Volatility Spreads and Innovation Grants Announcement Returns

Zih-Ying Lin, Guan-Ying Huang, and Pei-Fang Hsieh*

Abstract

Prior studies have documented that firms' innovation grants announcements contain information that is focused on the stock market. We examine the roles of informed traders who reveal information in the options market by examining the informational content of options trading on innovation grants announcement returns. The empirical results show that the call-put implied volatility spreads positively significantly predict a two-day innovation grants announcement return. In addition, the degree of announcement return predictability is stronger when the volatility spread is measured under high option liquidity, which in the literature is believed to happen during periods when more informed traders are in the options market.

Keywords: Call-Put implied volatility spread; Stock returns; Innovation grants announcement.

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1. Introduction

A key patent held by a company has a significant influence on its market value. The patent not only significantly helps create the firm's future cash flow, but also prevents competitors from entering the market under a similar production line. One famous case involves the patent wars in the smartphone market. For example Apple holds most of the key patents in this market, thus successfully barring competitors from using certain phone features. Another case is drug wars in the pharmaceutical industry. Only the company that is granted the drug patent could become the winner in the industry because it is empowered to produce, market, and sell the drugs. In other words, the pharmaceutical company can benefit itself by monopolizing the market.

In this paper we exploit the innovation grants announcement to identify the effect that the publication of firms' new patents has on stock returns. Firms' innovation grants announcements are different from other announcements, such as merger and acquisition (M&A) announcements or earnings announcements. The innovation generates higher uncertainty for a firm, making it harder to estimate the cost of capital for two reasons. First, it is difficult to measure the project risks and intangible capital requirements.[1] Second, the innovative activities exhibit a greater variation of future

[1] Mansfield (1968) indicated that most innovation grants are riskier than other projects, because of the high failure rate. For example, Cochrane (1991, 1996) indicated that intangible capital is an important element of input in innovation activities. The 2014 report of HM (Her Majesty's) Treasury pointed out that U.K. companies spend nearly £130 billion to invest in intangible assets for innovation.

cash flows due to the higher proportion of growth opportunities.[2] In addition, innovation results in information asymmetry between investors and enterprises (Aboody and Lev, 2000; Hall, Jaffe, and Trajtenberg, 2001), and hence we conjecture that firms with more innovation grants have more information asymmetry due to a greater difficulty in observing a project's expected value.

We investigate how the information contents of innovation grants announcements exist in the options market. The motives are based on two important categories of the literature. The first includes those studies finding evidence that the information contents of innovation grants announcement in the stock market have an effect on increasing the variation in stock price.[3] If information asymmetry exists in the stock market, then it is natural to expect that the information asymmetry also exists in the options market, because the high volatility of stock with innovative firm attracts more informed traders to trade in the options market.[4] The second category is that recent studies have demonstrated that the call-put implied volatility (*CPIV*) spread can predict future underlying stock returns (Bali and Hovakimian, 2009; Cremers and Weinbaum, 2010; Doran and Krieger, 2010; An, Ang, Bali, and Cakici,

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[2] Porter (1992) pointed out that firms with innovation maintain growth opportunities and upgrade their competitive advantages.

[3] Kogan, Papanikalaou, Seru, and Stoffman (2012) indicated that stock volume increases around the day that a firm is granted a patent and concluded that patent issuance conveys important information to the stock market. Campbell, Lettau, Malkiel, and Yexiao (2001), Shiller (2000), and Pastor and Veronesi (2005) found that the role of technological changes is in increasing firm specific and aggregate stock price volatility.

[4] Back (1993), Cao (1999), and Easley, O'Hara, and Srinivas (1998) mentioned why informed traders like to trade more in the options market.

2014). They concluded that a high *CPIV* spread contains a positive signal of stock returns from informed traders. Furthermore, Atilgan (2014) confirmed that the *CPIV* spread contains information on firms' earnings announcement events, especially in more liquid options as well as low liquid and high information asymmetric underlying stocks. Chan, Li, and Lin (2013) had similar findings using M&A announcement events.

