminish the interest of the market maker in such activities. Moreover, pinning itself is risky for the market maker (so-called pin risk) and manipulation would increase this risk. Pin risk arises because, due to transaction costs, the option writer (i.e. the market maker) cannot predict with certainty whether the marginally ITM options will be exercised at the expiration. Hence, pinning aggravates the risk of ending with a naked position in the future over the weekend. Finally, small movements of the future through the strike price will lead to dramatic adjustments in the hedge (for a vanilla short call the delta of the hedge goes from 0 to unity as the future moves through the strike price from below). As a result, the market maker should be wary to increase pinning through manipulation and needs to carefully balance benefits and costs.

**Hypothesis NI-1:** Futures volume is insignificantly related to pinning after accounting for delta-hedging. Once we account for the delta hedging based explanations of pinning, we do not expect manipulation to play a large role anymore. Thus, adding futures volume as a variable should only contribute insignificantly to explaining pinning.

### I.E Volatility and Pinning

Pinning may also be related to general conditions in the futures market. In times of high volatility when the futures price crosses several strikes in a single day, we may expect that future volatility obscures pinning effects, a point also made by Avellaneda and Lipkin (2003). In their model the “strength” of the anti-pinning force is inversely related to the volatility of the underlying. The same logic of volatility weakening pinning effects applies also to other explanations of pinning.
**Hypothesis NI-2:** Futures volatility is negatively related to pinning. Future volatility makes delta hedging of the market maker more difficult and is thus negatively related to pinning.

**II. Methodology**

We are interested in testing for pinning in different option classes associated with the S&P 500 and, given that we find such pinning, in explaining which mechanisms explain this pinning. For the purpose of testing for pinning, we employ logistic regressions and additionally use a binomial test based on the uniform distribution of futures prices. The first test is a logistic regression with fixed effects, just as in Ni, Pearson, and Poteshman (2005). We use 5 days before and after each expiration day.

\[
\text{Pinn}_\text{sym}_t = \alpha + \beta \text{Dumm}_t + \varepsilon_t
\]  

(Pinn_sym) is taken to be a zero/one variable which is 1 if the future price at settlement is within $0.25 below or above the ATM strike price.\(^7\) We always take the ATM strike price to be the strike price closest to the future settlement price.

\[
Pinn\_\text{sym}_t = \begin{cases} 
1, & \text{if } |Fut_t - K_{\text{ATM}}| \leq 0.25; \\
0, & \text{otherwise};
\end{cases}
\]  

We define \text{Dumm}_t as 1 for expiration days and 0 otherwise. Similar to Pinn\_sym, we define Pinn\_above\_t and Pinn\_below\_t to be the $0.25 half-intervals above and below the ATM strike price, respectively, and use them as alternative dependent variables in equation (1):

\(^7\) We vary the size of the interval in the Robustness Section to $0.125 and $0.5, respectively.
The above logistic regression tests if pinning on expiration days is significantly higher than on non-expiration days. However, we are also interested in testing if pinning on expiration days is significantly higher compared to pinning due to independent draws from a uniform distribution of futures prices. We can then compute the p-value based on the following approximation which can be used as long as the number of observations n exceeds 90, based on Johnson, Kotz, and Kemp (1992, p. 114, equation 3.27):

\[
\Pr[X \geq x] \approx 1 - \Phi(\{x - 0.5 - nq\} / \{nq(1-q)\}^{0.5})
\]

where \(\Phi\) is the cumulative normal density and where the probability q of symmetric pinning is 10%. In our further work, we simply report this binomial p-value alongside the p-value of the logistic regression.

Once we establish pinning, we explore which mechanisms can explain the pinning. We use logistic regressions where we drop the expiration dummy and focus only on expiration Fridays. In accordance with our hypotheses in form of equation (6), we use additional right-hand-side variables such as option open interest, volume, option early exercise and others. We detail our independent variables below.

\[
Pinn_{sym} = \alpha + \beta \text{ right-hand-side variables, } + \varepsilon_i
\]
III. Data

We now turn to the description of the data sources and presentation of descriptive statistics of all variables.

III.A Data Sources

We obtain the whole history of daily data for S&P 500 futures and SP options on S&P 500 futures directly from the Chicago Mercantile Exchange (CME).

The futures data provides daily open, low, high, close, and settlement prices along with the daily open interest and volume for all maturities of futures from their introduction on April 21st, 1982 to December 31st, 2009. Similarly, the SP options data provides daily open, high, low, and close prices along with the daily open interest, volume, and early exercise for all individual options from their introduction on January 28th, 1983 to December 31st, 2009.

To test for pinning in the S&P 500 cash index, we additionally obtain the special A.M. exercise-settlement values (SET) of the S&P 500 from Market Data Express. Quarterly SET values run from June 1991 to December 2009 and serial SET values run from November 1992 to November 2009.

We also employ daily data for SPX options on the S&P 500 index for the period January 2nd, 1990 to December 31st, 2009, which we obtain from Market Data Express. The SPX options data comes along with daily open, high, low, close prices, open interest, and volume for all individual SPX options and the value of the underlying S&P 500 cash index.

Finally, in tests for pinning in the SPDR exchange traded fund on the S&P 500, we employ daily prices of SPDR for the period from January 29th, 1993 to December 31st, 2009, which we obtain from Datastream.

In our main tests, we focus on settlement prices of nearest to maturity futures on serial expiration dates (usually the third Friday of the month) which are available in the data from August 1987 to November 2009.

We use settlement prices as those determine the value of the expiring SP options. Further, since SP options always expire in nearest to maturity futures, we abstract from
longer dated futures. We corroborate this by showing below that there is no pinning in the second to maturity futures.

Since SP options trade on a monthly cycle and futures trade on a quarterly cycle (March, June, September, and December), we primarily focus on serial expiration months (all months excluding the quarterly cycle: January, February, April, May, July, August, October and November). These serial expiration days provide us with a unique laboratory of cases when SP options expire and the underlying future continues to trade for an additional month or two. It is exactly this feature that enables the future to finish in the proximity of the strike price. As opposed to serial expirations, on quarterly expiration days futures and SP options expire simultaneously in the cash value of the S&P 500 index. As the whole basket of S&P 500 stocks is difficult to move, we do not expect to find pinning in quarterly expirations. Again, the results below confirm our conjecture.

Finally, since SP options were first traded on a quarterly cycle, just like futures, and serial expirations for SP options were introduced only in June 1987 (and there is no data for SP options expiring in July 1987), we restrict the analysis to the period from August 1987 to November 2009. Also, as it is standard in derivatives research, we regularly eliminate two crash months, October 1987 and October 2008. However, adding them back to the analysis has virtually no effect on the results. Appendix A elaborates further on the main characteristics of the S&P 500 derivatives and the changes in the settlement procedures of these derivatives. Appendix B details the raw data processing.

III.B Variable Definition

Having defined our dependent variables already above, we now turn to defining our independent variables. First, ATM open interest is measured on the Thursday before expiration with respect to the ATM strike price on the expiration Friday. It is composed of ATM put and ATM call open interest, respectively. We add 10 to each variable and take logarithms. The transformed variables are labeled $OI$, $Call_{OI}$, and $Put_{OI}$.

Second, ATM volume is measured with respect to the ATM strike price on the serial expiration Friday. Again, it is composed of ATM put and ATM call volume, respectively.
We add 10 to each variable and take logarithms. The transformed variables are labeled $VOL$, $Call\_VOL$, and $Put\_VOL$.

