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Pinning in the S&P 500 futures ☆

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ABSTRACT

We show that Standard & Poor's (S&P) 500 futures are pulled toward the at-the-money strike price on days when serial options on the S&P 500 futures expire (pinning) and are pushed away from the cost-of-carry adjusted at-the-money strike price right before the expiration of options on the S&P 500 index (anti-cross-pinning). These effects are driven by the interplay of market makers' rebalancing of delta hedges due to the time decay of those hedges as well as in response to reselling (and early exercise) of in-the-money options by individual investors. The associated shift in notional futures value is at least $115 million per expiration day.

1. Introduction

From first principles, stock prices would be expected to be uniformly distributed on any small interval. There should not be any attraction to one particular stock price or another. However, on option expiration days, stock prices tend to finish more frequently near a strike price.[2] This tendency, called pinning, is fascinating as it involves effects across two markets: the options market and the market for the underlying asset.

Pinning has been shown for individual stocks; see the instances described in Wall Street Journal (1982), Krishnan and Nelken (2001), or Augen (2009, p. 26). Ni et al. (2005) study stock option pinning and provide statistical evidence of its existence. In their paper, the main driving force for pinning is the market makers' adjustment of the delta hedge due to the time decay of the hedges (as modeled by Avellaneda and Lipkin (2003)) and stock price manipulation of proprietary traders.

In this paper, we take the analysis to the aggregate level for Standard & Poor's (S&P) 500 futures (henceforth, futures). The many interrelated derivative markets for the S&P 500 index (the futures on the index, the options written on the futures, and the options written on the index) provide a unique laboratory for analyzing pinning and testing for different possible explanations. We show that the at-the-money strike price can either attract or repel the price of the underlying asset on the options

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[2] The fact that pinning occurs only on expiration dates is different from clustering, which is the tendency of prices to be quoted on particular round values. Such clustering is independent of a day being an expiration day or not. See Schwarz et al. (2004) for a recent account of clustering in S&P 500 futures trade prices.

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expiration days, and we explain all effects in terms of delta hedging induced trades.

We first analyze pinning of futures on days when serial options on S&P 500 futures (henceforth, SP options) expire. Because SP options expire on a monthly cycle and futures expire on a quarterly cycle, these serial expirations (all expiry months except for the quarterly cycle) provide cases in which SP options expire and the underlying first-to-maturity futures continue to trade for an additional month or two. It is exactly this feature that enables first-to-maturity futures to pin to the nearest strike price. Pinning in first-to-maturity futures should not be possible on quarterly expirations when futures expire and must match the price of the underlying basket of the S&P 500, which is not affected by the hedging of SP options. Moreover, hedging of expiring SP options on quarterly expirations would be conducted in the more liquid and easier to trade second-to-maturity futures.

As futures are highly liquid (the typical expiration day notional open interest from August 1987 until November 2009 was some $90 billion and on each expiration day some 15% thereof was traded), it is hard to imagine that futures could be subject to manipulation and we provide evidence to this effect. Further, likely delta hedgers, such as market makers and possibly firm proprietary traders, are typically short options on the S&P 500 index (henceforth, SPX options), whereas they tend to be long individual stock options (Garleanu et al., 2009). We argue that this fact extends to the very similar market for SP options. Given such short positions of market makers in the SP options, the time decay of a delta hedge should then lead, according to the model of Avellaneda and Lipkin (2003), to anti-pinning in the S&P 500 futures and not to pinning.

Surprisingly, however, from November 1992 to November 2009, we find evidence of pinning in the serial expirations of first-to-maturity S&P 500 futures and not of the predicted anti-pinning. We use the method of Ni et al. (2005) to establish a lower bound on the associated average price move of at least $115 million in notional terms on each expiration date. Pinning is somewhat stronger in the more recent period from October 1998 until November 2009, in which the effect translates into a move in notional terms of at least $240 million on each expiration day. Our findings might thus also be of interest to exchanges and regulators due to the large size of the distortions and the importance of this market.

Given that the observed pinning is seemingly at odds with the main story for anti-pinning due to Avellaneda and Lipkin (2003), we explore in detail other potential explanations for pinning. Wall Street Journal (1982) suggests that, if options lead to physical delivery, investors could fear the price risk over the weekend and rather resell in-the-money options back to market makers right before expiration. Such last minute sales of in-the-money options by individual investors lead to pinning as market makers need to adjust the hedge afterward. By the same token, pinning can also arise because of early exercise of in-the-money options held by individual investors. 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.

Our regressions show that the time decay of the delta hedge of Avellaneda and Lipkin (2003) leads to anti-pinning, but the effects of the other two mechanisms overcompensate and the net effect is pinning due to the serial futures options. Further results suggest that manipulation is an unlikely explanation for the documented pinning.

In additional tests, we find that pinning is especially pronounced when the futures price is pushed from below to the vicinity of the at-the-money strike price. Intuitively, this asymmetry is because market makers (being the most likely delta hedgers) hold larger sold at-the-money put positions than sold at-the-money call positions. Thus, our hedging arguments are mainly driven by the put positions with an upward push from below the strike price.

We cannot find evidence of pinning in related markets and, similarly, no pinning exists in the S&P 500 index basket itself due to serial expirations of SPX options as market makers would not hedge SPX options through the index basket, but instead by trading the futures. Probing this issue further, we examine whether there is cross-pinning from one market onto the other. Intuitively, this could happen if in these closely related markets one underlying cannot be used for hedging (e.g., the index basket for the SPX options) but the futures could be used because they are a close substitute. We find that trading of SPX options leads to cross-pinning onto the futures price. Specifically, we present evidence that futures prices finish less frequently near the appropriately adjusted at-the-money strike price on SPX expiration days. This so-called cross-anti-pinning is intuitive, as here the dominant effect is the anti-pinning mechanism of Avellaneda and Lipkin (2003). The other two effects (selling and early exercise of in-the-money options) are not very important anymore as the SPX options are cash-settled and European. Customers, therefore, do not have to worry about obtaining physical delivery and bearing the associated price risk over the weekend.

Based on a literature review, the paper develops the hypotheses in Section 2. Section 3 introduces the econometric methodology of testing for pinning and documenting the driving mechanisms. All data are presented in Section 4. Results for pinning in the serial futures options follow in Section 5 and results for anti-pinning due to cross-pinning in Section 6. Robustness checks are presented in Section 7, and Section 8 concludes.

2. Hypotheses and literature

We now turn to possible reasons for pinning. Because many arguments relate to the delta hedging of market makers, we argue that market makers tend to be short at-the-money SP options and typically delta hedge. This has been shown for the S&P 500 index options market (see Table 1 in Garleanu et al., 2009).

For the same SPX options market, we argue that market makers have on average more written puts than written calls. Based on OpenClose data from Market Data Express on opening and closing SPX options volume for different investor types, we calculate a proxy for market maker open interest. For each option on each day and for each investor type, we first calculate the daily change in open interest as opening buy minus closing buy plus closing sell minus opening sell. For market makers, we set this value to be the negative of the sum of changes in open interest for nonmarket makers. Then we aggregate these daily changes in the open interest for each option from the day it first appears in the data until and including one day before the expiration day. For the period from November 1992 to November 2009, results imply that, one day before expiration, market makers hold on average −1840 at-the-money calls and −12,315 at-the money puts.

Unfortunately, such data are not available for the futures options market. However, we believe that market maker positions are likely to be similar because the two markets are closely related. The correlation between the S&P 500 index and the first-to-maturity futures 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 five days leading up to expiration Friday are 0.86 and 0.79, respectively.[3] We, thus, assume that market makers in the SP options market hold similar positions as in the SPX options market, i.e., market makers are typically short at-the-money SP options.

Individual investors do not normally hedge their positions because they are often constrained by transaction costs and financial know-how in hedging. Less clear is the role of firm proprietary traders who might hedge or not. Garleanu et al. (2009) find that the market share of firm proprietary traders tends to be small and show that including or excluding them as hedgers does not affect results. We, thus, use market makers as our hedgers for the remainder of the paper but realize that some firm proprietary traders might also hedge their positions.

Given the symmetry in the arguments, we explain all pinning mechanisms in terms of a sold call position and state differences with respect to a sold put position only when necessary. We, thus, take the perspective of market makers who typically hold short positions. The simplest mechanism is the change of delta hedging a sold call option position as the underlying future moves. As shown in Fig. 1, just before expiration, a sold call with the futures price close to the strike price has a negative delta of about −0.5, which is hedged with +0.5 long futures. The delta values are not exact but are simply meant to suggest possible values and magnitudes. As the future falls, the call gains delta and, thus, the hedger needs to lose delta by selling futures in the falling market. The reverse mechanism operates in increasing markets. This effect amplifies movements of the underlying future, which leads to higher volatility; see Pearson et al. (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 option.

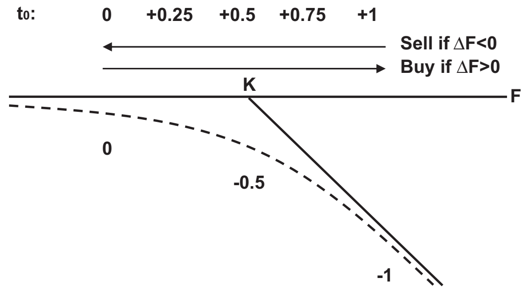

Fig. 1. Delta hedging of a short call. This figure depicts the hedging of an at-the-money sold call. F denotes the future and ΔF is the change in the futures price. K is the strike price. The delta of the hedge is noted at the top of the figure; the delta of the call, at the bottom.

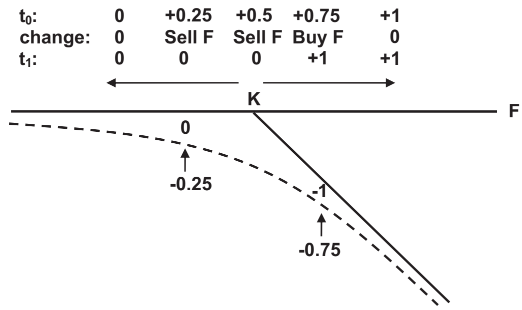

Fig. 2. Pinning mechanism of Avellaneda and Lipkin (2003). This figure depicts the hedging of an at-the-money sold call. F denotes the future and K is the strike price. The delta of the hedge is noted at the top of the figure; the delta of the call, at the bottom. The figure demonstrates how the hedge for different levels of the futures price changes as time passes from t_0 (dotted line) *to* t_1 (solid line). The resulting adjustment trades to the hedge cause anti-pinning as indicated by the arrows.