We provide herein evidence that a higher *CPIV* spread, which is caused by the difference between call implied volatility and put implied volatility, contains more information about the future returns of stocks from firms that have announced innovation grants. This fact supports that a positive *CPIV* spread reveals a greater possibility of patent success during the pre-announcement period. Our results are robust no matter whether we use an option implied volatility spread or a change in the option implied volatility spread to capture the informed trading.

We then separate our sample according to the viewpoint of Easley et al. (1998), who indicated the informed traders are more likely to reveal their private information when the options market is more liquid, the stock market is less liquid, and the information asymmetry of the stock market is high. We only find some evidence that supports the fact that the option implied volatility spread in the category of high option liquidity contains more information about future stock returns following innovation grants announcements. Our regression analysis also confirms the finding that there is a significantly positive relation between the option volatility spread and future stock returns following innovation grants announcements.

The remainder of this paper is organized as follows. Section 2 describes the hypothesis and methodology. Section 3 presents the sample and descriptive statistics. Section 4 reports the empirical results. Section 5 concludes.

2. Hypotheses and Methodology

Arrow (1962) and Hall and Lerner (2010) indicated that the process of innovation should be kept secret until it is successfully made public. Aboody and Lev (2000) and Hall, Jaffe, and Trajtenberg (2005) respectively found that firms with greater research and development (R&D) and innovation tend to be more information asymmetric. We then follow the empirical framework of Atilgan (2014) and investigate the information contents of the call-put implied volatility (*CPIV*) spread. We expect that if informed traders indeed know about the higher percentage of patent success (failure), then they will demand more call (put) options than put (call) options, which will increase the spread of call implied volatility as it relates to put implied volatility. This argument brings forth our hypothesis as follows:

The CPIV spread calculated from the pre-innovation grants announcement day has a positive relation to (abnormal) stock returns following the innovation grants *announcement.*

To examine our main hypothesis, we apply both panel regression and time-series regression to examine the relation between *CPIV* spread and a firm's stock returns. The model specification is as follows:

$$R_{i,[0,1]} = a_0 + \beta_1 VS + \beta_2 Return\,[-6,-1] + X'\beta + \varepsilon, \quad (1)$$

where $R_{i,[0,1]}$ is the buy-and-hold stock return from day 0 to day 1, and VS denotes the call-put implied volatility (*CPIV*) spread and/or changes the *CPIV* spread (△ *CPIV*) in replacement of the actual values of volatility spread signals. Return [-6,-1] is the lagged weekly stock return. Following Atilgan (2014), we calculate the firm size, book-to-market (BM), skewness (SK), and momentum (MOM) as control variables. Specifically, firm size is measured by the number of shares outstanding multiplied by the stock price, $BM_{i,t}$ is the stock's book value at the end of the prior fiscal year over the market value, $SK_{i,t}$ is computed as the daily returns over the prior year, and $MOM_{i,t}$ is defined as the buy and hold stock return over the past 12 months.

We base our analysis on the argument of Easley et al. (1998), who indicated that informed traders are more likely to trade in the options market when the information asymmetry of the underlying stock is high, the liquidity of the stock is low, or the liquidity of options is high. Therefore, we control the liquidity of options as well as the liquidity and information asymmetry of the stock market to reexamine the time-series correlation between volatility spread and (abnormal) return around the dates of innovation grants announcements. The high (low) option liquid indicator is measured by the corresponding options' bid-ask spread, which is ranked in the top (bottom) 30%. We create an information asymmetry index (*Asy-index*), which is proposed by Drobetz, Grüninger, and Hirschvogl (2010). The high (low) *Asy-index* indicator represents the top (bottom) 30%. In addition, we use the Amihud illiquidity ratio to proxy the liquidity of the underlying stock. The high (low) stock liquidity indicator has the same classification as the top (bottom) 30% firms ranked by the Amihud illiquidity ratio.

3. Sample and Descriptive Statistics

The primary dataset adopted for this study includes the daily transaction details of all stocks with options traded on a U.S. exchange and those of the options.[5] The options data are from OptionMetrics, including daily closing bid and ask quotes, implied volatilities, and volumes.[6] All the data of underlying stocks come from CRSP, including daily prices, returns, volumes, and shares outstanding. We obtain the innovation granted date from the National Bureau of Economics Research (NBER) Patent Citation Data File. Our sample period is from January 1996 to December 2006.

