Options Embedded in Convertible Bonds versus Exchange Traded Options: Do their Implied Volatilities Differ?

Mr. Supawut Sinthawat

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ออปชั่นที่แฝงอยู่ในพันธบัตรแปลงสภาพ กับ ออปชั่นที่ขายอยู่ในตลาด : ความผันผวนโดยนัยของออปชั่นทั้งสองแบบแตกต่างกันหรือไม่

นายสุภาวุฒิ สินธวัชต์

จุฬาลงกรณ์มหาวิทยาลัย
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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการเงิน ภาควิชาการธนาคารและการเงิน
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สุภวุฒิ สินธวัชต์ : ออปชั่นที่แฝงอยู่ในพันธบัตรแปลงสภาพ กับ ออปชั่นที่ขายอยู่ในตลาด : ความผันผวนโดยนัยของออปชั่นทั้งสองแบบแตกต่างกันหรือไม่ (Options Embedded in Convertible Bonds versus Exchange Traded Options: Do their Implied Volatilities Differ?) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อ. ดร. นราพงศ์ ศรีวิศาล, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: อ. ดร. ธนวิต แซ่ซือ, 56 หน้า.

พันธบัตรแปลงสภาพมีความเป็นพันธบัตรธรรมดาและความเป็นออปชั่นอยู่ในตัว ในปัจจุบันมูลค่าของพันธบัตรแปลงสภาพเกิดจากการรวมมูลค่าของคุณสมบัติทั้งสองเข้าด้วยกัน โดยส่วนของมุลค่าของออปชั่นนั้นจะถูกประเมินราคาโดยสมการของแบล็ก-โชลส์-เมอร์ตัน โดยให้ความผันผวนของหุ้นที่เกี่ยวข้องเป็นระดับเดียวกันกับความผันผวนที่ใช้ในการคำนวนราคาออปชั่นที่แลกเปลี่ยนในตลาด อย่างไรก็ตามวิทยานิพนธ์เล่มนี้ต้องการที่ชี้ประเด็นให้เห็นว่าความผันผวนของทั้งสองอย่างนั้นอาจจะแตกต่างกันได้ในโลกแห่งความเป็นจริง เหตุผลคือมุมมองของผู้มีส่วนเกี่ยวข้องในบริษัทและนักลุงทุนในตลาดที่มีต่อตัวบริษัทนั้นอาจความแตกต่างกัน วิทยานิพนธ์เล่มนี้สรุปได้ว่าในประเทศสหรัฐอเมริกา ความผันผวนของออปชั่นที่แฝงอยู่ในพันธบัตรแปลงสภาพมีค่าที่ต่ำกว่าความผันผวนของออปชั่นที่แลกเปลี่ยนในตลาดอย่างมีนัยสำคัญ และแม้ว่าจะความคุมปัจจัยต่างๆ อาทิเช่น การเติบโตของบริษัท ขนาดของบริษัท อายุของพันธบัตรแปลงสภาพ โอกาสที่จะผิดสัญญาของพันธบัตรแปลงสภาพ อัตรากู้หนี้ของบริษัท อัตราของคูปอง และสภาพทางการเงินของบริษัทแล้วก็ตาม ก็ยังมีส่วนของความแตกต่างซึ่งเกิดขึ้นอย่างไม่สามารถอธิบายได้และมีนัยสำคัญ ทำให้เห็นว่านักลงทุนสถาบันอาจมีความสามารถในการเก็บเกี่ยวผลประโยชน์จากความไม่เท่าเทียมนี้

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A convertible bond consists of a straight bond and an underlying stock option. Conventionally, its value is measured by adding up the values of these two components. The option value is calculated using the Black-Scholes-Merton model with an assumption that stock volatility is of the same level as the one used to price the exchange traded option. However, this paper aims to ascertain that the volatility between the two models could in fact be different since the perceptions of firm agents and market participants toward the option differ. The paper concludes that in the United States, the volatility of embedded options is significantly lower than the volatility of Exchange Traded Options. Additionally, using growth perspective, size, maturity, default probability, cost of debt, coupon rates, and financial health as control variables, abnormal volatilities are observed with statistical significance. This observation shows that institutional investors could seize arbitrage profits from this imparity.

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จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

CONTENTS

Page

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Introduction

Generally, financial instruments which are subject to the same risk and will have the same value in the future should have the same price today. Option is one of the best examples here, since a put option can be synthesized by going long (buy) a call option of the same stock, long (lend) a risk-free, and short (sell) an underlying asset. This implies that investors can obtain the same product with a different approach. The Arbitrage Theory has an important role here. If there are two products subjects to the same risk have different prices, investors can buy the ones with a lower price and sell the one with a higher price to obtain a riskless arbitrage profit. In the option case, a call option and a put option of the same underlying asset must have price parity to prevent arbitrage because a synthetic put option can be created by a call option, and vice versa.

Regardless, Convertible bond is a bond that can be converted to a certain amount of stocks before the maturity. It is a financial instrument that consists of a straight bond and a call option. A convertible bond is another product that can be used to synthesize a call option of the same underlying stock. Under the perfect market assumption, a synthetic call is created by going long (buy) a convertible bond and short (borrow) at risk-free rate. The straight bonds in a short and long position will offset each other leaving the embedded call option as the remainder. This paper will investigate the call option parity and determine whether it is possible to gain arbitrage profit from the embedded call option.

To proceed the call options parity confirmation, implied volatilities need to be extracted from both the exchange-traded option and the convertible bond embedded option. In the Black-Scholes-Merton option pricing model, factors such as stock volatility, underlying stock price, exercise price, time to maturity, cash dividend, and market risk-free rate cause the option price to differ from each other. Beside volatility, these factors will be controlled. The main reason why the stock volatility is chosen for this comparison is due to its important economic implications: the stock volatility reflects aggregate investors' perception toward the firm. In this case, the implied volatility of

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CHULALONGKORN UNIVERSITY

the exchange traded option is believed to be a representative of all market participants' perception toward the firm, while the embedded option's volatility is believed to be the perception of the firm itself, the underwriter, and institutional investors.

This research is essential since there is question whether the exchange traded option and embedded option have a price parity or not. Many people believe that the embedded option could have a higher implied volatility since the degree of aversion in risk of the debt investor is higher than the equity investor. Thus, the embedded option could serve as the convenient yield. On the other hand, some people believe that the IPO convertible bond would behave similarly to the stock because the option value will fluctuate along with the stock price. Therefore, it should be underpriced to attract investors to participate in IPO process. Therefore, this research could confirm which side of believe the data would support.

Literature Review

Black and Scholes (1972) came up with the equation which allow investors to approximate the value of an option. They assumed some conditions: the variance of the common stock return and the short-term interest rate is unchanged and known, there is a protection from distributions which affect the underlying asset price, the return on a common stock is a lognormal distribution. However, a lognormal distribution assumption is responsible for the volatility smile which is the problem about the different perception of investor toward the same asset. A different strike price yields a different implied volatility which implies that a lognormal distribution is not realistic. Regardless, the Black Scholes Merton model is the only tool which can easily price an option. This price will be fair for both long party and short party.

Nevertheless, a warrant is a call option which is issued by the firm itself. It will cause the earning per share to be diluted on the option redemption. Therefore, this effect should be incorporated in when we price a warrant. Galai and Schneller (1978) introduced the solution for this problem. They suggested that we should adjust the

Black Scholes Merton option price with the portion of an existing number of common shares by the total number of common shares. The total number of common shares is the number of common shares which we expect to see if the warrant is converted in to the common shares. This ascertain that the firm will not be able to gain benefit from issuing too large amount of warrant.

Now that we have a background for an option and a warrant, there is another security called convertible bond. Convertible bond is a hybrid security which is both debt and equity security. It usually yields lower coupons but gives the option for investors to convert to common stock. There are two methods which are commonly used to find the value of the convertible bond. One is the simple method which add the value of debt and equity together. The value of debt can be calculated by discounting coupons and principal back using the fair market rate for the respective market rate of the company. For the value of equity can be obtained by 2 ways which are the as a residual which is the expected value of the equity given that the option is exercised or a Black Scholes Merton option-pricing model. The other method relies on probability, since the convertible bond has some chance of still being a bond and some chance of being converted to common stocks. The method finds the expectation of both events is taken by multiply to value of each case with its probability of occurring(Arak et al. 2005). The process here would be the same as the other one but we multiply the probability of occurring to both straight bond fraction and embedded option fraction to determine the expected value of the convertible bond.

The risk-shifting hypothesis and the backdoor-equity hypothesis explain the firm decision for the convertible bond issuance. Lewis, et al. (1999) proved that the convertible bond can be perceived as an asset substitution or asymmetric information. Some firms issue a convertible bond as a straight debt to reduce the cost of agency conflict while others issue a convertible bond as a warrant or a common share to avoid the cost of adverse selection (Lewis et al. 1999). Thus, it is possible to assume a convertible bond to be either debt substitution or equity substitution.