2.1. 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.[4] Alas, given that index option market makers typically hold short (i.e., written) option positions, their mechanism leads to anti-pinning in the index futures. As shown in Fig. 2, initially at t_0 the hedge slightly below the strike price of the option is about +0.25. As expiration comes very close at time t_1, the delta of the option moves from about −0.25 to almost 0. Thus, the hedge involves selling the future to unwind the hedge as expiration nears and the futures price is below the strike. As a result, the futures price is being pushed downward and away from the strike. A similar mechanism establishes the predicted anti-pinning for the case in which the futures price is above the strike price, which we depict for a delta of the call of −0.75. Here, buying the future to increase the hedge pushes the futures price upward and away from the strike.

[3] 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 when we have data for SPX options from Market Data Express.

[4] See also Jeannin et al. (2007). The implications of Avellaneda and Lipkin (2003) hold also in the equilibrium model with feedback effects of Nayak (2007).

The main hypothesis related to Avellaneda and Lipkin (2003) (we express all hypotheses in terms of pinning; anti-pinning then being a lessening of pinning) is based on the maintained assumption that market makers are typically short options.

Hypothesis AL-1. At-the-money open interest decreases pinning.

The larger the at-the-money open interest on expiration Friday, the larger are the sold option positions that market makers need to hedge.[5] Thus, the higher the open interest, the weaker the pinning and the stronger the anti-pinning effect.

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 et al. (2005). However, as 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. At-the-money option volume increases pinning.

At-the-money 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 opens 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 needs of market makers. As a result, there should be less anti-pinning and more pinning.[6]

Hypothesis AL-3. At-the-money early option exercise increases pinning.

Early exercise of individual investors long positions would lead to reduced short positions of market makers and, thus, to reduced hedging needs. This would weaken the anti-pinning and strengthen pinning.

2.2. Reselling of slightly in-the-money options

Wall Street Journal (1982) argues that individual investors dislike long in-the-money option positions at expiration because they expose individual investors to price risk over the weekend. This concern is relevant for the SP options because they settle with physical delivery and the investor is then stuck with an unhedged futures position until after the weekend. Thus, investors sell their in-the-money

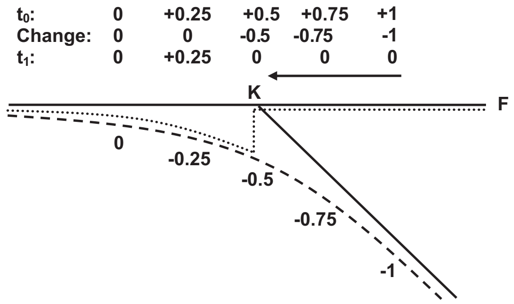

Fig. 3. Pinning mechanism of Wall Street Journal (1982). This figure depicts the hedging of an at-the-money sold call. *F* denotes the future and *K* is the strike price. The delta of the hedge is noted at the top of the figure; the delta of the call, at the bottom. The figure demonstrates how the hedge changes for different levels of the futures price as the unhedged investor sells the in-the-money option to market makers (the dashed line at t_0 is before the sale and the dotted line at t_1 is thereafter). The resulting hedge-adjustment trades cause pinning as indicated by the arrows.

positions to market makers who then need to adjust the hedge on the typical market maker short option position. In Fig. 3, the futures price starts above the strike price at some time t_0 before expiration and the in-the-money call changes its delta from about -0.75 to 0 as it is being sold back to market makers. The hedge needs to be unwound, and selling 0.75 futures pushes the futures price down toward the strike. Below the strike price nothing happens as the out-of-the-money call is held by the individual investor and hedged by market makers as before. The opposite story unfolds below the strike price for puts, which now pushes up the futures price toward the strike due to buying pressure as the hedge is unwound.

The described effects are applicable only to near-the-money options. As deep-in-the-money options are unlikely to finish out-of-the-money, investors resell them already several days before the expiration. It is only for near-the-money options that investors are uncertain whether their options will expire in- or out-of-the-money. Hence, investors wait until right before expiration and then sell their options if they go in-the-money.

Our hypotheses related to Wall Street Journal (1982) are twofold.

Hypothesis AN-1. At-the-money call volume increases pinning from above the strike price.

Volume is related to the closing of hedge positions. Thus, at-the-money call volume measures investors' activities as calls go in-the-money and leads to directional pinning, namely, to increased pinning from above the strike price as the futures price is being pushed downward and closer toward the strike price. We define pinning from above as a situation in which there is pinning and the futures price is being pushed below its fair value; details, also on pinning from below, follow in Section 3.

Hypothesis AN-2. At-the-money put volume increases pinning from below the strike price.

The mechanism is exactly the opposite of Hypothesis AN-1.

[5] 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 twice and we include those two months. For simplicity, we use the expression "expiration Friday" to denote all expirations, including those that fall on a Thursday.

[6] For parts of our cross-pinning sample, we even have (small and middle) customer closing buy data, which more accurately measure the quantity of interest: the number of open long positions of at-the-money options that are being closed by individual traders on the expiration day.

2.3. Early exercise of slightly in-the-money options

The next potential explanation of pinning is due to early exercise of in-the-money call options and simultaneous selling of the delivered underlying future by individual investors. This puts downward pressure on the futures price and, as the effect reverses for in-the-money put options, early options exercise can explain pinning. This behavior has been shown in Chiang (2010), albeit with a focus on the underlying stock returns and without referring to pinning.

The mechanism is very similar to Wall Street Journal (1982) but based on individual investors exercising their American in-the-money options instead of selling them as in Wall Street Journal (1982). This is a realistic concern as the SP options are American. Individual investors 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 Wall Street Journal (1982). The hypotheses related to early option exercise are twofold again.

Hypothesis EARLY-1. At-the-money call early option exercise increases pinning from above the strike price.

At-the-money call early option exercise measures investors winding down positions as the calls go in-the-money and leads to directional pinning, namely, to increased pinning from above the strike price as the futures price is being pushed downward and closer toward the strike price.

Hypothesis EARLY-2. At-the-money put early option exercise increases pinning from below the strike price.

The mechanism is exactly the opposite of the Hypothesis EARLY-1.

2.4. Manipulation of the underlying

Observationally equivalent to the pinning mechanisms of Wall Street Journal (1982) and the early exercise explanation is the market manipulation mechanism of Ni et al. (2005). Here, sophisticated market participants with short positions (i.e., typical market makers in the SP options or firm proprietary traders) could gain from manipulating the futures price. Namely, pushing the futures price downward from above the strike price would reduce payments to individual investors with long call option positions, while pushing the futures price 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 Wall Street Journal (1982) and early exercise mechanism. Residual pinning could then be attributable to market manipulation and would show up as additional explanatory power of the volume of futures trading, which we use to measure manipulation. A concern here is that futures volume could be related to all our hedging mechanisms. However, correlations with other regressors tend to be low and negative.

Still, it is hard to see that the highly supervised market makers could manipulate the futures price, a point also argued in Ni et al. (2005). That would leave only firm proprietary traders, with relatively small positions when compared with market makers, as potential manipulators. As the futures market is very large and liquid, any manipulation should be rather difficult as it would involve large unhedged trades to move the futures price sufficiently for the purpose of manipulation.[7] Such trades would leave the manipulator vulnerable to price risk over the weekend, which is undesirable for the manipulator. Further, the risk of detection of the manipulation further diminishes the interest of market makers in such activities. Moreover, pinning itself is risky for the manipulator (so-called pin risk) and manipulation would increase this risk. Pin risk arises because, due to transaction costs, option writers (i.e., market makers) cannot predict with certainty whether the marginally in-the-money options will be exercised at expiration. Hence, pinning aggravates the risk of ending up with a naked position in the future over the weekend. Finally, small movements of the futures price through the strike price lead to dramatic adjustments in the hedge (for a short call the delta of the hedge goes from zero to one as the futures price moves through the strike price from below). As a result, the manipulator 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 role anymore. Hence, adding futures volume as a variable should not contribute significantly to explaining pinning.

2.5. Volatility and pinning

Pinning could 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 can expect that futures 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 the pinning effect applies also to the other explanations of pinning, namely, Wall Street Journal (1982) and early option exercise.

Hypothesis NI-2. Futures volatility decreases pinning.

Futures volatility makes delta hedging of market makers more difficult and is, therefore, negatively related to pinning.

3. Methodology

We are interested in testing for (anti-)pinning in different option classes associated with the S&P 500 index

[7] Stivers and Sun (2011) find that expiration week returns on stocks with large option open interest can even be detected in the index itself.

and, given that we find such pinning, in explaining which mechanisms drive it. For the purpose of testing for pinning, we employ logistic regressions with fixed effects; see Ni et al. (2005). We use ten days before and after each expiration day. Our logistic model is

$$\Pr(Pinn\_sym_t = 1) = \frac{1}{1+e^{[-(\alpha+\beta Dumm_t)]}}, \tag{1}$$

where $Pinn\_sym_t$ is a binary variable, which is one if the futures price at settlement is within \$0.375 below or above the at-the-money strike price and zero otherwise. We vary the size of the interval in the robustness section to \$0.25 and \$0.5. We always take the at-the-money strike price to be the strike price closest to the futures settlement price.[8]

$$Pinn\_sym_t = \begin{cases} 1, & \text{if} \left| Fut_t - K_t^{ATM} \right| \le 0.375; \\ 0, & \text{otherwise}. \end{cases} \tag{2}$$

We define $Dumm_t$ as one for expiration days and zero otherwise. The above logistic regression tests if pinning on expiration days is significantly higher than on non-expiration days. We also compare pinning on expiration days with pinning due to independent draws from a uniform distribution of futures prices. Results are similar, and we typically do not report those *p*-values.