As suggested by Atilgan (2014), we exclude those options that meet the some

[5] Following the general practice in literature, we exclude financial and utility firms (with CRSP share codes other than 10 or 11) from the sample.
[6] All of the stock options traded in the U.S. market are American style.

conditions.[7] The implied volatilities of put and call options with the same strike price and expiration date should be equal. Therefore, the difference between the implied volatilities of a matched pair of put and call options is called implied volatility spread and can be used to proxy for price pressure in the option markets.[8]

Following Cremers and Weinbaum (2010), we compute the weighted average volatility spread for stock *i* on day *t* as follows:

$$CPIV_{it} = \sum_{j=1}^{N_{it}} w_{jt}\left(IVcall_{jt} - IVput_{jt}\right), \quad (2)$$

where *j* represents the j^{th} matched pair of put and call options with the same strike price and expiration date on stock *i*, N_{it} represents the number of valid option pairs for stock *i* on day *t*, $IVcall_{jt}$ ($IVputl_{jt}$) is the implied volatility of the call (put) option in the j^{th} pair of options *j*, and w_{jt} is the weight computed based on the average open interest of the j^{th} pair of call and put options.

Asy-index includes analyst forecast errors, firm size, R&D expenditure, Tobin's *Q*, and the number of analysts tracking the firm. We obtain R&D expenditure and total assets from Compustat. Details on the analyst forecasts and the number of tracking analysts are collected from I/B/E/S. The Amihud illiquidity ratios used to measure stock liquidity are collected from Joel Hasbrouck's website. The option

[7] Those excluded are when: (i) Prices violate the no-arbitrage condition; (ii) Midpoints are less or equal to 0.125; (iii) Maturities are not within 10-60 days; (iv) Implied volatilities are not between 3% and 120%; (v) Open interest is non-positive; and (vi) Trading volumes are missing.
[8] The implied volatilities have been adjusted for expected dividends and early exercise.

liquidity is measured by option volume and option bid-ask spread.

In Table 1 we show the descriptive statistics of the *CPIV* spread and the other variables, including the means, medians, standard deviations, and 10%, 50%, and 90% percentiles.

<Table 1 is inserted about here>

We provide the sum of aggregated total dollar volume for firms with/without innovation for each year across all optioned stocks from 1996 to 2006 in Figure 1.[9] We see that firms with innovation have higher options trading volumes, while firms without innovation have lower option volumes (Blanco and Wehrheim, 2015). This implies that option trading may contain more information for firms with innovation. We report the numbers of the innovation grants announcement events and the numbers of corresponding firms in Table 2, both of which exhibit an increasing trend across years. Table 2 presents that the number of events increases from 4998 in 1996 to 6347 in 2006.

<Figure 1 is inserted about here>

<Table 2 is inserted about here>

4. Empirical Results

4.1. Results of panel regression

[9] See Roll, Schwartz, and Subrahmanyam, (2009) for a more detailed discussion.

Table 3 reports our empirical results of panel regression. We find the coefficients of both interactions of the event dummy and *CPIV* spread or △ *CPIV* are significantly positive, indicating that the predictability of future returns is more pronounced during innovation grants announcement events.

<Table 3 is inserted about here>

The next investigation is based on quintiles that sorted the stocks according to their corresponding option volatility spread (*CPIV* spread *or* △ *CPIV*). We calculate both the buy-and-hold stock returns starting from the innovation grants announcement day, representing day interval [0, 1], and the abnormal returns measured by a five-factor model.[10] Table 4 presents the results. Quintile 1 is formed by stocks with relatively expensive put options. In contrast, quintile 5 is formed by stocks with relatively expensive call options. The first set in quintiles sorts stocks by using the *CPIV* spread. Consistent with our expectation, the equity return is monotonically increasing from quintile 1 (-0.0004) to quintile 5 (0.0043). Moreover, the abnormal returns in quintile 5 are found to be larger than those in quintile 1. The abnormal return for quintile 1 is -0.0009, whereas the abnormal return for quintile 5 is 0.0043.

