S&P 500 Index Inclusion and Implied Volatility Skew

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Abstract

Using S&P 500 index inclusion, we examine how a non-fundamental demand shock on the stock price affects the price structure of equity options. We find that the implied volatility skew of stocks added to the index becomes steeper in the months following index inclusion. This effect exists only for stocks that experience a high announcement return and fades after the announcement return reverses. Moreover, the implied volatility skew predicts next month's return, but this predictability is mostly subsumed by the return reversals of added stocks. Overall, our results are consistent with the notion that options market participants trade based on anticipated return reversals when stock prices deviate from their fundamental values.

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1 Introduction

The options market provides forward-looking information about the underlying stock price that is not necessarily 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 (Chakravarty, Gulen and Mayhew (2004)). 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 (Bali and Hovakimian (2009), Cremers and Weinbaum (2010), Xing, Zhang and Zhao (2010), An, Ang, Bali and Cakici (2014)). 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)).

This paper explores another mechanism through which option prices can predict stock returns. When temporary price pressure (or noise) causes a stock price to deviate from its fundamental value, options market participants anticipate the reversal of this price pressure and trade accordingly. 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 use S&P 500 index inclusion as a non-fundamental demand shock on the stock price to examine this mechanism and analyze how option prices change when the underlying stock is added to the index.[1]

S&P 500 index inclusions have been extensively studied in the literature. Many studies show 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 (see, e.g., Shleifer (1986), Harris and Gurel (1986), Beneish and Whaley (1996), Lynch and Mendenhall (1997), and Wurgler and Zhuravskaya (2002)). While earlier studies find that this price increase does not revert over a three-month window following index inclusion, Patel and Welch (2017) show that it reverts over a six-month window, especially for stocks added to the index after 2000. They

[1] We only examine 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.

conclude that index inclusion exerts only a temporary demand shift for the added stock due to buying of index investors, keeping the stock price above its fundamental value before it eventually reverts. Our paper analyzes how option prices respond to this long-lasting price pressure or noise in the stock market and how it can be related to the predictive power of options prices for future stock returns.

We use implied volatility skew as a proxy for the options price structure, defined as the difference between the implied volatility (IV) of the out-of-the-money (OTM) put and call options.[2] This is similar to the slope of the IV curve in Bakshi, Kapadia and Madan (2003) or Bollen and Whaley (2004). Given that IV measures the expensiveness of an option (Garleanu, Pedersen and Poteshman (2009)), the slope of the IV curve or IV skew measures how expensive it is to trade based on a significant downside movement in the stock price compared to its upside potential. Thus, it can gauge the options market's expectation about the direction of the change in the stock price. Moreover, Xing, Zhang and Zhao (2010) show that IV skew can predict future returns for up to six months, suggesting that option market participants with a negative view prefer to trade OTM put options.

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 about the stock after indexation. 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 highly significant.

We also control for other factors that can drive the increase in 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)). Moreover, we use the put-call ratio to

[2] In additional tests, we consider alternative variables to characterise the option price structure.

control for the net demand for puts vs. calls (Bollen and Whaley (2004)) and past return to control for the pre-inclusion momentum of added stocks (Kasch and Sarkar (2014) and Chen, Singal and Whitelaw (2016)). Even after controlling for these factors, the effect of indexation on IV skew remains similar, suggesting that it is not driven by an increase in systematic risk and subsequent hedging demand or by lost momentum.

To verify that the effect of index addition on IV skew is 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 most of this price increase reverts in the following five months. In line with the idea that the increase in IV skew is a forward-looking reflection of the announcement return reversal, we find that the effect of index inclusion on IV skew is significant only for stocks that experience high announcement returns. The effect fades after the five months following indexation, which coincides with the reversal 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 the next month's returns. However, in our sample, predictability exists only for added stocks and not for control stocks. Furthermore, predictability is subsumed mainly by the return reversals of added stocks. Overall, these results are consistent with the mechanism that options market participants anticipate the reversal of announcement returns and buy OTM put options accordingly. This causes the increase in IV skew and drives the predictability 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 shock drives it.

