Non-fundamental Shocks and Implied Volatility Skew: Evidence from S&P 500 Index Inclusions

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Abstract

When stock prices deviate from their fundamental values due to excess demand, investors anticipate reversals and trade in the options market to exploit the temporary misvaluation. This leads to options' predictability of stock returns beyond the well-known informed trading channel. Using S&P 500 index inclusions, we examine how option prices predict the reversal of a non-fundamental demand shock to the stock price. We find that the implied volatility skew of stocks added to the index becomes steeper in the months following index inclusion. This effect is not caused by an increase in systematic risk or the pre-inclusion momentum of added stocks. It exists only for stocks that experience a high index addition announcement return and fades after the announcement return reverses. Moreover, the implied volatility skew predicts next month's return for added stocks but this predictability is mainly driven by return reversals.

1 Introduction

The options market provides forward-looking information about the underlying stock price not contained in the stock market. Easley, O'Hara and Srinivas (1998) argue that informed traders may benefit from their private information in the options market because of options' implicit leverage or short-selling constraints in the stock market. Hence, information flows from the options market to the stock market. Along this line, numerous studies document that option prices predict future stock returns and suggest faster price discovery in the options market due to informed trading based on private information about firm fundamentals.[1]

This paper explores another mechanism through which option prices can predict future stock returns. When temporary price pressure or noise causes a stock price to deviate from its fundamental value, investors anticipate the reversal of this price pressure and trade in the options market to exploit the short-term mispricing. Under this mechanism, no private information flows from the options market to the stock market. Instead, the options market filters out the noise in the stock price and predicts a reversal once the price pressure disappears. We examine this mechanism using S&P 500 index inclusion as a non-fundamental demand shock to the stock price and analyze how option prices change when the underlying stock is added to the index. We document a significant increase in the implied volatility (IV) skew of added stocks, which predicts the reversal of their index addition announcement returns.

Excess demand can cause a stock to be temporarily overvalued. If investors cannot short-sell the stock to correct this overvaluation due to high costs associated with transacting in a noisy stock market or borrowing the stock, they can trade in the options market. They can buy out-of-the-money (OTM) puts or sell OTM calls to gain the same exposure. In the demand-based option pricing framework of Garleanu, Pedersen and Poteshman (2009), option market makers cannot perfectly hedge their positions. These trades therefore substantially move option prices. They make OTM puts more expensive than OTM calls, leading to a steeper IV curve or increased IV skew. Hence, option price structure filters out the noise in the stock price as the increased IV skew signals the expected price reversal.

S&P 500 index inclusions provide an ideal setting to analyze this mechanism. Many stud-

[1] See, e.g., Chakravarty, Gulen and Mayhew (2004), Bali and Hovakimian (2009), Cremers and Weinbaum (2010), Xing, Zhang and Zhao (2010), An, Ang, Bali and Cakici (2014)

ies document that a firm's stock price increases after it is announced that it will be added to the S&P 500 index, even though index inclusion does not contain fundamental information about the stock.[2] Patel and Welch (2017) show that this price increase reverses within a six-month window, especially for stocks added to the index after 2000. This suggests that index inclusion exerts a temporary demand shift for the added stock due to forced buying from index investors, pushing the stock price above its fundamental value. Since index additions are publicly announced, investors can recognize the non-fundamental nature of the price increase and execute option trades to benefit from its reversal over the following months.[3] Moreover, liquid option contracts for most of the stocks added to the S&P 500 index (representing the largest firms in the U.S.), makes these option trading strategies feasible.[4]

We use IV skew, defined as the difference between the IV of OTM put and call options, to represent the price structure of options since it measures how expensive it is to trade on a significant downside movement in the stock price compared to its upside potential. In other words, IV skew gauges the options market's expectation about the direction of the change in the stock price. Xing, Zhang and Zhao (2010) show that IV skew can predict future returns for up to six months in the whole cross-section of stocks. They suggest that informed traders with negative news prefer to trade OTM puts; hence, their private information is reflected in the IV skew through their option trading pattern. In our setup with S&P 500 index inclusions, IV skew still reflects the traders' option trading pattern, but they do not necessarily have private information. Instead, they filter out the noise in the stock price using public information and trade in the options market expecting a correction of the temporary overvaluation. Hence, in our setup, the predictive power of IV skew for future returns is mainly driven by anticipated return reversals rather than private information.[5]

[2]See, e.g., Shleifer (1986), Harris and Gurel (1986), Beneish and Whaley (1996), Lynch and Mendenhall (1997).

[3]Even though mutual fund fire sales also exert a non-fundamental demand shock on the stock price, similar to index additions, we do not use them due to the lack of public information surrounding fire sales (see, e.g. Honkanen and Schmidt (2021)). Furthermore, the price effect of fire sales reverses much more slowly (over a two-year window) compared to index additions, making it an unfavorable options trading strategy with a longer horizon.

[4]We only examine S&P 500 index additions but not deletions since the majority of the index deletions are due to acquisitions or delistings, meaning that there is no stock or options data after these deletions. Moreover, index deletions are usually associated with much smaller or even insignificant price effects (see, e.g., Lynch and Mendenhall (1997), Chen, Noronha and Singal (2004), Patel and Welch (2017)). Also, we do not use Russell 2000 index recompositions (such as in Cao et al. (2019)), since doing so would restrict our focus to small-cap stocks, for which liquid option contracts are much less likely to exist.

[5]We note that our paper does not rule out informed trading with private information in the options market. Instead, it suggests expected price reversals as another mechanism that can drive the option price-based stock return

Recently, Goncalves-Pinto, Grundy, Hameed, van der Heijden and Zhu (2020) argue that the options market provides an anchor for fundamental stock values that helps to distinguish between stock price movements due to price pressure or news. In their framework, stock price deviates from its fundamental value only for one day and reverts the next day. There is no abnormal trading in the options market over this two-day window. However, the deviation between actual stock price and option-implied stock price predicts the next day's return because of daily return reversals or simply due to liquidity (or market microstructure) effects.[6] In our framework with S&P 500 index inclusions, the stock price remains above the fundamental value for some months. More importantly, there is significant trading in the options market to correct the temporary mispricing of the stock, which predicts next month's return. Hence, our paper tests whether the options market trades based on expected price reversals rather than focusing on market microstructure issues as the main driver of option price-based predictability of stock returns.

Turning to our empirical tests, we find that the IV skew of stocks added to the S&P 500 index over 1996-2019 increased by 0.92% on average (from 3.66% to 4.58%) in the five months following index addition, implying that options market participants adopt a bearish view of the stock after index addition. To isolate the effect of index inclusion from industry trends or stock-specific characteristics, we use a difference-in-differences (DiD) approach and compare the change in IV skew of added stocks to that of control stocks matched based on industry, size, book-to-market ratio, and past returns. In this setting, the IV skew of added stocks increases by 0.72% more than control stocks, which is both economically and statistically significant.

We control for other factors that can increase IV skew upon index inclusion. Specifically, we account for increases in the stock liquidity (Hegde and McDermott (2003), Becker-Blease and Paul (2006)), systematic risk (Vijh (1994), Barberis, Shleifer and Wurgler (2005)) and overall volatility (Ben-David, Franzoni and Moussawi (2018)) associated with index additions. These variables are known to affect the IV skew or the slope of the IV curve for individual equity options (Dennis and Mayhew (2002), Duan and Wei (2009)). We also use the put-call ratio to control for the net demand for puts vs. calls (Bollen and Whaley (2004)) and past return to control for the change in the momentum of added stocks (Kasch and Sarkar (2014), Chen, Singal and Whitelaw (2016)).

predictability. Also, since we focus on S&P 500 index additions and do not examine the whole cross-section of stocks, our empirical setup does not allow to compare the relative importance of the two mechanisms.

[6] See, for example, Nagel (2012) on how daily return reversals can be seen as returns to liquidity provision.

Even after controlling for these factors, the effect of index addition on IV skew remains similar, suggesting that it is not driven by an increase in systematic risk and hedging demand or by past momentum.

To verify that the effect of index addition on IV skew is indeed caused by the deviation of the stock price from its fundamental value, we first divide the added stocks into two groups based on the magnitude of the non-fundamental shock proxied by their announcement returns. Similar to Patel and Welch (2017), the average stock in our sample earns an abnormal return of 3.42% after it is announced that it will be added to the S&P 500 index but this price increase fully reverts over the following five months. In line with the idea that the increase in IV skew is a forward-looking reflection of announcement return reversing in the future, we find that the effect of index inclusion on IV skew is significant only for stocks that experience high announcement returns. Furthermore, the increase in IV skew fades five months after index addition, which coincides with the reversal window of index addition returns.

In subsequent tests, we examine the predictive power of IV skew for future stock returns. Similar to Xing, Zhang and Zhao (2010), we find that the IV skew negatively predicts next month's returns. However, in our sample, predictability exists only for added stocks and not control stocks. Furthermore, the predictive power of the IV skew becomes insignificant on controlling for return reversals of added stocks. Overall, these results are consistent with the mechanism that investors anticipate the reversal of announcement returns and buy OTM puts (or sell OTM calls). This causes the increase in IV skew and drives the predictive power of IV skew for future returns as the announcement returns reverse.