It is quite common practice to assume that the premium of option embedded in a convertible bond can be calculated using the stock volatility. Therefore, we can see that this concern a convertible bond to be an equity substitution by fixing the value of the equity part. The question is can we safely assume that the option embedded in a convertible bond contain the same volatility with the one in the exchange traded option. This paper would like to try another approach by assume a convertible bond to be a debt substitution. The value of the debt part will be fixed and the remaining will be compared with the exchange traded option using their implied volatilities.

This paper is the first paper which checks the price parity of the embedded option and the exchange traded option. We also determine the factors which impact the difference in price using the implied volatilities as a proxy.

Assumptions

In order to begin the research, there are 4 main assumptions which will create the environment to ensure that our research is in the right direction.

Assumption 1: American option price in each period is insignificantly different from European option price.

In theory, there should be no difference in premiums for call options under the assumption that the underlying stock pays no dividends. The idea is that early exercise makes you pay exercise price upfront which, by the time value of money, is more expensive than paying at the maturity date. This means you always choose to delay your exercise even when the call option is in the money.

Since the options we focus on is call option, this assumption lead to the application of the Black Scholes Merton option pricing model with the American option. The rational investors will gather the profit from time value of American option. Therefore, they will wait until maturity which will cause the American option premium to be indifferent with that of the European option.

This assumption is important since the option embedded in the convertible bond can be called any period. The embedded option is considered to be an American Option. The assumption will allow us to extract out the implied volatility of the option embedded in the convertible bond. Furthermore, we also observe the American style more than European style in the United States exchange traded option. The implied volatility of this option also needs this assumption to ensure that the implied volatility will be comparable.

In case the bias exists in using Black-Scholes-Merton for American options, we claim that the result is unaffected by this bias. The direction of bias is often predictable. The implied volatilities, both in the embedded option and the exchange traded option, will be higher than they should be because the American option are slightly more expensive than the European option. The bias will cause the option premium to be slightly higher while the other input variable in Black Scholes Merton remain the same. Therefore, the volatility is the only variable that can absorb the effect of the higher premium. This implies that we will observe a slightly higher than it should be. Regardless, the regressand in this research is the difference in volatilities. The same direction of the bias is expected to cancel each other out.

Assumption 2: The credit rating of a bond is derived from the credit rating of the underlying firm.

This assumption lead to the application of the firm's credit default swap rate. In practice, the firm and its security may not always have the same credit rating due to many factors. A debt with highly liquid and valuable collaterals tends to have good rating which is possibly better than the firm itself. However, securities with such collaterals are uncommon and the difference in the ratings is usually not significant.

Under the assumption that the credit ratings of bond and the issuing firm are the same, the credit default swap rate will be used to proxy the bond's credit spread. The portfolio which contains the debt security and its credit default swap will have risk offset. As a result, this portfolio will be a riskless investment which means the rate of return should be the same with the market risk-free rate. In return, the credit default swap rate and the risk-free rate allow us to proxy the expected rate of return on bond. The value of the straight bond can then be derived from its expected rate of return.

Assumption 3: There is no correlation between the bond default risk and credit default swap default risk.

This assumption ascertains that creditor and the firm itself will not be the same firm or even if it is the same, they will not default at the same time. With absence of this assumption, the portfolio consisting of the convertible bond and its credit default swap will not consider to be a risk-free investment. Therefore, we cannot say that the require rate of return will be the same with the market risk-free rate.

The no correlation between the bond default risk and the credit swap default risk is enforced in the method of selecting data. Convertible bond data from various industries are selected so that the data is not concentrated on banking and financial sector where the majority of credit default swap issuers are from. Although, this method may not guarantee zero possibility, it ensures that the possibility of default risks from the same firm is low.

Assumption 4: The change in fair value of the convertible bond overtime is relatively small.

Theoretically, the bond price will change overtime due to interest rate risk. This fact also effects the convertible bond as well since the straight bond component is sensitive to the risk of interest rate change. However, the price of the stock made up for the lost. If the convertible bond is in the money, investors will perceive the convertible more like the stock option. Therefore, the fair value of the straight bond part would not change much overtime.

This assumption is important since the value of the convertible bond would change overtime. Since the strike price of the embedded option depend on the fair value of the convertible bond, it will make the strike price of the embedded option to fluctuate overtime as well. However, we concerned about the IPO convertible bond. With this assumption, we can use the value at the IPO date which is the issuance price of the convertible bond to proxy for the strike price of the embedded option.

We provide this assumption just for the sake of simplicity. Without this assumption, we have to use the more complicate variation of the Black-Scholes-Merton option pricing model which can price the option that have fluctuation of the strike price to find the value of the embedded option.

Hypotheses

1. The volatility of the exchange traded option is higher than the volatility of the embedded option.

Two different implied volatilities will be extracted, one from the exchange traded option and the other from the embedded option in the convertible bond. The volatility of the exchange traded option should be relatively higher due to three following reasons.

First, an initial public offering stock will face a dilutive effect, which will potentially pull down the price (Dawson 1987). The increased amount of the outstanding share cause by the new issuance stock will make the profit of the firm spread out to more investors or we can say it dilutes the earning per share. The option has a similar nature with the equity since the equity can be viewed as the option for the firm's asset. Moreover, the option will potentially be converted to the common stocks if the firm stock price rises. Therefore, the dilutive effect, which is caused by the option issuance, should exist as well. On one hand, the dilution effect will ensure that the firm will not issue too many stock options as it will depreciate the firm's stock price. On the other hand, the dilution effect will cause the stock price to drop which will make the value of the embedded option to be lower as well. The lower premium of the embedded option which has all identical other variable will have lower volatility.

The dilutive effect will immediately affect only the embedded option because the exchange traded option is not issued by the firm. As such, no actual new issuance of stock is involved in the exchange traded option will not suffer from the dilutive effect in short run. In an attempt to extract this dilutive effect from the result, the Galai-Schneller option pricing method is applied to the embedded option. However, the adjustment from the Galai- Schneller is only partial and the embedded option's volatility could still differ from the exchange traded option. The embedded option's volatility is expected to be lower relative to the exchange traded option even after the adjustment.

Second, the overvalued seasonal equity offering explains that the firms usually issue equity when they believe the stock price is overvalued(Cline et al. 2010). This implies that the firm will issue an embedded option when the stock price is higher than they expected. They can issue an option with premium that is calculated from a slightly lower stock price to attract investors. According to, the Black-Scholes-Merton option pricing model, the lower premium for the call option should be expected since the option premium directly proportionate to the stock price. The price is unobservable but it is not because the firm uses it for their option issuance. The firm's perspective on stock price is considered an insider information and is simply not publicly available. As a result, the volatility, an input in the Black-Scholes-Merton option pricing model, is a parameter that absorbs this deviation. The volatility of the embedded option should be lower than the volatility of the exchange traded option.

Third, the underwriter prices an initial public offering security with unobservable true market value. Rational investors will utilize their information by avoiding overpriced securities and collecting underpriced securities. Consequently, initial public offering securities would be slightly underpriced on average (Gondat-Larralde et al. 2008).

In this research, we focus on the initial public offering convertible bond. It is very likely that the convertible bond will be underpriced as well because rational investors will extract profits from their information. They will avoid overpriced convertible bond combines with the underwriter procedure which they ask the initial public offering participant for the price they are willing to pay. This will make the price of the initial public offering drop down to match with the demand for the security. Therefore, the volatility for the embedded option in the convertible bond is lower than the volatility of the exchange traded option.

The above reasons support the idea that the premium of an option embedded in a convertible bond is relatively underpriced at issuance. As a result, the volatility of the exchange traded option is higher than the volatility of an embedded option.

2. Higher Price to Book ratio contributes to higher volatility of the core option compared with the volatility of the embedded option in a convertible bond.

Price to Book ratio is a reliable growth proxy, this fact has been supported by a considerable number of models including the three-factor model (Fama et al. 1995) and the Simultaneously Growth Estimation model(Easton et al. 2002). We will follow these models and use Price to Book ratio as a growth proxy.

In general, Price to Book ratio captures the perception of the investors on aggregate towards the firm’s growth relative to the perception of the firm itself. The higher price-to-book ratio implies that the market has a high expectation on the stock in the future. On the other hand, the firm knows its true potential which means the firm will be indifferent about whether Price to Book ratio is high or low. In other words, Price to Book has no effect on the volatility of the embedded option. Consequently, the difference between the volatility of the core option and the volatility of the embedded option will be greater in firms with high Price to Book ratio since the market expectation is high while the firm expectation remains constant. In particular, the larger Price to Book ratio, the larger difference in volatilities.

3. Longer maturity of the embedded option will cause the difference in volatilities to be greater.

According to the Liquidity Preference Theory, the interest rate yield curve is upward sloping because the longer maturity bond has caused an investor to be less liquid with his asset. The reason is investors are averse to interest rate risk. They believe that a long-term investment is riskier than a short-term one. Therefore, they tend to require more interest rate for the longer-term investment to compensate for the increased level of risk.