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 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)). Moreover, 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 that document 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 option-implied volatility spreads, deviations from put-call parity, IV skew, and change in volatility spreads predict future stock returns, interpreting this as evidence of informed trading and price discovery in the options market.[3] On the other hand, Muravyev, Pearson and Broussard (2013) show that when stock and options market disagree about a stock's value, the option market quotes adjust to eliminate the disagreement, while the stock market quotes do not adjust, conflicting with the idea of price discovery in the options market.

In a more recent study, Goncalves-Pinto et al. (2020) argue that the options market provides an anchor for fundamental stock values that helps to distinguish between stock price movements due to pressure or news. Empirically, they show that large deviations between daily option-implied stock prices and actual stock prices are accompanied by high stock price pressure measured by abnormal stock order imbalance, turnover, and signed return. In their framework, stock price deviates from its fundamental value only for one day and reverts the next day. There is no significant

[3]Some studies find that variables related to option trading volume, rather than option prices, also predict future stock returns. See, for example, Roll et al. (2010), Johnson and So (2012) and Hu (2014)

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 liquidity effects.

In our framework with S&P 500 index inclusions, the stock price remains above the fundamental value for some months due to the temporary demand of index investors. Knowing this price level is temporary, options market participants trade based on a price reversal expectation, and option prices predict next month's return. Note that in our framework, the deviation of the stock price from its fundamental value or the noise lasts longer, giving the options market participants a window to trade and take advantage of the price reversal. Hence, our paper tests whether the options market can filter out the noise in stock price and trade based on expected price reversals, rather than focusing on 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.[4]

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 et al. (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

[4]We note that our paper does not rule out informed trading in the options market. Instead, it suggests expected price reversals as another mechanism that can drive the option price-based stock return predictability. Also, since we focus on S&P 500 index additions and do not examine the whole cross-section of stocks, our empirical set-up does not allow to compare the relative importance of the two mechanisms.

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 positively signal 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.

Some studies examine the impacts of S&P 500 index inclusion in the long run. Vijh (1994) and Barberis et al. (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. Indexation 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.[5] 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 month before that, which potentially includes the announcement date. On average, there is one week 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

[5] Our results remain qualitatively similar if we focus on index additions after 2000.

fully isolate the announcement effect, we consider the month before the effective change date as a part of the event window and exclude it from our analysis. Our before- and after-indexation 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-indexation periods.

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.[6] These are obtained directly from the IV surfaces available on OptionMetrics.[7] 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 conducted 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 indexation.

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 partic-

[6] Note that our IV skew measure is slightly different from Xing et al. (2010), who focus only 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 et al. (2003) and Bollen and Whaley (2004). We obtain qualitatively similar results when we use the definition of Xing et al. (2010).

[7] Using the IVs from OptionMetrics IV surfaces directly has the advantage of not making arbitrary decisions on which strikes or maturities to include to compute $IVOTMPut$ or $IVOTMCall$.

ular, 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 prior to index inclusion, but this difference is only marginally significant. To address the issue of 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 x Added* is a dummy variable that equals 1 for added stocks in the period after indexation. 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 indexation.[8]

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 et al. (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 include realized return over a month as an additional control variable to account for the lost momentum in the post indexation period.[9]

We also control for other factors whose change through indexation 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 indexation. 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.

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

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

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, Vijh (1994) and Barberis, Shleifer and Wurgler (2005) document that stocks added to the S&P 500 index co-move 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 also control for them. To control for 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.[10]

Bollen and Whaley (2004) show that investors mostly buy protective put options on the index for hedging purposes, while they mostly buy speculative calls on individual stocks. They argue that the net demand for puts vs. calls also 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 net buying pressures in the options markets by using the put-call ratio as a proxy for it. 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 indexation periods. All variables are winsorized at 1% and 99% levels to reduce the effect of extreme observations. 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

[10]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.

average value for the Amihud (2002) illiquidity measure is 0.08%.