Third, ATM early option exercise is measured with respect to the ATM strike price on the serial expiration Friday. And again, it is composed of ATM put and ATM call early option exercise, respectively. We add 10 to each variable and take logarithms. The transformed variables are labeled $OE$, $Call\_OE$, and $Put\_OE$.

Fourth, $Fut\_vol$ measures the logarithm of 10 plus the volume of futures contracts traded on the serial expiration Friday.

Last, $Fut\_sigma$ measures the volatility of futures one day before the expiration Friday. We use the Thursday before the expiration Friday to avoid endogeneity problems arising from the fact that pinning itself could lower the volatility of the future on expiration Friday. We approximate volatility by the Parkinson (1980) scaled daily realized range (see Martens and van Dijk, 2007):

$$Fut\_sigma = \frac{(\log(Fut\_high) - \log(Fut\_low))^2}{4 \log(2)}$$

(7)

where $Fut\_high$ is the intra-daily futures high price and $Fut\_low$ is the intra-daily futures low price.

Some independent variables have missing values. Since there is no generally accepted treatment for missing variables, we replace missing observations by the sample mean of the untransformed missing variable. If needed, we then transform all variables. Results are robust to alternative treatments of missing observations and are not affected if we use zero instead, nor if we eliminate the missing observations altogether. We provide details in the Robustness Section below.

More problematic is the early option exercise variable where the first half of the variable is missing. We are uncomfortable with imputing the missing values through some statistical procedure since too many observations are missing. Instead, we argue that we can start with the long sample of the standard model, which performs much like the short sample standard model where the option exercise is observable (January 1998 until November 2009).
Then, we can analyze the effect of options early exercise on the short sample. We detail the implementation of this approach in the results below.

### III.C Descriptive Statistics

We first look at the time pattern of SP option trading activity on the serial expiration dates as depicted in Figure 5. The data is used as reported in the original data (without taking logarithms and without the addition of 10) with missing values replaced by zeros. Panel A depicts ATM open interest, Panel B depicts ATM volume, and Panel C depicts ATM option exercise.

![Insert Figure 5 about here](image)

Figure 5 demonstrates that the SP option activity on the serial expiration dates rose over the years. Open interest and volume steadily increased from 1987 to approximately 1997, then they decreased somewhat and ramped again from 2004 to 2009. Hence, if pinning is related to option activity, we should observe more pinning in the more recent period which is confirmed in the results.

Table 1 reports the summary statistics of the transformed data for the full period from August 1987 to November 2009. Summary statistics for early options exercise is based on the short period from January 1998 to November 2009.

![Insert Table 1 about here](image)

Table 1 already reveals some interesting phenomena. First, from August 1987 to November 2009, 13.56% of futures prices settle within 0.25$ of the strike price on the serial expiration Fridays; on average much higher than the 10% expected under a uniform distribution. The result is even stronger if we focus on a more recent period which is characterized by increased options trading activity. Indeed, from January 1998 to November 2009, as much as 17.89% of futures prices settle within 0.25$ of the strike price.
Second, we notice that pinning from above the strike price is especially pronounced. For the full sample, pinning from above the strike price amounts to 8.47% and pinning from below the strike price amounts to 7.34%. In the short sample, the values are 11.58% for pinning from above and 9.47% for pinning from below.  

Table 2 reports the unconditional correlation structure between the main variables. Note that among the set of considered variables, option volume and early option exercise exhibit the highest unconditional correlations with symmetric pinning. The correlations are 0.14 and 0.16, respectively. Although the correlation between early option exercise and symmetric pinning is not directly comparable to the correlation between open interest and symmetric pinning because the latter is based on the short period, these results already suggest that option volume as well as option exercise play an important role for the documented pinning. Further, note that open interest is positively related to symmetric pinning. Although the correlation is very weak (0.01), the positive sign is somewhat surprising because, according to Avellaneda and Lipkin's (2003) anti-pinning argument, open interest should be negatively related to pinning. However, this unconditional correlation could be positive simply because open interest is highly correlated with option volume (pairwise correlation of 0.81). Indeed, we show in Section IV that, conditional on options volume, open interest is always negatively related to symmetric pinning. Finally, as expected, futures volatility is negatively related to pinning. Slightly surprising is the negative correlation between futures volume and pinning.

Table 3 complements Table 2 by providing unconditional correlations for the subvariables; symmetric pinning is broken down into pinning from above the strike price and pinning from below the strike price. Open interest, option volume, and early option exercise are reported separately for calls and puts. Although the correlations are not entirely conclusive, Table 3 demonstrates that volume and early option exercise for calls are specially

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8 Note that pinning from above and pinning from below do not exactly sum up to symmetric pinning as both include observations with zero deviation from the strike price.
related to pinning from above the strike price. For puts these quantities exhibit stronger
correlations with pinning from below the strike price.

[Insert Table 3 about here]

In unreported results, we find that recomputing Tables 1, 2, and 3 for the short sample
changes the point estimates but generally confirms the above descriptive statistics.

IV. Results

In our results section, we normally use the full sample from August 1987 to November 2009.
As detailed in Section III, there are some missing values and we replace those with the
sample mean of the respective variable. The variable early option exercise \((OE)\) misses the
first half of its values and we therefore analyze the effect of early option exercise only on the
short sample from January 1998 to November 2009. The dependent variable, \(Pinn\_sym\), will
be labeled \(Pinn\_sym^L\) in the long sample and \(Pinn\_sym^S\) in the short sample.

IV.A Pinning Does Exist in the Near Maturity Future Due to Serial SP Options

Using the long and short samples respectively, we analyze in equations (8) and (9) if
expiration Friday pinning (within $0.25 below and above the ATM strike price) is stronger
than pinning on the 5 days before and after expiration Friday. The p-values in parentheses
are based on the logistic regression. The p-values in brackets are based on the binomial
distribution of comparing Friday pinning against a uniform distribution without pinning.

\[
Pinn\_sym_i^L = -2.32 + 0.46 \text{ Dumm}_i + \epsilon_i
\]

\[
p\text{-value} \quad (0.00) \quad (0.05) \quad [0.07]
\]

(8)
\[ Pinn\ _{\text{sym}}^x = -2.41 + 0.89 \ Dumm_t + \varepsilon_i \]
\[
\begin{array}{c}
\text{p-value} \\
(0.00) \ (0.00) \ [0.01]
\end{array}
\]

For the long sample containing 177 expirations, we find supporting evidence for symmetric pinning, which affects the near maturity futures with p-values of 0.05 when compared to other days and of 0.07 when compared to the uniform distribution. Note however that in the period from June 1987 to December 1993 there exist liquid SPX options that also expire P.M. and could therefore disrupt pinning in the futures. Excluding this period, we find that both p-values decrease to 0.02. Further, as reported in equation (9), the evidence for pinning is even stronger, with p-values of 0.00 and 0.01 respectively, in the short sample despite the reduced sample size (95 expirations), indicating that pinning increased substantially during the last decade.