[10] The book-to-market factors and momentum factor are proposed by Fama and French (1993) and Carhart (1997), respectively. The skewness factor is created by ranking stocks based on the total skewness of their daily returns during the past year and forming three portfolios. The skewness factor is equal to the value-weighted return on the hedge portfolio, which buys 30% of the stocks with the most negative skewness and sells 30% of the stocks with the most positive skewness. We regress daily returns during the last twelve months on these five factors to obtain the factor loadings, respectively.

The difference between the high and low of abnormal returns is 0.0032 with a *t*-statistic of 4.31.

<Table 4 is inserted about here>

In Table 4 we also examine the quintiles that sorted the stocks according to the change in their corresponding option volatility spread during the pre-announcement week, representing day interval [-6, -1]. The five-factor adjusted abnormal return for quintile 1 is -0.0014. The abnormal return for quintile 5 is 0.0007, and the difference between quintile 1 and quintile 5 is 0.0021 with a t-statistic of 3.90. These results suggest that the change in volatility spreads ($\triangle$*CPIV*) can predict the announcement returns during the pre-announcement week.

Table 4 also reports the last set in quintiles that double-sorted the stocks by both *CPIV* spread and $\triangle$ *CPIV*.[11] We find that the difference between the extreme quintiles in quintile (1, 1) and quintile (5, 5) can earn a five-factor adjusted abnormal return of 0.0068 (t-statistic=4.96). In sum the results of different volatility spread quintiles also support our hypothesis and show evidence that a greater imbalance in buying pressure toward call (put) options contains more information of future positive (negative) stock returns.

Based on the viewpoints of Easley et al. (1998), we separate the full sample into

[11] We first sort stocks into five quintiles according to the level of volatility spreads on the end of day t-1 and then sort stocks into five quintiles according to the change of volatility spreads from the end of day t-6 to the end of day t-1.

two categories of subsamples according to option liquidity (panel A and panel B of Table 5), information asymmetry of the underlying stock (panel C of Table 5), and underlying stock liquidity (panel D of Table 5), respectively.

<Table 5 is inserted about here>

In Panel A of Table 5, for the option pairs with low average bid-ask spreads (more liquid), quintile 5 earns a greater abnormal return than quintile 1, and the abnormal return difference between the extreme volatility spread quintiles is 0.0189 with a t-statistic of 3.78. In contrast, when volatility spreads are measured by option pairs with high bid-ask spreads (less liquid), the difference between the two quintiles is insignificant. This empirical finding suggests that volatility spreads have stronger predictive power for innovation grants announcements when liquidity in the options market is taken into consideration.

In Panel B of Table 5, the liquidity of each option pair is measured by the average volume of the call and the put in the option pair. When the option pairs with high average volumes (more liquid) are used to measure volatility spreads, the abnormal return difference between the extreme quintiles (quintile 5 and quintile 1) is 0.0124 with a t-statistic of 3.45. In contrast, this abnormal return difference drops to 0.0086 (t-statistic = 3.05) when only option pairs with low average volumes (less liquid) are used.

In Panel C of Table 5, the results report that the abnormal return difference between extreme volatility spread quintiles is 0.0356 (0.0178) with a t-statistic of 3.29 (3.09) for the lowest (highest) *Asy-index* quintile during the two-day announcement window. In Panel D of Table 5, the abnormal return difference between extreme volatility spread quintiles is 0.0107 (0.0142) with a t-statistic of 5.50 (3.42) for the lowest (highest) illiquidity ratio quintile during the two-day announcement window. In summary, we find the importance of option liquidity for the predictability of innovation grants announcement returns when options provide higher liquidity.

4.2. Results of regression analysis

In the previous sections, we provide preliminary evidence that volatility spreads have the power to predict innovation grants announcement returns. Moreover, the predictive power is stronger when informed traders can exploit their private information in the options market (e.g., the higher liquidity in option market) or uninformed traders are unlikely to trade against informed investors' private information (e.g., the lower information asymmetry is, the higher the liquidity is in the stock market).

This section reexamines the results of quintiles in a panel regression specified in Equation (1), including the various firm specific variables and past returns, and with t-statistics based on robust standard errors clustered by firm. The dependent variable is the two-day announcement returns for individual stocks. As shown in Table 4, the first regression reports the level of the volatility spread one day preceding the innovation grants announcement. The coefficient on the *CPIV* spread is significantly positive. In the second column, volatility spread is based on the $\Delta CPIV$. There is a significantly positive relation between volatility spread and announcement returns. The last column includes both the *CPIV* spread and the $\Delta CPIV$. The coefficients on both the level and the change of the volatility spread are significantly positive, indicating that the information captured by both volatility spread signals does matter and significantly impacts announcement returns.