We also conduct a subperiod analysis since announcement returns to index additions decrease over time (Patel and Welch (2017), Bennett et al. (2020)). We find that the average announcement return in the first subperiod of our sample (1996-2007) is 4.86%, while it decreases to 1.55% in the second subperiod (2008-2019). Accordingly, the effect of index inclusion on IV skew is much stronger in the first subperiod than in the second subperiod, further supporting our argument that the non-fundamental demand shock drives it. Moreover, the predictive power of IV skew for future returns, caused by announcement return reversals, also mainly comes from the first subperiod in our sample with high announcement returns.

In robustness tests, we consider alternative measures of IV skew to address the concerns that

IV skew might depend on the volatility level. We first use a scaled version of IV skew, where we divide the difference between the IV of OTM puts and OTM calls by the average IV of at-the-money (ATM) calls and ATM puts, similar to Mixon (2011). We also compute model-free risk-neutral skewness by integrating over the entire spectrum of OTM puts and OTM calls, following Bakshi, Kapadia and Madan (2003). We obtain qualitatively similar results using both alternative measures.

Besides the IV skew or slope of the IV curve, the difference between implied and historical volatility is another variable used to characterize the option price structure as the level of the IV curve (Duan and Wei (2009)). The difference between implied and historical volatility (IV-HV spread) and the difference between IV of ATM puts and calls (IV ATM spread) also predict future stock returns (Bali and Hovakimian (2009)). Hence, we check if these variables change after index additions as well. However, we do not find any significant change in these variables, suggesting that option market participants mainly trade OTM puts to benefit from the reversal of announcement returns.

Our paper is related to different strands of literature. First, it builds on the studies documenting the predictive power of option prices for future stock returns. Bali and Hovakimian (2009), Cremers and Weinbaum (2010), Xing, Zhang and Zhao (2010), and An, Ang, Bali and Cakici (2014) find that implied volatility spreads, deviations from put-call parity, IV skew, and change in volatility spreads predict future stock returns. They interpret this as evidence of informed trading and price discovery in the options market.[7] Other studies support this argument by showing how option prices change and lead stock prices around informational events, such as earnings announcements (Jin, Livnat and Zhang (2012), Atilgan (2014)), changes in analyst recommendations and forecasts (Lin and Lu (2015)), and changes in credit ratings (Zhang (2019)).

On the other hand, using high-frequency data, Muravyev, Pearson and Broussard (2013) show that when the stock and options market quotes disagree about a stock's value, the options market adjusts to eliminate the disagreement, conflicting with the idea of price discovery in the options market. Similarly, Goncalves-Pinto, Grundy, Hameed, van der Heijden and Zhu (2020) argue that

[7]Some studies also find that option trading volume, rather than option prices, predict future stock returns (see, for example, Roll, Schwartz and Subrahmanyam (2010), Johnson and So (2012) and Hu (2014)). Additionally, Chen, Koutsantony, Truong and Veeraraghavan (2013) document that abnormal options trading volume in the period immediately preceding the S&P 500 index inclusion announcements predicts announcement returns.

the predictive power of option prices stems from market microstructure issues such as daily stock price pressures. Our paper differs from these studies by focusing on whether options market participants trade based on expected price reversals rather than examining liquidity effects. It further explores how the options market's ability to filter out the noise in the stock price can drive its predictive power beyond informed trading with private information.

Our paper contributes to the literature that studies the factors affecting the slope of the IV curve or IV skew in individual equity options. Bakshi, Kapadia and Madan (2003) show that individual equity options exhibit smaller slopes than index options due to their less negative risk-neutral skewness. Dennis and Mayhew (2002) find that stocks with a higher market beta, size, and trading volume have lower (more negative) risk-neutral skewness. Duan and Wei (2009) document that stocks with higher systematic risk exhibit steeper slopes in their IV curves similar to the index. While these papers focus on systematic risk as the main factor determining the cross-section of IV skew among stocks, we show that firm-specific events and stock price reactions around these events also affect the IV skew.

Finally, our paper contributes to the literature that documents the effect of index inclusion in financial markets. Early literature primarily focuses on the announcement effect of S&P 500 index additions. Harris and Gurel (1986) and Shleifer (1986) are the first studies to document that a firm's stock price increases after being announced that it will be added to the S&P 500 index. Shleifer (1986), Beneish and Whaley (1996), Lynch and Mendenhall (1997), and Wurgler and Zhuravskaya (2002) argue that the announcement effect is due to a demand shift for the stock and does not revert since long-term demand curves for stocks are downward sloping. On the other hand, Dhillon and Johnson (1991) and Dennis, McConnell, Ovtchinnikov and Yu (2003) argue that index inclusion might contain a positive signal about the firm's prospects. More recently, Patel and Welch (2017) show that, for stocks added to S&P 500 index after 2000, almost all of the positive announcement effect is reversed over the next six months, concluding that the demand shift due to index additions is now temporary and not permanent. Schnitzler (2018) shows that, besides the excess demand of index investors, the effective supply of stock also affects the index addition announcement returns. Hollstein and Wese Simen (2021) document a significantly positive response of delta-hedged option positions for companies that are announced to enter the S&P 500 index, in line with the increased volatility of stocks due to index membership (Ben-David, Franzoni and

Moussawi (2018)).

Some studies examine the impacts of S&P 500 index inclusion in the long run. Vijh (1994) and Barberis, Shleifer and Wurgler (2005) show that index addition increases the comovement between added stocks and the index, while Kasch and Sarkar (2014) and Chen, Singal and Whitelaw (2016) argue that the increase in comovement is simply a byproduct of the pre-inclusion momentum of added stocks. Bennett, Stulz and Wang (2020) find that long-run abnormal returns of added stocks have become significantly negative after 2007. Furthermore, index inclusion worsens stock price informativeness and some aspects of corporate governance. While these studies document the direct effects of indexation in the stock market, our paper focuses on the indirect effect in the options market, providing essential directional information about the underlying stock price not yet reflected in the stock market. Index addition leads to a steeper implied volatility curve, which predicts the reversal of announcement returns.

The rest of our paper is organized as follows. Section 2 describes our data, sample construction, and methodology. Section 3 presents our empirical results, while Section 4 concludes.

2 Data and Methodology

We obtain stock data from CRSP, corporate accounting data from Compustat, and options data from OptionMetrics. Since OptionMetrics data starts from 1996, we focus on the index additions from January 1996 to December 2019.[8] S&P 500 index additions, announcements, and effective change dates are from Sirius Research.

Our event window of index addition covers the month of effective change and the prior month, which potentially includes the announcement date. On average, there is a one-week gap between the announcement date and the effective change date. For 20% of the 631 index additions over 1996-2019, the announcement date falls in the month before the index addition. Hence, to fully isolate the announcement effect, we consider the month before the effective change date as a part of the event window. Our before- and after-index addition periods cover five months before and after this two-month event window. Our final sample includes 479 index additions with stock and options trading data over the entire before- and after-index addition periods.

[8] Our results remain qualitatively similar if we focus on index additions after 2000, where Patel and Welch (2017) find evidence of strong announcement return reversals.

We calculate our primary dependent variable, *IVSkew*, for each stock i at the end of each month t as:

$$IVSkew_{it} = IVOTMPut_{it} - IVOTMCall_{it} \tag{1}$$

where $IVOTMPut$ is the implied volatility of a 30-day out-of-the-money put option with Δ=-0.25, and $IVOTMCall$ is the implied volatility of a 30-day out-of-the-money call option with Δ=0.25. These are obtained directly from the IV surfaces available on OptionMetrics, which brings the advantage of not making arbitrary decisions on which options to include to compute $IVOTMPut$ or $IVOTMCall$.[9] Equity traders and analysts monitor the IV skew closely to gauge the market's expectation of downside risk vs. upside potential. Although $IVOTMPut$ is usually greater than $IVOTMCall$, there are circumstances where the IV skew reverses, especially when the market sentiment is very bullish about a particular stock.

When we examine the effect of index inclusion on IV skew, any changes we observe may reflect industry trends or stock-specific characteristics. Thus, we conduct a difference-in-differences (DiD) analysis to isolate these effects by creating a control sample. For each added stock, we select a control stock in the same industry (using the 49 industry classifications of Fama and French (1997) based on the SIC codes) that was not a part of the index during our sample period. We require the control stocks to have non-missing data over the entire before- and after-indexation periods. Finally, we identify our control stocks using propensity score matching based on log size, book-to-market ratio, and past 5-month return as of the month before index addition.

Table 1 reports the mean values of the matching variables for the added and control stocks. We cannot closely match each variable because we require an exact industry match. In particular, added stocks are significantly larger, even though they have similar book-to-market ratios compared to control stocks. Added stocks also have higher returns five months before index inclusion,

[9]It is common practice in the literature to consider options with an absolute delta of 0.25 as out-of-the-money (see, e.g., Mixon (2011)). Also, we use the 30-day option implied volatilities since they are the most liquid (see, e.g., An, Ang, Bali and Cakici (2014)).

