How Do Options Add Value? Evidence from the Convertible Bond Market

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Abstract

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1. Introduction

The options market has experienced a tremendous growth in the past four decades. An important and highly debated question about stock options is how such derivative assets add value to the financial market. In the frictionless world of Black and Scholes (1973) and Merton (1973), options are viewed as redundant because they can be perfectly replicated by the underlying assets and risk-free bonds. In the real world with all types of frictions, options could make markets more complete and reduce information asymmetries. As the theoretical literature suggests, options incentivize and facilitate informed trading by expanding hedging opportunities (Ross, 1976; Hakansson, 1982), providing lower transaction costs and higher leverage (Black, 1975; Back, 1993; Cao, 1999), and relaxing short-sale constraints (Diamond and Verrecchia, 1987; Figlewski and Webb, 1993). These theories spur an extensive empirical literature that studies the effects of options on information acquisition and price discovery.

But the empirical evidence thus far remains mixed and inconclusive. On the one hand, many studies examine the lead-lag relationship between stocks and options and find that options contain information about future stock prices, suggesting that the options market contributes to price discovery and is informationally more efficient (e.g., Easley, O'Hara, and Srinivas, 1998; Chakravarty, Gulen, and Mayhew, 2004; Pan and Poteshman, 2006). On the other hand, several recent papers cast doubt on this result by showing that informed traders initiate trade in the stock market (e.g., Chan, Chung, and Fong, 2002), price discovery in the options market is economically insignificant (Muravyev, Pearson, and Broussard, 2013), option listing increases uninformed trading (Hu, 2018), and the option price-based stock return predictability is mainly driven by stock price pressure rather than information (Goncalves-Pinto, Grundy, Hameed, van der Heijden, and Zhu, 2019). Moreover, even if informed traders do in fact prefer the options market, the overall

information environment does not necessarily improve if investors just migrate across markets but do not produce more information.

To shed more light on the added value of options, our paper examines the importance of listed options in the context of convertible bond issues. A convertible bond is a security whose holder has the right to convert the bond into a pre-specified number of equity shares of the underlying company. In other words, a convertible bond is essentially a straight bond combined with stock options. This "bond + options" payoff structure makes convertibles an interesting empirical setting to study the information role of options. This is because, besides default risk, investors effectively need the same information about the underlying company to price convertibles as they need to price options, such as volatility and upside potential. With or without the options market, the information needed to price convertibles should be already available in the stock and bond market. Investors do not need options to acquire information. Thus, if options do not provide additional information or facilitate information acquisition, the availability of listed options would not affect the valuations of convertible bonds.

To test this clear prediction in the data, we collect a sample of 1,357 convertible bond offerings issued by 815 unique U.S. public firms between 2000 and 2014. In 47% of the cases, the issuer does not have listed options available at the time of issuance. Consistent with prior studies such as Chan and Chen (2007), Mitchell, Pederson, and Pulvino (2007), and Henderson and Tookes (2012), convertibles in our sample are offered with a significant discount as the market price is in general lower than the theoretical value. However, the offering discount is significantly smaller for issues with listed options (13%) than for issues without (17%), which is an economically sizable reduction in underpricing of about 24%. This result is persistent throughout our sample period and cannot be explained by security design features such as callability and delta,

or other firm characteristics such as size, liquidity, and volatility. In addition, we find that the mitigating effect of options on convertible underpricing is more pronounced for issuers with worse information environment, suggesting that options indeed facilitate information acquisition and thereby reduce mispricing.

Of course, exchanges do not randomly select firms for option listing. In particular, firms that have lower information asymmetries or receive more investor attention are also the ones that are more likely to have listed options (Mayhew and Mihow, 2004). As such, our findings could be driven by other unobserved factors that influence both the availability of options and the pricing of the convertible bond at the same time. To examine this possibility, we exploit the Securities and Exchange Commission (SEC)'s individual stock option listing requirements. The SEC mandates a minimum of stock price requirement for the underlying company to be eligible for option listing. The closing price of the company's shares must have been at least $3.00 (or $7.50 until 2004) for a majority of trading days during the three calendar months preceding the date of selection (Hu, 2018). This ad hoc price cutoff creates a discontinuity in the likelihood of option listing. That is, firms with average stock prices just above the cutoff have a higher unconditional likelihood of being selected for option listing than firms just below the cutoff.

Using the distance between an issuer's average stock price and the cutoff price as the forcing variable, we employ a fuzzy regression discontinuity design (RDD) and restrict to the subsample of convertible issues just around the threshold to establish the causal effects of options on information efficiency. First, we show that the likelihood of option listing increases from about 22% to almost 50% as soon as the forcing variable passes the threshold and makes the issuer eligible for option listing. Next, we use this listing eligibility to instrument for the availability of options at the time of convertible issuance and estimate two-stage least squares (2SLS) regressions

controlling for the forcing variable and other firm characteristics. The 2SLS results confirm our main findings that the availability of listed options significantly reduces the offering discount of convertible bond issues.

After establishing the information role of options, we exploit the convertible bond market further to investigate whether options also add value through a capital supply channel. Provided that options allow more hedging opportunities and reduce information asymmetries, convertible bonds issued by firms with listed options may attract more investors and thus raise more capital. Collecting data on the convertible buyers, we find that the availability of listed options significantly increases the number of buyers (especially hedge fund buyers) by at least 15%, and also increases the bond issuance proceeds by at least 13%, after controlling for a variety of bond and firm characteristics. We also employ the fuzzy RDD to confirm that these effects are not driven by other confounding factors. Overall, these findings accord with the notion that options enable firms to attract more capital suppliers, showing an important real effect of the options market.

This paper contributes to several strands of literature. First, we provide causal evidence that options facilitate information acquisition, which accords with the information role predicted by a large theoretical literature going back to Black (1975), Grossman (1988), Back (1993), Huang and Wang (1997), Cao (1999), and Massa (2002). On the empirical side, existing evidence comes mostly from studies investigating whether the options market leads the stock market in price discovery (e.g., Hasbrouck, 1993; Chakravarty et al., 2004; Pan and Poteshman, 2006). Some recent papers examine whether options increase stock price informativeness (e.g., Hu, 2018; Cao, Goyal, Ke, and Zhan, 2019). We take a different approach by studying the option listing effect on the pricing of convertible bond issues, which circumvents the potential concerns with the lead-lag relationships between options and stocks (e.g., Muravyev et al., 2013; Goncalves-Pinto et al.,

2018). Our analysis also highlights the idea that the options market not only reflect information sooner but also improves the overall information environment for the underlying company.

Second, our paper provides novel evidence that options have real effects by facilitating corporate financing, contributing to the growing literature on the real effects of secondary financial markets (e.g., Bond, Edmans, and Goldstein, 2012). Previous studies provide ample evidence on the real effects of stock markets. For example, Brennan, Chordia, and Subrahmanyam (1998) and Datar, Naik, and Radcliffe (1998) find that higher stock trading activity reduces firms' costs of capital. Edmans, Goldstein, and Jiang (2012) shows that underpricing makes firms a more likely takeover target. Hau and Lai (2013) and Dessaint, Foucault, Fresard, and Matray (2019) find that mispricing distorts firms' investment decisions. In contrast, evidence on the options market is still very limited. Roll, Schwarts, and Subrahmanyam (2009) is an exception by showing that firms' investment sensitivity to stock prices increases with options trading. We show that listed options reduce information asymmetry and allow convertible bond investors to better hedge their positions, thereby attracting more capital suppliers.