3 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 effective change date and the month before that, potentially containing the announcement date. Prior to 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 the DiD analysis.[11] After indexation, the IV skew of the control stocks remains around the same level as before. The IV skew of the added stocks, on the other hand, increases significantly and remains at the higher level till at least five months post-index addition.

We quantitatively assess the significance of the break in IV skew post indexation 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 indexation, 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 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 indexation on IV Skew, as specified in Equation 2. We control for changes in additional factors that can affect IV skew.

Column (1) of Table 4 shows that the IV skew increases by 0.72% post-indexation 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 respect

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

to indexation, 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 indexation by using the 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 seen 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 seen in columns (5)-(6). However, the effect of indexation 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 indexation. We find that return is significantly positively related to IV skew at the end of the month. Nevertheless, the effect of indexation on IV skew reduces only to 0.65% after controlling for past returns and is still significant. This suggests that the effect of indexation on IV skew is not a result of added stocks losing their pre-inclusion momentum after indexation. 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 indexation on IV skew is not caused by the well-known changes associated with index additions. 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 demand 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%, whereas 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%, which fully reverses around the fifth month after index addition.[12] We note that the announcement return is a part of the event window, so it was not included in the DiD analysis of the previous section.

In order to test if the effect of indexation on IV skew is caused by the non-fundamental demand shock on the stock price, 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.[13] We replace the variable $AfterxAdded$ in Equation 2 with $AfterxAddedxHigh$ and $AfterxAddedxLow$, 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 non-fundamental demand shock drives the stock price.

We conjecture that, after the stock price increase upon index addition announcement, option market participants 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. If this conjecture holds, the increase in IV skew should be effective mainly during the months when the announcement returns reverse, which corresponds 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 overextended before- and after-indexation periods for ten months, compared to five months in our main tests.[14] We see that the IV skew of added stocks decreases after the fifth month, suggesting that the change in IV skew is temporary.

[12] We calculate daily abnormal returns based on the 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 announcement. We obtain qualitatively similar results when using alternative models, such as market adjustment, 1-factor CAPM or 3-factor Fama-French model (Fama and French (1993)).

[13] The median announcement return in our sample of added stocks is 2.83%.

[14] 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-indexation, compared to 479 stocks in our main sample.

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 indexation 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, and 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, they filter out the noise in the stock price. Knowing that the stock price is temporarily high due to the price pressure associated with indexation, 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.

Table 6 presents the results from regressing next month's returns on IV skew in our sample. In line with the results of Xing et al. (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 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 additionally 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 the IV skew is considerably reduced when we control for the current month's return, suggesting that the predictive power of the 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 expected return reversals in the presence of noise in the stock price, which drives the predictive power of IV skew for future returns.

3.5 Additional Tests

This section runs additional tests for our main result that documents the increase in IV skew after index addition. Specifically, we conduct a subperiod analysis, show that our result is robust to alternative measures of IV skew, and explore other variables used to characterize option price structure.

3.5.1 Subperiod Tests

Patel and Welch (2017) and Bennett et al. (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 1990s to about 2% around 2015. Bennett et al. (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.[15]

Since the announcement returns proxy the effect of the non-fundamental demand shock on the stock price in our setup, we repeat our main DiD regressions for IV skew for the two subperiods. Table 7 shows that index inclusion on IV skew is much stronger for the first subperiod than the second subperiod, where the average announcement return has decreased substantially. This further supports our argument that the non-fundamental demand shock drives the effect of index inclusion on IV skew on the stock price.

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

[15] The median announcement returns are 3.75% and 1.51%, respectively.

(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 et al. (2003). 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 et al. (2003).