This concept can also be applied to option because long-term debts issued by the firm will be subject to liquidity issue. Generally speaking, firms have limitation on the dilution of the embedded option they can issue. The securities and exchange commission allow the firm to issue securities with dilutive effect such as preferred stock, stock option (warrant), and convertible bond for only certain amount. This will make firm reluctant to issue the longer maturity option. As the result, they will charge more for the obligation they must face or we can view it as the liquidity risk because it disables the firm ability to issue convertible securities. Furthermore, the higher level of risk is better for an option since the option has limited down side risk but the unlimited upside gain. Therefore, the higher level of risk also means the volatility is higher which will make the option more valuable.

Unlike Hypothesis 2 which looks at the embedded option from a supply-side point of view and assumes the firm knows about its true growth, Hypothesis 3 investigates volatility from the demand side. In the demand-side viewpoint, the price-to-book ratio can influence the volatility of the embedded option. Since the higher price-to-book ratio show the tendency of the growth, in long run the IPO investor would value this direction of growth option along with its maturity. The maturity of the convertible bond, which is the representative of risk of the embedded option, is used to interact with the Price to

Book ratio to measure the volatility movement. This movement will affect the volatility of the embedded option directly while cause the volatility of the exchange traded option to deviate in the lower magnitude.

To recap, the magnitude of the embedded option's volatility will be higher while the exchange traded option's volatility remains the same. As a consequence, the difference between the exchange traded option's volatility and the embedded option's volatility will be lower as the interactive term grows.

4. The larger the size of the firm the smaller the difference in volatilities.

To confirm that this test will be in line with Fama-French 3 factors model which is used for pricing the asset, we will use the factors in Fama-French to check their impact on the difference in volatilities as well. Since the option is also one type of assets, the Fama-French 3 factors model will have explanatory power which the second hypothesis uses growth as a control variable. This hypothesis will include the size of the firms as another control variable. The size of the firm can be used as a proxy of market capitalization. This will ensure that the firm will be the control variable.

The market capitalization which is the total value of the firm is calculated from the product of stock value and volume. Previous research shows that the larger firms will have less information asymmetry Chae (2005), Atiase (1985), Bamber (1987), Freeman (1987), and Llorente et al. (2002). In turn, lower information asymmetry will improve market perception toward the larger firm. The larger cap firm is perceived to be less volatile which causes the volatility of the exchange trade option to be lower while the volatility of the embedded option remains constant since the firm's perception toward itself is unaffected by the market capitalization. The higher market capitalization therefore causes the lower difference between in the volatilities.

5. The difference in the probabilities of default of non-convertible bond and convertible bond of the same firm will lessen the difference in volatilities.

The convertible bonds have significantly lower default rate than the non-convertible bonds (Rosengren 1993). Since the convertible bond of the same firm is supposed to have the same rating with its non-convertible bond, the straight bond part will have the same value with the non-convertible bond. However, the fact the convertible bond has lower default probability is still there. This value will transfer to the embedded option portion which will result in the higher embedded option premium. As a result, the default probability of the convertible bond will have negative effect on the premium of the embedded option while the default probability of the non-convertible bond will have positive effect on the same premium. The explanation of the default probability's effect will be separated into two parts: the convertible bond part and the non-convertible bond part

First, the reason which supports this is as the default probability of the convertible bond become lower investors tend to value the embedded option more since they feel more certain that they have an alternative option in case that the firm could not manage to pay the debt. Furthermore, the previous research showed that there are two approaches to view the convertible bond: as a debt (asset substitution) or as an equity (asymmetric information)(Lewis et al. 1999). If investors concern about an asset substitution problem, the embedded option premium would contain value that cause the default probability to be lower. Since the default probability of the convertible bond has less positive relation with the embedded option premium, it also would have the less positive relation with the volatility of the embedded option. Consequently, when the default probability increased, the volatility of the embedded option would decrease which will enlarge the difference in volatilities of the options.

On the other hand, the non-convertible bond's probability of default could not be observed reliably because firms rarely issue the convertible bond and the non-convertible bond in the same period. It is almost impossible to find the default probability of them. However, the weighted average cost of debt is one of the possible proxy for measuring the default probability. The higher weighted average cost of debt is the result of the high default probability of the firm or we can say that the investment is riskier. The weighted average cost of debt is estimated by using various parameters include the probability of default. In brief, if we observe that the firm is subject to the higher weighted average cost of debt which compensate for the higher risk level, we can say that this firm has a high probability of default. As a result, investors would value the embedded option more as they feel more uncertainty about the firm ability to pay for the straight debt. The embedded option can be viewed as the insurance for the straight bond so they contain more value than just an ordinary stock option.

6. The higher the debt to equity ratio the smaller the difference in volatilities.

Leverage serves as the gearing for the firm performance but it comes with its cost. The higher level of leverage which is the high debt to equity ratio exposes the firm to the bankruptcy risk. Consequently, investors view the firm as a risky one which make them require a higher return to compensate for this risk. At the low and moderate level of the debt to equity ratio, rational investors tend to view the firm risk higher than the firm view itself because of information asymmetry. The firm still benefits from gearing effect by using debt because it does not subject to the high financial distress level. However, at the higher level of debt to equity ratio the firm tends to admit that they are risky or we can say that the cost of debt surpasses the benefit of the leverage. The perception toward risk of the aggregate investors and the firm will converge to each other. To recap, the higher the debt to equity ratio the smaller the gap between the volatility of the exchange traded option and the volatility of the option embedded in the convertible bond.

7. Higher coupon yield causes the larger difference in volatilities of the call option and the embedded option.

From the bond convexity, bonds with a lower coupon rate will be more sensitive to the interest rate volatility. However, in convertible bond the embedded option premium is the part that absorbs the effect of this interest rate volatility due to 2 reasons. First, the straight bond part of the convertible bond is set to be a constant in this research. Second, the convertible bond behaves more like a stock than a bond (Kihn 1996). Therefore, the embedded option's volatility will absorb the effect of the interest rate volatility.

The convertible bond will behave more like a stock option when the benefit of conversion surpasses the holding benefit. Since the higher coupon rate convertible bond tend to stay as a bond since its value is high, the embedded option will not likely to be exercise. As a result, the embedded option's volatility will be lower. This lead to the higher difference between the volatility of the exchange traded option and the volatility of the embedded option.

Data

The data of both convertible bonds and exchange traded call options is taken from United States stock markets from 2014 to early 2017 (end of March). The United States market is proper for this analysis because it is a very active option trading market with various underlying assets and large amount of trading volume. The time frame of 2014 to early 2017 was selected to represent the normal market condition as this period does not contain any financial crises.–Furthermore, the 3-year time length is appropriate because, according to the data the exchange traded options usually have maturity less than 2 years.

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Our regressand, the difference in implied volatilities, is the volatility of the exchange traded option subtracted by the volatility of the option embedded in the convertible bond. The preparation for a regressand in the regression analysis is divided into 4 steps: first identifying the embedded option part of convertible bond, second adjusting price by Galai-Schneller, third backsolving volatility, and fourth matching with exchange traded option.

First, we identify the embedded call premium using the fact that a convertible bond consists of a straight bond and a call option. We can write the equation for the price of convertible bond as

$$Convertible\ Bond = Straight\ Bond + Call\ Option$$

The convertible bond price at initial public offering can be found on Bloomberg via ISIN of the convertible bonds. Traditionally, we use the stock volatility of the same underlying stock to proxy for the call option premium. However, it cannot be done here since we want to test whether the volatilities perceived by different groups of investors are the same or different. Instead, we obtain embedded call premium by striping the straight bond from convertible bond, thus needing the proxy for straight bond prices. The straight bond prices can be proxied using the discounted cash flow method. This method finds the present value of the cash flow in each period to find the fair price for the bond. However, we still have to find the discount rate for each period which is investors required rate of return. Although the summation of risk-free rate and the firm credit spread is a possible method, which is widely used by analysts, most of the convertible bonds do not have a credit rating. Therefore, I used credit default swap rate instead of credit spread to find the required return rate. This credit default swap (CDS) can be used to ensure that investors will get their money without risk. As the result, holding a corporate and paying a credit default swap premium will yield the same return as risk-free rate for the same holding period. One drawback of this estimation is the fact that there could be a default correlation between CDS and convertible bonds. This test assumes away this correlation. This estimated required return will be used as yield to maturity to proxy the price of each straight bond by discounting a series of cash flows from coupon payments and principal payback. The remainder, which comes from subtracting an estimated straight bond price from the convertible bond price, is the embedded call option premium.

In the second step, the embedded call premium is adjusted by Galai-Schneller to eliminate the dilution effect. This is because the embedded option has a similar nature to a warrant. It can cause a dilution in earnings per share when the embedded option is exercised. The adjustment is done by multiplying the premium from previous step by the existing number of common shares and dividing by the total number of shares after exercise.

The third step focuses on deriving the implied volatility from the call premium. The data of stock price, exercise price, dividend yield, and risk-free rate used in the derivation are obtained from Bloomberg via ISIN codes of the convertible bonds. These parameters need to be matched with the convertible bonds' announcement date. The implied volatility of the convertible bond is then derived using the Black-Scholes-Merton option pricing model with dividend.