Finally, our findings contribute to the convertible bond literature. In particular, we provide new results to the literature on the initial underpricing of convertible bonds. Prior work has shown that convertible bond underpricing is influenced by bond ratings (Chan and Chen, 2007), by liquidity frictions (Mitchell et al., 2007), by combined offerings with stock repurchases (De Jong, Dutordoir, and Verwijmeren, 20011), and with investment banks' relationships with investors (Henderson and Tookes, 2012). We find that listed options mitigate information asymmetries and thereby reduce offering discounts. Moreover, we add to the literature on the interplay between convertible issuers and their investors, especially the convertible arbitrage hedge funds. The existing literature has studied the impact of investor demand on issuance decisions and security

design choices (e.g., Loncarski, ter Horst, and Veld, 2009; Choi, Getmansky, Henderson, and Tookes, 2010; Brown, Grundy, Lewis, and Verwijmeren, 2012; Grundy and Verwijmeren, 2018). We find that options allow convertible arbitrageurs to better implement their hedging strategies and thereby allow firms to raise more capital through convertible bond issues.

The remainder of the paper is organized as follows. Section 2 describes the data and explains the constructions of the used variables. Section 3 presents our main results of how options add value in the context of convertible bonds. Section 4 addresses the endogeneity concerns by using the fuzzy RDD analyses. Section 5 concludes.

2. Data and summary statistics

2.1. Data

We collect convertible bond offerings issued by U.S. public firms between 2000 and 2014 from the SDC database and PlacementTracker. We obtain deal-specific information from the Mergent Fixed Income Securities Database, financial statements information from Compustat, and stock return and price data from CRSP. After excluding issues by financial firms and utilities, we further collect the buyer information from registration statements available from the SEC's Edgar database and PlacementTracker. We also search through Bloomberg, Lipper TASS and Hedge Fund Research databases to check whether the identified buyers are hedge funds. Our final sample includes 1,357 convertible offerings issued by 815 unique firms for which we have either data available to compute the initial mispricing or information about the buyers.

To find out whether the convertible bond issuers have listed stock options, we rely on the OptionMetrics database and classify a firm as having options if the firm has option trading data available in the OptionMetrics database during the month of the convertible issue date. Out of our

final sample, 713 issues (53%) are made by the issuers with available options, and 644 issues without. Figure 1 shows the number of convertible bond issues and the percentage of issues by the issuers with listed options for each year over our sample period. As is shown, the annual number of convertible issues peaked between 2003 and 2006 and remained relatively constant after the financial crisis. The percentage of offerings made by the issuers with options ranges from 30% in 2005 to 93% in 2013.

2.2. Main variables

We now explain the construction of the main variables. Following the literature on convertible underpricing , we use the offering discount to measure the underpricing of convertible bonds. The offering discount is the difference between the theoretical price and the offer price divided by the theoretical price:

$$Offering\ discount = \frac{Theoretical\ price - Offer\ price}{Theoretical\ price}.$$

To calculate the theoretical value of convertibles, we use the Tsiveriotis and Fernandes (1998) model, which has also been used by Ammann, Kind, and Wilde (2003), Chan and Chen (2007), Loncarski et al. (2009) , and De Jong et al. (2011), and which is known to be the most popular convertible bond valuation method among practitioners (Zabolotnyuk, Jones, and Veld, 2010). Our theoretical price calculations need the following inputs: i) risk-free interest rate; ii) stock price; iii) stock return volatility; iv) conversion ratio; v) issue, settlement, and maturity dates; vi) dividend yield; vii) coupon rate and coupon payment frequency; viii) call schedule; and ix) credit spread. Note that the first six variables are exactly the same inputs needed to price options.

The risk-free interest rate is collected from Datastream and is the yield on US Treasury bills with a maturity date closest to the maturity of the convertible bond. To avoid possible impacts of arbitrage-related short-selling activities, stock prices are measured five trading days prior to the issue date. The stock return volatility is defined as the annualized volatility estimated from daily stock returns over the period, -240 to -40 trading days, as in Lewis, Rogalski, and Seward (1999). As explained earlier, the deal-related information is obtained from Mergent. Credit spreads are based on credit ratings for corporate industrial bonds with a maturity closest to that of the convertible bond obtained from Mergent. We collect credit spreads from Datastream. Since convertible bonds are popular among small and unrated issuers, a part (32%) of our sample offerings does not have a rating at issuance. Following previous studies (e.g., Loncarski et al. (2009)), we assign a BBB rating to unrated bonds for the purpose of calculating credit spreads.[1] In total, there are 721 convertibles for which we have sufficient information to calculate the offering discount. To avoid outlier effects, we winsorize the offering discounts at the 1% and 99% levels.

In our multivariate regression analyses, we control for a rich set of deal and firm characteristics. For each issue, we measure the sensitivity of the convertible bond price to the stock price movements by calculating its Delta as follows

$$Delta = e^{-\delta T} N\left\{\frac{\ln\left(\frac{S}{X}\right)+\left(r-\delta+\left(\frac{\sigma^2}{2}\right)\right)T}{\sigma\sqrt{T}}\right\},$$

where δ is the continuously compounded dividend yield calculated as common/ordinary dividends divided by the market value of equity, *N(.)* is the cumulative density function of the standard normal distribution, *S* is the price of the underlying stock measured on trading day -5, *X* is the

[1] This will lead to the overestimation of theoretical prices if the credit worthiness of unrated convertibles is on average less than that of the ones with a BBB rating.

conversion price, r is the yield on a ten-year US Treasury bond obtained from Datastream, σ is the annualized stock return volatility, and T represents an estimate of the effective life of the convertible as of its issuance date. Following de Jong et al. (2011), we use the length of the call protection period as an estimate of the effective maturity for the callable convertibles in our sample, and use the stated maturity for non-callable convertibles. In addition, we measure the offering size by the ratio Proceeds/MVE, which is the amount of proceeds raised at the offering divided by the market value of equity at the fiscal year-end preceding the issue date. We include dummy variables indicating respectively whether the issuer combines the convertible offering with stock repurchases (de Jong et al., 2011), whether the convertible is callable (Grundy and Verwijmeren, 2018), whether the convertible is privately placed under Rule 114A, and whether the issuer has a credit rating.

Moreover, we control for various firm characteristics: firm size measured by the natural logarithm of total assets, growth opportunities measured by the market-to-book ratio, stock liquidity proxied by the Amihud (2002) illiquidity measure (Amihud$\times 10^6$), and firm risk measured by the stock return volatility. Total assets and market-to-book ratios are obtained from the end of the fiscal year prior to the issue date. Amihud$\times 10^6$ is calculated as the average daily ratio of absolute value of stock return to dollar trading volume in millions during the window [-120, -20], and volatility is defined as the daily stock return volatility calculated from stock returns over the window [-240, -40] relative to the convertible issue date.

2.3. Summary statistics

Table 1 reports the descriptive statistics of all variables used in the analyses. Consistent with prior studies, the average offering discount is 14.33% with the standard deviation of 19.36%,

and the market-adjusted cumulative abnormal returns (CARs) around the announcement date are on average negative (-3.8% of over [-1, 1] and -3.7% over [-2, 2]). The average number of hedge fund buyers is around 22 (natural log-transformed value of 2.56), and the average number of total institutional investors is around 41 (natural log-transformed value of 2.91).

Out of our sample, 709 offerings are made by the issuers with listed options. Regarding the deal characteristics, the average delta of convertibles is about 0.7, indicating that on average, convertible bond prices increase by $0.70 as stock prices increase by $1.00 at the time of issuance. On average, convertible issuers raise 29% of the market value of equity from the convertible issuance. About 10% of our sample offerings are combined offerings that involve simultaneous announcements of share repurchases and 61% of our sample offerings are Rule 144A private placement offerings. Out of 908 offerings with available information, 65% are callable bonds.

Regarding firm characteristics, the average log-transformed total assets value in $million is 6.23 (i.e. $507.76 million), the average market-to-book asset value is 3.54, the average volatility of daily stock returns is 4%, and the average Amihud illiquidity measure (daily absolute return over dollar trading volume in millions) is 0.31. In addition, 47% of our sample offerings are made by issuers listed in the NASDAQ exchange. Finally, the average number of financial analysts covering our issuing firms is 8.6.