<Table 6 is inserted about here>

We next go on to run the regression model with control variables to reexamine the role of liquidity in the options market and the stock market as well as information asymmetry on the relation between volatility spread and announcement return. From the previous findings in quintiles, we expect that the predictive power is stronger under the condition when the options market is more liquid, the level of information asymmetry is lower, and the stock is less liquid.

Table 7 presents the analysis results, where the t-statistics are based on robust standard errors clustered by firm. The first two columns report the condition of liquidity in the options market. The coefficient on the interaction term of low option liquidity dummy is found to be negatively significant at the 5% level for both the level and change in volatility spread. These results are consistent with the findings of the prior portfolio testing in Table 5. This highlights the importance of option liquidity for the predictive power of volatility spread on announcement return. The middle two columns report the condition of information asymmetry. We find that the coefficient on the interaction term of *CPIV* spread and low *Asy-index* dummy is positively significant at the 5% level for both the *CPIV* spread and the $\triangle$ *CPIV*.[12] In addition, the coefficients in the last two columns are statistically significant for the high stock liquidity interaction term when the interaction term is measured by the *CPIV* spread.[13] Those results are consistent with the findings of the prior portfolio testing in Table 5 in which lower information asymmetry mitigates the possibility that uninformed investors may trade against informed traders with private information (Wang, 1993, 1994).

<Table 7 is inserted about here>

5. Conclusions

The prior literature documents that the *CPIV* spread can predict future stock returns and conjectures that it is driven by the trading activities of informed traders. Recent studies have indicated that the *CPIV* spread's predictability should be more

[12] In these regressions, we also use PIN to robust our empirical results and find similar results when the *ASY-index* measure is used. We obtain an updated version of PIN from Stephen Brown's website to proxy for information asymmetry.

[13] Pastor and Stambaugh (2003) used the liquidity ratio to proxy for the liquidity of each stock. The results are similar when we use the Amihud illiquidity ratio.

pronounced during some financial announcement events, including earnings announcements and merger and acquisition (M&A) announcements. We extend the work of prior studies to examine how the *CPIV* spread predicts future stock returns when firms are granted patents - that is, innovation grants announcement returns.

The empirical results reported herein, which are based on stocks with options traded in the U.S. market, reveal that informed traders will choose to trade in the options market under the release a firm’s innovation grant announcement. We find that the difference in abnormal returns between the extreme volatility spread is significant during a two-day announcement window. We also find that the *CPIV* spread has stronger predictability for future stock returns when a stock’s options are more liquid.

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Figure 1

This figure reports the sum of aggregated total dollar volume for firms with/without innovation for each year across all optioned stocks. The sample period is from 1996 to 2006.