Normally, the Black-Scholes-Merton model takes stock volatility as an input and produces option premium as the output. Different volatilities due to different views toward the underlying stock would produce different premiums. The volatility obtained from convertible bond would reflect the bond issuer's or the firm's own perspective towards the stock price. Nevertheless, volatility is an unobservable quantity and is often extracted by backsolving from option premium in the Black-Scholes-Merton model, such method produces the so called implied volatility. We follow this backsolving method by iteratively plugging in the implied volatility until we arrive with the matched option premium.

The last step, which will be proceed after the implied volatility of embedded option is derived, is to match it with the implied volatility of the exchange traded call options. The volatility of exchange traded options can be found on Bloomberg. They calculated the implied volatility of the exchange traded option by using weighted average of the volatilities of the closest-out-of-the-money call option. The date that will be used to match is the one that was calculated from call options on the date which convertible bonds were announced. Now the data for the regressand is ready for the regression analysis.

Variable Table

Table 1 Variable Description

Variable	Description	Unit	Source
S	Current Stock Price	$	Bloomberg
K	Call Option Strike Price	$	Bloomberg
t	Time to maturity	Year	Bloomberg
r	Risk free rate	Percentage Point per Annum	Bloomberg
q	Dividend yield	Percentage Point per Annum	Bloomberg
C	Call Premium	$	Bloomberg
σ_S	Stock Call Option Volatility	-	Bloomberg
σ_C	Embedded Call Option Volatility	-	Self-Calculation
$\Delta\sigma$	Difference in Volatilities	-	$\sigma_S - \sigma_C$
PB	Price to Book Ratio	-	Bloomberg
CAP	Market Capitalization	$	Bloomberg
PD	Default Probability of Convertible Bond	Percentage Point per Annum	Bloomberg
CoD	Cost of Debt of the company issued the Convertible Bond	Percentage Point per Annum	Bloomberg
CPN	Coupon Yield of the Convertible Bond	Percentage Point per Annum	Bloomberg
DE	Debt to Equity Ratio	-	Bloomberg
Y_{2015}	Dummy variable of year 2015 issuance bond and stock option	-	Take value of 1 if issued in 2015
Y_{2016}	Dummy variable of year 2016 issuance bond and stock option	-	Take value of 1 if issued in 2016
Y_{2017}	Dummy variable of year 2017 issuance bond and stock option	-	Take value of 1 if issued in 2017

Procedure for the Volatility of the Embedded Option

From the previous section, we know that the implied volatility can be calculated by backsolving the Black-Scholes-Merton model. The implied volatility will take a lot of time if we calculate it by hand. The reason is the Black-Scholes-Merton equation does not have a close form to find the implied volatility by using simple calculation. Instead of using analytical approach, we need to do this process using numerical approach Luckily, we have the more powerful computer unit that help us accelerating the computation process.

Figure 1 Straight Bond Value

IPO Bond	CDS	CPN	Required Rate of Return	Converstion Ratio	Straight Bond Value
$ 1,000.00	29	2.5	1.7154	25.5428	$ 918.51

GS factor
0.999973

Figure 1 is IPO bond price, credit default swap rate (CDS), coupon yield (CPN), conversion ratio, and Galai-Schneller adjusted factor (GS) from the tables in Appendix A. The require rate of return is the factor we need to proxy here. The formula that we use here is

$$Required\ Rate\ of\ Return = Risk\ Free\ Rate + Credit\ Default\ Swap\ Rate$$

The addition of the risk-free-rate and the credit default swap rate give us the required rate of return. The reason is the holding a corporate bond along with the credit default swap will guarantee that the investors will receive the cash flow for sure regardless to the bond default or not. Therefore, getting the required rate of return while paying for the swap rate will give the rate that is equal to the risk-free rate. The above formula moves the credit default swap rate to the other side of the equation since the variable that we need to find here is the required rate of return.

The straight bond value can be calculated by finding the present value of all the cash flow where the relevant variables are the face value (IPO bond), the coupon rate, and the required rate of return. The equation for discounting back all the cash flow in each period is

$$PV = \frac{Coupon}{(1+r)} + \frac{Coupon}{(1+r)^2} + \cdots + \frac{Coupon}{(1+r)^n} + \frac{FV}{(1+r)^n}$$

Or in short

$$PV = \sum_{i=1}^{n} \frac{Coupon}{(1+r)^i} + \frac{FV}{(1+r)^n}$$

PV is the present value of the straight bond, Coupon is the dollar value of coupon payment, FV is the face value of the bond, and r is the investors' required rate of return. The required rate of return is obtained by CDS as a proxy in previous step. Now, we arrive with the proper straight bond value. The excess amount left in the IPO bond price is the embedded option premium of the convertible bond.

However, the premium we need for the backsolving process is a single unit. We need to adjust the price to be a single unit using the fact that we know how many stock a single bond can convert to. The formula which will be used in this case is

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$$Option\ Premium\ (1\ Unit) = \frac{Option\ Premium\ (1\ Bond)}{Conversion\ Ratio}$$

In this example, we can see the premium of the embedded option is \$81.49 for the whole bond. This bond can convert to 25.5428 stocks. Therefore, a premium for a single stock is \$3.19.

Finally, we multiply this premium with the Galai-Schneller adjustment factor, which is

$$GS\ factor = \frac{Existing\ Common\ Share}{Total\ Common\ Share\ after\ Conversion}$$

And

$$Adjusted\ Option\ Premium\ (1\ Unit) = GS\ factor \times Option\ Premium\ (1\ Unit)$$

Now, we can define the value of the target call option premium. The stock volatility, which can give the same call premium in Black-Scholes-Merton model with the target call, is the implied volatility of the embedded option.

Figure 2 Black Scholes Merton Variables

Implied Call	STOCK PRICE	Risk Free Rate	Strike Price	Dividend Yield	DayToMaturity	l Volatility	d1	d2	Call Premium
$ 3.19	$ 28.90	1.4254	$ 39.15	0	1827	0.21756	-0.2337	-0.72044	$ 3.19

From figure 2, the example of stock price, risk-free rate, strike price, dividend yield, and the maturity are shown.

Since the whole bond usually can convert to multiple stock. The strike price of the embedded option is the whole convertible bond price divided by the conversion ratio. The reason is upon the conversion the bond holder must give up the right to get the remaining cash flow to exchange with the contract amount of stock. The equation for strike price calculation is

$$Strike\ Price = \frac{Face\ Value}{Conversion\ Ratio}$$

Now, we randomly plug in a number for the volatility until the output c is equal to the call premium which we calculated in the previous section.

$$c = Se^{-q(T-t)}N(d_1) - Ke^{-r(T-t)}N(d_2)$$

Where

$$d_1 = \frac{\ln\left(\frac{S}{K}\right)+(r-q+\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \quad ,d_2 = d_1 - \sigma\sqrt{T-t}$$

Here, S is the stock price, K is the exercise price, r is the risk-free rate, q is the dividend yield, T-t is the time to maturity for the option, σ is the stock volatility, N(.) is the cumulative normal distribution, and c is the call option premium.

We can see that the Target Call and the Call Premium column have the same value. It means the volatility of 0.21756 or 21.756% is the implied volatility of this embedded option. This volatility shows the perception of the firm agents and the underwriter toward the firm itself. The reason is this option is issued by the firm.

Table 2 Summary Statistic

Variable	Mean	Maximum	Minimum	SD	Unit
Bond Price	745.1711	1000	11.61	416.3973	$
CDS	176.7674	947	20	152.7534	Basis Point
Stock Price	86.1487	1270.12	1	185.8085	$
Risk-Free Rate	1.3590	2.6161	0.468	0.5505	Percentage Point
Strike Price	104.0534	2055.4985	1.3640	227.6624	$
Dividend Yield	1.9771	17.0482	0	3.7939	Percentage Point
Maturity	1504.7849	3660	186	841.3587	Day
Volatility (Bond)	25.2720	93.0785	1.7332	17.2674	Percentage Point
Volatility (Option)	41.8981	165.699	14.152	20.1056	Percentage Point
Conversion Ratio	32.1226	733.14	0.437	66.3042	Stock per Bond

Price to Book	6.5415	49.4071	0.5919	8.4262	-
Market Cap	46937.67	601439.27	70.9082	115712.35	$
Default Probability	0.3000	2.5181	0.0006788	0.4233	Percentage Point
Cost of Debt	1.7030	4.2505	0	1.0653	Percentage Point
Coupon Rate	4.3183	11.77	0	2.9907	Percentage Point
Debt to Equity	1.1469	5.2982	0	1.2897	-

Next, we need to ensure that the regression analysis will not have the multicollinearity problem. Then, we find the correlation among variable which are shown in Table 3.