Probing in more detail, we next investigate asymmetric pinning in the long sample. In equations (10) and (11) we analyze pinning from above and below, respectively.

\[ Pinn\ _{\text{above}}^L = -2.92 + 0.54 \ Dumm_t + \varepsilon_i \]
\[
\begin{array}{c}
\text{p-value} \\
(0.00) \ (0.07) \ [0.03]
\end{array}
\]

\[ Pinn\ _{\text{below}}^L = -2.96 + 0.43 \ Dumm_t + \varepsilon_i \]
\[
\begin{array}{c}
\text{p-value} \\
(0.00) \ (0.17) \ [0.10]
\end{array}
\]

While we find supporting evidence for pinning from above (p-values of 0.07 against other days and 0.03 against the uniform distribution), the evidence is weaker for pinning from below with p-values of 0.17 and 0.10. These findings are consistent with the fact that arbitraging away pinning from below is much harder than pinning from above. When pinning from below occurs, then the arbitrage trade involves selling the overpriced future and buying the index basket which is expensive but feasible. However, arbitraging pinning from below...
above involves buying the underpriced future and (short) selling the index basket which is much harder to do. Thus, pinning from above is likely to exist more often than pinning from below as the latter is easier to arbitrage away.

Same as for symmetric pinning, asymmetric pinning is stronger in the short sample with all p-values being lower. For pinning from above the p-values are now 0.01 and 0.00, respectively. For pinning from below, both p-values are 0.04 and thus provide stronger evidence for asymmetric pinning during the last decade.

IV.B Mechanisms of Pinning in the Near Maturity Future

Since we established pinning in the near maturity futures, we now embark on analyzing the mechanisms which drive this pinning. Our first set of hypotheses is based on the time-decay in the delta hedge as modeled by Avellaneda and Lipkin (2003).

Hypothesis AL-1 ATM open interest is negatively related to pinning and
Hypothesis AL-2 ATM option volume is positively related to pinning.

\[
Pinn_{sym}^L = -4.68 - 1.28 \text{OI}_t + 1.65 \text{VOL}_t + \varepsilon_t
\]

\[
p-value \quad (0.02) \quad (0.00) \quad (0.00)
\]

(12)

In the long sample, we find according to equation (12) that both variables are strongly significant and have indeed the expected signs. ATM open interest reduces pinning and ATM volume increases pinning.\(^{10}\)

In testing the remaining hypothesis of Avellaneda and Lipkin, we would like to investigate if it is true that

Hypothesis AL-3 ATM early option exercise is positively related to pinning.

The variable early option exercise (OE), which we would like to use here is problematic as we do not trust the first part of the sample where there are mostly zero values

\(^{10}\) There is little autocorrelation in the residuals as the AR(1) of the residuals is 0.05 and is statistically insignificant.
recorded and some few extremely low values. However, starting January 1998, the values are much more realistic. Rather than imputing the first half of the sample, we suggest the following method. We first reestablish the above results for hypotheses AL-1 and AL-2 on the short sample from January 1998 to November 2009. This is demonstrated in equation (13) and while the point estimates vary somewhat when compared to equation (12), the signs are stable and all coefficients are significant. Then we use the short sample while including early option exercise (OE) in our model and report the results in equation (14). While ATM early option exercise exhibits the correct sign, it is insignificant with a p-value of 0.30. We are afraid that this could be due to the reduced power as we are only using 95 observations in the short sample as opposed to 177 observations in the long sample.

\[
Pinn_{sym}^s = -4.39 - 1.11 OI_t + 1.49 VOL_t + \varepsilon_t
\]

\[
p-value \quad (0.05) \quad (0.03) \quad (0.02)
\]

\[
Pinn_{sym}^s = -4.28 - 1.14 OI_t + 1.27 VOL_t + 0.28 OE_t + \varepsilon_t
\]

\[
p-value \quad (0.05) \quad (0.03) \quad (0.05) \quad (0.30)
\]

Next, we turn our attention to the asymmetric pinning effects of Anders (1982). We conceptually revert to the setting of equation (12) where we investigated the effects of open interest and volume in the long sample. However, we now separate the volume effects into ATM call and put volume. The hypotheses are:

**Hypothesis AN-1**  
ATM call volume is positively related to pinning from above the strike price and

**Hypothesis AN-2**  
ATM put volume is positively related to pinning from below the strike price.

We use ATM call volume and ATM put volume in addition to ATM open interest in order to explain pinning from above the strike price in equation (15) and pinning from below the strike price in equation (16).
Pinning from above the strike price is supported by equation (15) since ATM call volume increases the propensity of pinning from above the strike price and ATM put volume is insignificant, as expected. The evidence in favor of pinning from below the strike price is somewhat weaker. ATM call volume in equation (16) is insignificant, as expected, but ATM put volume has the right sign but is insignificant with a p-value of 0.23. This asymmetry is not entirely surprising as we argued above in the light of arbitrage trades: since pinning from below involves buying the index, it is easier to arbitrage away than pinning from above where the arbitrage trade involves (short) selling the index. Using the short sample, the signs remain as in equations (15) and (16) while the p-values decrease.

Now we investigate the closely related mechanism of early option exercise which leads to following two hypotheses:

**Hypothesis EARLY-1**  
ATM call early option exercise is positively related to pinning from above the strike price and

**Hypothesis EARLY-2**  
ATM put early option exercise is positively related to pinning from below the strike price.

We are using again the standard model of equation (13) applied to the short sample due to the missing data in the early option exercise variable. Equation (17) shows the results for pinning from above the strike price and equation (18) for pinning from below the strike price. Pinning from above the strike price indeed seems to be driven by call early option exercise (although the p-value is only significant at the 10% level) and put early option exercise is insignificant, as expected. Pinning from below the strike price is also supported with a significant contribution on the put early option exercise and an insignificant coefficient of the call early option exercise. All early option exercise coefficients are positive.
\[ Pinn_{\text{above}, i}^S = -2.13 - 0.60\ OI_i + 0.26\ VOL_i + 0.48\ Call\ OE_i + 0.04\ Put\ OE_i + \varepsilon_i \]
\[ Pinn_{\text{below}, i}^S = -1.30 - 1.40\ OI_i + 0.42\ VOL_i + 0.44\ Call\ OE_i + 0.83\ Put\ OE_i + \varepsilon_i \]

We next turn to potential market manipulation and investigate:

**Hypothesis NI-1**  
*Futures volume is insignificantly related to pinning after accounting for delta-hedging.*

We use as a point of departure the model in equation (14) which includes ATM open interest, ATM volume, and early option exercise. As we use early option exercise, we can only use the short sample. We then add the variable future volume and report the result in equation (19). The result repeats much of equation (14) in that ATM open interest and volume are significant and while all variables have the right sign, early option exercise is insignificant. The addition of future volume leads, as expected, to insignificant coefficients. We conclude that market manipulation does not seem to explain pinning.

\[ Pinn_{\text{sym}, i}^S = -1.69 - 1.17\ OI_i + 1.29\ VOL_i + 0.26\ OE_i - 0.22\ Fut\ vol_i + \varepsilon_i \]

Finally, we analyze the influence of volatility on pinning and test

**Hypothesis NI-2:**  
*Futures volatility is negatively related to pinning.*

As in the case of Hypothesis NI-1, we use as a point of departure the short sample and model (14), which includes ATM open interest, ATM volume, and early option exercise. We then add future volatility and report the results in equation (20). In line with our hypothesis, futures volatility is negatively related to pinning but the p-value is insignificant at 0.13. Furthermore, adding futures volatility to model (14) slightly increases the significance of other variables, such as open interest and option volume. This suggests that volatility indeed weakens the pinning forces of the market maker’s delta hedging activity.
In summary, regarding the serial SP options we find evidence that pinning is explained by the interplay of time-decay of the delta hedge (anti-pinning due to Avellaneda and Lipkin 2003) and pinning due to the hedging effects of Anders (1982). Pinning due to the hedging effect caused by early option exercise is insignificant, possibly due to the shorter sample over which the data is available. Market manipulation does not seem to contribute to the explanation. Volatility of the underlying seems to have little impact on the pinning effects of delta hedging.