2.4. Univariate tests

In Table 2, we report the summary statistics for the issuers with and without listed options. In the last column, *t*-statistics for the test of the difference in averages of two groups are presented. Comparing issues without options to those with listed options, the univariate tests suggest that offering discounts are significantly smaller (17% vs. 13%) and the numbers of hedge fund buyers

and total buyers are significantly larger (15.9 vs. 30.1) when the issuers have listed options available. The differences in announcement-period abnormal returns are not statistically different from zero although those for the issuers with listed options are more positive (-4.1% vs. -3.5% of CAR[-1, 1]).

Figure 2 shows the differences in offering discounts and the number of hedge fund buyers between the issuers with and without options over three subperiods: 2000-04, 2005-09, and 2010-14. As is shown, the significant differences observed in the full sample are also persistent over time and not driven by any specific period.

We also find that, for the issuers with listed options, the delta and proceeds to market capitalization ratio are significantly lower (0.72 vs. 0.68 and 0.41 vs. 0.18, respectively), while the fraction of Rule 144A offerings (0.49 vs. 0.72), the fraction of issuers with credit ratings (0.22 vs. 0.52), and the fraction of issuers with investment grade credit ratings (0.04 vs. 0.15) are significantly higher. However, we do not find a significant difference between the percentage of issues with call provisions among issuers without listed options and the percentage among issuers with listed options.

Regarding firm characteristics, the average total assets (natural log transformed values of $5.11 vs. $7.24) and the average number of financial analysts covering issuing firms (3.43 vs. 9.01) are significantly greater for the issuers with listed options while the average market-to-book asset ratio (4.63 vs. 2.62), the stock return volatility (0.05 vs. 0.04) and the Amihud illiquidity measure (0.62 vs. 0.06) are significantly lower/smaller for the issuers with listed options. Moreover, the fraction of offerings made by Nasdaq-listed firms is marginally lower for the issuers with listed options (0.49 vs. 0.44).

3. Empirical results

This section provides the main results of our paper, showing that the availability of options reduces convertible underpricing and attracts more capital suppliers.

3.1. Options and convertible underpricing

To formally test the effect of having options on the pricing of convertible bonds, we estimate the following regression with year fixed effects:

$$y_i = \alpha + \beta \times Option_i + \gamma_1' X_i^{deal} + \gamma_2' X_i^{firm} + Year\ FE_i + \varepsilon_i, \quad (1)$$

where $Option$ is a dummy variable indicating whether the issuer has listed options available at the time of issuance, and X^{deal} and X^{firm} are a vector of deal- and firm-level characteristics respectively. The year fixed effects capture common time trends that affect all convertible issues in a given year, such as the rise of convertible arbitrage hedge fuds (Grundy and Verwijmeren, 2018). The dependent variable is the offering discount of convertible bonds. Under the null hypothesis that options do not provide additional information, β would not be different from zero.

Table 3 reports the estimation results. We start with only including the year fixed effects in Column (1) and additionally include deal- and firm-level characteristics in Column (2) and (3) respectively. As is shown, the coefficient estimates of β range between -0.023 and -0.062 and are statistically significant in all columns with different sets of control variables, implying that options reduce offering discount by 2.3% to 6.2%. These estimates suggest that having options reduces convertible underpricing by 13.8% to 37.1% relative to the average issues without options, which is an economically sizable effect. The control variables all have expected signs. Consistent with previous studies on convertible bonds (e.g., Loncarski et al, 2009; de Jong et al., 2011), we find that the offering discount is smaller for issues with lower Delta (i.e., more debt-like), combined

with stock repurchases, with call provisions, with credit ratings, and issued by larger firms and by firms with higher growth opportunities and with more liquid stocks. Untabulated analysis indicates that, conditional on having options, the liquidity of options (measured by option trading volume) does not significantly affect convertible underpricing.

To further test whether options reduce convertible underpricing by providing information, we investigate how the effect of options on underpricing varies with the level of information asymmetry that the issuer faces. If options indeed reduce underpricing through the information channel, they would add more value when the issuer faces an otherwise poorer information environment. Therefore, we would expect a stronger effect for issuers with higher information asymmetry. Empirically, we measure information asymmetry as the number of analysts covering the issuer in the year prior to the issue date (analyst coverage), which is a widely used proxy for firms' information environment in the recent empirical finance literature (e.g., Kelly and Ljungqvist, 2012; Derrien and Kecskes, 2013). In Column (4) and (5) of Table 3, we interact the $Option$ dummy variable with analyst coverage while controlling for other deal and firm characteristics. More analyst coverage indeed reduces information asymmetry and thereby mitigates underpricing. The coefficient estimates on $Option$ alone remain significantly negative and become much larger in magnitude than those in Column (1)-(3), while the interaction term between $Option$ and analyst coverage is significantly positive, which implies that the mitigating effect of options on underpricing is smaller for firms with better information environment (i.e., more analyst coverage). For firms without any analyst coverage, having options reduces underpricing by 5.1% to 6.4%. This beneficial effect decreases as the number of analysts increases and is close to zero with more than ten analysts, which is in line with the notion that listed options reduce convertible underpricing by facilitating information acquisition.

Moreover, if options improve the issuer's information environment and thereby reduce convertible underpricing, we expect the stock market to react more positively to the announcements of convertible offerings by firms with listed options. To study the market reaction, we calculate the cumulative abnormal stock returns (CARs) around the convertible bond announcement date, using the market model estimated over trading days [-200, -30]. Table 4 presents the results of estimating Equation (1) for CARs measured over two windows, [-1, +1] and [-2, +2], respectively. Even though the average convertible bond issue experiences a negative announcement return (-3.8%), which is similar to prior studies, we find that having options significantly increases the announcement returns by up to 2.9%, after controlling for other deal and firm characteristics. As expected, the market reacts more positively to the convertible issues made by the firms with listed options, indicating that the stock market also values the benefit of options to convertible issues.

3.2. Options and capital supply for convertible bonds

Do options also benefit convertible bond issues by attracting more capital suppliers? We start by investigating whether more institutional investors participate in convertible offerings issued by firms with listed options than by firms without options. While the univariate test in Table 2 suggests that issues with options indeed attract twice as many buyers as those without options (56 vs. 28), we again estimate Equation (1) to formally test this effect of options after controlling for other factors that could also affect the demand for convertibles, such as callability, credit rating, and firm size. Table 5 reports the estimation results. In columns (1)-(3), the dependent variable is the natural log-transformed total number of institutional investors who purchased the convertible bond. The significantly positive coefficient estimates of $Option$ variable range between 0.147 and

0.857, implying that issues with options attract at least 14.7% more capital suppliers than those without options do, after controlling for the rich set of deal and firm characteristics.

When the total number of buyers increases, firms would be able to raise more capital. In columns (4)-(6), we use the natural log-transformed offering proceeds as the dependent variable. Again, the coefficient estimates of $Option$ variable are significantly positive, suggesting that convertible issues with listed options can indeed raise more capital than issues without. After controlling for deal and firm characteristics, the coefficient of $Option$ is estimated to be 0.131, implying that listed options allow convertible issuers to raise 13.1% more proceeds, which can be used to finance firm growth and investments.

Why do convertible bond issues with listed options attract more investors? Our hypothesis is that options attract capital suppliers by reducing information asymmetry and allowing more hedging opportunities. We have already established the information role of options in the previous subsection. We now investigate whether the hedging opportunities provided by options also play a role. Specifically, we test whether the availability of options attracts more hedge funds to participate in the convertible offering.