The scaled IV skew is calculated as:

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

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 et al. (2003) over the entire spectrum of OTM puts and OTM calls as:

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

where

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

$R_{t,\tau}^3$ 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 volatility 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 or extrapolate the IV curve to get the option prices for strikes besides the available range. 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 8 gives the main DiD regressions results using the two alternative measures for IV skew. As shown in columns (1)-(2), 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 t-statistic of 3.25. Overall, the results in this section confirm that OTM puts become more expensive than calls after indexation, irrespective of how we measure 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), 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 volatility realized 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 indexation.

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 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 the change predicts next month's return as directional measures from the options market. Thus, we check if IV ATM spread changes significantly after indexation for completeness.

Table 9 presents the results of the main DiD regressions for IV-HV spread 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 indexation. In untabulated results, similar to Ben-David et al. (2018), we find that historical realized volatility increases significantly in the months after indexation. However, the IV of ATM puts and ATM calls also increase proportionally, leaving the IV-HV spread unchanged.

Columns (3)-(4) show that the IV ATM spread of added stocks also does not change significantly since the increase in IV of ATM puts and calls are similar. This suggests that option market participants prefer to buy OTM puts to trade based on expected price reversal rather than ATM puts. 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 stock change. 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 as the only mechanism through which option prices can predict future stock returns. This paper explores another mechanism. When stock price deviates from its fundamental value due to a temporary demand shock or price pressure, option market participants anticipate the reversal of this shock and trade accordingly. Hence, option prices filter out the noise in the stock price and predict future stock returns through return reversals.

We examine this 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 post-indexation 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 indexation. 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 drives the increase in IV skew on the stock price.

To further test if the increase in IV skew is a forward-looking reflection of announcement return reversals, we examine the predictive power of IV skew for next month's return in our sample. We show that the IV skew is negatively related to next month's return, implying that the options market leads the stock market. However, this predictability exists only for our sample's added stocks rather than control stocks. Moreover, it is subsumed mainly by the return reversals of added stocks. Overall, our results align with the notion that option market participants buy OTM puts to benefit from anticipated return reversals when the stock price goes above its fundamental value, which leads to the predictive power of IV skew for future 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

Variable	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: Subperiod 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: Robustness Tests:
Alternative Measures of IV Skew

	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 8 presents the results of robustness tests where we use alternative variables for IV skew. 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 9: Additional Tests:
IV-HV Spread and IV ATM Spread

	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 9 presents the results of tests 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