**IV.C No Pinning in Second to Maturity Futures**

SP options expire in the nearest (first) to maturity futures. Hence, if pinning is related to option expiration, it should be present in the first to maturity futures, as documented in Subsection IV.A, and it should be absent for longer maturity futures. To investigate whether there is any evidence for pinning in longer maturity futures, we next measure symmetric pinning in the second to maturity futures on serial expiration dates.\textsuperscript{11} We repeat the model of equation (8):

\[
Pinn_{sym}^{s} = -3.56 - 1.39\text{ OI}_{t} + 1.53\text{ VOL}_{t} + 0.28\text{ OE}_{t} - 6.32\text{ Fut}_{t} \sigma_{t} + \varepsilon_{t}
\]

\text{p-value} \begin{pmatrix} (0.13) \\ (0.01) \\ (0.03) \\ (0.30) \\ (0.13) \end{pmatrix}

(20)

\[
Pinn_{sym}^{L} = -1.95 - 0.36\text{ Dumm}_{t} + \varepsilon_{t}
\]

\text{p-value} \begin{pmatrix} (0.00) \\ (0.19) \end{pmatrix}

(21)

In the long sample, based on the insignificant p-values we conclude that there is no evidence for pinning in the serial expiration dates for second to maturity futures. This finding continues to hold in the short sample.

\textsuperscript{11} We do not use third to maturity futures since their strike price intervals are either $10 or $25 instead of always $5 for the first and second to maturity futures.
IV.D No Pinning in Quarterly Expirations

We next investigate whether there is any evidence for pinning in the future settlement price on quarterly expiration days. As opposed to the above analyzed serial expirations, on quarterly expiration days futures and SP options expire simultaneously in the value of the underlying S&P 500 index. Thus, pinning should be much harder in the quarterly expirations as the future needs to finish in the value of the underlying and any pinning in the settlement prices of futures would imply that there is pinning in the S&P 500 index. As the whole basket of S&P 500 stocks is difficult to move, we do not expect to find pinning in quarterly expirations for futures.

Also, on quarterly expirations, SP options expire into the cash-settled value of the underlying whereas the above serial SP options expire in the physically delivered future. Therefore, the fear of ending up with a naked position in the underlying does not apply to SP quarterly options and Anders (1982) story of reselling options on the expiration date does not work. For the same reason, the early exercise story does not apply. The only remaining explanation for pinning (ignoring manipulation) is the anti-pinning story of Avellaneda and Lipkin (2003). Thus, if there is any pinning in the futures settlement prices on quarterly expirations, it should be anti-pinning.

Before measuring pinning on quarterly expirations, one final remark is in order. Note that we have the data for quarterly expirations for the whole period from March 1983 to December 2009. But the settlement procedures for quarterly expirations underwent two important changes (see Appendix A for details). To take into account these changes, we measure pinning on quarterly expirations using the P.M. settlement futures prices on the third Thursday for the period from March 1983 to March 1984, the P.M. settlement futures price on the third Friday from June 1984 to March 1987, and the A.M. settlement price (which is determined by the first opening price of all the constituents of the S&P 500 index) for the period from June 1987 to December 2009. Altogether we have 108 quarterly expirations.

We cannot use our usual logistic regressions of equations (8) and (9) as we do not have A.M. settlement prices for the days surrounding the expiration Friday. However, we can test against the uniform distribution. With a p-value of 0.77 in the long sample, we do
not find evidence in favor of pinning in the quarterly expirations. The same picture emerges in the short sample with a p-value of 0.72 which due to a small number of observations (48), we calculate directly from the binomial distribution.

To further complicate matters, the quarterly SPX options on the S&P 500 index also expire at the same time into the same value. However, from June 1987 to December 1993 two types of SPX options co-existed, one that expired P.M. and another that expired A.M. Since this can potentially disrupt pinning in the quarterly expirations, we rerun the long sample without this period (the short sample remains unaffected by this period). The p-value goes up to 0.91. Realizing that 1 minus the p-value is the one-sided test for having anti-pinning, this, if anything, is slight evidence for anti-pinning in line with Avellaneda and Lipkin (2003). However, extending our research into this direction and running the mechanism regression of equation (12), we only obtain insignificant coefficients on open interest and option volume.

IV.E No Pinning in the S&P 500 Index Due to Serial SPX Options

If pinning is related to option expirations, we could potentially also observe pinning in the S&P 500 index itself as there are very liquid SPX options written on the index. However, as we argued in Section IV.D, it is hard to imagine that market makers’ hedging needs would be strong enough to move the whole basket of 500 stocks.

Also, the market maker does not necessarily hedge SPX options by trading the underlying basket of S&P 500 stocks. As an alternative to trading the basket, the market maker could hedge SPX options by trading the SPDR (an exchange traded fund replicating the S&P 500 index), by trading S&P 500 futures, or by trading options on the SPDR (SPY options). It is beyond the scope of the current paper to analyze the cross effects between these markets, but it is on our research agenda. Any such hedging would weaken potential pinning in the index itself.

Furthermore, from April 1986 to May 1987, all SPX options expired in the P.M. value of the underlying S&P 500 index. Some SPX options continued to do so until December 1993. However, starting in June 1987 some SPX options settle in the so-called A.M.
exercise-settlement value which became the standard settlement for all SPX options starting January 1994. Since the main reason behind the introduction of the so-called A.M. settlement was to prevent manipulation, the likelihood of detecting pinning should be even smaller.

Last, contrary to serial SP options, SPX options are cash settled (just like quarterly SP options). Therefore, the fear of ending with a naked position in the underlying does not apply to SPX options and Anders (1982) story of reselling options on the expiration date does not work. Further, the early exercise story is ruled out as SPX options are European. The only remaining explanation for pinning (ignoring manipulation) is the negative pinning story of Avellaneda and Lipkin (2003). Thus, if there is any pinning in the S&P 500 itself, it should be anti-pinning.

We test for pinning in the S&P 500 index on serial expirations in the long sample (we exclude quarterly observations as they are already analyzed above). The European serial SPX options exist since April 1986, but the settlement procedures for SPX options underwent some changes (see Appendix A for details). In line with these changes, we measure pinning using P.M. values of S&P 500 from April 1986 until October 1992 and A.M. exercise-settlement values of the S&P 500 from November 1992 to November 2009. As usual, we eliminate October 1987 and October 2008. We are left with 188 expirations.

We cannot use our usual logistic regressions of equations (8) and (9) as we do not have A.M. settlement prices for the days surrounding the expiration Friday. However, we can test against the uniform distribution. With a p-value of 0.62 in the long sample, we do not find evidence in favor of pinning. The same picture emerges in the short sample with a p-value of 0.63.