Following Brown et al. (2012), we identify hedge fund buyers among the institutional investors participated in each convertible bond issue. As shown in prior work (e.g., Grundy and Verwijmeren, 2018), hedge funds dominate the convertible bond market in the past 15 years. In contrast to other types of investors, hedge funds care less about the firms' fundamentals or information environment as long as they can hedge their positions to implement arbitrage strategies. A typical convertible arbitrage strategy combines a long position in the convertible with a short position in the underlying stock, and options are well known for relaxing short-sale constraints. In addition, Calamos (2003), a practitioner text, also documents that convertible arbitrageurs utilize

listed options to create interesting hedge profiles that are not available with the traditional long convertible and short stock hedge. Thus, the hedging opportunities provided by options are particularly attractive to hedge funds,

As shown in Table 2, on average, there are about 31 hedge funds involved when the issuers have options outstanding while there are only about 16 hedge funds when the issuers do not have listed options. To control for various deal and firm characteristics that could also affect hedge fund involvement, we estimate Equation (1) with the dependent variable being the natural logarithm of the number of hedge fund buyers. The coefficient estimates of $Option$ are again significantly positive. The estimate from the most tight specification implies that about 11.8% more hedge funds participate in the convertible offering when the issuer has options outstanding. Control variables have the expected signs. In columns (4)-(6), we replace the $Option$ dummy variable with two variables capturing the liquidity of option markets, Put and Call volume, measured over the 30 trading days around the announcement date [-15, +15]. As is shown, only the coefficient estimates of "Put volume" are significantly positive, consistent with the notion that hedge funds use more puts options to implement convertible arbitrage strategies.

Taken together, our findings provide strong evidence that listed options enable firms to raise more capital through convertible bond issues by reducing information asymmetry and allowing investors (especially arbitrageurs) to better hedge their positions. This financing channel shows an important real effect of the options market.

4. Identification: a Fuzzy Regression Discontinuity Design (RDD)

Our baseline results suggest that options significantly affect the pricing and financing of convertible bonds. These effects are unlikely subject to reverse-causality, because it is hard to

conceive that convertible issues with less underpricing or more buyers lead firms to have listed options. Nevertheless, exchanges do not randomly select firms for option listing. In particular, firms that have lower information asymmetries or receive more investor attention are also the ones that are more likely to have listed options (Mayhew and Mihow, 2004). As such, our findings could be driven by other unobserved factors that influence both the availability of options and the pricing of the convertible bond at the same time.

To address this endogeneity concern, we exploit the SEC's individual stock option listing requirements. Among others, the SEC mandates a minimum of stock price requirement for the underlying company to be eligible for option listing. The closing price of the company's shares must have been at least $3.00 (or $7.50 until 2004) for a majority of trading days during the three calendar months preceding the date of selection (Hu, 2018). This ad hoc price cutoff creates a discontinuity in the likelihood of option listing. That is, firms with average stock prices just above the cutoff have a higher unconditional likelihood of being selected for option listing than firms just below the cutoff.

Using the distance between an issuer's average stock price and the cutoff price as the forcing variable, we employ a regression discontinuity design (RDD) and restrict to the subsample of convertible issues just around the threshold to estimate the causal effects of options. Specifically, we define the forcing variable, *Price distance*, for each issuing firm i in issuing year t, as follows

$$Price\ distance_{i,t} = \begin{cases} prc_{i,t} - 7.5, & if\ t \leq 2004 \\ prc_{i,t} - 3, & if\ t > 2004 \end{cases} \tag{2}$$

where $prc_{i,t}$ is the average stock price of firm i over the first three months in year t. Crossing the price threshold makes a firm eligible to have listed options, so our treatment assignment variable is

$$Eligible = \mathbf{1}(Price\ distance > 0). \quad (3)$$

However, because exchanges could have some other considerations and incentives when selecting stocks for option listing, which are unobservable to us as the econometrician, the $Eligible$ firms are only more likely but not guaranteed to have options, and the non-$Eligible$ firms could also be selected for option listing. Given the potential misassignment of treatment, we choose to implement a fuzzy RDD instead of a sharp RDD.

Specifically, we estimate a two-stage least squares (2SLS) regression model with the following first-stage specification:

$$Option_i = \gamma_0 + \gamma_1 \times Eligible_i + \gamma_2 \times Price\ distance_i + \gamma' X_i + Year\ FE_i + u_i. \quad (4)$$

We then use the predicted value $\widehat{Option}$ to test for the effect of options on convertible pricing and financing in the following second-stage specification:

$$y_i = \beta_0 + \beta_1 \times \widehat{Option}_i + \beta_2 \times Price\ distance_i + \beta' X_i + Year\ FE_i + \varepsilon_i, \quad (5)$$

where *y* is either offering discounts or natural log-transformed numbers of hedge fund buyers, and β_1 provides the 2SLS estimate of the added value of options. We follow Imbens and Kalyanaraman (2012) to derive the asymptotically optimal bandwidth under a squared-error loss. The choices of the bandwidth are determined by the data structure and therefore different across outcome variables. To check the sensitivity of our results, we also use an alternative and narrower bandwidth of [-2, 2] for each outcome variable.

First, we illustrate the presence of a discontinuity in the probability of having options by plotting the percentage of convertible bond issues with listed options against the forcing variable price distance in Figure 3. Comparing the two sides of the threshold, we can clearly observe a jump in the likelihood of having options. The likelihood increases from around 22% to around 50% as

soon as the forcing variable passes the threshold and makes the convertible issuer eligible for option listing.

Next, we formally estimate the first-stage relationship between the eligibility for option listing and the availability of options at the time of convertible issuance. The results are reported in Table 7. Consistent with the graphic pattern, we find that the listing eligibility significantly increases the likelihood of having options. Convertible bond issuers who are eligible are about 24.3% to 30.1% more likely to have listed options available than those who are not eligible. The coefficient estimates of $Eligbile$ are stronger and statistically more significant when we control for other firm characteristics or narrow the estimation bandwidth. Moreover, The F-statistics from the first-stage range from 15.96 to 32.87, suggesting that the listing eligibility is unlikely a weak instrument.

Provided the strong results from the first-stage, we proceed to use the listing eligibility to instrument for the availability of options and examine the causal effects of options on convertible pricing and financing. We again start with a graphical analysis by plotting the outcome variables of interest (offering discount and hedge fund involvement) against the forcing variable of pricing distance in Figure 4. The average offering discount (hedge fund involvement) is clearly lower (higher) above the price cutoff.

Table 8 reports the second-stage estimation results. The dependent variable is the offering discount in Panel A and the natural log-transformed number of hedge fund buyers in Panel B. As is shown, the predicted availability of listed options has a significantly negative effect on the offering discount and a significantly positive effect on the number of hedge fund buyers, which is consistent with our baseline results. The estimation results are again robust to including additional control variables and to a narrower estimation bandwidth.

The 2SLS estimation results of the fuzzy RDD confirm our main findings that the availability of listed options significantly reduces underpricing and attracts more capital suppliers for convertible bond issues. These 2SLS results

5. Conclusion

In this paper we use convertible bond issues as a setting to investigate the importance of stock options in the financial market. Our objective is to shed light on two questions: First, do options facilitate information acquisition and improve the overall information environment for the underlying company? Second, what are real effects of the derivative markets? These questions are examined in the context of convertible bonds.

We show that the availability of listed options significantly reduces convertible bond underpricing, especially for issuers with worse information environment. We also find that listed options attract more capital suppliers to buy the bonds at the time of issuance, especially convertible arbitrageurs who can use options to hedge their positions. These results are persistent over time, robust to a rich set of observable bond- and firm-level controls, and cannot be contaminated by omitted variable bias. Overall, our findings are consistent with the idea that options add value to the financial market by facilitating information acquisition and corporate financing, highlighting the value relevance of the options market.

Providing that options complete markets and reduces information asymmetries, an interesting area for future research is to explore other potential real effects of the derivative markets. While many studies have looked at the effects of stock market on corporate decisions, there is little evidence from the options market. For example, do managers learn differently from options trading activities than from stock prices? Do capital providers act differently to signals from the options

market? On the other hand, one can also interpret our findings as showing that convertible bond investors use stock options as a cross-market reference asset when pricing the bonds and making purchasing decisions. It is interesting to see whether such a cross-market reference relationship extends to other securities and other asset markets.