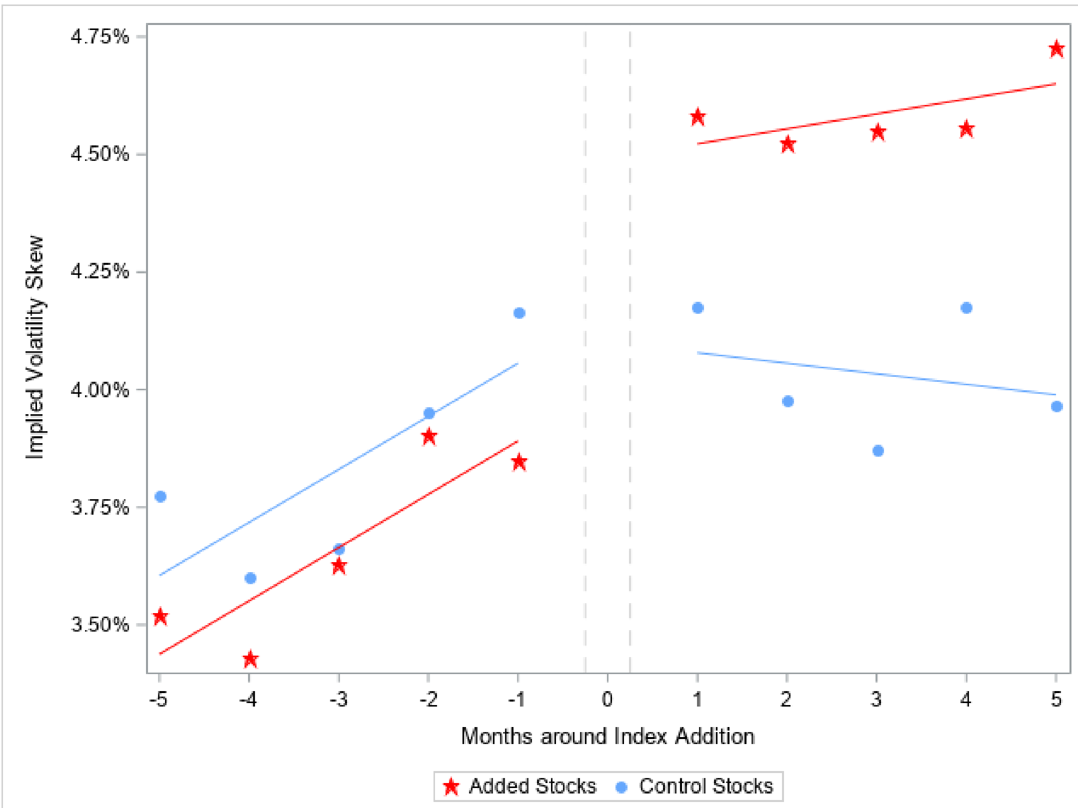

Figure 1 plots the IV skew of stocks added to the S&P 500 index and their corresponding control stocks for 5 months before and 5 months after the event window of index addition, along with their pre- and post-event trend lines. The event window of index addition is excluded, which is the month of effective 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