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Table 3 Covariance Matrix

	dV	*lnPB*	*lnPBM*	*lnCAP*	*lnPD*	*CoD*	*CPN*	*DE*	*Y2015*	*Y2016*	*Y2017*
dV	1										
lnPB	0.03	1									
lnPBM	-0.10	0.74	1								
lnCAP	-0.11	0.32	-0.10	1							
lnPD	0.33	-0.13	-0.21	0.02	1						
CoD	-0.22	-0.08	0.05	-0.06	0.04	1					
CPN	0.36	-0.20	-0.57	0.29	0.33	0.01	1				
DE	-0.10	0.11	-0.06	0.18	0.27	0.16	0.33	1			
Y2015	-0.07	-0.02	0.17	-0.26	-0.14	0.04	-0.24	-0.05	1		
Y2016	0.26	-0.13	-0.51	0.42	0.45	-0.15	0.62	0.22	-0.47	1	
Y2017	0.11	0.06	-0.08	0.21	0.03	0.00	0.18	0.00	-0.07	-0.11	1

Regression Analysis

Similarly, all regressors also use the convertible bond announcement date as a reference date for data point~~s~~ collection. The regression analysis is divided into 2 steps.

First, the simple T-test will be used to find whether the volatilities of a call option and an embedded option have, or do not have, a significant difference.

$$\Delta\sigma_i = \beta_0 + \epsilon$$

Where: $\Delta\sigma$ is the implied volatility of an exchange traded option minus implied volatility of an option embedded in convertible bond.

Second, the regression model will incorporate factors which were discussed in Hypothesis part and the sample convertible bonds and stock options are picked from 2014 to early 2017 which can have different economic environment. Therefore, 3 dummy variables are added to capture time fixed effects which makes the regression model become

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$$\Delta\sigma_i = \beta_0 + \beta_1 lnPB_i + \beta_2 lnPBM_i + \beta_3 lnCAP_i + \beta_4 lnPD_i + \beta_5 CoD_i + \beta_6 CPN_i + \beta_7 DE_i + \beta_8 Y_{2015_i} + \beta_9 Y_{2016_i} + \beta_{10} Y_{2017_i} + \epsilon_i$$

Where: $\Delta\sigma$ is the difference between implied volatility of an exchange traded option and implied volatility of an option embedded in convertible bond.

PB is the price to book ratio of the firm issued the convertible bond.

PBM is the product of price to book ratio with the maturity of the convertible bond

CAP is the market capitalization.

PD is the default probability of the convertible bond.

CoD is the cost of debt of the firm issued the convertible bond.

CPN is the coupon yield of the convertible bond.

DE is the debt to equity ratio of the firm issued the convertible bond.

Y_{2015} is time fixed effect of year 2015 which will take value of 1 if the convertible bond issued in 2015

Y_{2016} is time fixed effect of year 2016 which will take value of 1 if the convertible bond issued in 2016

Y_{2017} is time fixed effect of year 2017 which will take value of 1 if the convertible bond issued in 2017

Data Selection Process

First, there are 944 convertible bonds issued in the United States between 2014 and early 2017 in the Data Stream. However, the Data Stream does not provide conversion ratio which is essential for the embedded option premium estimation. The conversion ratio is used to proxy the amount of the stock the bond holder will get upon the conversion. This ratio can be used to find the option premium for a single unit of the underlying stock.

Second, we moved to the Bloomberg data based using ISIN code of the bonds. The reason we cannot use the Bloomberg data based at first place is Bloomberg does not categorize the bond like the Data Stream. We arrived with 724 convertible bonds on Bloomberg data based.

Third, Bloomberg data based also does not provide some samples' conversion ratio. It is inevitable to remove those samples because the premium of an embedded options cannot be measure reliably. It could cause the regression to be inconsistent if we insist to use those samples.

Forth, 88 samples were eliminated since they are Private Placement. The private placement is the security that is not publicly trade. They are not fully driven by the market demand and supply instead the security can be accessed by some investors. Therefore, these samples should be removed since investors cannot obtain this security. The price of these securities is not proper which can cause the error in the estimation.

Fifth, the samples are reduced to 265 since the implied volatility of the exchange traded option, stock price, market capitalization, or Price-to-Book could not be found. The reason behind this is that some convertible bonds are issued before the firms are listed in the stock exchange. The data for the regression analysis is incomplete for those samples so they are removed to avoid the mismeasurement error.

Last, there are samples which are impossible to find the implied volatility which can make the Black Scholes Merton model yield the correct premium for the option embedded in the convertible bond. Therefore, those sample are also removed since we cannot find the implied volatility of the embedder option which reflect the premium of the option in the market. As the result, the sample size is reduced to 172 samples.

Result

First, the difference between implied volatility of an exchange traded option and implied volatility of an option embedded in convertible bond can be checked whether there is a significant difference or not. Furthermore, the direction of the difference can be observed by looking at the constant magnitude. The positive magnitude of the constant term shows that the implied volatility of an exchange traded option is greater than the implied volatility of an option embedded in convertible bond of the same firm. On the other hand, the negative magnitude implied the other direction of the relationship. The implied volatility of an exchange traded option is less than the implied volatility of an option embedded in convertible bond.

Table 4 Difference Confirmation

VARIABLES	(1) Difference in Volatilities
Constant	16.63***
	(1.725)
Observations	172

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The Table 4 shows the positive magnitude of the constant term. This confirms that the volatility of the exchange traded option is higher than the volatility of the embedded option.

Since we can confirm that there is a significant difference between the volatility of the exchange traded option and the volatility of the embedded option. We can continue the next step regression which will test whether the variables in the hypotheses have impacts on this difference.

Due to the limitation about the amount of the sample size, the regression will take place even without the separation of the industry sector. The samples came from 9 industry sectors, which are Basic Materials (2), Communications (20), Cyclical Consumer (38), Non-cyclical Consumer (40), Energy (14), Financial (26), Industrial (12), Technology (17), and Utilities (3). Furthermore, these sectors can be divided into 42 industry groups which is the dummy variable which should be used to classify the level of the debt-to-equity ratio. However, we have only 172 samples which have sufficient data for the regression analysis. Therefore, the sample size for each industry group will be insufficient to use the Central Limit Theorem.

Table 5 Main Regression

VARIABLES	(1) Difference in Volatilities	(2) Difference in Volatilities (No year fixed effect)
lnPB	5.609***	6.184***
	(2.004)	(2.016)
lnPBM	0.219	0.0122
	(0.451)	(0.441)
lnCAP	-4.011***	-3.518***
	(1.072)	(0.974)
lnPD	4.157***	4.828***
	(1.467)	(1.310)
CoD	-3.611***	-3.890***
	(1.340)	(1.369)
DE	-4.928***	3.895***
	(1.080)	(0.735)
CPN	3.493***	-5.107***
	(0.836)	(1.085)
Y2015	2.643	
	(3.745)	
Y2016	6.751	
	(6.372)	
Y2017	19.26**	
	(7.870)	
Constant	63.07***	66.25***
	(14.00)	(13.63)

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Observations	172	172
R-squared	0.406	0.395

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

From Table 5 (1), we can see that most of the variables are statistically significant at 99% confidence levels.

First, lnPB has a positive coefficient. The implication is the higher Price-to-Book ratio causes the difference between implied volatilities to be larger. The higher market expectation causes the Price-to-Book ratio to be high. The market perceives the higher growth which cause the implied volatility of the exchange traded option to be higher. While the implied volatility of the embedded option remains the same since the firm know its true growth. Therefore, the difference between the implied volatilities became larger as the Price-to-Book ratio increase.

Second, lnCAP has a negative coefficient. The implication is the higher the market capitalization causes the difference between implied volatilities to be less. The higher the market capitalization means there are more participants in the stock. Therefore, there are more information available which lessen the information asymmetry (Adverse Selection). The lower the information asymmetry causes the firm and the investors to have the similar perception toward the firm. To conclude, the higher the market capitalization leads to the similar perception of investors and the firm toward the firm. As the result, the difference between the implied volatilities is less as the market capitalization is increase.

Third, lnPD has a positive coefficient. The implication is the higher the default probability the convertible bond causes the embedded option to worth less in the convertible security investor opinion. As the result, the implied volatility of the embedded option response to the conversion right premium value reduction. The implied volatility of the embedded option is lower as the default probability of the convertible increase. This enlarge the gap between the volatility of the exchange traded option and the volatility of the embedded option. In short, the higher the default probability of the convertible bond cause the difference in the volatilities to be larger. Some may argue that investors use the default probability of the convertible bond to find the risk of the firm. However, the effect of default probability of the convertible bond on the investors perceived risk level is relatively small compared to the direct effect of the default probability of the convertible bond on the conversion option.

Forth, CoD has a negative coefficient. The implication is the higher the cost of debt shows the likelihood that the debt security issued by the firm will default. Therefore, investors will value the embedded option more because it will serve as the backup plan, if the bond tends to default. The higher embedded option premium drives the implied volatility of the option embedded in the convertible bond to be higher. As the result, the difference between the volatilities becomes smaller as the cost of debt increase.

Fifth, DE has a negative coefficient. The implication is the higher debt-to-equity ratio arises the problem about the financial distress cost. The financial distress cost drives the perception of investors and the firm to converge to each other. As the result, the higher the debt-to-equity ratio causes the gap between the volatilities to be smaller.