Furthermore, we split $Pinn\_sym_t$ into pinning from above, $Pinn\_above_t$, and pinning from below, $Pinn\_below_t$, and use them as alternative dependent variables in Eq. (1). We define $Pinn\_above_t$ as a case in which the futures price is pushed below its fair value; $Pinn\_below_t$, the futures price is above its fair value. We calculate the fair value of the first-to-maturity futures settlement value, Fut_t*, by adjusting the second-to-maturity futures settlement value. We obtain the adjustment factor for each day by matching within minute observations of first-to-maturity futures and second-to-maturity futures and by calculating their ratios and taking the median of these ratios for all matched pairs between 9:00 and 14:30.

$$Pinn\_above_t = \begin{cases} Pinn\_sym_t = 1 \text{ and } Fut_t \le Fut_t^*; \\ 0, \quad \text{otherwise}; \end{cases} \tag{3}$$

$$Pinn\_below_t = \begin{cases} Pinn\_sym_t = 1 \text{ and } Fut_t \ge Fut_t^*; \\ 0, \quad \text{otherwise}. \end{cases} \tag{4}$$

Once we establish (anti-)pinning, we explore which mechanisms can explain pinning. We use logistic regressions in which we drop the expiration dummy and focus only on expiration Fridays. In accordance with our hypotheses, we use in Eq. (5) additional right-hand-side variables such as option open interest, option volume, option early exercise, and others.

$$\Pr(Pinn\_sym_t = 1) = \frac{1}{1+e^{[-(\alpha+\beta \text{ right-hand-side variables}_t)]}}. \tag{5}$$

4. Data

We now turn to the description of the data sources and the definitions of variables.

4.1. Data sources

We obtained 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 provide daily open, high, low, close, and settlement prices along with the daily open interest and volume for all maturities of futures from their introduction on April 21, 1982 to December 31, 2009. In addition, we purchased from CME the intradaily record of all futures trades for the same sample. The SP options data provide 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 28, 1983 to December 31, 2009.

In tests for cross-pinning we also employ daily data for SPX options on the S&P 500 index for the period January 2, 1990 to December 31, 2009, which we obtained from Market Data Express. The SPX options data come with daily open, high, low, close prices, open interest, and volume for all individual SPX options, as well as the value of the underlying S&P 500 cash index. Our primary variable of interest is not volume per se but the number of open contracts bought by individual customers that are being closed on expiration days. To this end, we also bought for the same sample the SPX OpenClose data from Market Data Express. Here we have daily observations for each option of open buy, close buy, open sell, and close sell for the four trader groups small customers, middle customers, large customers, and firm proprietary traders. Unfortunately, similar data are not available from the CME for the SP options.

To test for pinning in the S&P 500 cash index, we also obtained the special AM exercise-settlement values (called SOQ or SET) of the SPX options from Market Data Express.[9] Quarterly SOQ values run from June 1991 to December 2009, and serial SOQ values run from November 1992 to November 2009.

As it is standard in derivatives research, we regularly eliminate two crash months, October 1987 and October 2008. We include two expiration days that fall on Thursdays as opposed to Fridays. However, ignoring these observations has almost 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.

[8] In case of cross-pinning in Section 6, where we investigate the impact of SPX options trading onto the futures price, some of our quantities need to be redefined accordingly, e.g., the at-the-money strike price is typically the cost-of-carry adjusted strike price defined with respect to the S&P 500 index.

[9] The SOQ is determined by the first opening prices of all the constituents of the index.

4.2. Variable definition

Having defined our dependent variables, we now define our independent variables.[10] First, at-the-money open interest is measured on the Thursday before expiration with respect to the at-the-money strike price on the expiration Friday. The variable is composed of at-the-money call and at-the-money put open interest. The variables are labeled *OI*, *Call_OI*, and *Put_OI*.

Second, at-the-money volume is measured with respect to the at-the-money strike price on expiration Friday. Again, it is composed of at-the-money call and at-the-money put volume. The variables are labeled *VOL*, *Call_VOL*, and *Put_VOL*.

Third, at-the-money early option exercise is measured with respect to the at-the-money strike price on the expiration Friday. Again, it is composed of at-the-money call and at-the-money put early option exercise. The variables are labeled *OE*, *Call_OE*, and *Put_OE*. Disconcertingly, early option exercise almost exclusively takes a value of zero during the first half of the sample. We are uncomfortable with imputing the values through some statistical procedure because too many observations have zero value. Instead, we define a short sample in which the early option exercise is nonzero (October 1998 until November 2009). We can then analyze the effect of early options exercise during the short sample.

Fourth, *Fut_vol* measures the volume of futures contracts traded on the expiration Friday.

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

$$Fut\_sigma = \frac{(\log(Fut\_high) - \log(Fut\_low))^2}{4\log(2)}, \tag{6}$$

where *Fut_high* is the intradaily futures high price and *Fut_low* is the intradaily futures low price.

Some independent variables have missing values. Because no generally accepted treatment exists for missing variables, we eliminate the missing observations altogether. Results are robust to alternative treatments of missing observations and are not affected if we use zeros instead or if we replace missing observations by the sample mean of the untransformed missing variable. We provide details in Section 7.

5. Results for pinning

Now we present our results for pinning in the future due to serial SP options on the future. We start with the sample and descriptive statistics. We next discuss pinning and thereafter explain the mechanisms that cause the pinning. Finally, we look at pinning in related markets.

5.1. Pinning sample

In our main tests, we focus on the settlement price of the first-to-maturity futures as those determine the value of the expiring SP options. Because SP options trade on a monthly cycle and futures trade on a quarterly cycle, we use the serial expiration months (all months excluding the quarterly cycle: January, February, April, May, July, August, October, and November). These serial expiration days provide a unique laboratory of cases in which SP options expire and the underlying future continues to trade for an additional month or two. It is exactly this feature that enables the futures price to finish in the proximity of the strike price. For the quarterly expirations, the situation is different because the underlying first-to-maturity future expires into the S&P 500 basket, which is not affected by hedging of SP options. Moreover, any hedging would be conducted in the more liquid and easier to trade second-to-maturity futures, a feature that we revisit in Section 6.

While the serial SP options exist since August 1987, the first years of this sample involve simultaneously traded SPX options, which also expire Friday PM and can, therefore, disrupt pinning due to SP options. Our concern is that SPX options, just as the SP options, are most likely being hedged with first-to-maturity futures. As we show in Section 6, such hedges might induce anti-pinning around the cost-of-carry adjusted strike price of the at-the-money SPX options. We then have two different forces, one due to pinning driven by the SP options and the other due to anti-pinning caused by the SPX options. Both forces have potentially interfering effects on the futures price. As we cannot establish clear rules for separating the effects, we do not use this period—in particular, small changes in what we consider the force field for pinning and anti-pinning in either sample lead to rather different results. Therefore, we start only in November 1992 when we can be certain that there is no more cross-pinning possible and end in November 2009 (long sample).

The variable early option exercise (*OE*) misses the first half of its values and we, therefore, analyze the effect of early option exercise only from October 1998 to November 2009 (short sample). The dependent variable, *Pinn_sym*, is labeled $Pinn\_sym^L$ in the long sample and $Pinn\_sym^S$ in the short sample.

We next turn to some descriptive statistics and look at the complete time pattern of SP option trading activity (in number of contracts) on serial expiration dates as depicted in Fig. 4. The data are reported with missing values replaced by zeros. Panel A depicts at-the-money option open interest, Panel B depicts at-the-money option volume, and Panel C depicts at-the-money early option exercise. Fig. 4 demonstrates that the SP option activity on the serial expiration dates rose over the years. Open interest and volume steadily increased from 1987 until approximately 1996, then they decreased somewhat and ramped again from 2004 to 2009.

[10] Here we explain variables for Section 5 and for parts of Section 6. In other parts of Section 6, some of the variables need to be slightly redefined, which we explain below as required. For better readability, we drop the time index when referring to the variables in the main text.

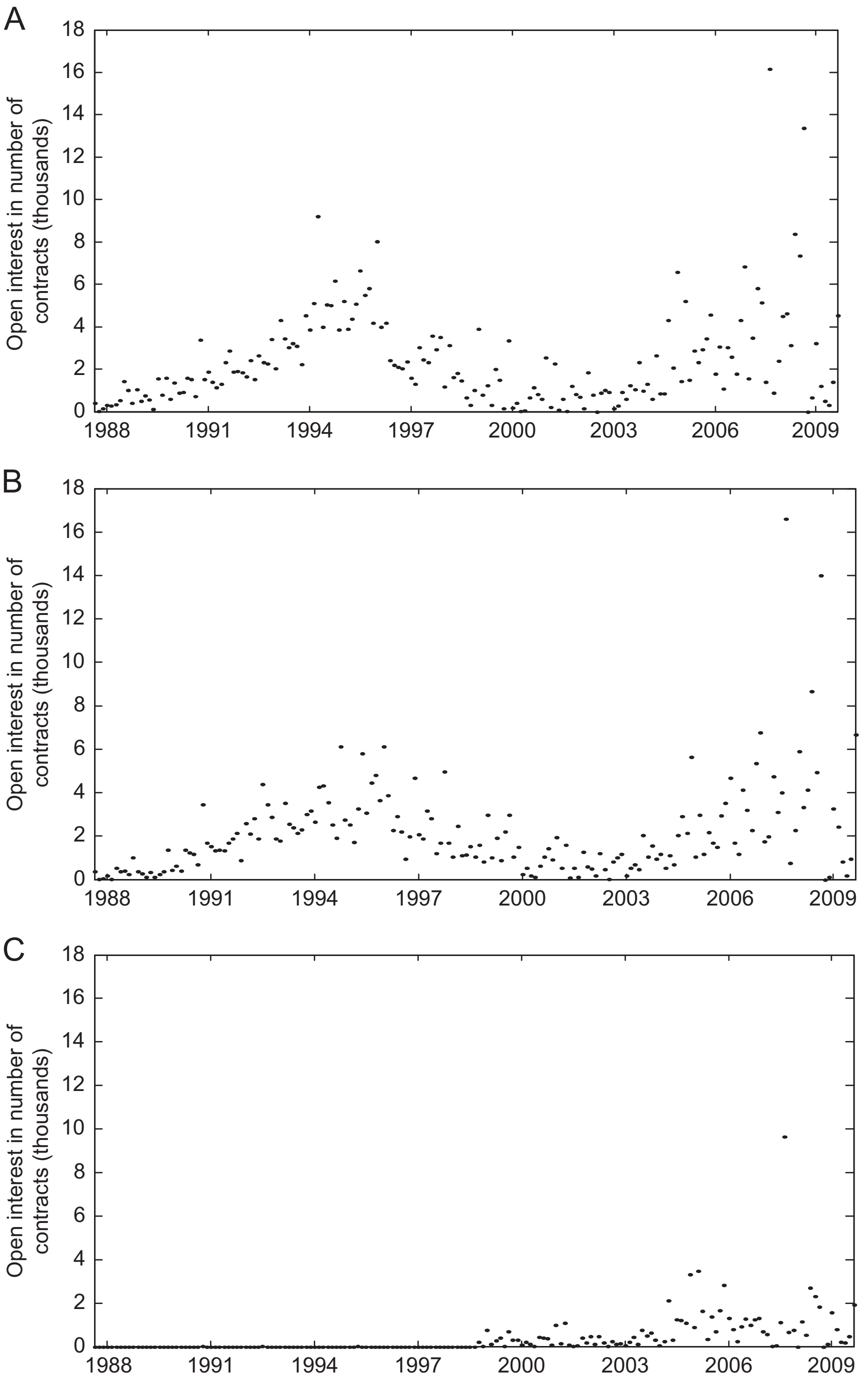

Fig. 4. Time patterns of open interest, volume, and early exercise of at-the-money options. This figure depicts trading activity (in number of contracts) of serial options on Standard & Poor's 500 futures (SP options) for serial expiration dates between August 1987 and November 2009. Panel A depicts SP option open interest measured one day before the serial expiration Friday with respect to at-the-money strike price on the serial expiration date. Panel B depicts at-the-money option volume measured on the serial expiration Friday. Panel C depicts at-the-money early option exercise measured on the serial expiration Friday. Missing values are replaced by zeros.