Appendix

Definitions of Variables[2]

The following describe how each variable is measured.

Variables	Definitions
Dependent variables	
Offering discounts (in%)	Offering discounts in percentage are measured as the difference between theoretical and offer prices over theoretical prices, and are winsorized at the 1st and 99th percentiles. Theoretical prices are calculated using the method of Tsiveriotis and Fernandes (1998), a binomial approach. Inputs used in the model are described in details in Subsection 3.2.
CAR [-1, 1] in (5) (or CAR[-2, 2] in (%))	Cumulative abnormal stock returns (CARs) in percentage during the window [-1, 1] (or [-2, 2]) around a convertible debt announcement date. Daily abnormal returns are calculated based on the market model parameters estimated over the window [-200, -30] relative to the announcement date using the CRSP equally-weighted index as a market portfolio proxy.
Hedge fund buyers	Number of hedge funds buyers who are identified as hedge funds from the full list of hedge fund managers in Bloomberg, Lipper TASS and Hedge Fund Research (HFR) databases. Log(Hedge fund buyers) is the natural log of the number of hedge funds buyers.
Total buyers	Number of buyers identified from registration statements available at the SEC's Edgar database as in Grundy, Lewis, and Vermijweren (2012). Log(Total buyers) is the natural log of the number of all buyers.
Main explanatory variables	
Option	A dummy variable to indicate that stock options are available for trading. It is set to be one if the option trading data are available for the issuer in OptionMetrics in the month of the convertible issue date.
Call volume	Natural logarithm of the average daily trading volumes of call options over [-15, +15] around the announcement date
Put volume	Natural logarithm of the average daily trading volumes of put options over [-15, +15] around the announcement date

[2] The italicized names in parentheses are Compustat variable names.

Deal characteristics	
Delta	A measure of the sensitivity of convertible bond price to the stock price movement. The exact definition is described in Subsection 3.2.
Proceeds/MV	Amount of capital raised at a convertible bond offering over the market capitalization (*casho* × *prcc_f*) at the end of fiscal year prior to the announcement of a convertible bond offering.
Combined offering	A dummy variable to indicate combined offerings with a concurrent buyback announcement (or an intention to use the proceeds to buy back shares) within the window of eleven days around the convertible bond announcement date
Rule 144A	A dummy variable to indicate a Rule 144A private placement.
Callable	A dummy variable to indicate callable bonds.
Rated	A dummy variable to indicate offerings with an available S&P credit rating
Investment grade	A dummy variable to indicate offerings with an investment grade credit rating (an S&P credit rating of BBB - or higher)
Firm Characteristics	
Log(Assets)	Natural log of total assets of a firm (*at*) at the fiscal year end prior to the announcement of convertible bond issuance.
Market-to-book	Market-to-book asset ratio that is defined as total assets (*at*) plus market value of equity (*casho* × *prcc_f*) minus book value of equity (*ceq*) divided by total assets (*at*) as of the fiscal year end prior to a convertible announcement date.
Volatility	Volatility is defined as the daily stock return volatility calculated using stock returns over the window [-240, -40] relative to a convertible bond offering announcement date.
Amihud×10^6	An illiquidity measure based on Amihud (2002) times 1,000,000. It is calculated as the average absolute value of daily stock returns over trading volume in millions during the window [-120, -20] relative to a convertible bond offering announcement date.
NASDAQ	A dummy variable to indicate the issuers listed in the Nasdaq
Analyst coverage	Number of financial analysts covering the offering firm, which is collected from the IBES database.

Fuzzy RDD related variables	
Price distance	Difference between the average three-month stock price at the beginning of the calendar year of an offering announcement and the minimum stock price of $3.0 ($7.5 until2004) required by the SEC for option listing as specified in equation (1).
Eligible	A dummy variable to indicate that "Price distance" of the offering firm is positive and therefore, the offering firm is likely to be eligible for listing of options written on its stock.

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Table 1
Summary statistics

This table presents summary statistics of variables used in the paper. We describe how we estimate each variable in Appendix. The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014.

	N	Mean	Std. Dev.	Min.	p25	Median	p75	Max.
Dependent variables								
Offering discount (in%)	721	14.33	19.36	-49.85	4.03	13.86	27.10	63.24
CAR [-1, +1] (in %)	1,338	-3.77	8.62	-30.91	-8.51	-3.29	0.75	22.96
CAR [-2, +2] (in %)	1,338	-3.67	9.88	-30.37	-9.19	-3.40	1.54	24.08
Hedge fund buyers	1,014	22.15	19.94	0	4	20	34	138
Log(Hedge fund buyers)	1,014	2.56	1.28	0.00	1.61	3.04	3.56	4.93
Total buyers	1,081	40.56	45.17	1	3	29	64	320
Log(Total buyers)	1,081	2.91	1.48	0.69	1.39	3.40	4.17	5.77
Main explanatory variables								
Option	1,357	0.53	0.50	0	0	1	1	1
Put volume	709	5.27	2.56	0.00	3.46	5.40	7.05	11.79
Call volume	709	6.06	2.31	0.00	4.50	6.04	7.67	11.93
Deal characteristics								
Delta	754	0.69	0.17	0.00	0.61	0.72	0.80	1.00
Proceeds/MV	1,344	0.29	3.15	0.00	0.08	0.15	0.25	115.32
Combined offering	1,357	0.10	0.31	0	0	0	0	1
Rule 144A	1,357	0.61	0.49	0	0	1	1	1
Callable	908	0.65	0.48	0	0	1	1	1
Rated	1,357	0.38	0.48	0	0	0	1	1
Rated×Investment grade	1,357	0.10	0.30	0	0	0	0	1
Firm characteristics								
Log(Assets)	1,357	6.23	2.04	-1.78	5.03	6.39	7.62	12.50
Market to book	1,348	3.56	16.78	0.52	1.31	1.82	2.95	502.11
Volatility	1,314	0.04	0.03	0.01	0.02	0.04	0.05	0.53
Amihud×10^6	1,276	0.31	2.64	0.00	0.02	0.04	0.13	88.65
NASDAQ	1,351	0.46	0.50	0	0	0	1	1
Analyst coverage	1,357	6.36	6.86	0	0	5	9	38

Table 2
Differences between issues with and without option listings

This table presents summary statistics for issues with and without listed individual stock options written on offering firms' stocks. We describe how we estimate each variable in Appendix. The last column reports *t*-statistics for the test of the difference between issues with and without listed options. The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	No option			With options			Difference
	N	Mean	SD	N	Mean	SD	*t*-stat
Dependent variables							
Offering discount	215	0.17	0.19	506	0.13	0.20	2.13**
CAR [-1, +1] (in %)	625	-4.12	0.94	713	-3.46	0.79	-1.40
CAR [-2, +2] (in %)	625	-3.99	1.08	713	-3.38	0.90	-1.14
Hedge fund buyers	586	15.93	16.89	428	30.67	20.65	-12.48***
Total buyers	599	28.10	34.04	482	56.06	52.02	-10.63***
Log(Hedge fund buyers)	586	2.17	1.28	428	3.10	1.07	-12.18***
Log(Total buyers)	599	2.54	1.41	482	3.37	1.45	-9.55***
Deal characteristics							
Delta	217	0.72	0.17	537	0.68	0.17	2.36**
Proceeds/MV	634	0.41	4.58	710	0.18	0.21	1.33***
Combined offering	644	0.06	0.23	713	0.15	0.35	-5.38***
Rule 144A	644	0.49	0.50	713	0.72	0.45	-8.81***
Callable	308	0.69	0.46	600	0.64	0.48	1.55
Rated	644	0.22	0.41	713	0.52	0.50	-12.17***
Rated× Investment grade	644	0.04	0.20	713	0.15	0.35	-6.76***
Firm characteristics							
Log(Assets)	644	5.11	2.00	713	7.24	1.46	-22.48***
Market to book	635	4.63	23.95	713	2.62	4.44	2.20**
Volatility	605	0.05	0.03	709	0.04	0.02	7.85***
Amihud×10^6	565	0.62	3.94	711	0.06	0.34	3.78***
NASDAQ	642	0.49	0.50	709	0.44	0.50	1.92*
Analyst coverage	644	3.43	4.65	713	9.01	7.44	-16.37***