Sixth, CPN has a positive coefficient. The implication is the higher coupon yield is less sensitive to the change in the interest rate. The conversion right absorbs this risk and causes the higher coupon yield bond to be less risky compare to the lower coupon yield bond. Consequently, the higher coupon yield bond will provide an option which incorporates the lower implied volatility. To conclude, the higher coupon yield bond causes the difference between the implied volatility of the exchange traded option and the implied volatility of the option embedded in the convertible bond to be lower.
Last, Constant is positive. This constant illustrates the abnormal volatility. According to the result, the stock volatility measured in percentage point indicates that the exchange traded option usually have 63.07% higher volatility than the volatility of the option embedded in the convertible bond that was issued by the underlying firm. This

implied that an embedded option will be sold at significantly lower premium than the exchange traded option premium with all else equal (ceteris paribus).

The result shows that this an arbitrage opportunity in the debt-equity market due to the imparity between the exchange traded option and the embedded option in convertible bond. Consequently, institutional investors could seize this opportunity by going long (buy) the convertible bond, and short (sell) a call option and the straight bond. Nevertheless, the arbitrage opportunity is limited within a small group of investors. Only those who have access to the initial public offering of convertible bonds such as institutional investors are the ones benefiting from arbitrage.

Moreover, there is thing that must be concerned about this arbitrage opportunity. This result is based on the perfect market assumption which mean the buying and selling price is indifferent. This could be a factor that can cause the arbitrage strategy to be impossible.

In the regression analysis section, we suspect that the year may have fixed effect on this regression because the perception of the investors and firm agents may change across time. Before we follow that model, let's have a look at the version without the year fixed effect.

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From Table 5 (2), we can see that most of the variables are statistically significant at 99% confident levels. However, the magnitude of each variable is slightly higher than the model with year fixed effect. It proves that the year fixed effect is necessary for the regression. The year factor influences the difference in the volatilities because the information asymmetry will be different in each year. Therefore, the perception of the investors toward the firm and the firm agents toward the firm itself will be different in each year.

To check whether there is a significant difference in the volatility of the embedded option and the volatility of the exchange traded option. The simple T-test can be used to find whether the difference in volatilities is significant in each industry or not.

The communications sector has 20 samples for the matching convertible bonds and exchange traded call options. This sector cannot be regressed since there is insufficient data point.

The consumer with the cyclical product sector has 38 samples for the matching convertible bonds and exchange traded call options.

The energy sector has 14 samples for the matching convertible bonds and the exchange traded call option. This sector also has a very small sample size.

The financial sector has 14 samples for the matching convertible bonds and the exchange traded call option. This sector also has a very small sample size.

The industrial sector has 12 samples for the matching convertible bonds and the exchange traded call option. The sector has a very small sample size.

The technology sector has 17 samples for the matching convertible bonds and the exchange traded call option. The sector has a small sample size.

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Finally, there are 3 samples from the utility sector which is the electric subsector. Therefore, these samples are included in the energy sector to find whether there is any change. The combined sector has 17 samples for the matching convertible bonds and the exchange traded call option. The sector has a very small sample size.

Table 6 Sector T-test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Communications	Cyclical	Non-Cyclical	Energy	Financial	Industrial	Technology	Energy&Utility
Constant	18.30***	14.29***	19.61***	24.82***	16.40***	13.57	12.58**	21.43***
	(4.578)	(3.240)	(3.350)	(6.134)	(4.073)	(12.22)	(4.809)	(5.478)
Observations	20	38	40	14	26	12	17	17
R-squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The simple T-test in Table 6 (1) shows that the communication sector has a significant difference in the volatility of the embedded option and the volatility of the exchanged traded option at 99% confident level. The positive sign of the constant confirms that the volatility of the exchange traded option is higher than the one of the embedded option.

The simple T-test in Table 6 (2) shows that the consumer with the cyclical product sector has a significant difference in the volatility of the embedded option and the volatility of the exchange traded option at 99% confident level. Similarly, this sector also has positive sign of the constant term. Therefore, the volatility of the exchange traded option is significant higher than the volatility of the embedded option.
The consumer with non-cyclical product sector has 40 samples for the matching convertible bonds and exchange traded call options.

The simple T-test in Table 6 (3) shows that the consumer with the non-cyclical product sector has a significant difference in the volatility of the embedded option and the volatility of the exchange traded option at 99% confident level. This constant term of this sector also has a positive magnitude which implied that the volatility of the exchange traded option is significantly higher than the volatility of the embedded option.

The simple T-test in Table 6 (4) shows that the volatility of the exchange traded option and the volatility of the embedded option are significant different at 99% confident level. The constant term of the energy sector has a positive sign. The implication is the volatility of the exchange traded option is significantly higher than the volatility of the embedded option.

The simple T-test in Table 6 (5) shows the financial sector has a significant difference in the volatility of the embedded option and the volatility of the exchange traded option at 99% confident level. The sector has a positive sign which shows the volatility of the exchange traded option is significantly higher than the volatility of the embedded option.

The simple T-test in Table 6 (6) shows the industrial sector does not have significant difference in the volatility of the embedded option and the exchange traded option. However, the small sample size is one of the factor that cause the result to be this way.

The simple T-test in Table 6 (7) shows that the technology sector has the difference in the volatility of the embedded option and the volatility of the exchange traded option at 95% confident level. The positive sign of the constant term presents that the volatility of the exchanged traded option is higher than the volatility of the embedded option.

The simple T-test in Table 6 (8) shows that the combined sector also has the significant difference in the volatilities at 99% confident level. However, the positive magnitude of the constant term has a lower in number than the energy sector alone. Interestingly, this may lead to the implication that that normally in the energy sector the difference in the volatilities is higher than other sectors. Nevertheless, the amount of sample sizes in each sector is extremely small. The rigid conclusion about the highest difference in volatilities among different industries could not be made.

From Table 6, we can clearly see that the difference in the volatility of the exchange traded option and the volatility of the embedded option could potentially be different in each industry.

To confirm whether this difference is significant or not, we have to do the F-test using sector as dummy variable. In this case we give communication, cyclical, non-cyclical, energy, financial, industrial, and technology a dummy variable. The other industry will be represented in the constant term.

Table 7 F-test sector

VARIABLES	(1) Sector
Communication	15.10
	(11.36)
Cyclical	11.09
	(10.81)
Non-cyclical	16.41
	(10.77)
Energy	21.62*
	(11.83)
Financial	13.20
	(11.09)
Industrial	10.37
	(12.09)
Technology	9.386
	(11.56)
Constant	3.195
	(10.16)
Observations	172
R-squared	0.033
F-stat	0.79
Prob>F	0.5969

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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From Table 7, we still cannot conclude that each industry has such a high distinguish difference in volatilities. Beside the energy sector has significantly higher different in volatility than the other sector with 90% confident level. We observe that the p-value of F-stat is quite high due to the small amount of sample. It still too early to conclude.

The level of debt to equity ratio is industry specific some number could consider to be high debt to equity ratio for one industry while consider to be low debt to equity ratio for the other industry. Since there is a concern about whether debt to equity ratio have effect on the premium which the firm can issue for their conversion right. The sample is equally divided into two group the high debt to equity ratio and low debt to equity ratio. We want the sample size to be equal so we use the median of each industry to divide the debt to equity ratio to be two groups. We do the simple T-test to check whether in each group has difference in the volatility of the exchange traded option and the volatility of the embedded option.

Table 8 Simple T-test Separated by Debt to Equity

	(1)	(2)
VARIABLES	High DE	Low DE
Constant	14.07***	19.19***
	(1.937)	(2.839)
Observations	86	86

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8 shows that both portfolios of High DE firms and Low DE firms have statistically significance difference of the implied volatilities. Next, we have to check whether their difference is significantly different from each other. Then we could continue our full regression to check whether all of the variable still have effect on the difference or not.

Table 9 High DE vs Low DE

	(1)
VARIABLES	Difference
High	-5.122
	(3.437)
Constant	19.19***
	(2.430)
Observations	172
R-squared	0.013

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 9 shows that the higher than median debt-to-equity group of each industry is not significantly different from the lower than median debt-to-equity group. However, after we investigate more by using the industry dummy variable.

Table 10 F-test High DE vs Low DE

	(1)	(2)
VARIABLES	High DE	Low DE
Communication	31.90***	-6.160
	(10.82)	(20.35)
Cyclical	18.48*	-0.756
	(10.22)	(19.53)
Non-cyclical	22.37**	5.987

	(10.18)	(19.49)
Energy	23.02**	15.76
	(11.35)	(21.07)
Financial	21.66**	0.282
	(10.53)	(19.96)
Industrial	-3.975	20.25
	(11.63)	(21.45)
Technology	20.86*	-6.273
	(11.13)	(20.54)
Constant	-5.739	16.60
	(9.494)	(18.58)
Observations	86	86
R-squared	0.231	0.086
F-stat	3.34	1.05
Prob>F	0.0036	0.4024

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Table 10 shows that there are more sectors with significant different in the higher than debt-to-equity median group. The implication is the confident of the investor and firm tend to converge to each other at the different rate among sectors.