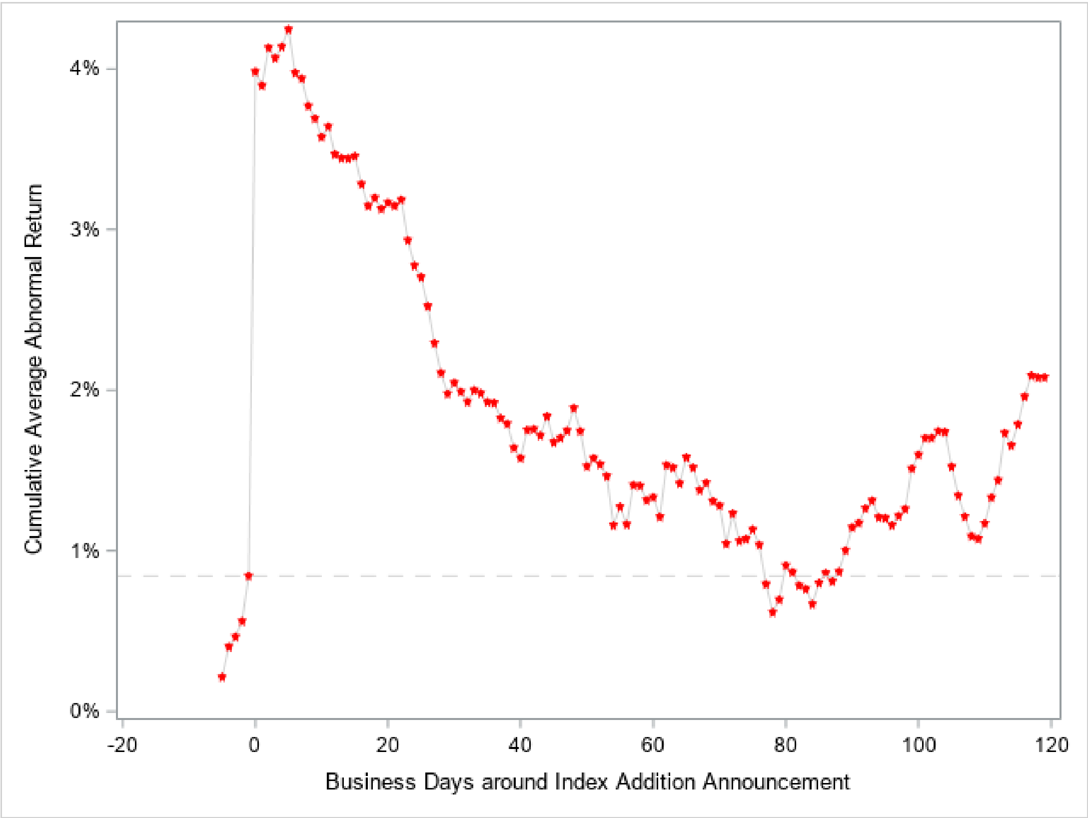

Figure 2 plots the daily cumulative average abnormal return for stocks added to the S&P 500 index from day -5 to day 120 around the index addition announcement. Day 0 is the day following the announcement, since additions are announced after the markets close. Daily abnormal returns are calculated based 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

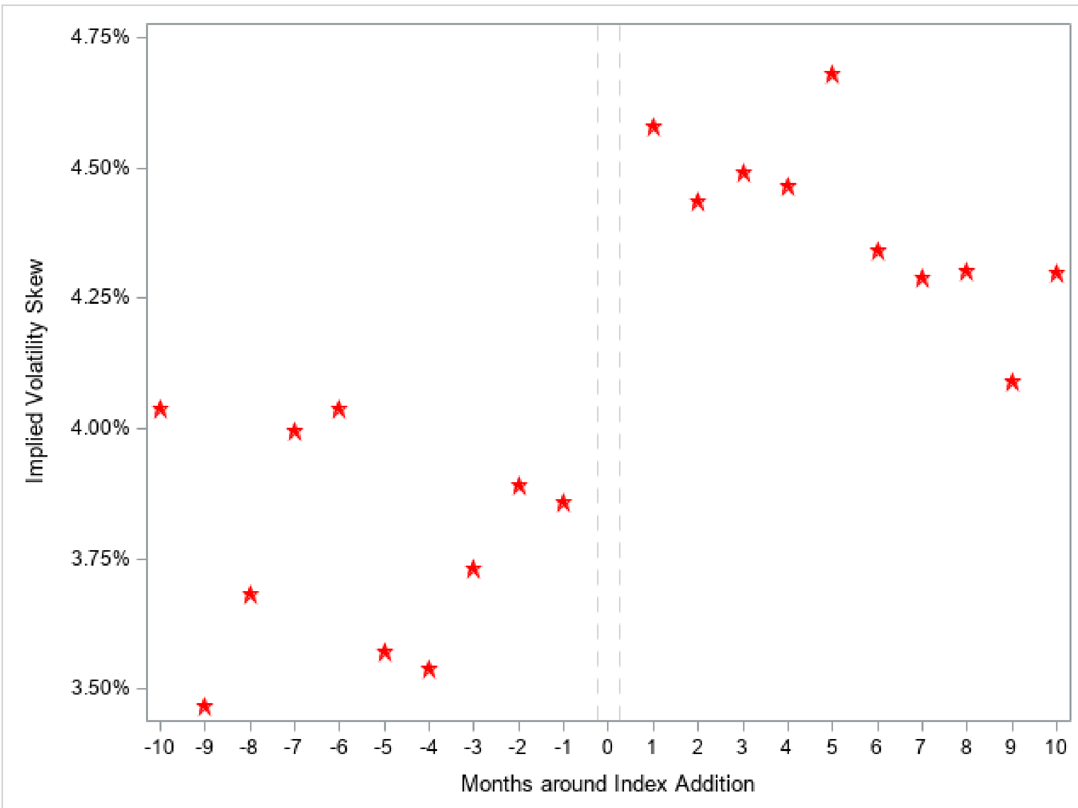

Figure 3 plots the IV skew of stocks added to the S&P 500 index for the extended 10 months before and 10 months after the event window of index addition. Here, we consider 458 added stocks that have complete options and stock data over the extended 10-month before and after periods, compared to 479 added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