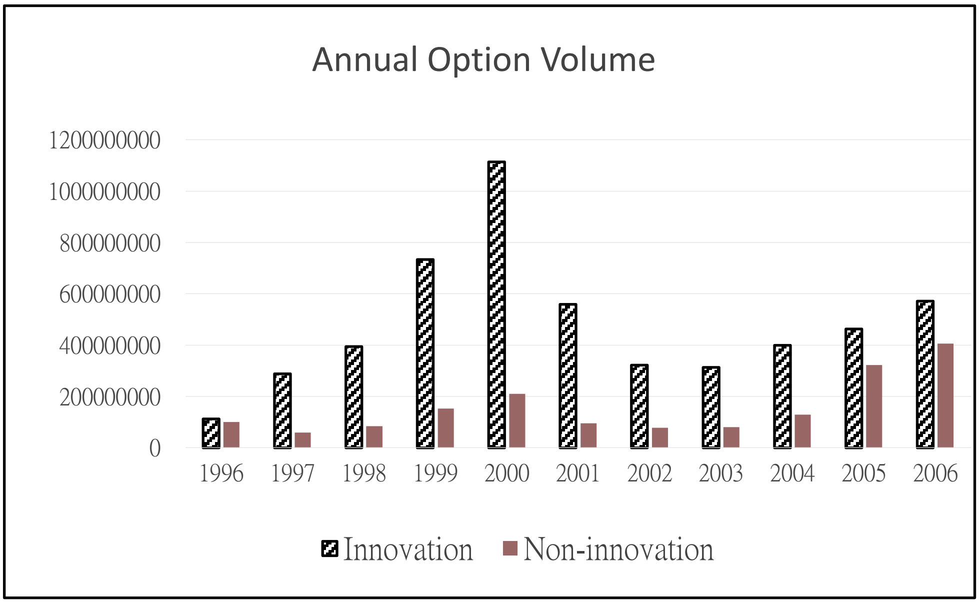

Table 1

This table reports the summary statistics on the characteristics of the call-put implied volatility spread. *CPIV* spread is based on the level of the volatility spreads one day before the innovation grants announcement dates, and △ *CPIV* is based on the change in volatility spreads during the pre-announcement week, while stock liquidity is measured by the Amihud Illiquidity, information asymmetry is created by *ASY-index*, and option liquidity is measured by option volume and option bid-ask spread. The full sample period is January 1996 to December 2006.

Variables	P10	P50	P90	Mean	S.D.
CPIV spread	-0.0535	-0.0066	0.0333	-0.0087	0.0529
△ *CPIV*	-0.0581	0.0000	0.0575	-0.0002	0.0656
Amihud Illiquidity	0.0066	0.0192	0.0699	0.0320	0.0400
ASY-index	12.0000	15.0000	18.0000	14.8628	2.3500
Option Volume	2.5000	43.8333	555.3750	237.0006	711.5352
Option Bid-Ask Spread	0.1088	0.2204	0.5131	0.2723	0.1767

Table 2
This table shows the summary statistics on the total number of innovation grants announcement events in each of the sample years from 1996 to 2006. Stock and options exist for all firms.

Year	No. of Events	No. of Firms
1996	4998	460
1997	6100	544
1998	7016	625
1999	7004	629
2000	6820	635
2001	7067	626
2002	6707	610
2003	7358	593
2004	7553	664
2005	6712	615
2006	6347	584
Total	73682	6585

Table 3

This table presents the results of the panel regressions on the effects of innovation grants announcements on the relationship between call-put implied volatility (*CPIV*) spread and future stock returns, where the dependent variable is the two-day [t, t+1] returns for stocks on each date t. *CPIV* spread is based on the level of the volatility spreads one day before the innovation grants announcement dates, and △ *CPIV* is based on the change in volatility spreads during the pre-announcement week. Eventdummy takes the value of 1 if the day is an innovation grants date; otherwise 0. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level. All t-statistics are adjusted following Newey and West (1987).

Intercept	0.0018	0.0014
	(52.91)***	(42.75)***
CPIV spread	0.0334	
	(50.89)***	
△ *CPIV*		0.0195
		(41.80)***
Eventdummy	0.0000	0.0000
	(-0.35)	(-0.08)
CPIV *Eventdummy	0.0162	
	(3.63)***	
△ *CPIV* *Eventdummy		0.0144
		(4.36)***
Adjust R squared	0.0023	0.0012

Table 4

Returns on quintiles formed based on volatility spread signals. This table presents innovation grants announcement returns for stocks and forms five groups based on various pre-announcement volatility spread signals. The announcement returns accrue from the opening of the innovation grants announcement day to the closing of the next day. Value-weighted returns and abnormal returns (ret) are reported for each volatility spread group. Abnormal returns are with respect to the market, size, book-to-market (Fama and French (1993)), momentum (Carhart (1997)), and skewness factors. *CPIV* spread is based on the level of the volatility spreads one day before the innovation grants announcement dates, and △ *CPIV* is based on the change in volatility spreads during the pre-announcement week. *CPIV* spread/△ *CPIV* results are defined with double-sorts based on both *CPIV* spread and △ *CPIV*. The last two columns represent the raw return and abnormal return differences between the extreme volatility spread groups and t-statistics associated with these differences. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level. All t-statistics are adjusted following Newey and West (1987).