Table 3
Option listing and offering discount

Table reports the results of regression analyses of convertible bond offering discounts on various factors including the indicator for issuers with available options (Option) and its interactive variable with the number of financial analysts covering the offering firms (Option × Analyst coverage). The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014. The definitions of variables are available in Appendix. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	Offering discount				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Option	**-0.062*** **	**-0.032** **	**-0.023* **	**-0.064*** **	**-0.051** **
	(-3.799)	**(-2.472)**	**(-1.742)**	**(-3.389)**	**(-2.547)**
Option × Analyst coverage				**0.005** **	**0.004** **
				(2.570)	**(2.002)**
Delta		0.607***	0.575***	0.612***	0.584***
		(13.391)	(10.821)	(13.678)	(10.997)
Proceeds/MV		0.035	0.002	0.016	-0.006
		(1.228)	(0.110)	(0.712)	(-0.272)
Combined offering		-0.051***	-0.043***	-0.047***	-0.042***
		(-3.327)	(-2.747)	(-3.129)	(-2.742)
Rule 144A		-0.027*	-0.017	-0.023	-0.017
		(-1.783)	(-1.196)	(-1.601)	(-1.186)
Callable		-0.030**	-0.033***	-0.030**	-0.033***
		(-2.503)	(-2.770)	(-2.536)	(-2.769)
Rated		-0.054***	-0.042***	-0.049***	-0.043***
		(-4.693)	(-3.067)	(-4.138)	(-3.159)
Rated×Investment grade		-0.009	0.006	0.003	0.010
		(-0.446)	(0.311)	(0.147)	(0.480)
Log(Assets)			-0.014**		-0.010*
			(-2.401)		(-1.669)
Market to book			-0.008***		-0.007**
			(-2.829)		(-2.525)
Volatility			0.777		0.669
			(1.303)		(1.110)
Amihud×10^6			0.081*		0.061
			(1.670)		(1.357)
NASDAQ			-0.024**		-0.017
			(-2.220)		(-1.466)
Analyst coverage				-0.007***	-0.005**
				(-3.709)	(-2.539)
Constant	0.186***	-0.180***	-0.073	-0.140***	-0.069
	(14.889)	(-4.737)	(-1.184)	(-3.587)	(-1.105)
Observations	721	656	645	656	645
R-squared	0.152	0.509	0.526	0.522	0.532
Year FE	Yes	Yes	Yes	Yes	Yes

Table 4
Regression analysis of announcement-period returns

Table reports the results of regression analyses of convertible bond offering announcement returns on various factors including the indicator for issuers with available options (Option). The announcement-period returns are measured by the cumulative abnormal returns (CAR) measured around the announcement date of a convertible bond offering. We describe the details on how we estimate announcement-period CAR as well as other variables in Appendix. The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	CAR [-1, +1]			CAR [-2, +2]		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Option	**0.009***	**0.025*****	**0.023*****	**0.009***	**0.029*****	**0.027*****
	(1.857)	**(3.804)**	**(3.509)**	**(1.649)**	**(3.884)**	**(3.551)**
Delta		-0.068***	-0.055**		-0.075***	-0.068***
		(-3.471)	(-2.580)		(-3.456)	(-2.796)
Proceeds/MV		-0.003	0.001		-0.020	-0.019
		(-0.222)	(0.057)		(-1.365)	(-1.178)
Combined offering		0.041***	0.041***		0.048***	0.048***
		(4.891)	(4.863)		(4.953)	(4.873)
Rule 144A		0.001	0.001		0.001	0.003
		(0.082)	(0.111)		(0.122)	(0.314)
Callable		0.004	0.003		0.008	0.007
		(0.482)	(0.450)		(1.003)	(0.870)
Rated		0.013*	0.009		0.017**	0.017*
		(1.960)	(1.281)		(2.268)	(1.922)
Rated×Investment grade		0.011	0.006		0.003	-0.000
		(1.554)	(0.752)		(0.375)	(-0.026)
Log(Assets)			0.004			0.003
			(1.602)			(0.970)
Market to book			0.002			0.001
			(1.458)			(0.528)
Volatility			-0.108			-0.039
			(-0.380)			(-0.110)
Amihud×10^6			0.032			0.048**
			(1.318)			(2.036)
NASDAQ			-0.008			-0.005
			(-1.335)			(-0.727)
Constant	-0.043***	-0.035**	-0.070***	-0.042***	-0.036*	-0.064**
	(-10.896)	(-2.023)	(-2.672)	(-9.381)	(-1.937)	(-2.093)
Observations	1,338	696	685	1,338	696	685
R-squared	0.027	0.140	0.143	0.030	0.140	0.144
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 5

Regression analysis of institutional investor participation

Table reports the results of regression analyses of the number of institutional investors who participated in convertible bond offerings on various factors including the indicator for issuers with available options (Option) , and put and call option volumes (Put volume and Call volume). Natural log-transformed numbers of institutional investors who purchased bonds are used as values of the dependent variable. The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014. The definitions of variables are available in Appendix. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log(Total buyers)			Log(Proceeds)		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Option	**0.857*** **	**0.268*** **	**0.147* **	**1.612*** **	**0.354*** **	**0.131*** **
	(11.595)	**(2.968)**	**(1.679)**	**(20.777)**	**(5.456)**	**(2.882)**
Delta		0.040	0.270		-0.292*	0.213
		(0.090)	(0.528)		(-1.737)	(1.537)
Proceeds/MV		-0.190	-0.185			
		(-1.550)	(-1.160)			
Combined offering		0.111	0.152		0.273***	0.141**
		(0.874)	(1.162)		(3.235)	(2.406)
Rule 144		0.476*	0.264		0.071	0.049
		(1.740)	(0.911)		(0.906)	(0.919)
Callable		-0.130	-0.174		-0.040	-0.068
		(-1.175)	(-1.570)		(-0.646)	(-1.446)
Rated		0.208**	-0.008		0.562***	0.055
		(2.332)	(-0.074)		(9.426)	(1.089)
Rated*Investment grade		0.072	-0.108		0.530***	0.103*
		(0.501)	(-0.752)		(7.010)	(1.775)
Log(Assets)			0.150***			0.427***
			(3.390)			(18.744)
Market to book			-0.002			0.103***
			(-0.063)			(5.716)
Volatility			-0.699			-4.253**
			(-0.188)			(-2.423)
Amihud*10^6			-0.539**			-0.924***
			(-2.584)			(-2.599)
NASDAQ			-0.089			0.181***
			(-1.021)			(4.244)
Constant	2.531***	2.778***	2.136***	3.742***	4.861***	1.878***
	(49.545)	(6.389)	(3.785)	(57.647)	(28.576)	(8.128)
Observations	1,081	449	444	1,357	697	685
R-squared	0.395	0.610	0.629	0.329	0.350	0.671
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 6
Regression analysis of hedge fund participation