Again, we are concerned about the period from July 1987 until November 1993 where SPX options existed expiring both A.M. and P.M. Eliminating this period from the sample yields a p-value of 0.73. We conclude that there is no evidence of pinning due to the SPX options in the index.
IV.F No Pinning in the SPDR Due to SPY Options

The last market for which we investigate pinning is the SPDR exchange traded fund on the S&P 500 index. American SPY options on the SPDR exist since January 2005 (with data available until December 2009), trade on a monthly cycle, have physical delivery, and expire on the third Friday of the expiration month. Thus, in principle all three theoretical mechanisms could lead to pinning in this market. However, much like the basket of 500 securities for the index, shorting the SPDR is difficult. We repeat the model of equation (9) where the p-value for the uniform distribution is calculated from the binomial distribution directly as the number of observations is only 59:

\[
Pinn_{sym}^s = -2.20 + 0.19 Dum_{i} + \epsilon_{i}
\]

\[
p-value \quad (0.00) \quad (0.65) \quad [0.38]
\]

Based on the insignificant p-values we conclude that there is no evidence for pinning in the SPDR.

V. Robustness

We show that our results are robust to a number of methodological changes. The biggest concern is the correct choice of the pinning interval which we so far set to $0.25 above and below the ATM strike price. Here, the significance of the results can be affected. Other changes to the methodology such as the treatment of missing variables, the treatment of holidays occurring on the third Friday of a month, or the inclusion of two crash months does not affect the results at all.
V.A Pinning Intervals

Our definition of pinning as cases when the futures settlement price is within $0.25 of the nearest strike price is somewhat arbitrary, even though Ni, Pedersen, and Poteshman (2005) also use this value as well as $0.125. Theory does not provide a clear suggestion for the size of the pinning interval. Choosing the interval too small results in very few instances of pinning and the associated test statistics will be very noisy. Choosing the interval too large and beyond the region where hedging pressure is influencing futures prices will again lead to insignificant results.

We recall the standard model in equations (8) and (9) where we test for pinning on expiration Fridays compared to other days and compared to the uniform distribution. The p-values for the interval of $0.25 below or above the strike price were 0.05 and 0.07, respectively, in the long sample, and even stronger at 0.00 and 0.01 in the short sample.

We now repeat the regressions with intervals restricted to $0.125 below or above the strike price:

\[
Pinn_{sym, L} = -3.05 + 0.24 \pmb{Dumm} + \varepsilon, \]
\[
\text{p-value} \quad (0.00) \quad (0.50) \quad [0.41] \quad (23)
\]

\[
Pinn_{sym, S} = -3.23 + 0.70 \pmb{Dumm} + \varepsilon, \]
\[
\text{p-value} \quad (0.00) \quad (0.10) \quad [0.21] \quad (24)
\]

As expected, the p-values increase and are all insignificant, 0.50 and 0.41 in the long sample and 0.10 and 0.21 in the short sample. The sign of the dummy variable stays positive.

We finally repeat the regressions with intervals restricted to $0.5 below or above the strike price:

\[
Pinn_{sym, L} = -1.28 + 0.26 \pmb{Dumm} + \varepsilon, \]
\[
\text{p-value} \quad (0.00) \quad (0.14) \quad [0.02] \quad (25)
\]
\[ Pinn_{sym}^S = -1.24 + 0.42 \, Dumm_i + \varepsilon_i \]  

\[
p-value \quad (0.00) \quad (0.08) \quad [0.01] \]

The p-values increase somewhat compared to the interval based on $0.25$. For the long sample, the p-values are 0.14 and 0.02. For the short sample, the p-values are 0.08 and 0.01. Thus, only the logistic regression is insignificant at the 10% level in the long sample. All coefficients are positive.

We interpret these findings to imply that the interval over which pinning effects occur is indeed restricted and is approximately $0.25$ below and above the ATM strike price. This relatively small interval further suggests that ITM or OTM variables from outside the force-field will not lead to pinning. For this reason, in the explanations for pinning, we focus exclusively on trading activity of ATM options.

With regard to the mechanisms explaining pinning, we recomputed all regression models in equations (14) through (20) and summarize the results as follows. Results in the long sample are generally robust to the choice of the size of the interval, but results weaken somewhat in the short sample. Also, the anti-pinning effect of Avellaneda and Lipkin (2003) seems to be somewhat stronger for smaller intervals. Altogether, we conclude that our results are robust to variations in the pinning interval.

V.B Missing Values

Results seem robust to alternative treatments of missing values. Our main runs are based on filling in missing values with the sample mean of the variable (the first half of option early exercise is never filled in but treated separately by running short sample regressions). We compare two different treatments of missing values by rerunning equation (12). However, eliminating observations with missing values from the sample (8 missing observations) does not change the qualitative results. As reported in model (27), the estimated parameters are only marginally different from model (12) and they remain highly statistically significant.
\[ Pinn_{sym_i} = -4.65 - 1.23 \text{OI}_i + 1.60 \text{VOL}_i + \epsilon_i \]

\[ p\text{-value} \quad (0.02) \quad (0.00) \quad (0.00) \] (27)

Results are also robust to replacing missing observations with zeros which we test in equation (28). In this case, the estimated parameters on open interest and option volume decrease by about half a standard deviation and open interest has a slightly higher p-value but remains significant at the 5% level.

\[ Pinn_{sym_i} = -5.19 - 0.98 \text{OI}_i + 1.43 \text{VOL}_i + \epsilon_i \]

\[ p\text{-value} \quad (0.01) \quad (0.02) \quad (0.00) \] (28)

V.C Holidays on the Third Friday

Expiration days usually fall on the third Friday of the month. If the third Friday is a holiday then the Thursday before the third Friday is used. In our sample, it occurs only three times that the serial expiration does not fall on a Friday. Since these are unusual expiration days, we next estimate our main expiration dummy models (8) and (9) using only serial expirations that occur on Fridays. We are left with 174 observations. The sign of the coefficient stays positive and all p-values stay the same or even decrease. Finally, we rerun equation (12) and, as reported in equation (29), all results survive and even exhibit larger coefficients.

\[ Pinn_{sym_i} = -4.12 - 1.44 \text{OI}_i + 1.74 \text{VOL}_i + \epsilon_i \]

\[ p\text{-value} \quad (0.04) \quad (0.00) \quad (0.00) \] (29)

V.D Crash Months

In our main runs we always exclude October 1987 and October 2008. We rerun our main expiration dummy models (8) and (9) using all the serial expiration days which gives us
179 observations. All results come through with minimally smaller coefficients and minimally larger p-values. Rerunning equation (12), we confirm in equation (30) that the inclusion of the crash months does not have an impact on our conclusions as the results remain virtually unchanged.

\[
Pinn_{sym,t} = -4.71 - 1.29 \text{ } OI_t + 1.67 \text{ } VOL_t + \epsilon_t
\]

p-value \hspace{1cm} (0.02) \hspace{1cm} (0.00) \hspace{1cm} (0.00) \hspace{1cm} (30)

VI. Conclusion

We investigate SP option induced pinning in the market for futures on the S&P 500 index. Pinning describes the tendency of the underlying future to be attracted to strike prices on expiration Friday of the option. Such behavior is surprising in light of our typical understanding of finance which suggests that any closing price of the underlying is reached with equal probability.

Ni, Pearson, and Poteshman (2005) documented such behavior for stock options and practitioners believe strongly that stock pinning exists even though the statistical verification is at times replaced by verbal assertion, e.g. Augen (2009, pp. 26). Here, we document pinning in the much larger and more liquid futures market on the S&P 500 index. We show that S&P 500 futures finish in the proximity of the strike price more often on days when SP options on S&P 500 futures expire and the underlying future continues to trade than on other days. Interestingly, there is no pinning in the S&P 500 index itself nor in the SPDR exchange traded fund on the S&P 500 index as both underlying securities (the basket of 500 securities and the SPDR, respectively) are much harder to trade - and virtually impossible to short - than the future on the S&P 500 index.