Table 1 reports the summary statistics of the data for the long sample from November 1992 to November 2009. Summary statistics for early option exercise are based on the short sample from October 1998 to November 2009.

Table 1 already reveals some interesting findings. First, from November 1992 to November 2009, 21.32% of futures prices settle within \$0.375 of the strike price on the serial expiration Fridays. Assuming that futures prices

Table 1
Summary statistics.

This table collects the summary statistics for the serial expiration dates in the period November 1992 to November 2009 (excluding October 2008). Symmetric pinning *Pinn_sym* is a binary variable, which is one if the futures settlement price is within $0.375 to the left or right of the at-the-money strike price and zero otherwise. *Pinn_above* (*Pinn_below*) is a binary variable that takes a value of one if there is pinning and the futures settlement price is below (above) the fair value based on the second-to-maturity future and zero otherwise. At-the-money open interest *OI* is measured one day before the serial expiration day with respect to at-the-money strike price on the serial expiration day. At-the-money open interest is the sum of at-the-money call open interest *Call_OI* and at-the-money put open interest *Put_OI*. At-the-money volume *VOL* and at-the-money option exercise *OE* are both measured on the serial expiration date with respect to the at-the-money strike price. At-the-money volume is the sum of at-the-money call volume *Call_VOL* and at-the-money put volume *Put_VOL*. Similarly, at-the-money option exercise *OE* is the sum of at-the-money call option exercise *Call_OE* and at-the-money put option exercise *Put_OE*. Futures volume *Fut_vol* measures number of futures 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 omit missing observations. Numbers in brackets next to number of observations denote the number of nonmissing observations for each variable. Summary statistics for *OE* are based on the period October 1998 to November 2009. Variables measuring options and futures trading activity (*OI* through *Fut_vol*) are expressed in thousands.

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Pinn_sym	136 (136)	0.2132	0.4111	0.0000	1.0000
Pinn_above	136 (136)	0.0662	0.2495	0.0000	1.0000
Pinn_below	136 (136)	0.1471	0.3555	0.0000	1.0000
OI	136 (129)	2.8363	2.4610	0.0240	16.1640
Call_OI	136 (130)	1.6522	1.5499	0.0020	8.0940
Put_OI	136 (134)	1.1771	1.5290	0.0010	11.6000
VOL	136 (135)	2.4753	2.2920	0.0840	16.5940
Call_VOL	136 (135)	1.4042	1.6679	0.0260	11.8200
Put_VOL	136 (136)	1.0633	1.1310	0.0020	5.8510
OE	89 (88)	0.8184	1.2123	0.0000	9.6610
Call_OE	89 (88)	0.4051	0.7288	0.0000	3.4800
Put_OE	89 (89)	0.4087	0.8877	0.0000	7.2720
Fut_vol	136 (136)	55.0479	23.9308	15.0600	160.5500
Fut_sigma	136 (136)	0.1384	0.0941	0.0357	0.6830

are uniformly distributed between the option strike prices, which are spaced $5 apart, we would expect 15% of the futures prices to finish within $0.375 of the closest strike price.[11] The result is slightly stronger at 22.47% if the focus is on the short sample from October 1998 to November 2009, which is characterized by increased options trading activity.

Second, pinning from below the strike price is especially pronounced. For the full sample, while pinning from above the strike price amounts to 6.62%, pinning from below the strike price is 14.71%. In the short sample, the values are 7.87% for pinning from above and 14.61% for pinning from below.

To show that pinning is related to option expirations, we depict in Fig. 5 the pinning percentage for all days starting ten days before expiration to ten days after expiration. From November 1992 until November 2009, the expected frequency of 15% is elevated on expiration days as opposed to the ten preceding or following days (see Panel A). Panel B shows that this effect is somewhat stronger in the more recent period from October 1998 until November 2009.

Next we would like to gain some feeling for the economic importance of the futures price shifts. We employ the method of Ni et al. (2005), who bound the expected absolute return shift from below by the absolute of the sum of absolute returns times the differences of their respective probabilities on expiration Fridays and nonexpiration Fridays. We repeat their Eq. (3) here:

$$\left|E(\widehat{a}_i)-E(a_i)\right| \approx \left|\sum_{b=1}^{B}[\widehat{p}(b)-p(b)]a(b)\right|, \tag{7}$$

where $b=1,\ldots,B$ indexes B absolute return intervals, $a(b)$ is the absolute return of interval b, and $\widehat{p}(b)-p(b)$ is the difference in the probability that a future's absolute return falls in interval b on expiration and nonexpiration Fridays. Ni et al. (2005) suggest using a very fine return grid, and we employ a spacing of 0.1 basis points (bps; going to 0.01 basis points does not affect our results in the first four decimals). We find in the long sample (November 1992 until November 2009) a shift of at least 11.00 bps from Thursday PM to expiration Friday PM. This translates into an average change in notional value of at least $115 million based on an average futures open interest of 410,890 contracts at $1013.46 each. An amazing $59 million shifts solely within the last 30 min of trading. For the short sample (October 1998 until November 2009), the average shift from Thursday to Friday is even larger at $240 million based on an average open interest of 515,694 contracts at $1202.48 each. The last 30 min account for as much as $105 million in this case.

Table 2 reports the unconditional correlation structure between the main variables. Among the set of considered variables, option volume exhibits the highest unconditional correlation with symmetric pinning at 0.36 and, thus, plays an important role for the documented pinning. Further, open interest (0.22) and early option exercise (0.22) are relatively

[11] Over longer horizons the futures prices are distributed according to some more complicated distribution, which is often assumed to be the lognormal. However, locally over any small interval, any continuous distribution is well approximated by a uniform distribution.

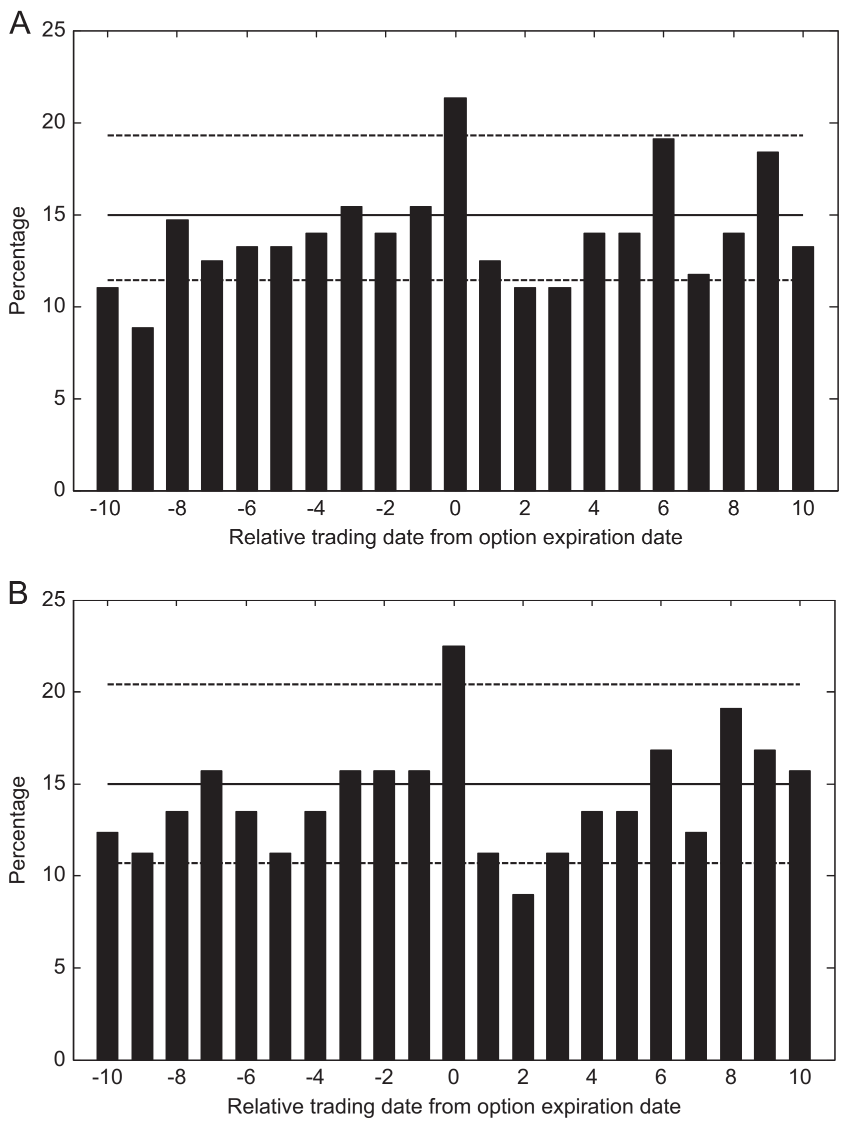

Fig. 5. Percentage of Standard & Poor's (S&P) 500 futures finishing within $+/-\$0.375$ of the strike price. This figure depicts the percentage of S&P 500 futures settlement prices that are within the $+/-\$0.375$ range around the at-the-money strike price. This proportion should be 15% if prices are uniformly distributed around the strike price (horizontal line plus bounds for the 10th and 90th percentile based on a binomial distribution). The figure presents results for the ten days before and after the serial expiration dates and for the serial expirations themselves. Panel A depicts results for the period from November 1992 to November 2009, and Panel B depicts results for the period from October 1998 to November 2009. Both panels exclude October 2008.

strongly related to symmetric pinning. The positive sign for open interest is somewhat surprising because, according to the Avellaneda and Lipkin (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 0.88). We show below that, conditional on option volume, open interest is always negatively related to symmetric pinning. Finally, as expected, futures volatility is negatively related to pinning (-0.13). Slightly surprising is the negative correlation between futures volume and pinning (-0.11). In untabulated results, we find that recomputing Tables 1 and 2 for the short sample changes the point estimates but generally confirms the above descriptive statistics.