Table reports the results of regression analyses of the natural log-transformed number of hedge fund buyers in convertible bond offerings on various factors including the indicator for issuers with available options (Option), and put and call option volumes (Put volume and Call volume). Natural log-transformed numbers of hedge fund buyers are used as values of the dependent variable. The sample covers US convertible bond issues with available deal and firm characteristic from various sources during the sample period, 2000-2014. The definitions of variables are available in Appendix. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	Log(Hedge fund buyers)					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Option	**0.830*** **	**0.224*** **	**0.118* **			
	(12.385)	**(2.980)**	**(1.718)**			
Put volume				**0.082** **	**0.063** **	**0.060** **
				(2.340)	**(2.164)**	**(2.040)**
Call volume				**0.004**	**0.033**	**-0.004**
				(0.111)	**(1.047)**	**(-0.123)**
Delta		0.048	0.293		0.020	0.195
		(0.172)	(1.034)		(0.056)	(0.519)
Proceeds/MV		-0.077	0.310		-0.206	0.159
		(-0.350)	(1.196)		(-0.598)	(0.430)
Combined offering		0.126	0.135*		0.194*	0.218**
		(1.588)	(1.715)		(1.805)	(1.975)
Rule 144		0.931**	0.747*		0.712	0.844
		(2.580)	(1.665)		(0.813)	(0.938)
Callable		-0.162**	-0.136*		-0.075	-0.072
		(-1.986)	(-1.787)		(-0.669)	(-0.647)
Rated		0.216***	0.054		0.242***	0.131
		(2.806)	(0.638)		(2.707)	(1.360)
Rated×Investment grade		0.157*	-0.038		-0.029	-0.174
		(1.785)	(-0.407)		(-0.289)	(-1.599)
Log(Assets)			0.186***			0.163***
			(5.003)			(3.270)
Market to book			0.038*			0.053*
			(1.912)			(1.897)
Volatility			-1.936			2.492
			(-0.616)			(0.730)
Amihud×10^6			-0.437**			-0.321
			(-2.002)			(-0.403)
NASDAQ			0.064			-0.075
			(0.981)			(-0.996)
Constant	2.212***	2.145***	0.928*	2.678***	2.024**	0.685
	(46.261)	(5.518)	(1.773)	(24.271)	(2.522)	(0.735)
Observations	1,014	390	385	425	239	237
R-squared	0.344	0.367	0.427	0.465	0.556	0.582
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 7
The first stage results of fuzzy Regression Discontinuity Design (RDD) analysis

Table report the results of the first stage RDD analysis of option listings. We use the optimal bandwidth following Imbens and Kalyanaraman (2012) in column (1) and (2), and use an alternative bandwidth of [-2, +2] in column (3) and (4). The forcing variable, Price distance, is defined as the difference between the average stock price over the first three months of the calendar year of convertible bond issuance and the minimum stock price for option listings required by the SEC ($7.5 until 2004 and $3 from 2005). Issuers with positive price distances are expected to be eligible for option listing and issuers with negative price distances are expected to be ineligible for option listing. The first stage results of the fuzzy RDD is based on the regression of the option listing indicator on the treatment variable (Eligible = 1 for positive Price distances and 0 otherwise) and other control variables. The definitions of variables are available in Appendix. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	Option			
	Optimal bandwidth		Bandwidth [-2, +2]	
VARIABLES	(1)	(2)	(3)	(4)
Eligible	**0.243****	**0.301*****	**0.336*****	**0.394*****
	(2.358)	**(2.860)**	**(2.908)**	**(3.201)**
Price distance	-0.001	-0.051	-0.054	-0.105**
	(-0.033)	(-1.414)	(-1.145)	(-2.018)
Log(Assets)		0.118***		0.123***
		(7.509)		(6.978)
Market to book		0.016***		0.019**
		(2.670)		(2.588)
Volatility		0.130		0.053
		(0.171)		(0.066)
Amihud×10^6		-0.000		-0.002
		(-0.011)		(-0.101)
NASDAQ		-0.037		-0.026
		(-0.668)		(-0.406)
Constant	-0.121	-0.781***	-0.178	-0.967***
	(-1.506)	(-5.176)	(-1.550)	(-6.583)
Observations	295	255	230	203
R-squared	0.275	0.426	0.275	0.442
Year FE	Yes	Yes	Yes	Yes
F-stat	30.17	32.87	15.96	24.60

Table 8
The results of fuzzy Regression Discontinuity Design (RDD) analysis

Table report the results of the fuzzy RDD analyses of offering discounts (Panel A) and hedge fund participations (Panel B). We use the optimal bandwidth following Imbens and Kalyanaraman (2012) in column (1) and (2), and use an alternative bandwidth of [-2, +2] in column (3) and (4). The forcing variable, Price distance, is defined as the difference between the average stock price over the first three months of the calendar year of convertible bond issuance and the minimum stock price for option listing required by the SEC ($7.5 prior to 2005 and $3 since 2005). Issuers with positive price distances are expected to be eligible for option listing and issuers with negative price distances are expected to be ineligible for option listing. In the first stage, the option listing indicator is regressed on the treatment variable (Eligible = 1 for positive price distances and 0 otherwise) and other control variables. In the second stage, offering discounts and natural log-transformed numbers of hedge fund buyers are regressed on the predicted value of option listing indicator, along with price distance and other control variables. The definitions of variables are available in Appendix. *T*-statistics calculated using White heteroscedasticity-consistent standard errors are reported in parentheses. *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

	Optimal bandwidth		Bandwidth [-2, +2]	
VARIABLES	(1)	(2)	(3)	(4)
Panel A: Offering discount				
Option	**-0.434***	**-0.407****	**-0.482***	**-0.466****
	(-1.655)	**(-2.206)**	**(-1.661)**	**(-2.202)**
Price distance	0.003	0.015	0.015	0.024
	(0.127)	(0.633)	(0.403)	(0.714)
Log(Assets)		0.004		0.006
		(0.198)		(0.259)
Market to book		-0.022		-0.000
		(-0.507)		(-0.003)
Volatility		2.516		3.347**
		(1.604)		(1.963)
Amihud×10^6		-0.104		-0.250
		(-0.370)		(-0.737)
NASDAQ		-0.057		-0.023
		(-0.805)		(-0.333)
Constant	0.741***	0.672***	0.659***	0.630**
	(2.820)	(3.011)	(4.247)	(2.507)
Observations	79	78	68	67
R-squared	0.015	0.102	0.077	0.145
Year FE	Yes	Yes	Yes	Yes
Panel B: Log(Hedge fund buyers)				
Option	**1.671***	**1.577***	**1.288**	**1.231***
	(1.657)	**(1.729)**	**(1.588)**	**(1.712)**
Price distance	-0.021	-0.017	0.027	0.019
	(-0.279)	(-0.269)	(0.370)	(0.284)
Log(Assets)		0.001		0.045
		(0.008)		(0.398)
Market to book		-0.036*		-0.036

		(-1.858)		(-1.633)
Volatility		-0.066		0.457
		(-0.022)		(0.164)
Amihud*10^6		-0.061		-0.038
		(-1.244)		(-0.767)
NASDAQ		0.000		0.058
		(0.003)		(0.353)
Constant	-0.500	-0.100	-0.283	-0.130
	(-0.791)	(-0.226)	(-0.585)	(-0.339)
Observations	254	214	202	175
R-squared	0.360	0.363	0.407	0.426
Year FE	Yes	Yes	Yes	Yes