In analyzing the economic mechanisms which drive index futures pinning, we find that they differ considerably from the mechanisms driving stock pinning. Concerning stock pinning, Ni, Pearson, and Poteshman (2005) suggest that the effect is largely driven by the time-decay of the delta hedge of market makers who are typically long the stock options, see Avellaneda and Lipkin (2003) for the model. Also, Ni, Pearson, and Poteshman (2005) argue
that manipulation plays a role. For index futures pinning, neither of these two effects is wholly convincing. For one, Garleanu, Pedersen, and Poteshman (2010) report that the market maker is typically short index options as opposed to long stock options which suggests anti-pinning and not pinning in the closely related market for SP options on the index futures. Second, manipulation seems much harder in the index futures and is thus less likely to serve as an explanation.

We resolve the puzzle by introducing two additional effects which lead to pinning, namely hedging pressure resulting from individual investors selling their in-the-money options (Anders 1982) and a related mechanism of individual investors early exercising their in-the-money options. We can document that the time-decay of the delta hedge does indeed lead to anti-pinning but is overcompensated by the two additional mechanism. We do not find evidence of manipulation.

An exciting field of study beyond the scope of the current paper is the interaction across markets. So could pinning in the future also be driven by the SP options on the underlying S&P 500 index while pinning from the options on the index future should be much less likely to lead to pinning in the (hard to move) index itself.
References

Appendix A: The Main Characteristics of S&P 500 Derivatives

S&P 500 Futures and SP Options on S&P 500 Futures. Futures on S&P 500 and options on S&P 500 futures are traded on the Chicago Merchandise Exchange (CME). Futures were introduced on April 21st, 1982 and SP options were introduced approximately one year later, on January 28th, 1983. SP options are American. First and second closest to maturity options have strike price intervals of $5 and options for deferred months trade with strike price intervals of either $10 or $25.

When futures and SP options were first introduced, they initially expired in the P.M. cash value of the S&P 500 index on the third Thursday in a quarterly cycle (March, June, September, and December). This settlement procedure however underwent three important changes. In June 1984, CME decided to shift expiration dates from the third Thursday to the third Friday of the month.

In June 1987, two additional changes were introduced. First, quarterly futures and SP options no longer expired in the P.M. value of the index, but in the special opening value of the index on the third Friday of the month, the so called A.M. expiration. The special opening value of the index is determined by the first opening prices of all the constituents of the index. It is also called special opening quotation (SOQ) or exercise-settlement value of the index (SET). Second, CME introduced serial SP options that expire in the closest to maturity futures on the third Friday of the serial months (January, February, April, May, July, August, October, and November).

This last introduction of the serial options is of crucial importance for our study. We state three main differences between quarterly and serial SP options:

- First, while quarterly SP options expire simultaneously with the underlying future, serial SP options expire while the underlying future continues to trade for an additional month or two.

- Second, while quarterly SP options expire in the A.M. value of the S&P 500 index (like futures), serial SP options expire in the P.M. value of the underlying future.
Third, while quarterly SP options are cash settled, serial SP options lead to physical delivery of the underlying future.

**SPX Options on the S&P 500 Index.** European SPX options on S&P 500 index are traded on the Chicago Board of Options Exchange (CBOE) since April 2nd, 1986. All SPX options are cash-settled and trade on a monthly cycle (serial expirations plus quarterly expirations). Nearest to maturity options have strike price intervals of $5 and options for deferred months have strike price intervals of $25.

Initially, SPX options expired in the P.M. value of the S&P 500 on the third Friday in a month. With the introduction of the A.M. settlement for futures and quarterly SP options by the CME in June 1987, CBOE decided to introduce another set of options that also expire A.M. For a while both sets of options coexisted, until in June 1992, CBOE decided that all SPX options should expire A.M. Ever since, all SPX options (serial expirations and quarterly expirations) expire in the special A.M. opening value. Thus, on quarterly expirations, SPX options, SP options, and futures expire in the same special opening value of the S&P 500 index.

**SPY Options on the SPDR Exchange Traded Funds on the S&P 500 Index.** SPY options on SPDR exist since January 2005. Like SPX options, SPY options trade on a monthly cycle and expire on the third Friday of the expiration month (see Footnote 11). However, unlike SPX options, SPY options are American and are settled by delivery of the underlying

The above information is also summarized in Table A.1.

[Table A.1 about here]

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12 Technically, it is the Saturday following the third Friday of the month. However, since the settlement value is being determined on Friday already, we will keep on referring to all expiration dates as (third) Fridays.
Appendix B: Treatment (Filtering) of the Main Data

We obtain the data from two sources: the Chicago Mercantile Exchange (CME) and Market Data Express, the official provider of Chicago Board of Options Exchange (CBOE) data. From CME, we obtain the whole history of daily data for S&P 500 futures and SP options on S&P 500 futures. From Market Data Express, we obtain daily data for SPX options on the S&P 500. From Market Data Express, we also obtain a separate file with exercise-settlement values (SET) for SPX options.


In all the datasets, we first filter out observations with missing values for any of the key variables. Further, we eliminate duplicate entries (that is, we keep one of the duplicate entries). Below, we describe specific adjustments to each dataset.

S&P 500 Futures. CME does not provide exact expiration dates. The data only contains the expiration year and the expiration month. Therefore, we manually complement the data with the exact expiration dates (usually the third Friday in the quarterly cycle) and eliminate futures with negative time to maturity.

SP Options on S&P 500 Futures. Similarly to the futures data, the SP options data only contains the expiration year and the expiration month. Therefore, we manually complement the data with the exact expiration dates (usually the third Friday of the month) and eliminate options with negative time to maturity.

SPX Options on the S&P 500 Index. Market Data Express is a comprehensive source for SPX options, covering not only standard SPX options, but also LEAPS (long dated options), quarterlies, weeklies, and mini options.
First, we eliminate all the options with last bid equal to 998 and last ask equal to 999 as those values stand for erratum in the data. Further, we eliminate LEAPS, non-index options, weeklies, quarterlies, and mini options. Finally, as all the expiration dates in the Market Data Express are set to Saturday following the third Friday in a month, we move the expiration dates one day to the third Friday.
Table 1: Summary Statistics