5.2. *Pinning does exist in the first-to-maturity future due to serial SP options*

Using the long and short samples, we analyze if expiration Friday pinning (within $0.375 below and above the at-the-money strike price) is stronger than pinning during the ten days before and after the expiration Friday. We collect all results for our logistic regressions of this section in Table 3.

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 November 1992 to November 2009 (excluding October 2008). Symmetric pinning *Pinn_sym* is a binary variable, which is one if the futures settlement price is within $0.375 to the left or right of the at-the-money strike price and zero otherwise. At-the-money open interest *OI* is measured one day before the serial expiration day with respect to at-the-money strike price on the serial expiration day. At-the-money volume *VOL* and at-the-money option exercise *OE* are both measured on the serial expiration date with respect to the at-the-money strike price. Futures volume *Fut_vol* measures number of futures 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 omit missing observations. Correlations for *OE* are based on the period October 1998 to November 2009.

Variable	*Pinn_sym*	*OI*	*VOL*	*OE*	*Fut_vol*	*Fut_sigma*
Pinn_sym	1.0000	0.2223	0.3641	0.2235	−0.1132	−0.1264
OI		1.0000	0.8845	0.7903	−0.1057	−0.1126
VOL			1.0000	0.7546	−0.1180	−0.0941
OE				1.0000	−0.1450	−0.0361
Fut_vol					1.0000	0.1581
Fut_sigma						1.0000

For the long sample from November 1992 to November 2009 (136 expirations), we find in Model 1 supporting evidence for symmetric pinning, which affects the near maturity futures with a *p*-value of 0.01 when compared with other days. The evidence for pinning in the short sample from October 1998 to November 2009 (Model 2) is similarly strong with a *p*-value of 0.03, despite the reduced sample size (89 expirations).

We next investigate asymmetric pinning in the long sample. In Models 3 and 4 we analyze pinning from above and below, respectively. While we do not find supporting evidence for pinning from above (*p*-value of 0.99), the evidence is very strong for pinning from below (*p*-value of 0.00). These findings are consistent with our analysis of market maker positions in the SPX market reported in Section 2, where we find short average positions of −1840 at-the-money calls and −12,315 at-the-money puts. The larger put positions would dominate aggregate pinning and, thus, we are not surprised that pinning from below due to the puts is stronger than pinning from above due to the calls. Below in the explanatory runs, we investigate the

Table 3
Logistic regressions for pinning.

This table presents results of the logistic regressions showing pinning, based on our long sample (November 1992 to November 2009; superscript *L*) and our short sample (October 1998 to November 2009; superscript *S*). Symmetric pinning *Pinn_sym* is a binary variable, which is one if the futures settlement price is within $0.375 below or above the at-the-money strike price and zero otherwise. *Pinn_above* (*Pinn_below*) is a binary variable that takes a value of one if there is pinning and the futures settlement price is below (above) the fair value based on the second-to-maturity future and zero otherwise. At-the-money open interest *OI* is measured one day before the serial expiration day with respect to at-the-money strike price on the serial expiration day. At-the-money open interest is the sum of at-the-money call open interest *Call_OI* and at-the-money put open interest *Put_OI*. At-the-money volume *VOL* and at-the-money option exercise *OE* are both measured on the serial expiration date with respect to the at-the-money strike price. At-the-money volume is the sum of at-the-money call volume *Call_VOL* and at-the-money put volume *Put_VOL*. Similarly, at-the-money option exercise *OE* is the sum of at-the-money call option exercise *Call_OE* and at-the-money put option exercise *Put_OE*. Futures volume *Fut_vol* measures number of futures 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 omit missing observations. Variables measuring options and futures trading activity (*OI* through *Fut_vol*) are expressed in thousands. We report *p*-values in parentheses below each coefficient. Finally, we report the number of observations used for each regression.

Right-hand side regression variables	1 $Pinn\_sym_t^L$	2 $Pinn\_sym_t^S$	3 $Pinn\_above_t^L$	4 $Pinn\_below_t^L$	5 $Pinn\_sym_t^L$	6 $Pinn\_sym_t^S$	7 $Pinn\_sym_t^S$	8 $Pinn\_above_t^L$	9 $Pinn\_below_t^L$	10 $Pinn\_above_t^S$	11 $Pinn\_below_t^S$	12 $Pinn\_sym_t^S$	13 $Pinn\_sym_t^S$	14 $Pinn\_sym_t^L$
Constant α	−1.85	−1.82	−2.64	−2.58	−2.15	−2.01	−2.02	−2.62	−2.43	−2.67	−2.38	−2.09	−0.27	−1.73
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.75)	(0.00)
$Dummy_t$	0.54	0.59	−0.01	0.83										−0.22
	(0.01)	(0.03)	(0.99)	(0.00)										(0.42)
Open Interest OI_{t-1}					−0.35	−0.86	−0.87					−0.87	−1.08	
					(0.09)	(0.02)	(0.02)					(0.02)	(0.01)	
Volume VOL_t					0.69	1.13	1.13					1.13	1.28	
					(0.00)	(0.00)	(0.00)					(0.00)	(0.00)	
Option Exercise OE_t							0.05					0.05	0.13	
							(0.92)					(0.92)	(0.75)	
$Call\_OI_{t-1}$								−1.07		−1.33				
								(0.04)		(0.06)				
$Call\_VOL_t$								0.99		1.06				
								(0.03)		(0.07)				
$Call\_OE_t$										0.49				
										(0.66)				
Put_OI_{t-1}									−0.48		−0.88			
									(0.11)		(0.22)			
Put_VOL_t									1.01		1.40			
									(0.00)		(0.02)			
Put_OE_t											0.10			
											(0.91)			
Fut_vol_t												0.00		
												(0.93)		
Fut_sigma_{t-1}													−13.03	
													(0.03)	
Number of observations	2813	1839	2813	2813	129	82	82	130	134	83	87	82	82	2813

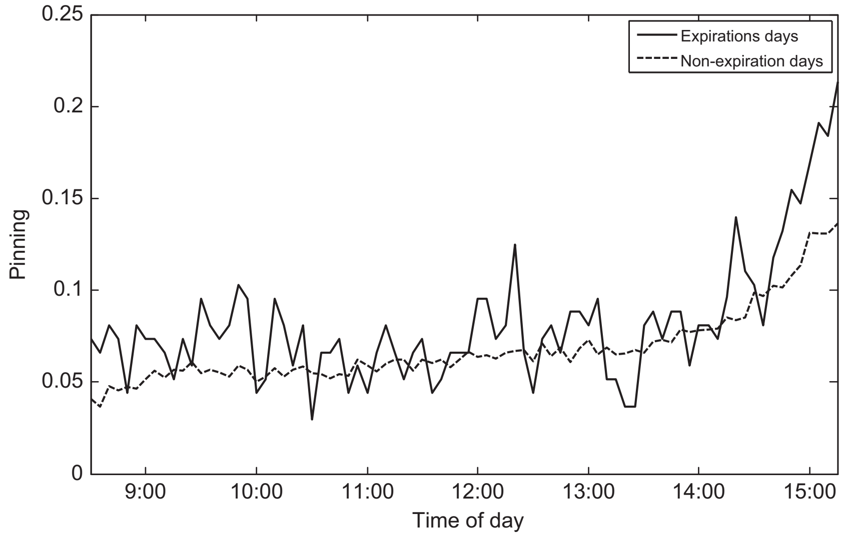

Fig. 6. Intradaily pinning. This figure depicts intradaily pinning percentages averaged either across all nonexpiration days (dashed line) or across all expiration days (solid line) in a +/−10 day window around expirations. The sample period is from November 1992 until November 2009, and pinning is based on a symmetric pinning interval of +/−\$0.375 around the at-the-money strike price.

exact mechanisms for this behavior in more detail. In the short sample, the estimated coefficient is positive in both cases and the *p*-value for pinning from above is 0.68 and 0.01 for pinning from below.

Before launching into explanations for pinning, we also explore intradaily pinning. To this end, we form intervals of 5 min and use the first trade price in each interval. We then analyze the evolution of pinning on serial expiration days for expiration days and nonexpiration days during the +/−10 day around expirations. We always define the at-the-money strike price with respect to the futures settlement price. Fig. 6 plots the intradaily evolution of pinning and shows, interestingly, that pinning occurs only during the last half an hour of trading on serial expiration days, starting at around 14:45.

5.3. Mechanisms of pinning in the first-to-maturity future

Because we establish pinning in the first-to-maturity futures, we now embark on analyzing the mechanisms that 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. At-the-money open interest decreases pinning.

Hypothesis AL-2. At-the-money option volume increases pinning.

In the long sample from November 1992 to November 2009, we find according to Model 5 that both variables have the expected signs: At-the-money open interest reduces pinning, and at-the-money volume increases pinning. While *OI* exhibits a *p*-value of 0.09, the effect of *VOL* is very strong with a *p*-value of 0.00. There is little autocorrelation in the residuals as the AR(1) of the residuals is statistically insignificant at 0.05.

We then investigate Hypothesis AL-3.

Hypothesis AL-3. At-the-money early option exercise increases 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 recorded and some few extremely low values. However, starting in October 1998, the values are much more realistic. Instead of 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 and show that the results strengthen in the short sample from October 1998 to November 2009. This is demonstrated in Model 6, as the point estimates in the short sample double and the *p*-value on the *OI* decreases to 0.02 while the *p*-value on the *VOL* remains at 0.00. Then we include early option exercise (*OE*) in our model and report the results in Model 7. While at-the-money early option exercise exhibits the correct sign, it is insignificant. We are afraid that this could be partially due to the reduced statistical power of the regression as we are using only 82 observations in the short sample as opposed to 129 observations in the long sample.

Next, we turn our attention to the asymmetric pinning effects of Wall Street Journal (1982).

Hypothesis AN-1. At-the-money call volume increases pinning from above the strike price.

Hypothesis AN-2. At-the-money put volume increases pinning from below the strike price.