Note that our IV skew measure is slightly different from Xing, Zhang and Zhao (2010), who focus on the left portion of the IV skew by defining it as $IVOTMPut - IVATMCall$. This measure considers only the market expectation of downside risk. In contrast, our measure incorporates both downside risk and upside potential, similar to the slope of the IV curve in Bakshi, Kapadia and Madan (2003) and Bollen and Whaley (2004). Nevertheless, we obtain qualitatively similar results when we use the definition of Xing, Zhang and Zhao (2010).

In section 3.5.2, we show that our results are robust to using a scaled version of IV skew as in Mixon (2011) or the risk-neutral skewness of Bakshi, Kapadia and Madan (2003) calculated over the entire spectrum of OTM puts and OTM calls.

but this difference is only marginally significant. To address the differences in matching variables, especially for size, we include them as additional control variables in our DiD analysis.

We use a DiD regression of the form:

$$IVSkew_{it} = \alpha + \beta \cdot After \times Added_{it} + \gamma \cdot X_{it} + \mu_i + v_t + \epsilon_{it} \tag{2}$$

where *After* $\times$ *Added* is a dummy variable that equals 1 for added stocks in the period after index addition. X is a vector of control variables, μ is the stock fixed effect, v is the time fixed effect, and ϵ is the error term. Our time fixed effects include calendar month fixed effects to account for economy-wide factors (such as the S&P 500 index volatility) and fixed effects for the month with respect to index addition.[10]

Our first set of control variables includes the matching variables that were used to create the control sample: log size, calculated as the natural logarithm of the market value of equity in millions of dollars, and book-to-market ratio, calculated as the ratio of the book value of equity to the market value of equity. Kasch and Sarkar (2014) and Chen, Singal and Whitelaw (2016) document that stocks added to the S&P 500 index exhibit a strong momentum before inclusion, while this momentum fades afterward. Our control stocks have a similar pre-inclusion momentum since we use the past 5-month return in our propensity score matching. We also include realized return over the past month as an additional control variable to account for the lost momentum in the post index addition period.[11]

We control for other factors whose change through index addition can affect IV skew. Hegde and McDermott (2003) and Becker-Blease and Paul (2006) show that the liquidity of the stocks added to the S&P 500 index permanently improves in the months following index addition. Hence, we control for changes in a stock's liquidity using the Amihud (2002) illiquidity measure, calculated as the average ratio of daily absolute stock return to dollar trading volume within a month.

Ben-David, Franzoni and Moussawi (2018) show that index membership increases the volatility of stocks since ETFs' trading activity introduces noise into stock prices. On the other hand,

[10] We do not include the *After* and *Added* dummy variables separately since they are subsumed by month with respect to index addition and stock fixed effects, respectively.

[11] We obtain qualitatively similar results when we use the past 5-month return instead of the past 1-month return as an additional control variable, although the effect of the past 5-month return on IV skew is weaker than that of past 1-month return.

Vijh (1994) and Barberis, Shleifer and Wurgler (2005) document that stocks added to the S&P 500 index comove more with the index, implying a significant increase in the stocks' systematic risk. Since these factors can affect IV skew (Duan and Wei (2009)), we include them as control variables. To control for the overall volatility, we use the historical volatility (HV) of a stock's daily returns realized over a month, directly available from OptionMetrics. We measure systematic risk as the R-squared of the regression of daily stock excess returns on market excess returns over a month.[12]

Bollen and Whaley (2004) show that investors mostly buy put options on the index for hedging purposes, while they buy calls on individual stocks. They then argue that the net demand for puts vs. calls affects the option price structure. Since an increase in co-movement with the index and systematic risk can alter the demand for hedging (and hence the net demand for puts vs. calls), we also control for the relative demand of puts vs. calls by using the put-call ratio. The put-call ratio is calculated as the total volume of put option contracts to the total volume of call option contracts traded during the month.

Table 2 reports the summary statistics for the main variables used in our study for a panel of 9,850 stock-month observations, including both added and control stocks over the entire before and after index addition periods. All variables are winsorized at 1% and 99% levels to reduce the effect of outliers. The average IV skew in our sample is 4.03%. Our sample includes large stocks with a mean log size of 8.81, corresponding to a market capitalization of $6.7 billion, while added stocks are larger than control stocks (see, e.g., Table 1). The mean book-to-market ratio is low at 0.32, suggesting that our sample stocks can be considered growth stocks. On average, annualized historical volatility is 41.38%, while 29% of the variance in sample stocks' returns can be explained by systematic risk. Unlike the index, investors mostly buy call options compared to put options on individual stocks. Our sample stocks' mean put-call ratio is 0.73, in line with Bollen and Whaley (2004). Finally, the average monthly return for the sample stocks is 1.42%, while the average value for Amihud (2002)'s illiquidity is 0.08%.

[12]We measure the systematic risk as the R-squared rather than the slope coefficient or beta of the regression since Duan and Wei (2009) argue that it is the portion of total risk explained by systematic risk, not beta, that matters for the option price structure. However, we obtain qualitatively similar results when we use beta, since the two measures are highly correlated.

Note that we measure stock's historical volatility and systematic risk using daily returns over a month with non-overlapping periods, compared to rolling 12-months as commonly done in the literature, since we are mainly interested in month-to-month changes in these variables in our DiD set up with stock fixed effects.

3 Empirical Results

3.1 Preliminary Analysis for IV Skew

We begin our empirical analysis with univariate tests for IV skew. Figure 1 plots the month-end IV skew for added vs. control stocks over the five months before and after index addition. The event window for index addition is excluded, which is the month of the effective change date and the month prior to that, potentially containing the announcement date. Before index addition, the IV skew of the added stocks is slightly lower than that of the control stocks but not significantly. The two samples have a similar pre-treatment IV skew trend, satisfying the parallel trend assumption for DiD analysis.[13] After index addition, the IV skew of the control stocks remains around the same level as before. On the other hand, the IV skew of the added stocks increases significantly and remains at a higher level for at least five months after index addition.

We quantitatively assess the significance of the break in IV skew post index addition in Table 3. The average IV skew of the added and control stocks are 3.66% and 3.83% before index addition, respectively. The difference of -0.17% is not statistically significant. Post index addition, the IV skew of the added stocks increases by 0.92% to 4.58%, which is highly significant with a t-statistic of 4.76. On the other hand, the IV skew of the control sample increases by 0.20% to 4.03%, which is not significant. Overall, the IV skew of added stocks increases by 0.72% more than control stocks, implying that OTM puts on the added stocks become more expensive than calls, and the options market adopts a bearish view about the stock after index inclusion. This is our baseline result, which we further explore in the following sections.

3.2 Difference-in-Differences Analysis for IV Skew

This section carries out a multivariate DiD analysis to estimate the effect of index addition on IV skew, as specified in Equation 2 while controlling for changes in additional factors that can affect IV skew.

Column (1) of Table 4 shows that the IV skew increases by 0.72% after index addition compared to the control sample (t-statistic: 3.27). Here, we use calendar month fixed effects to account for economy-wide factors (such as the S&P 500 index volatility), fixed effects for a month with

[13] In untabulated results, we confirm that the pre-treatment trends for the two groups are not statistically significantly different from each other.

respect to index addition, and stock fixed effects to account for any stock-specific variation that can affect IV skew. We obtain similar results to our univariate test in Section 3.1. In column (2), we control for firm size and book-to-market ratio, and the various fixed effects. The increase in IV skew of added stocks compared to control stocks reduces to 0.68% after controlling for these variables, but it is still highly significant with a t-statistic of 3.02.

In column (3), we control for the change in the stock's liquidity after index addition by using Amihud (2002)'s illiquidity measure. We find that the stock's liquidity is only marginally significant in explaining IV skew. Similarly, the historical volatility does not affect IV skew, as in column (4). On the other hand, in line with the results of Duan and Wei (2009) and Bollen and Whaley (2004), systematic risk and put-call ratio are significantly positively related to IV skew, as shown in columns (5)-(6). However, the effect of index addition on IV skew is unaltered after controlling for these factors, implying that it is not driven by increased systematic risk or hedging demand.

In column (7), we include monthly realized returns to account for the change in the performance of added stocks after index addition. We find that return is significantly positively related to IV skew at the end of the month, implying that the options market adopts a negative view of the underlying stock after it experiences high returns and expects return reversals. Nevertheless, the effect of index addition on IV skew reduces only to 0.65% after controlling for past returns and is still significant. This suggests that the effect of index addition on IV skew is not a result of added stocks losing their pre-inclusion momentum after index addition. Finally, we include all our control variables in the regression in column (8). All the controls together only subsume about 8% of the increase in IV skew on addition to the S&P 500 index. The IV skew of the added stocks increases by 0.66% post index inclusion compared to the control stocks and is highly significant.

3.3 Effect of Announcement Return Reversals on IV Skew

The results from the previous section show that the effect of index addition on IV skew is not caused by the well-known changes associated with index additions, such as increased systematic risk and hedging demand or decreased momentum. In this section, we test if it is instead caused by the demand shock that pushes the stock price over its fundamental value temporarily and the reversal of this shock.