This table collects the summary statistics for the serial expiration dates in the period August 1987 to November 2009 (excluding October 1987 and October 2008). Symmetric pinning \( Pinn\_sym \) is a zero/one variable, which is 1 if the future settlement price is within $0.25 to the left or right of the ATM strike price. Similarly, \( Pinn\_above \) and \( Pinn\_below \) are zero/one variables that take a value of one if the future settlement price is within $0.25 above or below of the ATM strike price, respectively. ATM open interest \( OI \) is measured one day before the serial expiration day with respect to ATM strike price on the serial expiration day. It is a sum of ATM call open interest \( Call\_OI \) and ATM put open interest \( Put\_OI \). ATM volume \( VOL \) and ATM options exercise \( OE \) are both measured on the serial expiration date with respect to the ATM strike price. ATM volume is the sum of ATM call volume \( Call\_VOL \) and ATM put volume \( Put\_VOL \). Similarly, ATM option exercise \( OE \) is the sum of ATM call option exercise \( Call\_OE \) and ATM put option exercise \( Put\_OE \). Futures volume \( Fut\_vol \) measures the number of contracts traded on the serial expiration Friday. Futures volatility \( Fut\_sigma \) is a scaled realized daily range measured one day before the expiration date. We replace missing observations by the mean of non-missing observations. Numbers in brackets next to number of observations denotes a number of non-missing observations for each variable. Summary statistics for \( OE \) are based on the period January 1998 to November 2009. We add 10 to all open interest, option and futures volume, and early option exercise values and take logarithms.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subvariable</th>
<th>NObs</th>
<th>Mean</th>
<th>StdDev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Pinn_sym )</td>
<td>177 (177)</td>
<td>0.14</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>( Pinn_above )</td>
<td>177 (177)</td>
<td>0.09</td>
<td>0.28</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>( Pinn_below )</td>
<td>177 (177)</td>
<td>0.07</td>
<td>0.26</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>( OI )</td>
<td>177 (169)</td>
<td>7.43</td>
<td>0.98</td>
<td>3.53</td>
<td>9.69</td>
<td></td>
</tr>
<tr>
<td>( Call_OI )</td>
<td>177 (170)</td>
<td>6.75</td>
<td>1.21</td>
<td>2.48</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td>( Put_OI )</td>
<td>177 (175)</td>
<td>6.24</td>
<td>1.38</td>
<td>2.40</td>
<td>9.36</td>
<td></td>
</tr>
<tr>
<td>( VOL )</td>
<td>177 (175)</td>
<td>7.27</td>
<td>1.04</td>
<td>3.09</td>
<td>9.72</td>
<td></td>
</tr>
<tr>
<td>( Call_VOL )</td>
<td>177 (175)</td>
<td>6.56</td>
<td>1.17</td>
<td>2.94</td>
<td>9.38</td>
<td></td>
</tr>
<tr>
<td>( Put_VOL )</td>
<td>177 (177)</td>
<td>6.21</td>
<td>1.34</td>
<td>2.30</td>
<td>8.68</td>
<td></td>
</tr>
<tr>
<td>( OE )</td>
<td>95 (94)</td>
<td>5.78</td>
<td>1.55</td>
<td>2.30</td>
<td>9.18</td>
<td></td>
</tr>
<tr>
<td>( Call_OE )</td>
<td>95 (94)</td>
<td>4.29</td>
<td>2.01</td>
<td>2.30</td>
<td>8.16</td>
<td></td>
</tr>
<tr>
<td>( Put_OE )</td>
<td>95 (95)</td>
<td>4.30</td>
<td>1.97</td>
<td>2.30</td>
<td>8.89</td>
<td></td>
</tr>
<tr>
<td>( Fut_vol )</td>
<td>177 (177)</td>
<td>10.79</td>
<td>0.43</td>
<td>9.62</td>
<td>11.99</td>
<td></td>
</tr>
<tr>
<td>( Fut_sigma )</td>
<td>177 (177)</td>
<td>0.13</td>
<td>0.10</td>
<td>0.03</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Unconditional Correlation Structure for the Main Variables

This table collects the unconditional correlations for the main variables for the serial expiration dates in the period August 1987 to November 2009 (excluding October 1987 and October 2008). Symmetric pinning $Pinn_{sym}$ is a zero/one variable, which is 1 if the future settlement price is within $0.25 to the left or right of the ATM strike price. ATM open interest $OI$ is measured one day before the serial expiration day with respect to ATM strike price on the serial expiration day. ATM volume $VOL$ and ATM options exercise $OE$ are both measured on the serial expiration date with respect to the ATM strike price. Futures volume $Fut_{vol}$ measures the number of contracts traded on the serial expiration Friday. Futures volatility $Fut_{sigma}$ is a scaled realized daily range measured one day before the expiration date. We replace missing observations by the mean of non-missing observations. Correlations for $OE$ are based on the period January 1998 to November 2009. We add 10 to open interest, option and futures volume, and early option exercise values and take logarithms.

<table>
<thead>
<tr>
<th></th>
<th>$Pinn_{sym}$</th>
<th>$OI$</th>
<th>$VOL$</th>
<th>$OE$</th>
<th>$Fut_{vol}$</th>
<th>$Fut_{sigma}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Pinn_{sym}$</td>
<td>1.00</td>
<td>0.01</td>
<td>0.14</td>
<td>0.16</td>
<td>-0.10</td>
<td>-0.04</td>
</tr>
<tr>
<td>$OI$</td>
<td>1.00</td>
<td>0.81</td>
<td>0.44</td>
<td>0.00</td>
<td>-0.07</td>
<td>-0.18</td>
</tr>
<tr>
<td>$VOL$</td>
<td>1.00</td>
<td>0.49</td>
<td>0.00</td>
<td>-0.50</td>
<td>-0.03</td>
<td></td>
</tr>
<tr>
<td>$OE$</td>
<td>1.00</td>
<td></td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Fut_{vol}$</td>
<td></td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Fut_{sigma}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Unconditional Correlation Structure for the Subvariables

This table collects unconditional correlations for the subvariables for the serial expiration dates in the period August 1987 to November 2009 (excluding October 1987 and October 2008). Symmetric pinning \( \text{Pinn}_\text{sym} \) is a zero/one variable, which is 1 if the future settlement price is within $0.25 to the left or right of the ATM strike price. Similarly, \( \text{Pinn}_\text{above} \) and \( \text{Pinn}_\text{below} \) are zero/one variables that take a value of one if the future settlement price is within $0.25 above or below of the ATM strike price, respectively. ATM open interest \( \text{OI} \) is measured one day before the serial expiration day with respect to ATM strike price on the serial expiration day. It is a sum of ATM call open interest \( \text{Call}_\text{OI} \) and ATM put open interest \( \text{Put}_\text{OI} \). ATM volume \( \text{VOL} \) and ATM options exercise \( \text{OE} \) are both measured on the serial expiration date with respect to the ATM strike price. ATM volume is the sum of ATM call volume \( \text{Call}_\text{VOL} \) and ATM put volume \( \text{Put}_\text{VOL} \). Similarly, ATM option exercise \( \text{OE} \) is the sum of ATM call option exercise \( \text{Call}_\text{OE} \) and ATM put option exercise \( \text{Put}_\text{OE} \). We replace missing observations by the mean of non-missing observations. Correlations for \( \text{OE} \) are based on the period January 1998 to November 2009. We add 10 to all open interest, option volume, and early option exercise values and take logarithms.