We conceptually revert to the setting of Model 5 where we investigate the effects of open interest and volume in the long sample. However, we now separate for pinning from above the strike price in Model 8 and pinning from below the strike price in Model 9. Accordingly, we split the right-hand-side variables into at-the-money call and put open interest and at-the-money call and put volume.

Pinning from above the strike price is supported by Model 8 with a *p*-value of 0.03 because at-the-money call volume increases the propensity of pinning from above the strike price, as expected. The evidence in favor of pinning from below the strike price is even stronger in statistical terms, as at-the-money put volume in Model 9 is significant with a *p*-value of 0.00. Using the short sample, the signs remain as in Models 8 and 9 while the *p*-values increase slightly.

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

Hypothesis EARLY-1. At-the-money call early option exercise increases pinning from above the strike price.

Hypothesis EARLY-2. At-the-money put early option exercise increases pinning from below the strike price.

We use the standard model (Model 7) applied to the short sample due to missing data in the early option exercise variable. Model 10 shows the results for pinning from above the strike price; Model 11 for pinning from below the strike price. All early option exercise coefficients are positive but insignificant with a *p*-value of 0.66 in case of calls and 0.91 in case of puts, suggesting that early exercise does not play a large role in individual customers' unwinding of open option positions.

We next turn to potential market manipulation and investigate Hypothesis NI-1.

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

Again, we use as a point of departure Model 7, which includes at-the-money open interest, at-the-money volume, and at-the-money early option exercise. As we include early option exercise, we can use only the short sample. We then add the variable futures volume and report the result in Model 12. We were concerned that futures volume could be correlated with our mechanism variables, but from Table 2 we know that correlations tend to be negative and low. The result repeats much of Model 7 as open interest and volume are significant and, while all variables have the right signs, early option exercise is insignificant. The addition of futures volume leads, as expected, to an insignificant coefficient (*p*-value 0.93). We conclude that market manipulation does not seem to explain pinning, and we draw the same conclusion when using the long sample without option early exercise.

Finally, we analyze the influence of volatility on pinning and test Hypothesis NI-2.

Hypothesis NI-2. Futures volatility decreases pinning.

As in the case of Hypothesis NI-1, we use as a point of departure the short sample and Model 7. We then add futures volatility and report the results in Model 13. In line with our hypothesis, futures volatility is negatively related to pinning, and the *p*-value is significant at 0.03 but becomes insignificant (*p*-value of 0.16) when using the long sample without option early exercise.

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 Wall Street Journal (1982). Pinning due to the hedging effect caused by early option exercise is insignificant, possibly due to the shorter sample over which the early option exercise variable is available. Market manipulation does not appear to contribute to the explanation. Volatility of the underlying seems to have some impact on the pinning effects of delta hedging.

5.4. No pinning in second-to-maturity future due to serial SP options

SP options expire in the first-to-maturity futures. Hence, if pinning is related to option expiration, it should be present in the first-to-maturity futures, as shown in Section 5.2, and it should be absent in longer maturity futures. To investigate whether any evidence exists for pinning in longer maturity futures, we next measure symmetric pinning in the second-to-maturity futures on serial expiration dates.[12] Based on the insignificant *p*-values in Model 14, we conclude that no evidence exists for pinning in the serial expiration dates for second-to-maturity futures in the long sample. This finding continues to hold in the short sample.

5.5. 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.[13] Unlike serial SP options, SPX options are cash settled (just like quarterly SP options). Therefore, the fear of ending up with a naked position in the underlying does not apply to SPX options and the Wall Street Journal's (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 anti-pinning story of Avellaneda and Lipkin (2003). Thus, if there is any pinning in the S&P 500 itself, it should be anti-pinning. However, it is hard to imagine that market makers' hedging needs would be strong enough to move the whole basket of 500 stocks.

We test for pinning in the S&P 500 index on serial expirations in the long sample. The European serial SPX options exist since April 1986, but the settlement procedures for SPX options underwent some changes (see Appendix A

[12] We do not use third-to-maturity futures because their strike price intervals are either $10 or $25 instead of always $5 for the first- and second-to-maturity futures.

[13] There also exists the SPDR exchange traded fund on the S&P 500 with the associated SPY options. However, as we do not know the market maker positions in this market and options exist only since 2005, we have no clear prior on what to expect in terms of pinning. We, thus, do not investigate these data further. Inital checks did not reveal any pinning.

for details). In line with these changes, we use November 1992 to November 2009 when settlement occurs in the special opening quotation SOQ (Friday AM). We cannot run our usual logistic regressions as SOQ values exist only on expiration days. However, the average count for pinning (15.44%) is very close to the theoretical value of 15%, and a test of pinning in the SOQ settlement value due to the SPX options against a uniform distribution turns out to be insignificant with a *p*-value of 0.49.

6. Results for cross-pinning

Continuing to think about the SPX options market, it seems much more realistic for market makers to hedge SPX options through the futures market rather than the underlying S&P 500 basket itself. In that case, the SPX market could cross-pin onto the futures market. We now turn to this fascinating subject in which we can establish anti-cross-pinning. Plus, cross-pinning can also be due to, e.g., the quarterly SP options written on the first-to-maturity future (simultaneously expiring with the option itself), which might cross-pin onto the second-to-maturity future as that is the most realistic hedge for the quarterly SP options. Just like the SPX options, quarterly SP options are cash settled and should, therefore, also lead to cross-anti-pinning.

6.1. Cross-pinning samples

Before we can embark on our analysis of cross-pinning, we need to sort through the many different available option samples that could potentially cross-pin. All the subsamples share the common feature of containing cash-settled options. The sample cutoffs are determined by regulation changes at the exchanges, where certain options change their settlement procedure and settlement time (details are collected in Appendix A). Altogether we identify 245 day on which to check for cross-pinning. As we check for cross-pinning from the SPX options and from the SP options, we also encounter dual periods when (anti-)pinning could arise either due to the SPX options or the SP options. For details on the samples, see Appendix C.

When analyzing cross-pinning from the SPX options onto the future, we first determine the at-the-money strike price of the closing value of the index. We then adjust this strike price for the cost-of-carry and check for pinning in the futures price reported at 15:00 (or the first trade reported after 15:00).[14] We typically check for cross-pinning in the first-to-maturity future, except when the liquidity is already higher in the second-to-maturity future as traders rolled over their positions from the first-to-maturity future. This happens, for example, in quarterly expirations when the first-to-maturity future is hardly being traded and hedging is conducted in the second-to-maturity future. In such cases, we determine the at-the-money strike price with respect to the settlement value of the first-to-maturity future and analyze pinning in the settlement value of the second-to-maturity future.[15] When analyzing cross-pinning from the SP options (quarterly expirations), we determine the at-the-money strike price with respect to the expiring first-to-maturity futures and check for cross-pinning in the second-to-maturity futures. In dual samples, we combine the samples and count as pinning if there is pinning in both samples. Otherwise, we do not record a pinning event. Also, we restrict ourselves to days when the adjusted strike prices of SPX options and SP options are within the distance of one pinning interval. Throughout, we use the cost-of-carry adjusted strike price. For example, if we check for cross-pinning from the SPX market onto the first-to-maturity future, we adjust the SPX at-the-money strike price to the forward value to which the future might pin. The adjustment is calculated as the median ratio of the first-to-maturity future and the index by matching within minute observations from 9:00 to 14:30 on the same day. For all other samples we use similar adjustments.

SPX options and SP quarterly options in more recent samples expire in the Friday AM special opening quotation value, which is difficult to time stamp. Therefore, for AM expirations, we check for cross-pinning in the closing value of the index on the evening before the expiration day (typically Thursday).

6.2. Cross-pinning does exist

We observe pinning (within \$0.375 below and above the at-the-money strike price) on 9.39% of our 245 expiration days, which compares with 14.71% on non-expiration days. As shown in Table 4, Model 15, this difference is statistically significant with a *p*-value of 0.02 and, thus, provides evidence of symmetric anti-cross-pinning.

This result is robust to the exclusion of sample SP1Q (see Appendix C for details on particular samples), which is a pure sample of futures options' cross-pinning and possibly not as obvious a case for cross-pinning as the SPX related samples, which clearly cross-pin from a different market (the *p*-value in Model 15 increases from 0.02 to 0.03). Our result weakens only slightly when we use all dual periods in which there is potential cross-pinning from SP as well as SPX options completely. That is, independent of adjusted strike prices being close to each other or not, we consider a pin in a dual sample already if there is a cross-pin from the SPX market (as opposed to our usual requirement of simultaneous pinning from the SPX and the SP options market). The *p*-value then increases to 0.05.

6.3. Mechanisms of cross-pinning

Because we establish anti-cross-pinning, we now embark on analyzing the mechanisms that drive it. As SPX options data are available only from 1990, we

[14] Stocks in the basket of S&P 500 trade until 15:00 pm, and options and futures trade until 15:15 pm.

[15] If the settlement value of the expiring first-to-maturity future is not available (such as in the spillover of the dual sample SP2Q and SPX2Q; see Appendix C), we approximate it by the closing value of the S&P 500.

Table 4
Logistic regressions for cross-pinning.

This table presents results of the logistic regressions showing cross-pinning. Symmetric pinning *Pinn_sym* is a binary variable, which is one if the futures settlement price is within $0.375 below or above the at-the-money strike price (appropriately adjusted for the cost-of-carry) and zero otherwise. At-the-money open interest *OI* is measured on the same day as cross-pinning with respect to at-the-money strike price of the SPX options. At-the-money volume *VOL* and at-the-money close buy of small and medium customers *CB* are both measured on the same day as cross-pinning with respect to the at-the-money strike price of the SPX options. Futures volume *Fut_vol* measures number of futures contracts traded. Futures volatility *Fut_sigma* is a scaled realized daily range measured one day before the day on which we test for cross-pinning. We omit missing observations. Variables measuring options and futures trading activity (*OI* through *Fut_vol*) are expressed in thousands. We report *P*-values in parentheses below each coefficient. Finally, we report the number of observations for each regression. Model 15 is based on the 245 expiration days in which we check for cross-pinning (see Appendix C for details) against the surrounding +/−10 day, and Models 16 to 20 are based on the 122 day in which we test for cross-pinning from AM expiring SPX options.