We proxy the magnitude of the non-fundamental shock with index addition announcement returns. Patel and Welch (2017) show that the average two-day abnormal event return following S&P 500 index addition announcements is 3%-4%, and this return reverses within the next six months. Similarly, Figure 2 shows that the added stocks in our sample have an average announcement return of 3.42%, where we calculate daily abnormal returns based on the 4-factor Fama-French-Carhart model (Carhart (1997)) with betas estimated over a 252-day window ending 50 days before the index addition announcement.[14] A big part of the announcement return reverses within the first two months, while the full reversion is completed around the fifth month after index addition. We note that the announcement return is a part of the event window, so it was not accounted for in the DiD analysis of the previous section.

In order to test if a non-fundamental demand shock on the stock price causes the effect of index addition on IV skew, we repeat our DiD analysis by dividing the added stocks into two groups; those that experience *High* or *Low* (above or below median) announcement returns, where the median announcement return is 2.83%. We replace the variable $After \times Added$ in Equation 2 with $After \times Added \times High$ and $After \times Added \times Low$, where *High* or *Low* denote dummy variables equal to 1 if a stock belongs to that particular group. Table 5 reports the new regression results. We find that the increase in the IV skew of added stocks with high announcement returns is roughly four times that of the stocks with low announcement returns (1.06% vs. 0.24% in our full specification in column (8)). Moreover, the increase in IV skew is significant only for stocks with high announcement returns and not for firms with low announcement returns, confirming that the temporary overvaluation of stocks caused by the non-fundamental demand shock drives the increase in IV skew.[15]

We conjecture that, after the stock price increases upon index addition announcement, investors anticipate the reversal of this increase over the following months since it was not driven by fundamental information. Hence, they buy OTM put options to benefit from this reversal, making OTM put options more expensive than calls and leading to an increase in IV skew under the demand-based option pricing approach of Garleanu, Pedersen and Poteshman (2009). Also, investors buy OTM puts rather than short-selling the stock to benefit from the temporary overval-

[14] We obtain similar results when we use alternative models, such as market adjustment, 1-factor CAPM, or 3-factor Fama-French model (Fama and French (1993)).

[15] We also consider dividing the added stocks based on their market capitalisation before index inclusion, but we do not find a significant difference in the increase of the IV skew of large vs. smaller cap stocks, since announcement returns do not strongly correlate with size.

uation since borrowing the stock is currently expensive and options provide higher leverage with lower transaction costs (Easley, O'Hara and Srinivas (1998)).

If our conjecture holds, the increase in IV skew should be observed mainly during the months when the announcement returns reverse, corresponding to the first five months following index additions (see Figure 2). We find this to be the case. Figure 3 plots the IV skew of added stocks over extended before- and after-index addition periods for ten months, compared to five months in our main tests.[16] We see that the IV skew of added stocks decreases back after the fifth month, suggesting that the change in IV skew is temporary.

3.4 Predictive Power of IV Skew for Future Returns vs. Return Reversals

In order to further examine if the increase in IV skew upon index addition is a forward-looking indicator of the announcement return reversals, in this section, we look at the predictive power of IV skew for next month's stock returns.

Xing, Zhang and Zhao (2010) find that IV skew can predict future stock returns for up to six months in the whole cross-section of stocks and argue that the options market contains superior information compared to the underlying stock market. They conjecture that informed traders with negative news prefer to trade OTM puts; hence their private information is reflected in the IV skew. In our context with S&P 500 index inclusions, option market participants do not necessarily have private information but instead process the public information better and filter out the noise in the stock price. Knowing that the stock price is temporarily high due to the price pressure associated with index addition, they anticipate a return reversal and buy OTM puts to benefit from this reversal. Thus, in our setup, the predictive power of IV skew for future returns is mainly driven by return reversals.[17]

Table 6 presents the results from regressing next month's stock returns on IV skew in our sample. In line with the results of Xing, Zhang and Zhao (2010), in column (1), we find that IV skew is significantly negatively related to next month's returns after controlling for the stock and time fixed effects, implying that options markets lead stocks markets in the sense that OTM puts

[16] For this figure, we consider 458 stocks added to the S&P 500 index that have complete data over the extended periods of ten months before- and after-index addition, compared to 479 stocks in our main sample.

[17] Rehman and Vilkov (2012) and Stilger, Kostakis and Poon (2017) find that the risk-neutral skewness of Bakshi, Kapadia and Madan (2003) also predict future stock returns similar to IV skew. In line with our argument, they find that overvalued stocks drive this predictability. Investors buy OTM put options (or sell OTM call options) when a stock is overvalued, especially if there are high short-selling constraints.

become more expensive compared to OTM calls before a stock has negative returns. An increase of one percentage point in IV skew results in a nine basis point decrease in next month's stock return. We obtain a similar result in column (2) when we control for changes in systematic risk, size, book-to-market ratio, or liquidity. In column (3), we also control for the current month's return. We find that this month's return is significantly negatively related to next month's return, indicating the presence of strong return reversals in our sample. More importantly, the predictive power of IV skew is considerably reduced when we control for the past month's return, suggesting that the predictive power of IV skew is mainly concentrated around return reversals.

Columns (4)-(6) and (7)-(9) repeat the same regressions with the samples of added and control stocks separately. We find that IV skew predicts next month's return only for added stocks but not for control stocks in our sample. Moreover, the return reversals are much stronger among added stocks than control stocks. Finally, the predictive power of the IV skew is again subsumed by the return reversals of added stocks. Overall, these results are consistent with the mechanism that we propose. Option market participants trade based on an expected reversal of index addition returns (or noise in the stock price), which drives the predictive power of IV skew for future returns.

3.5 Additional Tests

In this section, we first conduct a subperiod analysis for our main results. Then, we show that our results are robust to using alternative measures of IV skew. Finally, we explore the effect of index addition on other variables that are used to characterize the option price structure.

3.5.1 Subperiod Tests

Patel and Welch (2017) and Bennett, Stulz and Wang (2020) find that the announcement returns for stocks added to the S&P 500 index decrease over time. For example, Patel and Welch (2017) document that the two-day announcement return associated with index additions has declined from about 4% in the 1990s to about 2% around 2015. Bennett, Stulz and Wang (2020) examine the index additions in the subperiods of 1997-2007 vs. 2008-2017 and report similar results. In line with these two studies, we find that the mean announcement return in our sample for the first subperiod over 1996-2007 is 4.86%, while it is 1.55% for the second subperiod over 2008-2019. The median announcement returns are 3.75% and 1.51%, respectively.

Since the announcement returns measure the non-fundamental demand shock on the stock price, we repeat our main analysis for the two subperiods in our sample. Table 7 reports the results of DiD regressions for IV skew for 1996-2007 and 2008-2019 separately. Comparing columns (1)-(2) with columns (3)-(4) shows that the effect of index inclusion on IV skew is more substantial for the first subperiod compared to the second subperiod, where the average announcement return has decreased substantially. This further supports our argument that the non-fundamental demand shock on the stock price drives the effect of index inclusion on IV skew.

In Table 8, we repeat the predictive regressions for next month's stock returns for the two subperiods. We find that the IV skew predicts future stock returns strongly for the first subperiod in our sample, as shown in columns (1) and (2), while this predictability is subsumed by return reversals (column (3)). Here we report the regression results including all firms, but in untabulated results, we confirm that this predictability is again driven by the added stocks, similar to Table 6. Columns (4)-(6) show that the predictive power of IV skew is only marginally significant in the second subperiod, and return reversals barely affect it. This implies that the increase in IV skew of added stocks predicting return reversals exists mainly in the first subperiod of our sample, with substantially higher announcement returns as the key driver.

3.5.2 Robustness Tests with Alternative IV Skew Measures

Our primary dependent variable, IV skew, is the difference between the implied volatilities of OTM put and call options ($IVOTMPut - IVOTMCall$) with Δ=-0.25 and Δ=0.25, respectively. Finance literature has used various measures for the slope of the IV curve or IV skew. Mixon (2011) discusses some of these measures and argues that $IVOTMPut - IVOTMCall$ depends on the volatility level. He suggests that a scaled version of IV skew is a more stable measure that does not depend on overall volatility and has similar features to the risk-neutral (RN) skewness of Bakshi, Kapadia and Madan (2003). Moreover, Rehman and Vilkov (2012) and Stilger, Kostakis and Poon (2017) find that RN skewness also predicts future stock returns, especially for overvalued stocks. Hence, in this section, we conduct robustness tests, where we replace our measure of IV skew with the scaled IV skew measure of Mixon (2011) and the RN skewness of Bakshi, Kapadia and Madan (2003).

The scaled IV skew is calculated as:

$$ScaledIVSkew_{it} = \frac{IVSkew_{it}}{IV_{it}} = \frac{IVOTMPut_{it} - IVOTMCall_{it}}{(IVATMPut_{it} + IVATMCall_{it})/2} \tag{3}$$

where $IVATMPut_{it}$ is the IV of a 30-day ATM put with with Δ=-0.50 and $IVATMCall_{it}$ is the IV of a 30-day ATM call with Δ=0.50.