		Volatility spread quintiles					(5–1)	
		1	2	3	4	5	Return	Abnormal ret
CPIV spread								
	Return	-0.0004	0.0006	0.0014	0.0028	0.0043	0.0047	0.0032
	Abnormal ret	-0.0009	-0.0007	-0.0004	0.0008	0.0023	(6.48)***	(4.31)***
△ *CPIV*								
	Return	0.0000	0.0030	0.0028	0.0020	0.0016	0.0016	0.0021
	Abnormal ret	-0.0014	0.0001	0.0000	0.0006	0.0007	(3.90)***	(3.90)***
		1,1	2,2	3,3	4,4	5,5		
CPIV spread /△ *CPIV*								
	Return	-0.0022	0.0054	0.0081	0.0183	0.0066	0.0088	0.0068
	Abnormal ret	-0.0033	-0.0009	-0.0003	0.0102	0.0035	(6.52)***	(4.96)***

Table 5

This table reports innovation grants announcement returns for each group. For each stock, all option pairs are sorted into three groups based on the average liquidity of the pair on the pre-announcement day. We then form five groups based on pre-announcement day volatility (*CPIV*) spread when the volatility spread is measured by highest or lowest option liquidity. Liquidity of an option pair is measured using either its average bid/ask spread (Panel A) or its average volume (Panel B). Similarly, all stocks are sorted into three groups based on the *ASY-index* (Amihud illiquidity) on the pre-announcement day and form five groups based on pre-announcement day volatility (*CPIV*) spread when the volatility spread is measured by highest or lowest *ASY-index* (Panel C)/(Amihud illiquidity) (Panel D). The announcement returns accrue from the opening of the innovation grants announcement day to the closing of the next day. Value-weighted returns and abnormal returns (ret) are reported for each volatility spread group. Abnormal returns are with respect to the market, size, book-to-market (Fama and French (1993)), momentum (Carhart (1997)), and skewness factors. The last two columns represent the raw return and abnormal return differences between the extreme volatility spread groups and t-statistics associated with these differences. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level. All t-statistics are adjusted following Newey and West (1987).

		Volatility spread quintiles					(5–1)	
		1	2	3	4	5	Return	Abnormal ret
Panel A: Bid/ask spread								
More liquid	Return	-0.0015	0.0032	0.0074	0.0109	0.0268	0.0283	0.0189
	Abnormal ret	-0.0055	-0.0010	0.0014	0.0012	0.0134	(6.12)***	(3.78)***
Less liquid	Return	0.0002	0.0026	0.0034	0.0032	0.0059	0.0056	-0.0011
	Abnormal ret	0.0032	0.0022	-0.0032	0.0027	0.0021	(1.69)*	(-0.32)
Panel B: Volume								
More liquid	Return	-0.0022	0.0010	0.0059	0.0089	0.0163	0.0184	0.0124
	Abnormal ret	-0.0033	-0.0030	0.0004	0.0029	0.0091	(5.14)***	(3.45)***
Less liquid	Return	0.0020	0.0063	0.0012	0.0116	0.0120	0.0100	0.0086
	Abnormal ret	0.0003	0.0017	-0.0051	0.0021	0.0089	(3.71)***	(3.05)***
Panel C: *ASY-index*								
Higher *ASY-index*	Return	-0.0051	0.0023	0.0049	0.0052	0.0166	0.0217	0.0178
	Abnormal ret	-0.0077	-0.0043	-0.0001	0.0013	0.0101	(3.24)***	(3.09)***
Lower *ASY-index*	Return	-0.0021	-0.0023	0.0097	0.0116	0.0347	0.0368	0.0356
	Abnormal ret	-0.0130	0.0026	0.0055	-0.0042	0.0225	(4.02)***	(3.29)***
Panel D: Amihud illiquidity								
More liquid	Return	-0.0023	0.0011	0.0033	0.0073	0.0181	0.0204	0.0142
	Abnormal ret	-0.0053	-0.0026	-0.0011	0.0020	0.0089	(4.87)***	(3.42)***
Less liquid	Return	-0.0018	0.0031	0.0047	0.0100	0.0098	0.0116	0.0107
	Abnormal ret	-0.0031	-0.0043	-0.0072	0.0029	0.0076	(5.84)***	(5.50)***