Right-hand side Regression variables	15 *Pinn_sym$_t$*	16 *Pinn_sym$_t$*	17 *Pinn_sym$_t$*	18 *Pinn_sym$_t$*	19 *Pinn_sym$_t$*	20 *Pinn_sym$_t$*	21 *Pinn_sym$_t$*	22 *Pinn_sym$_t$*	23 *Pinn_sym$_t$*	24 *Pinn_sym$_t$*	25 *Pinn_sym$_t$*
Constant α	−1.76	−1.53	−1.34	−1.44	−1.32	−1.51	−1.39	−0.53	−0.90	−0.66	−0.63
	(0.00)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.60)	(0.29)	(0.50)	(0.50)
Dummy$_t$	−0.51										
	(0.02)										
Open Interest OI$_t$		−0.03		−0.02		−0.03		−0.02		−0.03	
		(0.12)		(0.39)		(0.13)		(0.26)		(0.12)	
Volume VOL$_t$				−0.02							
				(0.67)							
Close Buy CB$_t$						−0.05		−0.32		−0.08	
						(0.94)		(0.64)		(0.90)	
Put_OI$_t$			−0.11		−0.11		−0.12		−0.11		−0.13
			(0.05)		(0.12)		(0.05)		(0.08)		(0.05)
Put_VOL$_t$					−0.01						
					(0.93)						
Put_CB$_t$							0.59		0.58		0.77
							(0.61)		(0.63)		(0.53)
Fut_vol$_t$								−0.02	−0.01		
								(0.25)	(0.48)		
Fut_sigma$_{t-1}$										−7.72	−7.66
										(0.29)	(0.34)
Number of observations	4440	122	122	122	122	122	122	122	122	122	122

restrict our sample to the subsamples SPX4S and the dual samples SP4Q and SPX4Q, which all expire Friday AM.[16] We also exclude the years 1998 to 2002 due to missing observations.[17] Altogether, we have 122 observations. Cross-anti-pinning on those days exhibits a *p*-value of 0.06 in our logistic regression. As the cross-pinning samples are characterized by cash settlement instead of physical delivery (as is the case for the SP serial options), we focus on the time decay in the delta hedge as modeled by Avellaneda and Lipkin (2003).

We analyze cross-pinning on the evening before the expiration and can, therefore, use the open interest from that same Thursday. Thus, as opposed to the main analysis in which we use open interest from one day before expiration and then correct it with the contemporaneous volume (and options early exercise), we can now test for the Avellaneda and Lipkin (2003) effect using the contemporaneous open interest.

For the observations corresponding to the dual sample SP4Q and SPX4Q we add open interest and volume for SP and SPX options.

Hypothesis AL-1. At-the-money open interest decreases pinning.

We find evidence of the Avellaneda and Lipkin (2003) mechanism as open interest has the right sign in Model 16. While the effect is insignificant with a *p*-value of 0.12, it turns significant (*p*-value 0.05) in Model 17 when we use put open interest instead. This strengthening is not surprising as we know from the OpenClose data that the market makers positions in puts are much larger than in calls.

Hypothesis AL-2. At-the-money option volume increases pinning.

We are less certain if volume matters because the Wall Street Journal (1982) effect should not be strongly present in cross-pinning and volume would pick that up. We check such volume effect in Model 18 and it turns out to be insignificant: Volume even decreases the significance

[16] Theoretically, we could also include subsample SPX4EoQ and part of the sample SPX3Q, but we prefer to keep the analysis parsimonious and focus only on the largest samples of AM expirations. Furthermore, many observations are missing for the sample SPX4EoQ. See Appendix C for details.

[17] Daily Optsum and OpenClose data, both obtained from Market Data Express, exhibit a large number of missing observations for at-the-money options in the period from January 1998 to December 2002. As there are no missing observations outside those years, we feel that the missing observations are due to a problem in the data and we feel uncomfortable using the data from these years. Putting this period back preserves the qualititative results but leads to insignificant parameter coefficients. OptionMetrics SPX daily data in this period exhibit virtually the same pattern of missing observations.

of the open interest variable. Repeating the exercise for put open interest and put volume in Model 19 yields somewhat stronger but still insignificant results.

Volume, however, is not the right variable to explain Avellaneda and Lipkin (2003). The quantity that interests us is the closing volume of individual customers. We use our OpenClose data and measure closing volume of open buy at-the-money options on the day before expiration for small and medium individual customers. We call this variable *CB*, which stands for Close of a Buy. The correlation coefficient between *CB* and *VOL* is 0.39. However, we do not expect *CB* to matter much because the SPX options are cash settled and the motive to resell the in-the-money options is, thus, greatly reduced. Using *CB* in Model 20 as opposed to *VOL* in Model 18 does not change the main results. Just to the contrary, *CB* has an insignificant coefficient (p-value of 0.94) in Model 20 and open interest gains in the explanatory power, but it remains insignificant. Turning to put open interest in combination with put *CB* in Model 21, put open interest comes out significant with a p-value of 0.05 and put *CB* remains insignificant. Again, the larger market makers positions seem to drive the stronger results. If we use only medium customers as opposed to small and medium customers, the results remain largely unchanged.

Manipulation does not apply as an argument to cross-pinning. As the underlying is a different security than the pinning security, any manipulation would need to occur in the underlying itself to benefit the manipulator. Therefore, as expected, futures volume is insignificant in Models 22 and 23. Futures volatility is negatively related to pinning but is insignificant as reported in Models 24 and 25.

7. Robustness

We show that our results are robust to a number of methodological changes. We consider excluding two expiration days that occur on Thursday as opposed to the typical Friday. The p-value in Table 3, Model 1 remains unchanged at 0.01. Similarly, the p-value does not change if we include the crash month of October 2008 (October 1987 is relevant only for cross-pinning). Next, we change the treatment of missing variables in the explanatory runs from eliminating the observations (Model 5 with p-values of 0.09 and 0.01 on open interest and volume, respectively) to using them with a value of zero (p-values of 0.08 and 0.00) or with a value set to the average of the variable for nonmissing observations (p-values of 0.07 and 0.00).

Another important concern is the correct choice of the pinning interval, which we so far set to \$0.375 above and below the at-the-money strike price. 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 are very noisy. Choosing the interval too large and beyond the region where hedging pressures influence futures prices again leads to insignificant results.

We recall the standard models in which we test for pinning on expiration Fridays compared with nonexpiration days. The p-values for the interval of \$0.375 below or above the strike price were 0.01 (Model 1, long sample) and 0.03 (Model 2, short sample). Moving to an interval of $+/-$\$0.25, the p-values are 0.02 and 0.00, while they are 0.04 and 0.06 for an interval of $+/-$\$0.5. In the case of cross-pinning, we have to use our collection of subsamples and the main Model 15 has a p-value of 0.02 for the interval of \$0.375. The p-value changes to 0.07 for \$0.25 and to 0.04 for \$0.5 as an interval choice. We find our results to be robust with respect to these variations in the pinning interval.

With regard to the mechanisms explaining pinning, we recompute Models 5 through 13 of Table 3 while varying the size of the interval from \$0.375 to \$0.25 and \$0.5, respectively. Results are robust to small variations in the pinning interval. Moving to the alternative pinning intervals improves the statistical significance of the explanatory variables, except for Model 9 and, less so, Model 11 where results weaken somewhat, affecting the explanations of pinning from below due to put options. Next we repeat the explanatory regressions of Table 4, Models 16 through 25 for cross-pinning. Here, the move to alternative pinning intervals weakens results somewhat, but the negative sign on open interest is preserved in all specifications and the estimated coefficients on put open interest typically have p-values below 0.10. Altogether, our results for explanatory runs for cross-pinning are not affected much by small changes in the pinning interval.

Next, we investigate the scaling of our variables in the explanatory runs. In light of the large swings in our main variables (going from zero to over 16 thousand; in the case of cross-pinning even to 400,000), we transform the variables by taking logarithms in which we ignore missing values whenever the original variables are zero. Scaling does not affect results much for pinning. For cross-pinning, significance in put open interest tends to change into significance in total open interest.

While the logistic regression model is appropriate for models with binary dependent variables, we check that the simpler linear probability model does not change the main results. In all the models in which we test for presence of (anti-)pinning (Models 1–4, 14, and 15), the results remain unchanged. In the explanatory runs for pinning, the estimated coefficients tend to have even lower p-values. In the case of explanatory runs for cross-pinning, p-values increase and estimated parameters turn insignificant but preserve the right sign.

8. Conclusion

We show that SP options induce 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.

In analyzing the economic mechanisms that drive index futures pinning, we show that they differ considerably from the mechanisms driving stock pinning. Concerning stock pinning, Ni et al. (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 et al. (2005) argue that manipulation plays a role. For index futures pinning, neither of these two effects is wholly convincing. For one, Garleanu et al. (2009) report that market makers are 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. The serial SP options are settled into physical delivery, and investors with long in-the-money options could, therefore, fear the price risk over the weekend. Hence, they sell their in-the-money options (Wall Street Journal, 1982) or early exercise their in-the-money options just before the expiration. The resulting hedging pressure would lead to pinning. We show that the time decay of the delta hedge does lead to anti-pinning but is overcompensated by the two additional mechanisms in the case of SP serial options pinning.

As there exist very liquid options on the S&P 500 index itself, but the basket of 500 index securities is difficult to trade for hedging purposes, we also investigate the possibility that SPX options are hedged via the S&P 500 futures. We show this fascinating effect and find anti-cross-pinning. Here the anti-pinning is intuitive as SPX options are cash settled and only the Avellaneda and Lipkin (2003) mechanism applies.

Further, for the case of pinning, we show extensive movements of at least $115 million worth of futures value per expiration day that is temporarily being moved closer to the strike nearest the futures settlement price. This number increases to $240 million in the more recent period from October 1998 until November 2009. These large shifts of notional value in the futures market could also be of concern to the regulators and the exchanges.

Appendix A. The main characteristics of S&P 500 derivatives

Appendix A covers the futures related derivatives on the S&P 500 as well as the options written directly written on the S&P 500.

A.1. S&P 500 futures and SP options on S&P 500 futures

Futures on S&P 500 index and options on S&P 500 futures are traded on the Chicago Merchandise Exchange. Futures were introduced on April 21, 1982; SP options on January 28, 1983. SP options are American. First- and second-to-maturity options have $5 strike price intervals, and options for deferred months have strike prices either $10 or $25 apart.

SP futures and options initially expired in the PM cash value of the S&P 500 index on the third Thursday on a quarterly cycle (March, June, September, and December). This settlement procedure underwent three important changes. In June 1984, the CME shifted 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 PM value of the index, but in the special opening value of the index (AM expiration), the special opening quotation (SOQ) or exercise-settlement value of the index (SET). This value is determined by the first opening prices of all the constituents of the index. Second, the CME introduced serial SP options that expire in the first-to-maturity futures on the third Friday of the serial months (January, February, April, May, July, August, October, and November).