Table 11 Full Regression Separated by Debt to Equity

	(1)	(2)
VARIABLES	High DE	Low DE
lnPB	5.325*	10.41**
	(2.984)	(5.109)

lnPBM	-0.706	0.300
	(0.742)	(0.873)
lnCAP	-0.538	-8.006***
	(1.161)	(1.678)
lnPD	4.142**	4.322**
	(1.661)	(1.900)
CoD	-0.693	-1.838
	(2.432)	(1.870)
CPN	1.477	4.539***
	(0.970)	(1.035)
Y2015	-0.636	7.076
	(5.198)	(5.243)
Y2016	3.614	7.878
	(7.812)	(7.195)
Y2017	16.22	14.21
	(17.85)	(18.37)
Constant	32.26*	81.73***
	(17.57)	(16.77)
Observations	86	86
R-squared	0.327	0.531

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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From Table 11, we observe similar result with Table 5. The low debt to equity ratio group has statistical significances at higher than 95% confident level for all of variables except maturity.

At high level of debt to equity ratio, firm size, cost of debt, and coupon rate do not cause any difference in perception toward the firm any more. In previous section, the firm size contributes to the lower differences in volatility in the general case. In the case of high debt to equity ratio, investors do not think the firm size is matter anymore at this high level of risk.

The results in Table 16-19 show that the perception of the overall investors and the firm agents tend to converge to each other when the firm has a higher debt to equity ratio. Therefore, the significant level of all regressors and the abnormal volatility are decrease for the firms that have high debt to equity ratio relative to their peers. However, we do not have enough evident to create a solid conclusion so this is another puzzle which is needed to be solved.

Suggestion

There are three more things to concern about this research which are the debt to equity ratio of each industry sector problem and the reversal of the unequal volatilities.

First, the improved method for the bifurcation can be used to improve the accuracy of the embedded option volatility measurement. According to Arak & Martin 2005, the new method for bifurcation is to proxy for the probability of the convertible bond being a debt and the probability of the convertible bond being convert to a security.

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However, the probability of the convertible bond being convert to a security can be proxied by the $N(d_2)$ in Black-Scholes Merton model. The $1\text{-}N(d_2)$ is the chance of the convertible bond remaining a bond. This method is a little bit complicate if we do not assume the volatility to be the same with the stock volatility which is used to price the exchange traded option. The iteration process until we find the volatility that satisfy the condition which the convertible bond price equal to the expected value of debt and expected value of equity.

Second, we know that the debt to equity ratio should be categorized to its industry since the difference industries will have different level of debt to equity ratio. For instance, the debt to equity ratio of 1.5 is considered to be low for the finance sector, however, this level of debt to equity ratio is extremely high for the technology sector. Therefore, the dummy variable which control the debt to equity ratio should be add to this regression. Nevertheless, we have such a small amount of complete data sample which obtained from the United State stock market. This market is large market with various securities and firms.

There are two solution which can yield a larger sample. First, the global market data can be used instead of the United State stock market. However, this market will require a lot more dummy variable such as country specific risk or continent specific risk. Second, the period can be expanded into the past more. This solution seems to be a good idea at first sight. The problem is the Greece crisis which cause the country in Europe to suffer has ended in 2014. Therefore, if the years prior to 2014 are included into the regression, it will cause the regression to be inconsistent.

Third, the large magnitude of the constant term is observed in the regression. It has a statistical significant so we can view it as an abnormal volatility. However, we suspect that the different will be reverse out because the initial public offering is underpriced. The constant term magnitude should be lower as the time pass. There are samples which are traded in the stock exchange market.

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The procedure for the test is divided into 4 steps. First, we gather the price of the convertible bond and the implied volatility of the call option 1 month after the initial public offering. Second, we repeat the same steps with this research to extract out the implied volatility of the embedded option and run the regression for the constant term. If the constant term or the abnormal volatility is statistically significant, we continue with the third step. Third, we compare this new abnormal volatility of one month later with our original abnormal volatility to find whether it is statistically different or not. The last step is checking whether the magnitude of the new abnormal volatility is lower than the original abnormal volatility. Therefore, we can conclude that there is the reversal of the abnormal volatility after the initial public offering.

Conclusion

There is an abnormal volatility which is caused by an option embedded in a convertible bond. It arises from the fact that a volatility of an exchange trade call option already has a parity with a volatility of an exchange trade put option of the same underlying asset. The abnormal volatility supports the idea that initial public offering securities are on-average underpriced which was proven for stocks in previous researches such as Dawson (1987), Cline et al. (2010) , and Gondat-Larralde et al. (2008).

The United States convertible bond sample from 2014 to March 2017 shows that the investors, who can participate in the initial public offering, could seize an arbitrage profit from an abnormal volatility if they can find the credit default swap rate combine with the risk-free rate equal to the corporate bond rate of return, and short sell a call option with the same strike price and maturity. However, the analysis does not concern the transaction cost which could cause this arbitrage strategy to be impossible.

Moreover, the factors which cause the volatility used in option pricing to be differ are price to book ratio, market capitalization, convertible bond default probability, cost of debt, coupon rate, and debt to equity ratio. However, for the high debt to equity ratio, only price to book ratio and the convertible bond default probability effect the difference in volatility of the exchange traded option and the volatility of the option embedded in the convertible bond.

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REFERENCES

Arak, M. and A. L. Martin (2005). "Convertible Bonds: How Much Equity, How Much Debt?" Financial Analysts Journal: 44-50.

Atiase, R. K. (1985). "Pre-disclosure information, firm capitalization, and security price behavior around earnings announcements." Journal of Accounting Research: 21-36.

Bamber, L. S. (1987). "Unexpected earning, firm size, and trading volume reactions to announcements." Accounting Review: 510-532.

Black, F. and M. Scholes (1972). "The Valuation of Option Contracts and a Test of Market Efficiency." The Journal of Finance **399-417**.

Black, F. and M. Scholes (1973). "The Pricing of Options Corporate Liabilities." Journal of Political Economy **637-654**.

Butler, A. W. (2002). "Revisiting optimal call policy for convertibles." Financial Analysts Journal **58**(1): 50-55.

When a company calls its convertible bonds, it typically must give the bondholders a notice period of approximately 30 days to decide whether to convert the bonds. This important institutional detail substantially affects the optimal call policy for convertible bonds. When the company calls the bonds, it fixes the price at which bondholders can redeem them, effectively giving bondholders a 30-day put option. The optimal time to call the convertibles minimizes the value of the conversion option net of the put option. This optimization problem is solved here, and a simple decision rule

for the company results. This solution contains those of previous researchers as a special case.

Chae, J. (2005). "Trading Volume, Information Asymmetry, and Timing Information." The Journal of Finance: 413-442.

Cline, B. N. and X. Fu (2010). "Executive Stock Option Exercise and Seasoned Equity Offerings." Financial Management: 1643-1670.

Dawson, S. M. (1987). "Initial Public Offer Underpricing: The Issuer's View -- A Note." The Journal of Finance: 159-162.

Easton, P., et al. (2002). "Using Forecasts of Earnings to Simultaneously Estimate Growth and the Rate of Return on Equity Investment." Journal of Accounting Research: 657-676.

Fama, E. F. and K. R. French (1995). "Size and Book-to-Market Factors in Earnings and Returns." The Journal of Finance: 131-155.

Flannery, M. J., et al. (2012). "Leverage Expectations and Bond Credit Spreads." Journal of Financial and Quantitative Analysis **47**(4): 689-714.

In an efficient market, spreads will reflect both the issuer's current risk and investors' expectations about how that risk might change over time. Collin-Dufresne and Goldstein (2001) show analytically that a firm's expected future leverage importantly influences the spread on its bonds. We use capital structure theory to construct proxies for investors' expectations about future leverage changes and find that these significantly affect bond yields, above and beyond the effect of contemporaneous leverage. Expectations under the

trade-off, pecking order, and credit-rating theories of capital structure all receive empirical support, suggesting that investors view them as complementary when pricing corporate bonds.

Freeman, R. N. (1987). "The association between accounting earnings and security returns for large and small firms." Journal of Accounting and Economics: 195-228.

Galai, D. and M. I. Schneller (1978). "Pricing of Warrants and the Value of the Firm." The Journal of Finance: 1333-1342.

Gondat-Larralde, C. and K. R. James (2008). "IPO Pricing and Share Allocation: The Importance of Being Ignorant." The Journal of Finance: 449-478.

Keynes, J. M. (1936). The General Theory of Employment, Interest and Money., Palgrave Macmillan.

Kihn, J. (1996). "The Effect of Embedded Options on the Financial Performance of Convertible Bond Funds." Financial Analysts Journal: 15-26.

Lewis, C. M., et al. (1999). "Is Convertible Debt a Substitute for Sraight Debt or for Common Equity." Financial Management: 5-27.

Llorente, G., et al. (2002). "Dynamic volume-return relation of individual stocks." Review of Financial Studies: 257-300.

Penman, S. H. (1996). "The Articulation of Price-Earning Ratios and Market-to-Book Ratios and the Evaluation of Growth." Journal of Accounting Research: 235-259.

Rosengren, E. S. (1993). "Defaults of Original Issue High-Yield Convertible Bonds." The Journal of Finance: 345-362.

Smith, C. W. (1976). "Option Pricing A Review." Journal of Financial Economics: 3-51.

Stein, J. (1989). "Overreaction in the Options Market. ." 1011-1023.