We calculate the RN skewness of Bakshi, Kapadia and Madan (2003) over the entire spectrum of OTM puts and OTM calls as:

$$RNSkewness(t,\tau) = \frac{E_t^{\mathbb{Q}}\left\{\left(R_{t,\tau} - E_t^{\mathbb{Q}}[R_{t,\tau}]\right)^3\right\}}{\left\{E_t^{\mathbb{Q}}\left(R_{t,\tau} - E_t^{\mathbb{Q}}[R_{t,\tau}]\right)^2\right\}^{3/2}} = \frac{e^{r\tau}W_{t,\tau} - 3\mu_{t,\tau}e^{r\tau}V_{t,\tau} + 2\mu_{t,\tau}^3}{\left[e^{r\tau}V_{t,\tau} - \mu_{t,\tau}^2\right]^{3/2}} \tag{4}$$

where

$$\begin{aligned}
\mu_{t,\tau} =& E_t^{\mathbb{Q}}(R_{t,\tau}) \\
V_{t,\tau} =& E_t^{\mathbb{Q}}(e^{-r\tau}R_{t,\tau}^2) \\
=& \int_{S_t}^{\infty} \frac{2\left(1 - \ln\left[\frac{K}{S_t}\right]\right)}{K^2} C(t,\tau;K)dK + \int_0^{S_t} \frac{2\left(1 + \ln\left[\frac{S_t}{K}\right]\right)}{K^2} P(t,\tau;K)dK \\
W_{t,\tau} =& E_t^{\mathbb{Q}}(e^{-r\tau}R_{t,\tau}^3) \\
=& \int_{S_t}^{\infty} \frac{6\ln\left[\frac{K}{S_t}\right] - 3\left(\ln\left[\frac{K}{S_t}\right]\right)^2}{K^2} C(t,\tau;K)dK - \int_0^{S_t} \frac{6\ln\left[\frac{S_t}{K}\right] + 3\left(\ln\left[\frac{S_t}{K}\right]\right)^2}{K^2} P(t,\tau;K)dK
\end{aligned}$$

$R_{t,\tau}^3$ and $R_{t,\tau}^2$ are the second and third power of log returns $R_{t,\tau} = \ln\left[\frac{S_{t+\tau}}{S_t}\right]$; $V_{t,\tau}$ and $W_{t,\tau}$ are the price of the quadratic and cubic contracts, respectively, and $\mu_{t,\tau}$ is the risk-neutral expectation of the stock's log returns from time t to $t+\tau$. $C(t,\tau;K)$ and $P(t,\tau;K)$ denote the time t prices of call and put options with strike price K and maturity τ. We approximate the above integrals using the 30-day IV curve directly available in OptionMetrics, which we convert back to OTM option prices. We interpolate the IV curve linearly within the available strikes and extrapolate outside of the available range to get option prices in the moneyness range from 1/3 to 3. To make the sign of the RN skewness consistent with other IV skew measures, we multiply it by -1 so that the more negative the RN skewness is, the more pronounced it is.

Table 9 gives the main DiD regressions results using the two alternative measures of IV skew. As shown in columns (1)-(2), the scaled IV skew of added stocks increased by 1.93% compared to the control sample. Our results using this measure are even more robust, with a t-statistic of 3.04 for the full specification compared to 2.94 in Table 4. Columns (3)-(4) report that the RN skewness of added stocks increases by 3.57% compared to the control sample on index addition, which is statistically more significant than our benchmark result with a t-statistic of 3.25. Overall, Table 9 confirms that OTM puts become more expensive than calls after index addition, irrespective of how we measure IV skew.

Table 10 reports the results of regressing next month's stock returns on the two alternative measures of IV skew. As shown in columns (1)-(2) and (4)-(5), scaled IV skew and RN skewness significantly negatively predict future stock returns similar to IV skew. Furthermore, the predictive power of both measures is concentrated around return reversals, so that past returns subsume their significance in columns (3) and (6). This is similar to column (3) in Table 6. In untabulated results, we also confirm that the predictive power of these measures exists only among added stocks rather than control stocks. The results in this subsection imply that the increases in both measures are forward-looking reflections of announcement return reversals of added stocks, similar to our benchmark results with IV skew.

3.5.3 IV-HV Spread and IV ATM Spread

Although the focus of our paper is on the IV skew or slope of the IV curve, another variable used to characterize the option price structure is the difference between implied and historical volatility (IV-HV spread), also known as the level of the IV curve (Duan and Wei (2009)). Bali and Hovakimian (2009) argue that the difference between implied volatility and historical realized volatility over the past month can be viewed as a proxy for volatility risk. They show that this difference can predict next month's return. Hence, we also examine if the IV-HV spread of firms added to the S&P 500 index changes significantly post index addition.

We define IV-HV spread as:

$$IV\text{-}HVSpread_{it} = (IVATMPut_{it} + IVATMCall_{it})/2 - HV_{it} \tag{5}$$

where $IVATMPut_{it}$ is the IV of a 30-day ATM put with Δ=-0.50, $IVATMCall_{it}$ is the IV of a 30-day ATM call with Δ=0.50, and HV_{it} is the historical volatility of daily returns realized over the past month, as before.

Finally, we consider the difference between the IV of ATM put and ATM call, which we term as IV ATM spread:

$$IVATMSpread_{it} = IVATMPut_{it} - IVATMCall_{it} \tag{6}$$

Bali and Hovakimian (2009) and An, Ang, Bali and Cakici (2014) find that this variable or its change can predict next month's return as directional measures from the options market. Thus, we check if IV ATM spread changes significantly after index addition for completeness.

Table 11 presents the main DiD regression results for IV-HV and IV ATM spread. Columns (1)-(2) show that the IV-HV spread of stocks added to the S&P 500 index does not change significantly post index addition. In untabulated results, similar to Ben-David, Franzoni and Moussawi (2018), we find that historical realized volatility increases significantly in the months after index inclusion. The IV of ATM puts and calls also increase proportionally. While the historical realized volatility significantly exceeds the implied volatility during the 2-month event window due to intensive trading of index investors, the difference between the increases in the two volatility measures is not significant after the event window.

Columns (3)-(4) show that the IV ATM spread of added stocks also does not change significantly since the increases in IV of ATM puts and calls are similar. This suggests that option market participants prefer to buy OTM puts (with lower premium and higher leverage) rather than ATM puts to exploit the overvaluation of the stock. Hence, there is a significant increase in IV skew but not in IV ATM spread. In unreported tests, we also examine how the composition of options trading volume for the added stocks changes. We confirm a significant increase in the portion of OTM puts traded on the added stocks compared to overall put volume and total options trading volume.

4 Conclusion

Existing studies focus on informed trading in the options market based on private information as the main mechanism through which option prices can predict future stock returns (see, e.g., Bali and Hovakimian (2009), Cremers and Weinbaum (2010), Xing, Zhang and Zhao (2010), An, Ang, Bali and Cakici (2014)). We explore another mechanism. When stock price deviates from its fundamental value due to a demand shock, investors anticipate the reversal of this shock and trade in the options market to exploit the temporary mispricing. Hence, option prices filter out the noise in the stock price based on public information and predict future stock returns through return reversals. Also, this mechanism is different from the effect of market microstructure on the option price-based stock return predictability suggested by Goncalves-Pinto et al. (2020) recently, who focus on daily return reversals without any significant trading in the options market.

We examine our proposed mechanism using S&P 500 index inclusions as a non-fundamental demand shock on the stock price. It is well-known that a firm's stock price increases after it is announced it will be added to the S&P 500 index, even though index inclusion does not contain fundamental information about the stock. Furthermore, this price increase reverts over the following months, implying that it is caused by temporary price pressure or noise. Thus, our paper studies how option prices respond to this noise after index addition and how it can drive the predictive power of option prices for future stock returns.

Using a difference-in-differences approach, we find that the implied volatility (IV) skew of stocks added to the S&P 500 index becomes steeper in the months following index additions. In other words, out-of-the-money (OTM) puts become more expensive than calls for the added stocks, indicating that the options market adopts a negative view of the stock upon index addition. Moreover, the increase in IV skew is significant only among stocks that experience high announcement returns and fades after five months, corresponding to the period over which the announcement returns reverse. This suggests that the non-fundamental demand shock on the stock price drives the increase in IV skew.

We also show that the IV skew is negatively related to next month's return, implying that the options market leads the stock market, in line with the previous research. However, this predictability exists only for the stocks added to the index rather than the control stocks in our sample. Moreover, the past month's return renders the predictive power of IV skew insignificant, suggesting that the predictability is driven mainly by the return reversals of added stocks in our sample. Overall, our results align with the notion that option market participants buy OTM puts to benefit from anticipated return reversals when the stock price increases above its fundamental value, which leads to the predictive power of IV skew for future stock returns.