The introduction of serial options is crucial for our study. We state three main differences between quarterly and serial SP options.

(1) While quarterly SP options expire simultaneously with the underlying futures, serial SP options expire and the underlying futures continues to trade for an additional month or two.
(2) While quarterly SP options expire in the AM value of the S&P 500 index (like futures), serial SP options expire in the PM value of the underlying futures.
(3) While quarterly SP options are cash settled, serial SP options lead to physical delivery of the underlying futures.

A.2. SPX options on the S&P 500 index

SPX options trade on the Chicago Board of Options Exchange (CBOE) since July 1, 1983. All SPX options are cash settled. Nearest to maturity options have $5 strike price intervals, and options for deferred months have strike prices $25 apart.

Initially, SPX were American and traded on a quarterly cycle. They expired in the PM value on the third Friday in a quarterly cycle.[18] In April 1986, the CBOE replaced American SPX options with the European SPX options and introduced serial expirations.

With the introduction of the AM settlement for SP futures and quarterly SP options by the CME in June 1987, the CBOE introduced another set of quarterly options that also expire AM (serial options continued to be settled PM). For a while both sets of quarterly options coexisted, until in June 1992, the CBOE decided that all SPX options should expire AM. Ever since, all SPX options (serial expirations and quarterly expirations) expire in the special AM 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. The above information is summarized in Table A1.

Appendix B. Treatment (filtering) of the main data

We obtain the data from two sources: the Chicago Mercantile Exchange and the Market Data Express, the

[18] Technically, it is the Saturday following the third Friday of the month. However, because the settlement value is being determined on Friday already, we keep on referring to all expiration dates as (third) Fridays.

Table A1
Main characteristics of the Standard & Poor's (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). AM settlement price is based on the special opening value of the underlying. PM settlement price is based on last prices of the underlying on an expiration day. The table is based on the information obtained from the Chicago Mercantile Exchange (CME) webpage (http://www.cmegroup.com), Chicago Board of Options Exchange (CBOE) webpage (www.cboe.com), Stoll and Whaley (1986, 1991), and CBOE Regulatory Circular Number RG92-46. ∗ indicates that serial expirations for SPX options were introduced in April 1986.

Characteristic	SPX options	SP futures	SP options
Underlying	S&P 500 index	S&P 500 index	SP futures
Opening date	July 1, 1983	April 21, 1982	January 28, 1983
Strike price interval	5 points (first nearest month) 25 points (deferred months)	–	5 points (first and second nearest month) 10 and 25 points (deferred months)
Type	European (American before April 1986)	–	American
Trading hours (central time)	8:30 AM–3:15 PM	8:30 AM–3:15 PM	8:30 AM–3:15 PM
Expiration months	Three serial months Three months in the quarterly cycle	Eight months in the quarterly cycle	Three serial months Eight months in the quarterly cycle
Settlement at expiration	Q+S: cash settlement	Q: cash settlement	Q: cash settlement S: physical delivery
		Settlement value	
Until June 1984	Q: PM settlement (third Friday)	Q: PM settlement (third Thursday)	Q: PM settlement (third Thursday)
June 1984 to June 1987	Q+S∗: PM settlement (third Friday)	Q: PM settlement (third Friday)	Q: PM settlement (third Friday)
June 1987 to December 1993	Q+S: coexistence of AM and PM. settled options (third Friday)	Q: AM settlement (third Friday)	Q: AM settlement (third Friday) S: PM settlement (third Friday)
December 1993 onward	Q+S: AM settlement (third Friday)	Q: AM settlement (third Friday)	Q: AM settlement (third Friday) S: PM settlement (third Friday)

official provider of Chicago Board of Options Exchange data. From the CME, we obtain the whole history of daily data for S&P 500 futures and SP options on S&P 500 futures. In addition, we bought from the CME the intradaily record of all the future trades. From Market Data Express, we obtain daily data for SPX options on the S&P 500 and the SPX OpenClose data on bought and sold volume separated by investor groups. From Market Data Express, we also received a separate file with AM exercise-settlement values (SOQ or SET) for SPX options.

All data end in December 2009. The futures data start in April 1982, SP options data start in January 1983, and SPX options data start in January 1990. The AM exercise settlement values (SOQ) start either in June 1991 (quarterly expirations) or November 1992 (serial expirations).

In all the data sets, we first filter out observations with missing values for any of the key variables. Further, we eliminate duplicate entries.

S&P 500 futures. The CME does not provide exact expiration dates. The data contain only the expiration year and the expiration month. 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 contain only the expiration year and the expiration month. Again, 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 covers standard SPX options as well as LEAPS (long dated options), 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, nonindex options, weeklies, and mini options. Finally, as all the expiration dates in the Market Data Express are set to the Saturday following the third Friday in a month, we move expiration dates by one day to the third Friday.

OpenClose data for SPX options on the S&P 500 index. Similarly to the daily records for SPX options, we eliminate LEAPS, nonindex options, weeklies, and mini options.

Appendix C. Cross-pinning samples

All samples that make up our cross-pinning sample are depicted in Fig. C1. Each sample is labeled in the form Underlying_SampleNumber_Type in which the Underlying can be either SP or SPX; the SampleNumber can be 1: January 1983–May 1984, 2: June 1984–May 1987, 3: June 1987–July 1992, or 4: August 1992–December

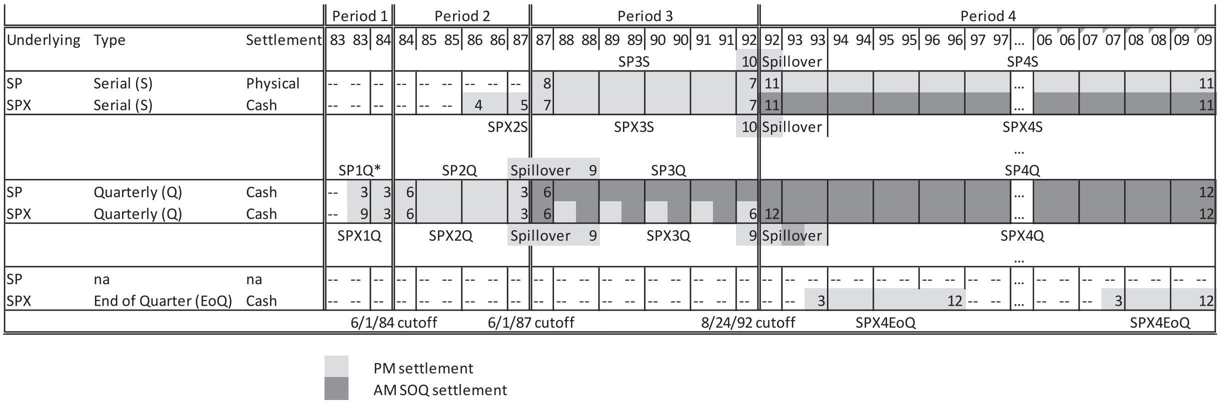

Fig. C1. Sample structure

This table depicts the sample structure of the data using the notation Underlying_SampleNumber_Type where the Underlying can be SP or SPX; the SampleNumber can be 1 (January 1983–May 1984), 2 (June 1984–May 1987), 3 (June 1987–July 1992), or 4 (August 1992–December 2009); and Type can be S (serial), Q (quarterly), or EoQ (end of quarter). The exact starting months of different samples due to data availability are indicated as numbers at the beginning of the sample. e.g., SP3S starts in August 1987 indicated by the 8. That sample ends in July 1992 (indicated by the 7) but there is a spillover of available options which only expire as late as October 1992 (indicated by the 10 Spillover above). * The typical expiration date is Thursday afternoon.

2009; and Type can be: S: Serial, Q: Quarterly, or EoQ: End of Quarter.

SP3S and SPX3S are serial samples that represent pinning and cross-pinning, respectively, and both expire simultaneously into the Friday PM value. Because SPX options would lead to anti-pinning and SP options should cause pinning, we leave out those samples as results depend too much on our assumptions concerning the respective force fields of pinning and anti-pinning. SP4S is our main (long) pinning sample of serial SP options used in Section 5.

SPX2S is our first sample included in the cross-pinning analysis. It contains serial SPX options that expire into the Friday PM value. Next is the SPX4S sample, our largest cross-pinning sample, consisting of serial SPX options expiring Friday AM, which could lead to cross-pinning on Thursday afternoon.

SP1Q is a quarterly SP option sample expiring Thursday PM, which would be hedged with the second-to-maturity future as the underlying first-to-maturity future expires on the same day in the S&P 500 index, which is difficult to move. The contemporaneous sample SPX1Q also expires PM but one day later (on Friday) and could lead to cross-pinning in the first-to-maturity future. Here we use the expiration date as the rollover date in separating between first- and second-to-maturity futures. Thus, in Period 1 we can check both samples SP1Q and SPX1Q independently for cross-pinning.

The following samples SP2Q and SPX2Q are dual in that both quarterly options expire into the Friday PM index and both are hedged with the second-to-maturity future. As both options are cash settled and similar mechanism of pinning apply, we combine the samples and consider days only if the adjusted strike prices are within $0.375 of each other. Otherwise those days are not considered in the sample. Pinning is then flagged if there is pinning in both samples. Otherwise we do not record a pinning event.

The next sample is also a dual sample, containing SP3Q and SPX3Q. Here we have AM settled SP options and both PM and AM settled SPX options. Theoretically, we could observe pinning due to AM and PM options. It is important, however, to understand the mechanics of the introduction of the new SPX AM settled options, which attracted little interest compared with the established PM settled options. Namely, volume and open interest only moved to the AM options as late as at year-end of 1992 (when the samples SP3Q and SPX3Q end) and remained with the PM options throughout the samples. We, thus, consider only the PM sample SPX3Q for cross-pinning.

The final dual sample is SP4Q and SPX4Q in which both SP and SPX expire in the special opening value on Friday morning (PM options having been phased out by now with some small spillover) and we can, therefore, test for cross-pinning on Thursday afternoon. We use the same mechanism as above to combine the dual samples into one if adjusted strike prices are within $0.375 of each other, and we count only simultaneous pinning in both subsamples as a pinning event. Our last sample SPX4EoQ is a pure cross-pinning sample of end-of-quarter SPX options, which expire PM on the last business day of each quarter.

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