Table 6

This table reports the panel regression of the innovation grants announcement returns on various call-put implied volatility (*CPIV*) spread, where the dependent variable is the two-day announcement returns for stocks. In the first two columns, *CPIV* spread on the pre-announcement day and/or volatility spread changes (△ *CPIV*) during the pre-announcement week are included in the regression. In the last column, both *CPIV* spread and △ *CPIV* are included in the regression. The announcement returns accrue from the opening of the innovation grants announcement day to the closing of the next day. All control variables include firm size as measured by the market value of equity, book-to-market ratio, momentum (Jegadeesh and Titman, 1993), and skewness measured from daily returns over the prior year. The stock returns during the pre-announcement week (Return [-6,-1]) are also controlled for in each regression. The t-statistics are based on robust standard errors clustered by firm. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level.

	1	2	3
Intercept	0.0070	0.0062	0.0067
	(3.15)***	(2.77)***	(2.99)***
CPIV spread	0.0503		0.0326
	(4.14)***		(1.98)**
△ *CPIV*		0.0372	0.0209
		(4.49)***	(1.85)*
Return[-6,-1]	-0.0048	-0.0069	-0.0047
	(-0.46)	(-0.65)	(-0.44)
Control variables	Yes	Yes	Yes
Adjust R squared	0.0110	0.0105	0.0070

Table 7

This table shows the panel regressions results on the effects of options liquidity, information asymmetry, and stock liquidity on call-put implied volatility (*CPIV*) spread during innovation grants announcement returns. Announcement returns on various volatility spread signals or their interactions with quintile dummies are formed based on *ASY-index*/Amihud (2002) illiquidity ratio/option bid/ask spread. Stocks are sorted into quintiles each month based on their *ASY-index* values or stock liquidity or option bid/ask spread. Low *ASY-index* dummy (high *ASY-index* dummy) equals one for stocks with the lowest (highest) *ASY-index* values and zero otherwise. High stock liquidity dummy (low stock liquidity dummy) equals one for stocks with the lowest (highest) Amihud illiquidiy ratios and zero otherwise. High option liquidity dummy (low option liquidity dummy) equals one for stocks with the lowest (highest) option bid/ask spread and zero otherwise. Each column includes *CPIV* spread on the pre-announcement day or volatility spread changes (△ *CPIV*) during the pre-announcement week in the specification and the volatility spread signals are interacted with high *ASY-index*/Amihud/option bid/ask spread dummy and low *ASY-index*/ Amihud/option bid/ask spread dummy. The announcement returns accrue from the opening of the innovation grants announcement day to the closing of the next day. All control variables include firm size as measured by the market value of equity, book-to-market ratio, momentum (Jegadeesh and Titman, 1993), and skewness measured from daily returns over the prior year. The stock returns during the pre-announcement week (Return [-6,-1]) are also controlled for in each regression. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level. The t-statistics are based on robust standard errors clustered by firm.

	Option bid/ask spread		*ASY-index*		Amihuid	
Intercept	0.0069	0.0061	0.0068	0.0061	0.0069	0.0061
	(3.08)***	(2.75)***	(3.05)***	(2.76)***	(3.12)***	(2.77)***
CPIV spread	0.0614		0.0472		0.0478	
	(3.69)***		(2.79)***		(3.40)***	
△ *CPIV*		0.0455		0.0295		0.0477
		(4.05)***		(2.45)**		(3.92)***
High *ASY-index* interaction			-0.0079	0.0084		
			(-0.31)	(0.48)		
Low *ASY-index* interaction			0.0613	0.0507		
			(2.28)**	(2.50)**		
Low bid/ask spread interaction	0.0095	-0.0011				
	(0.32)	(-0.05)				
High bid/ask spread interaction	-0.0712	-0.0473				
	(-2.40)**	(-2.52)**				
Low Amihuid interaction					0.0431	0.0180
					(2.41)**	(0.85)
High Amihuid interaction					0.0005	-0.0226
					(0.04)	(-1.32)
Return [-6,-1]	-0.0027	-0.0059	-0.0046	-0.0066	-0.0051	-0.0067
	(-0.26)	(-0.55)	(-0.43)	(-0.62)	(-0.49)	(-0.62)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Adjust R squared	0.0127	0.0114	0.0116	0.0110	0.0111	0.0109