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Table 1: Matching Variables for Added vs. Control Stocks

Variables	Added Stocks	Control Stocks	Difference	t-stat
Log Size	8.99	8.66	0.33***	(5.98)
Book-to-Market	0.31	0.31	-0.00	(-0.07)
Past Return	2.57%	1.78%	0.79%*	(1.77)

Table 1 gives the differences between the matching variables for the 479 stocks added to the S&P 500 index from January 1996 to December 2019, and their corresponding control stocks as of the month before index addition. The control sample is selected based on an exact industry match (Fama-French 49 industry classifications based on SIC codes), and propensity score matching based on log-size, book-to-market ratio and past 5-month return. Both added and control stocks are required to have complete data for 5 months before and 5 months after the 2-month event window of index addition. Event window is the month of effective change date and the month before that, which can potentially contain the announcement date. Size is the log of market value of equity in million dollars. Book-to-market is the ratio of book value of equity to market value of equity. Past return is the geometric average of the monthly returns over the past 5 months. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 2: Summary Statistics

Variables	Mean	Std Dev	Lower Quartile	Median	Upper Quartile
IV Skew	4.03%	5.48%	1.44%	3.63%	6.35%
Log Size	8.81	0.72	8.35	8.79	9.26
Book-to-Market	0.32	0.23	0.15	0.26	0.44
Amihud Illiquidity	0.08%	0.18%	0.01%	0.03%	0.08%
Historical Volatility	41.38%	27.16%	22.89%	33.56%	51.02%
Systematic Risk	0.29	0.22	0.10	0.26	0.46
Put-Call Ratio	0.73	0.77	0.30	0.54	0.87
Return	1.42%	12.42%	-4.99%	1.19%	7.88%

Table 2 reports the summary statistics of the main variables used in this study. The sample consists of 479 stocks added to the S&P500 index from January 1996 to December 2019, and their corresponding control stocks. The event window for index addition is excluded as the month of effective change date and the month before that, which can potentially contain the announcement date. All added and control stocks have full data for 5 months before and 5 months after the event window, leading to a total of 9,580 stock-month observations. The control stocks are selected based on an exact industry match (Fama-French 49 industry classifications based on SIC codes), and propensity score matching based on log-size, book-to-market ratio, and return over the past 5 months before index addition. The main dependent variable IV skew is calculated as the difference between the IV of a 30-day OTM put option with Δ=-0.25 and OTM call option with Δ=0.25 at the end of a month. Log size is the logarithm of the market value of equity in million dollars. Book-to-Market is the ratio of book value of equity to market value of equity. Amihud illiquidity is calculated as the average of the ratio of daily absolute stock return to dollar trading volume within a month as in Amihud (2002). Historical volatility is the annualized volatility of daily stock returns realized over a month. Similar to Duan and Wei (2009), systematic risk is calculated as the R^2 of the regression of daily stock excess returns on market excess returns over a month. Put-Call ratio is the ratio of put options volume to call options volume traded during the month, which is used as a measure of relative demand for puts vs. calls. Return is the realized return over a month. All variables are winsorized at 1% and 99% levels to reduce the effect of extreme observations.

Table 3: Preliminary Analysis for Implied Volatility Skew

	IV Skew			
	Before	After	Difference	t-stat
Added Stocks	3.66%	4.58%	0.92%***	(4.76)
Control Stocks	3.83%	4.03%	0.20%	(1.04)
Difference	-0.17%		0.72%***	
t-stat	(-0.69)		(2.61)	

Table 3 compares the average IV skew of stocks added to the S&P 500 index and their control stocks during 5 months before and 5 months after index addition. Control stocks are selected based on an exact industry match (Fama-French 49 industry classifications based on SIC codes), and propensity score matching based on log-size, book-to-market ratio, and return over the past 5 months before index addition. IV skew is calculated as the difference between the implied volatility of a 30-day OTM put option with Δ=-0.25 and OTM call option with Δ=0.25.

Table 4: Difference-in-Differences Analysis for Implied Volatility Skew

	IV Skew							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
After x Added	0.72***	0.68***	0.68***	0.68***	0.67***	0.69***	0.65***	0.66***
	(3.27)	(3.02)	(3.04)	(3.02)	(2.97)	(3.06)	(2.92)	(2.94)
Log Size		0.24	0.09	0.25	0.22	0.23	0.52*	0.37
		(0.83)	(0.30)	(0.85)	(0.75)	(0.80)	(1.71)	(1.23)
Book-to-Market		0.10	0.22	0.07	0.06	0.10	0.24	0.27
		(0.11)	(0.25)	(0.08)	(0.07)	(0.11)	(0.27)	(0.31)
Amihud Illiquidity			-1.78*					-1.53
			(-1.85)					(-1.58)
Historical Volatility				0.22				0.48
				(0.43)				(0.96)
Systematic Risk					0.65**			0.67**
					(2.07)			(2.10)
Put-Call Ratio						0.22**		0.26***
						(2.32)		(2.72)
Return							2.62***	2.75***
							(5.09)	(5.41)
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calendar month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	9,580	9,580	9,580	9,580	9,580
Adjusted R-squared	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Table 4 reports the results of difference-in-differences regressions as in Equation 2 to estimate the change in IV skew for stocks added to the S&P 500 index compared to control stocks. IV skew is calculated as the difference between the implied volatility of OTM put option with Δ=-0.25 and OTM call option with Δ=0.25. The definitions of control variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 5: Difference-in-Differences Analysis for Implied Volatility Skew:
High vs Low Announcement Returns

	IV Skew							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
After x Added x High	1.12***	1.08***	1.08***	1.08***	1.07***	1.09***	1.06***	1.06***
	(4.02)	(3.85)	(3.86)	(3.85)	(3.81)	(3.89)	(3.79)	(3.81)
After x Added x Low	0.32	0.27	0.28	0.27	0.26	0.28	0.24	0.24
	(1.26)	(1.03)	(1.06)	(1.04)	(1.00)	(1.07)	(0.91)	(0.95)
Log Size		0.27	0.12	0.28	0.25	0.26	0.54*	0.41
		(0.92)	(0.40)	(0.95)	(0.84)	(0.89)	(1.81)	(1.33)
Book-to-Market		0.18	0.30	0.16	0.14	0.18	0.33	0.36
		(0.20)	(0.35)	(0.18)	(0.16)	(0.21)	(0.36)	(0.40)
Amihud Illiquidity			-1.76*					-1.51
			(-1.83)					(-1.56)
Historical Volatility				0.21				0.47
				(0.42)				(0.95)
Systematic Risk					0.64**			0.65**
					(2.04)			(2.06)
Put-Call Ratio						0.22**		0.26***
						(2.32)		(2.73)
Return							2.63***	2.76***
							(5.12)	(5.44)
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calendar month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	9,580	9,580	9,580	9,580	9,580
Adjusted R-squared	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Table 5 repeats the difference-in-differences regressions of Table 4 by dividing the *Added* stocks into two groups as those experiencing *High* or *Low* (above or below median) announcement returns. Announcement returns are the two-day abnormal returns after it is announced that a stock will be added to the S&P 500 index. Daily abnormal returns are calculated based on Fama-French-Carhart 4-factor model, in which betas are estimated using a 252-day window ending 50 days before the index addition. The median announcement return in the sample is 2.83%, while the mean is 3.42%. The definitions of all variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 6: Predictive Power of Implied Volatility Skew for Future Returns vs. Return Reversals

	Next Month's Return								
	All Firms			Added Firms			Control Firms		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IV Skew	-0.09***	-0.08***	-0.06*	-0.09**	-0.10**	-0.06	-0.06	-0.05	-0.04
	(-2.82)	(-2.60)	(-1.85)	(-1.97)	(-2.30)	(-1.41)	(-1.30)	(-1.17)	(-0.88)
Systematic Risk		-0.00	-0.00		-0.00	-0.00		-0.01	-0.00
		(-0.48)	(-0.21)		(-0.41)	(-0.23)		(-0.50)	(-0.33)
Log Size		-0.07***	-0.09***		-0.09***	-0.12***		-0.07***	-0.09***
		(-8.11)	(-8.87)		(-7.94)	(-8.58)		(-5.31)	(-5.78)
Book-to-Market		0.11***	0.10***		0.17***	0.16***		0.06**	0.05*
		(5.54)	(4.73)		(6.48)	(5.34)		(2.05)	(1.67)
Amihud Illiquidity		-4.39	-6.05**		-9.38	-14.38**		-3.36	-4.32
		(-1.61)	(-2.08)		(-1.55)	(-2.25)		(-1.18)	(-1.43)
Return			-0.17***			-0.22***			-0.12***
			(-9.06)			(-11.19)			(-4.14)
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calendar Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	4,790	4,790	4,790	4,790	4,790	4,790
Adjusted R-squared	0.23	0.26	0.28	0.23	0.26	0.29	0.23	0.26	0.26

Columns (1)-(3) of Table 6 show the result of regressing next month's return on IV skew, this month's return, and other variables in the sample. Columns (4)-(6) and (7)-(9) consider the added and control stocks separately. The variable definitions are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 7: Subperiods: Difference-in-Differences Analysis