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Appendix A Data

BP	CDS	SP	RF	EP	DY	Mat	BVol	CVol	CR
1000	77	22.24	2.23	30.88	0.00	2548	30.79	46.90	32.39
1000	127	44.58	2.15	55.94	0.00	7306	35.39	61.56	17.88
1000	123	67.27	1.63	86.28	1.78	2018	31.62	74.47	11.59
1000	54	101.14	2.17	143.62	0.85	2567	33.17	26.95	6.96
1000	131	8.39	1.04	9.17	7.15	1453	30.37	34.28	109.10
1000	224	19.48	1.56	27.09	0.00	1827	36.68	47.20	36.91
1000	311	36.09	1.56	45.00	0.00	1829	34.78	82.55	22.22
1000	54	60.03	1.52	89.56	0.00	1825	28.77	27.88	11.17
1000	133	252.54	1.48	359.87	0.00	1826	31.79	57.23	2.78
1000	133	252.54	2.08	359.87	0.00	2555	35.66	57.23	2.78
1000	137	47.51	2.17	59.39	0.00	2563	28.61	30.36	16.84
1000	191	14.37	1.62	20.12	0.00	1828	35.23	65.71	49.69
1000	64	30.98	1.62	33.53	1.94	7307	118.06	19.03	17.27
1000	273	4.89	1.59	6.01	0.00	1815	31.95	50.02	166.26
1000	223	17.03	2.13	22.50	0.59	2556	40.21	33.46	44.45
1000	216	82.00	1.55	110.70	0.00	1840	34.33	61.56	9.03
1000	100	59.84	2.29	70.93	4.85	2568	43.51	21.58	14.10
1000	230	9.50	1.61	10.07	0.00	1744	19.56	46.05	99.30
1000	156	71.16	1.67	203.46	0.79	1832	93.95	47.54	3.96
1000	359	11.55	1.82	13.20	0.00	2015	32.80	67.66	75.76
1000	435	9.01	1.24	5.33	0.00	1386	N/A	63.80	187.69
1000	55	47.78	1.74	71.91	0.00	1813	30.52	27.28	13.91
1000	181	17.37	2.62	23.06	0.00	3658	39.94	33.51	43.36
1000	145	11.25	1.52	13.10	5.18	1824	35.91	30.04	76.36
1000	145	11.25	2.04	13.10	5.18	2555	45.91	30.04	76.36
1000	233	21.53	1.55	26.29	0.00	1825	29.13	46.32	38.04
1000	171	22.74	1.55	34.68	0.00	1820	38.51	25.03	28.84
1000	199	10.01	1.53	13.26	0.00	1841	32.09	47.84	75.40
1000	58	21.84	1.53	31.35	0.00	7308	30.39	38.15	31.90
1000	136	35.25	1.64	46.51	0.00	1835	28.45	34.11	21.50
1000	90	168.95	1.64	254.34	0.00	1833	32.56	36.13	3.93
1000	260	33.78	2.18	48.76	0.00	2548	46.32	43.84	20.51
1000	90	168.95	2.18	254.34	0.00	2566	36.08	36.13	3.93
1000	47	17.57	1.85	19.64	8.48	2014	39.08	14.15	50.91
1000	77	47.84	2.23	68.93	2.10	5482	59.67	28.22	14.51

Where

BP is the bond price

CDS is the credit default swap basis point

SP is the stock price of the underlying asset

RF is the risk-free rate

EP is the strike price

DY is the dividend yield

Mat is the bond maturity

BVol is the volatility of the embedded option

CVol is the volatility of the exchange traded option

CR is the conversion ratio

This table is to show that in most of the case convertible bond is issued at par. The bond price is quoted to be 1000 face value. It also shows there are some cases which the implied volatility of the embedded option could not be found.

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PB	CAP	Mat	PD	CPN
1.66	841.99	2548	0.000394376	2.875
11.93	988.10	7306	0.000886233	2.75
12.33	7956.57	2018	0.001339339	2
3.31	13649.69	2567	0.000752344	0
10.35	1181.05	1453	0.000898627	4
2.46	528.64	1827	0.002038215	2.5
4.72	1521.84	1829	0.011447037	4.25
4.08	8425.44	1825	0.000201411	0
46.60	18516.45	1826	0.001008788	0.25
46.60	18516.45	2555	0.001008788	1.25
2.11	1279.47	2563	0.001016654	2.875
33.46	28277.44	1828	0.001049457	1.5
4.17	9029.43	7307	0.000201988	1.125
1.58	265.78	1815	0.004970495	5.25
1.99	356.64	2556	0.003238102	2.75
14.92	16866.64	1840	0.001432196	2.25
2.58	1854.17	2568	0.000046779	3.25
3.22	273.08	1744	0.00290843	8
4.30	9033.93	1832	0.00129396	0.125
5.71	748.63	2015	0.007922655	5
7.21	736.38	1386	0.00506793	3.5
2.58	10605.72	1813	0.000197917	0.5
3.40	7457.33	3658	0.002421571	3.125
1.36	4070.64	1824	0.000308359	2.875
1.36	4070.64	2555	0.000308359	3.75
6.53	1870.74	1825	0.001455541	2.5
3.27	4359.65	1820	0.001810321	2.5
0.63	465.07	1841	0.002852609	2.75
4.82	1259.51	7308	0.000254604	2.625
15.90	2620.51	1835	0.000964269	2
13.79	18235.37	1833	0.000500664	0
3.64	3985.47	2548	0.005167151	0.875
13.79	18235.37	2566	0.000500664	0.5
1.15	599.11	2014	0.000030526	5.25
3.07	2336.37	5482	0.000432166	3.25

Where

PB is price to book ratio

CAP is the market capitalization

Mat is the bond maturity

PD is the convertible bond's probability of default

CPN is the coupon yield of the convertible bond

This table is to show that there are zero coupon convertible bond can be issued at par. The investors take the conversion right as a return for the investment.

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IPO Bond	CDS	CPN	Required Rate of Return	Converstion Ratio	Straight Bond Value	GS factor
$ 1,000.00	29	2.5	1.7154	25.5428	$ 918.51	0.999973

Implied Call	STOCK PRICE	Risk Free Rate	Strike Price	Dividend Yield	DayToMaturity	l Volatility	d1	d2	Call Premium
$ 3.19	$ 28.90	1.4254	$ 39.15	0	1827	0.21756	-0.2337	-0.72044	$ 3.19

This table shows the full step of the implied volatility of the embedded option calculation.

Appendix B Suggestion

1. **New method of bifurcation**

   From Arak & Martin 2005, we learned that the value of the convertible bond should not simply equal to the value of debt plus the value of equity. Instead it should equal to the sum of the **expected** value of debt plus the **expected** value of equity. The question is how to find this expect value of each component.

   We also learned that the expectation can be calculated by the chance of happening multiply by the value of the scenario. We can view $N(d_2)$ as the chance of the option is exercised and converted the bond into the stock. Therefore, $1-N(d_2)$ is the chance of the convertible bond remains a bond. To find the most appropriate volatility, all equations must be satisfied.

$$Convertible\ Bond\ Price = [1 - N(d_2)](Straight\ Bond) + N(d_2)(c)$$

$$c = Se^{-q(T-t)}N(d_1) - Ke^{-r(T-t)}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + (r - q + \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \quad , d_2 = d_1 - \sigma\sqrt{T-t}$$

   This will need a bit of iteration process since we do not use the stock volatility to input the equation like what Arak & Martin 2005 did. Instead we plug in the volatiltiy until the convertible bond price is equal to the initial pubic offering price.

2. **Industry debt to equity ratio**

   There are multiple ways to improve the regression analysis is the division of the industry sector out to regress the difference in volatilities in each industry. This will confirm that the factors we suspect effect every industry.

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First, I suggest that the debt to equity ratio can be demeaned out the industry average to ensure that the investors will really view the firm as a risky one if the debt to equity ratio is higher than the peers.

Second, I suggest that the regression can be run separately for each industry like the one that is done for the difference in volatilities check in the result section.

However, these two methods have not been done since the size of the sample is quite small because the data we need to use is available after 2008 and to avoid the Eurozone crisis. Consequently, the sample for the convertible bonds is quite small in the 3 years sample period.

3. **Reversal of underpricing**

First, we gather the price of the convertible bond and the implied volatility of the call option 1 month after the initial public offering. This data is available for the convertible bond which is traded in the stock market. However, some samples are not traded in the stock market.

Second, we extract out the implied volatility of the embedded option which is defined in the procedure. We run the regression for the constant term which is the regression difference in volatility only to find whether the constant term is positive or not. If the constant term or the abnormal volatility is statistically significant, we continue with the third step.

Third, we compare this new abnormal volatility of one month later with our original abnormal volatility to find whether it is statistically different or not. We subtract out the new volatility from the initial public offering one. If there is statistically significant difference with the positive sign, it means that the abnormal volatility is reverse out after certain period. If it does not, it means that it is not the initial public offering underpricing but there might be other

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factors which effect the different in nature of the volatility of the exchange traded option and the volatility of the embedded option.

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