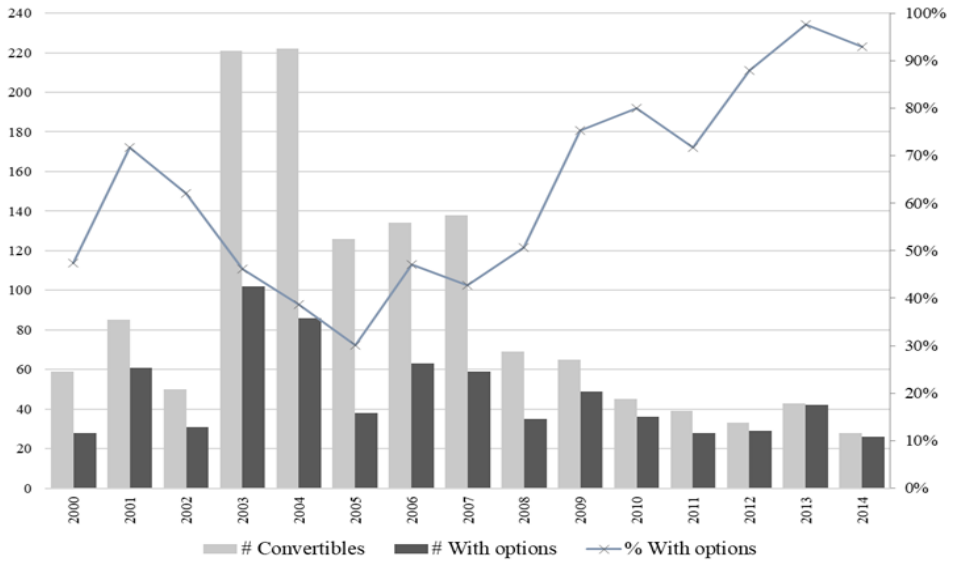

Figure 1. Number of convertible bond issues, and number and percentage of issuers with options. The sample covers US convertible bond issues with available deal and firm characteristics from various sources during the sample period, 2000-2014. The bars (left scale) show the numbers of convertible bond issues (lighter bars) and issuers with listed options written on the offering firms' stocks (darker bars) in each year, and the line shows the percentage of issuers with listed options (right scale) in each year.

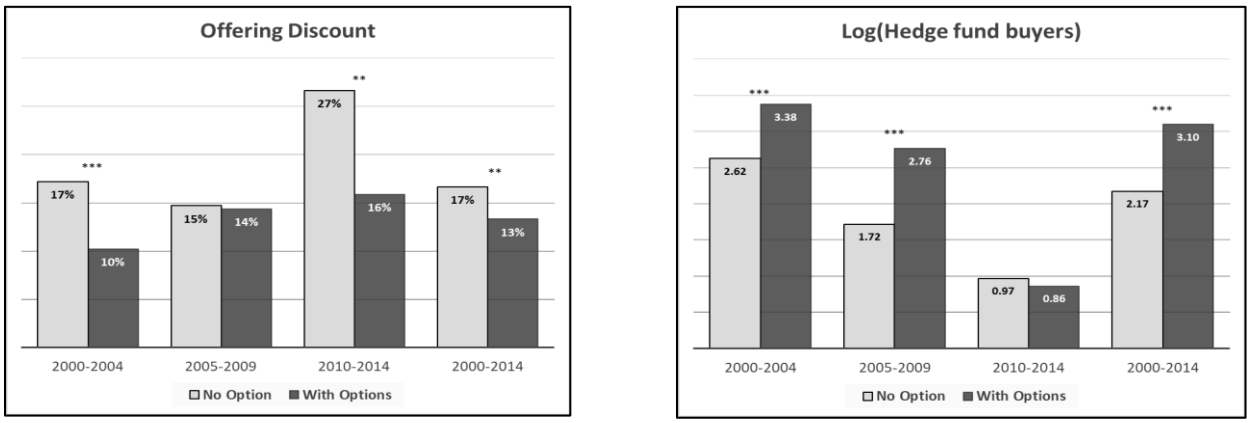

Figure 2. Differences between issues with and without listed options. The sample covers US convertible bond issues with available deal and firm characteristics from various sources during the sample period, 2000-2014. The bars show the average offering discount (left) and the average natural log-transformed number of hedge fund buyers per issue (right) in three subperiods as well as total sample period. *, **, and *** indicate that the difference between the averages of issues with and without listed options is statistically significantly different from zero at the 10%, 5%, and 1% levels, respectively.

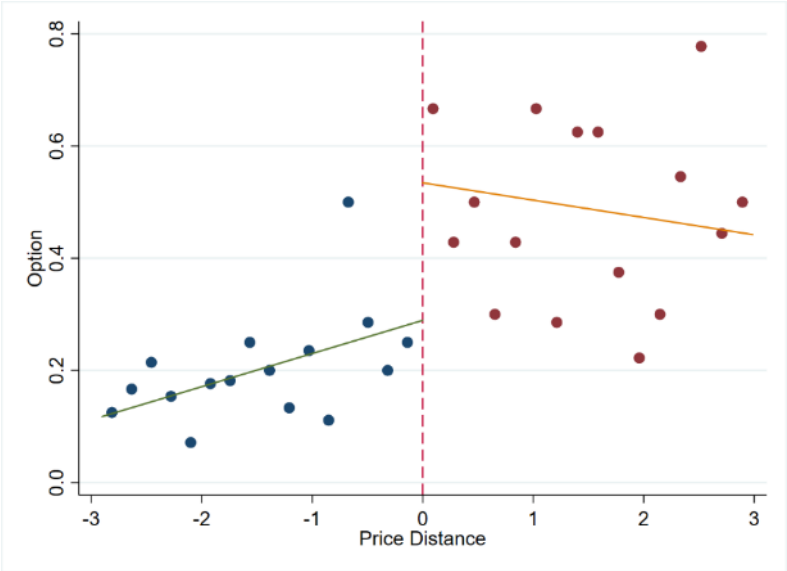

Figure 3. Percentage of convertible bond issues with options around the price cutoff point. The graph plots the percentage of convertible bond issues with listed options (y-axis) against the forcing variable, price distance (x-axis), with the corresponding slopes.. The price distance is the difference between the average stock price of the convertible issuer during the first three months of the calendar year of issuance and the minimum stock price ($7.5 until 2004 and $3.5 since 2005) for option listings required by the SEC. Issuers to the right of zero are expected to be eligible for option listings and issuers to the left of zero are expected to be ineligible for option listings.

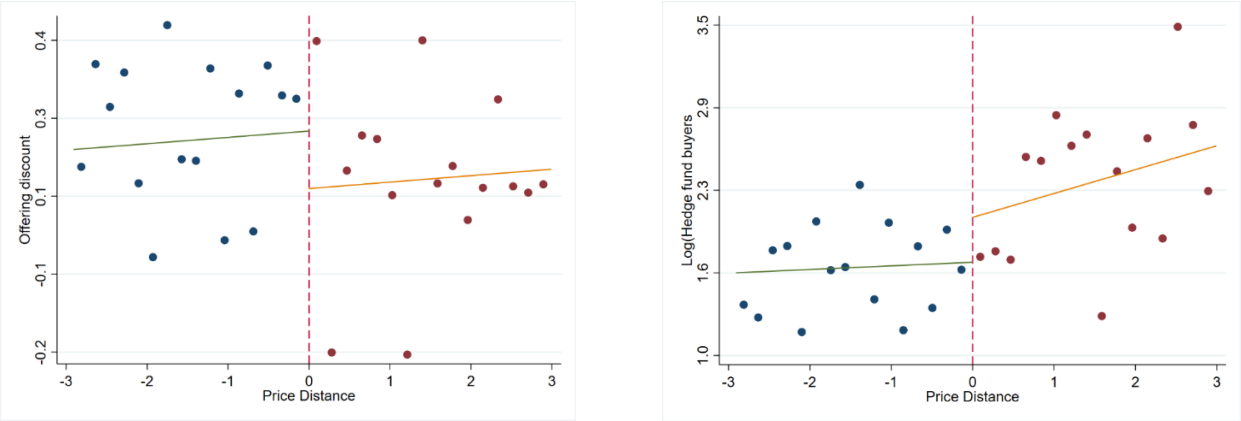

Figure 4. Offering discount and the number of hedge fund buyers around the price cutoff point. The x-axis plots the distance of average stock price during the first three months of the calendar year of issuance from the minimum stock price ($7.5 until 2004 and $3.5 since 2005) for option listings required by the SEC. Issuers to the right of zero are expected to be eligible for option listings and issuers to the left of zero are expected to be ineligible for option listings. The y-axis shows the average offering discounts (left), and the average natural log-transformed number of hedge fund buyers (right) within each price distance bin.