	IV Skew			
	1996-2007		2008-2019	
	(1)	(2)	(3)	(4)
After x Added	0.82***	0.74**	0.58*	0.63*
	(2.74)	(2.46)	(1.82)	(1.86)
Log Size		0.18		-0.18
		(0.52)		(-0.25)
Book-to-Market		0.43		-0.58
		(0.34)		(-0.46)
Amihud Illiquidity		-3.24**		0.63
		(-2.37)		(0.14)
HV		0.16		0.91
		(0.26)		(1.11)
Systematic Risk		0.19		1.24***
		(0.42)		(2.87)
Put-Call Ratio		0.19		0.26**
		(1.37)		(2.11)
Return		2.88***		2.19**
		(4.69)		(2.23)
Stock FE	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes
Calendar month FE	Yes	Yes	Yes	Yes
Observations	5,420	5,420	4,160	4,160
Adjusted R-squared	0.26	0.27	0.40	0.40

Table 7 reports the first and last difference-in-differences regressions of Table 4 for the subperiods of 1996-2007 and 2008-2019 in our sample separately. There were 271 index additions over 1996-2007 with a mean (median) announcement return of 4.86% (3.75%), while there were 208 index additions over 2008-2019 with a mean (median) announcement return of 1.55% (1.51%). The definitions of all variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 8: Subperiods: Predicting Future Returns

	Next Month's Returns					
	1996-2007			2008-2019		
	(1)	(2)	(3)	(4)	(5)	(6)
IV Skew	-0.11**	-0.10**	-0.06	-0.05*	-0.05*	-0.04
	(-2.06)	(-1.97)	(-1.23)	(-1.69)	(-1.88)	(-1.54)
Systematic Risk		-0.02*	-0.02		0.01	0.01
		(-1.71)	(-1.40)		(1.39)	(1.31)
Log Size		-0.08***	-0.10***		-0.09***	-0.10***
		(-5.92)	(-6.91)		(-5.96)	(-6.07)
Book-to-Market		0.11***	0.08*		0.14***	0.15***
		(2.74)	(1.79)		(6.48)	(6.10)
Amihud Illiquidity		-1.80	-3.25		18.47**	15.42**
		(-0.49)	(-0.85)		(2.39)	(2.00)
Return			-0.19***			-0.15***
			(-7.92)			(-5.71)
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes	Yes	Yes
Calendar month FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,420	5,420	5,420	4,160	4,160	4,160
Adjusted R-squared	0.22	0.25	0.27	0.26	0.30	0.32

Table 8 reports the first three predictive regressions of Table 6 for the subperiods of 1996-2007 and 2008-2019 in our sample separately. There were 271 index additions over 1996-2007 with a mean (median) announcement return of 4.86% (3.75%), while there were 208 index additions over 2008-2019 with a mean (median) announcement return of 1.55% (1.51%). The definitions of all variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 9: Robustness Tests with
Alternative Measures of IV Skew:
Difference-in-Differences Analysis

	Scaled IV Skew		RN Skewness	
	(1)	(2)	(3)	(4)
After x Added	2.23***	1.93***	4.06***	3.57***
	(3.50)	(3.04)	(3.72)	(3.25)
Log Size		1.79**		3.07**
		(2.36)		(2.45)
Book-to-Market		-0.48		-3.58
		(-0.20)		(-1.01)
Amihud Illiquidty		-2.71		2.47
		(-0.90)		(0.42)
Historical Volatility		-2.85***		-10.57***
		(-2.89)		(-6.24)
Systematic Risk		1.01		1.40
		(1.09)		(0.85)
Put-Call Ratio		0.57*		1.06
		(1.65)		(1.57)
Return		10.04***		16.50***
		(8.84)		(8.64)
Stock FE	Yes	Yes	Yes	Yes
Calendar Month FE	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	9,580
Adjusted R-squared	0.17	0.18	0.15	0.16

Table 9 presents the results of robustness tests where we use alternative variables for IV skew for difference-in-differences analysis. Scaled IV skew is defined as $IVSkew/IV$ where IV skew is the difference between the implied volatility of OTM put option with Δ=-0.25 and OTM call option with Δ=0.25 as before, and IV is the average of the implied volatilities of ATM put option with Δ=-0.50 and ATM call option with Δ=0.50, similar to Mixon (2011). Risk-Neutral skewness is calculated over the entire spectrum of OTM puts and OTM calls similar to Bakshi et al. (2003). We flip the sign of RN skewness by multiplying it with -1 to make it consistent with the other IV skew measures. The definitions of control variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 10: Robustness Tests with Alternative Measures of IV Skew: Predicting Future Returns

	Next Month's Return					
	(1)	(2)	(3)	(4)	(5)	(6)
Scaled IV Skew	-0.03***	-0.02***	-0.01			
	(-3.31)	(-2.71)	(-1.40)			
RN Skewness				-0.01***	-0.01**	-0.00
				(-3.21)	(-2.42)	(-1.06)
Systematic Risk		-0.00	-0.00		-0.00	-0.00
		(-0.51)	(-0.24)		(-0.52)	(-0.24)
Log Size		-0.07***	-0.09***		-0.07***	-0.09***
		(-8.13)	(-8.89)		(-8.17)	(-8.91)
Book-to-Market		0.11***	0.10***		0.11***	0.10***
		(5.52)	(4.72)		(5.52)	(4.72)
Amihud Illiquidity		-4.33	-6.00**		-4.24	-5.96**
		(-1.59)	(-2.06)		(-1.56)	(-2.06)
Return			-0.17***			-0.17***
			(-9.07)			(-9.09)
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Calendar Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	9,580	9,580	9,580
Adjusted R-squared	0.23	0.26	0.28	0.23	0.26	0.28

Table 10 presents the results of robustness tests where we use alternative variables for IV skew for predicting next month's stock returns. Scaled IV skew is defined as $IVSkew/IV$ where IV skew is the difference between the implied volatility of OTM put option with Δ=-0.25 and OTM call option with Δ=0.25 as before, and IV is the average of the implied volatilities of ATM put option with Δ=-0.50 and ATM call option with Δ=0.50, similar to Mixon (2011). Risk-Neutral skewness is calculated over the entire spectrum of OTM puts and OTM calls similar to Bakshi et al. (2003). We flip the sign of RN skewness by multiplying it with -1 to make it consistent with the other IV skew measures. The definitions of control variables are as in Table 2. T-statistics in parentheses are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table 11: Additional Tests with
IV-HV Spread and IV ATM Spread:
Difference-in-Differences Analysis

	IV-HV Spread		IV ATM Spread	
	(1)	(2)	(3)	(4)
After x Added	0.74	0.73*	0.10	0.13
	(1.33)	(1.77)	(0.73)	(0.96)
Log Size		-4.08***		-0.16
		(-4.79)		(-0.80)
Book-to-Market		4.13**		-0.90*
		(2.20)		(-1.81)
Amihud Illiquidity		-4.74*		-0.51
		(-1.92)		(-1.00)
Historical Volatility		-76.13***		-0.56*
		(-71.96)		(-1.92)
Systematic Risk		1.40**		-0.25
		(2.41)		(-1.24)
Put-Call Ratio		0.33***		0.02
		(3.28)		(0.38)
Return		-15.85***		2.39***
		(-14.90)		(6.75)
Stock FE	Yes	Yes	Yes	Yes
Calendar Month FE	Yes	Yes	Yes	Yes
Month wrt Index FE	Yes	Yes	Yes	Yes
Observations	9,580	9,580	9,580	9,580
Adjusted R-squared	0.28	0.82	0.17	0.17

Table 11 presents the results of difference-in-differences regressions where we consider additional variables to characterise the option price structure. IV-HV spread is the difference between implied and historical volatilities. Implied volatility (IV) is the average of the implied volatilities of 30-day ATM put option with Δ=-0.50 and ATM call option with Δ=0.50 measured at the end of the month. Historical volatility (HV) is the volatility of daily returns realized over the past month. IV ATM Spread is the difference between implied volatilities of 30-day ATM put option with Δ=-0.50 and ATM call option with Δ=0.50 measured at the end of the month. The definitions of control variables are as in Table 2. T-statistics for differences are calculated using robust standard errors clustered by stock. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Figure 1: Implied Volatility Skew of Added vs. Control Stocks