<table>
<thead>
<tr>
<th></th>
<th>( \text{Pinn}_\text{sym} )</th>
<th>( \text{Pinn}_\text{above} )</th>
<th>( \text{Pinn}_\text{below} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Pinn}_\text{sym} )</td>
<td>1.00</td>
<td>0.77</td>
<td>0.71</td>
</tr>
<tr>
<td>( \text{Pinn}_\text{above} )</td>
<td>1.00</td>
<td>0.23</td>
<td>1.00</td>
</tr>
<tr>
<td>( \text{Pinn}_\text{below} )</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>( \text{OI} )</td>
<td>0.01</td>
<td>-0.05</td>
<td>-0.09</td>
</tr>
<tr>
<td>( \text{Call}_\text{OI} )</td>
<td>0.00</td>
<td>-0.02</td>
<td>-0.10</td>
</tr>
<tr>
<td>( \text{Put}_\text{OI} )</td>
<td>0.00</td>
<td>-0.07</td>
<td>-0.02</td>
</tr>
<tr>
<td>( \text{VOL} )</td>
<td>0.14</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>( \text{Call}_\text{VOL} )</td>
<td>0.12</td>
<td>0.09</td>
<td>-0.02</td>
</tr>
<tr>
<td>( \text{Put}_\text{VOL} )</td>
<td>0.12</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>( \text{OE} )</td>
<td>0.16</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>( \text{Call}_\text{OE} )</td>
<td>0.27</td>
<td>0.24</td>
<td>0.03</td>
</tr>
<tr>
<td>( \text{Put}_\text{OE} )</td>
<td>0.09</td>
<td>-0.11</td>
<td>0.20</td>
</tr>
</tbody>
</table>
**Figure 1:** Percentage of S&P 500 Futures Finishing Within +/-0.25$ of the Strike Price

This figure depicts the percentage of S&P 500 futures settlement prices which are within $0.25 of the ATM strike price. This proportion should be 10% if prices are uniformly distributed around the strike price. The figure presents results for the 5 days before and after the serial expiration dates and for the serial expirations themselves. Panel A depicts results for the period from August 1987 to November 2009 and Panel B depicts results for the period from January 1998 to November 2009. Both panels exclude October 1987 and October 2008.

**Panel A:** August 1987 – November 2009

![Bar chart for Panel A]

**Panel B:** January 1998 – November 2009

![Bar chart for Panel B]
**Figure 2: Delta-Hedging of Short Straddles (Sold Gamma Positions)**

This figure depicts the hedging of an ATM sold straddle where the delta of the hedge is noted at the top of the figure and the delta of the straddle at the bottom.

\[ t_0: \quad -1 \quad 0 \quad 1 \]

- Sell if \( \Delta F < 0 \)
- Buy if \( \Delta F > 0 \)
**Figure 3:** Pinning Mechanism of Avellaneda and Lipkin (2003)

This figure depicts the hedging of an ATM sold straddle where the delta of the hedge is noted at the top of the figure and the delta of the straddle at the bottom. The figure demonstrates how the hedge for different levels of the future changes as time passes from $t_0$ (dotted line) to $t_1$ (dashed line). The resulting adjustment trades to the hedge cause anti-pinning as indicated by the arrows.

\[ t_0: \begin{array}{cccccc} -1 & 0 & 0 & 0 & 1 \\ \text{change:} & 0 & \text{sell F} & \text{buy F} & 0 \\ t_1: & -1 & -1 & 1 & 1 \end{array} \]
Figure 4: Pinning Mechanism of Anders (1982)

This figure depicts the hedging of an ATM sold straddle where the delta of the hedge is noted at the top of the figure and the delta of the straddle at the bottom. The figure demonstrates how the hedge for different levels of the future changes as the unhedged investor sells the ITM option to the market maker ($t_0$ is before the sale and $t_1$ thereafter). The resulting adjustment trades to the hedge cause pinning as indicated by the arrows.

| $t_0$: | -1 | -0.50 | 0  | +0.50 | +1 |
| change: | +1 | +0.75 | -0.75 | -1 |
| $t_1$: | 0  | 0.25  | -0.25 | 0  |

K

F
**Figure 5:** Time Pattern of Open Interest, Volume, and Options Exercise of ATM Options

This figure depicts SP option trading activity for serial expiration dates between August 1987 and November 2009. Panel A depicts SP option open interest measured one day before the serial expiration Friday with respect to ATM strike price on the serial expiration date. Panel B depicts ATM option volume measured on the serial expiration Friday. Panel C depicts ATM early option exercise measured on the serial expiration Friday. Missing values are replaced by zeros. Quantities have not been transformed by logarithms or the addition of 10.

**Panel A: ATM Open Interest**

![ATM Open Interest Graph]

**Panel B: ATM Option Volume**

![ATM Option Volume Graph]

**Panel C: ATM Early Option Exercise**

![ATM Early Option Exercise Graph]
Table A.1: The Main Characteristics of the S&P 500 Derivatives
This table collects the main characteristics of the S&P 500 index related derivatives. Q stands for quarterly expiration cycle (March, June, September and December). S stands for serial expiration months (January, February, April, May, July, August, October and November). A.M. settlement price is based on the special opening value of the underlying. P.M. settlement price is based on last prices of the underlying on an expiration day. The table is based on the information obtained from CME webpage (http://www.cmegroup.com), CBOE webpage (www.cboe.com), Stoll and Whaley (1991), and the CBOE Regulatory Circular Number RG92-46.

<table>
<thead>
<tr>
<th></th>
<th>SPX options</th>
<th>SP futures</th>
<th>SP options</th>
<th>SPY options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Underlying</strong></td>
<td>S&amp;P 500 index</td>
<td>S&amp;P 500 index</td>
<td>SP futures</td>
<td>SPDR (ETF, 1/10th of S&amp;P 500 index)</td>
</tr>
<tr>
<td><strong>Strike price interval</strong></td>
<td>5 points (first nearest month)</td>
<td>-</td>
<td>5 points (first and second nearest month)</td>
<td>1 point</td>
</tr>
<tr>
<td></td>
<td>25 points (deferred months)</td>
<td>-</td>
<td>10 and 25 points (deferred months)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>European (American before April 1986)</td>
<td>-</td>
<td>American</td>
<td>American</td>
</tr>
<tr>
<td><strong>Trading hours</strong></td>
<td>8:30 A.M. - 3:15 P.M.</td>
<td>8:30 A.M. - 3:15 P.M.</td>
<td>8:30 A.M. - 3:15 P.M.</td>
<td>8:30 A.M. - 3:15 P.M.</td>
</tr>
<tr>
<td><strong>Expiration months</strong></td>
<td>3 serial months</td>
<td>8 months in the quarterly cycle</td>
<td>3 serial months</td>
<td>3 serial months</td>
</tr>
<tr>
<td></td>
<td>3 months in the quarterly cycle</td>
<td>-</td>
<td>8 months in the quarterly cycle</td>
<td>3 months in the quarterly cycle</td>
</tr>
<tr>
<td><strong>Settlement at expiration</strong></td>
<td>Q+S: Cash-settlement</td>
<td>Q: Cash-settlement</td>
<td>Q: Cash-settlement</td>
<td>Q+S: Physical delivery</td>
</tr>
<tr>
<td><strong>Settlement value</strong></td>
<td>Q: P.M. settlement (3rd Friday)</td>
<td>Q: P.M. settlement (3rd Thursday)</td>
<td>Q: P.M. settlement (3rd Thursday)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Q+S*: P.M. settlement (3rd Friday)</td>
<td>Q: P.M. settlement (3rd Friday)</td>
<td>Q: P.M. settlement (3rd Friday)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Q+S: Co-existence of A.M. and P.M. settled options (3rd Friday)</td>
<td>Q: A.M. settlement (3rd Friday)</td>
<td>Q: A.M. settlement (3rd Friday)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Q+S: A.M. settlement (3rd Friday)</td>
<td>Q: A.M. settlement (3rd Friday)</td>
<td>Q: A.M. settlement (3rd Friday)</td>
<td>Q+S: P.M. price (3rd Friday)</td>
</tr>
</tbody>
</table>

*Serial expirations for SPX options were introduced in 1986 (they exist for sure since April 2nd 1986).