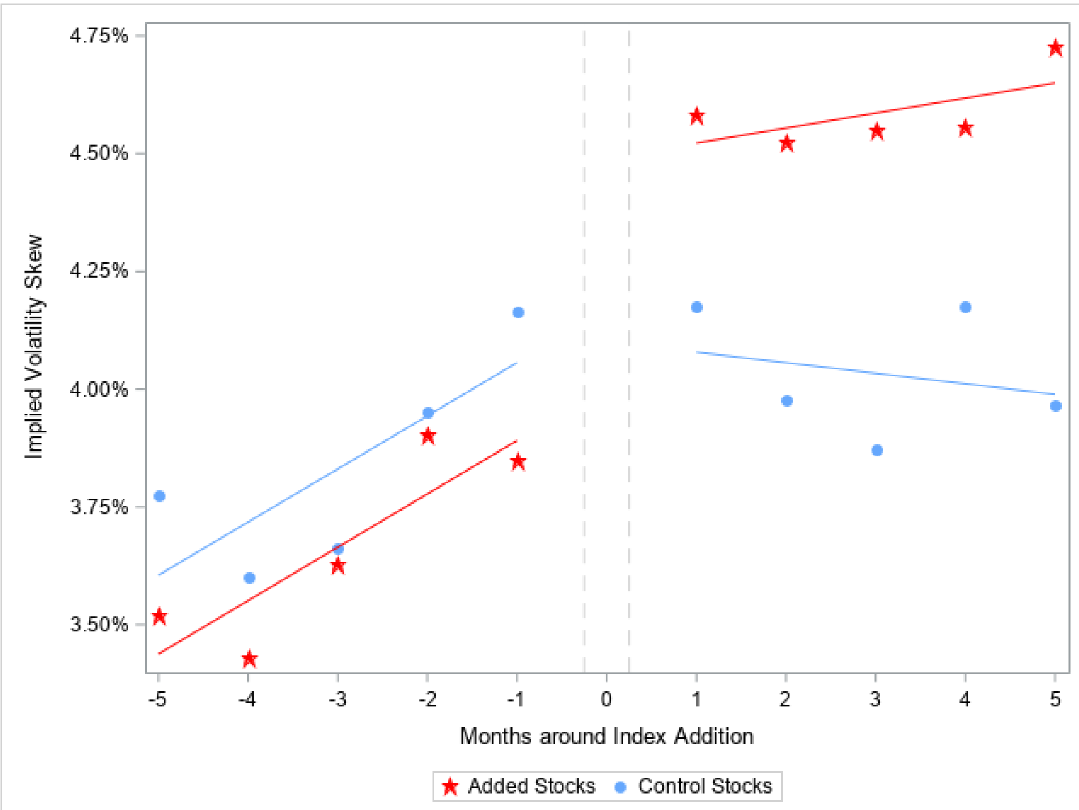

Figure 1 plots the IV skew of stocks added to the S&P 500 index and their corresponding control stocks for 5 months before and 5 months after the event window of index addition, along with their pre- and post-event trend lines. The event window of index addition is excluded, which is the month of effective change date and the month before that, which potentially contains the announcement date. The control sample is selected based on exact industry match (Fama-French 49 industry classifications based on SIC codes), and propensity score matching based on log-size, book-to-market ratio, and past 5-month return before indexation. IV skew is calculated as the difference between the IV of a 30-day OTM put option with Δ=-0.25 and OTM call option with Δ=0.25.

Figure 2: Announcement Return Reversals for Added Stocks

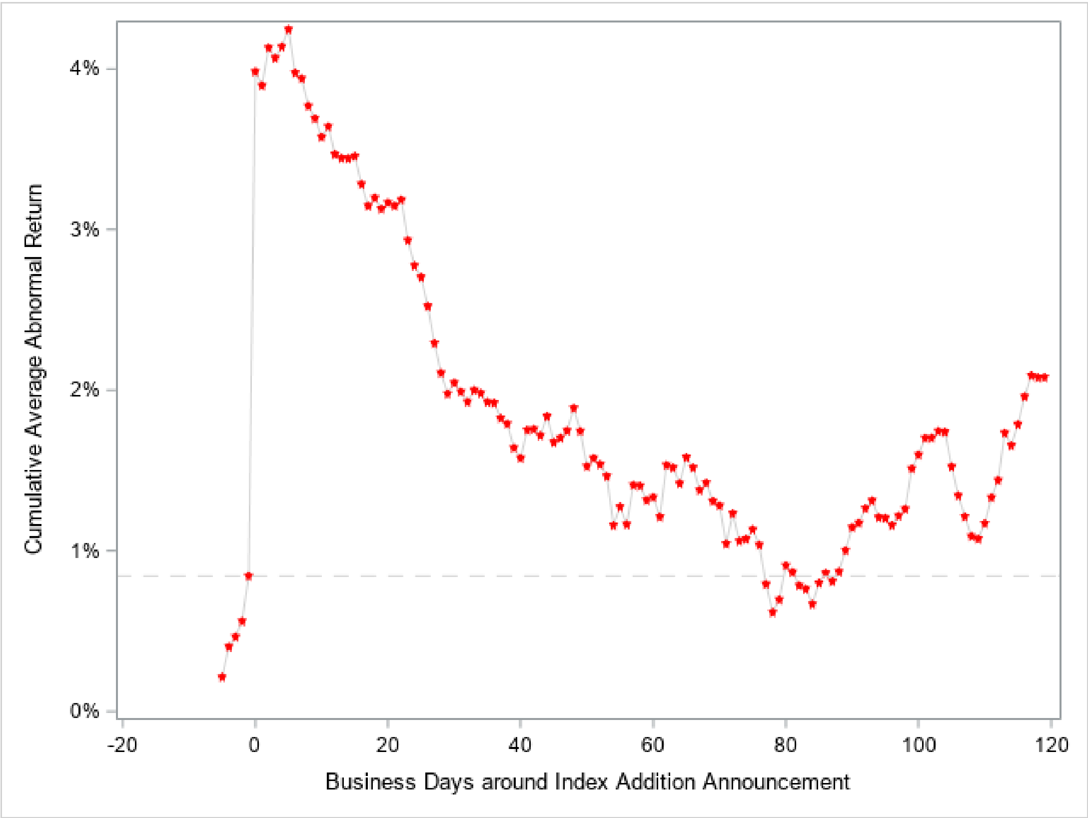

Figure 2 plots the daily cumulative average abnormal return for stocks added to the S&P 500 index from day -5 to day 120 around the index addition announcement. Day 0 is the day following the announcement, since additions are announced after the markets close. Daily abnormal returns are calculated based on 4-factor Fama-French-Carhart model (Carhart (1997)), in which betas are estimated using a 252-day window ending 50 days before the index addition. Average abnormal return for the two-day event (day 0 to day 1) is 3.42%, which reverses over the next months.

Figure 3: Implied Volatility Skew of Added Stocks over Extended Periods

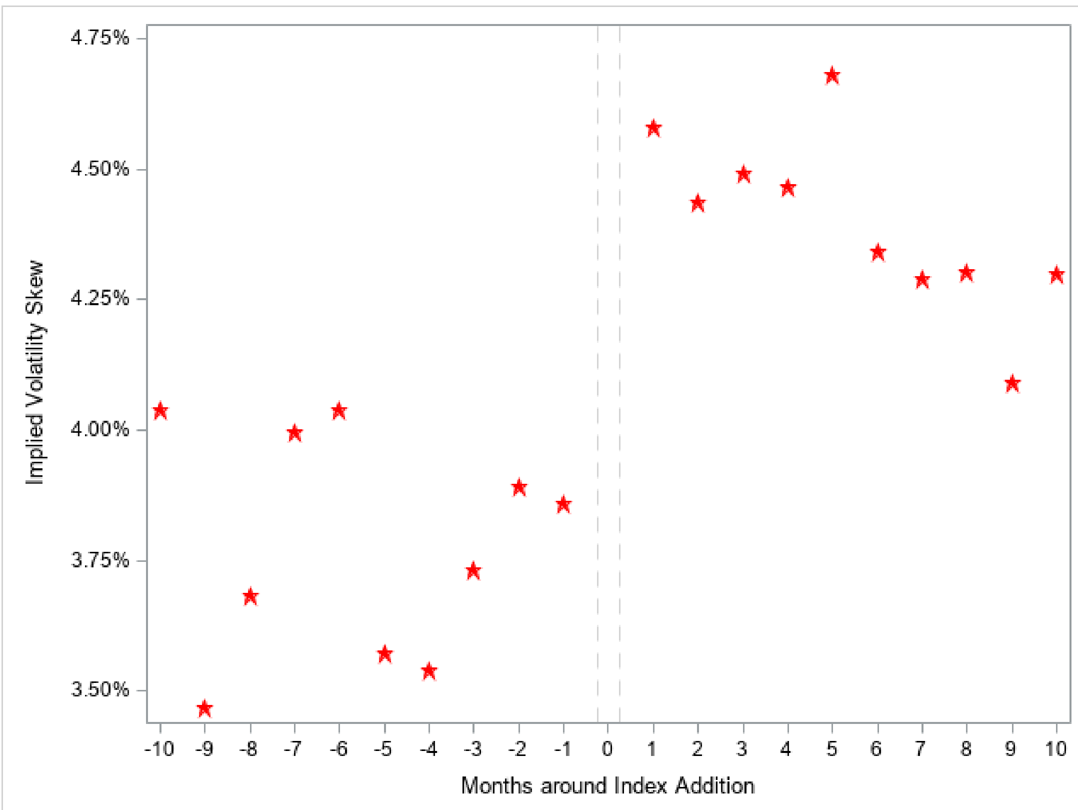

Figure 3 plots the IV skew of stocks added to the S&P 500 index for the extended 10 months before and 10 months after the event window of index addition. Here, we consider 458 added stocks that have complete options and stock data over the extended 10-month before and after periods, compared to 479 added stocks in our main tests with 5-month periods.