Counterparty Credit Risk and Options Pricing: An Empirical Study

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January, 2014

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I thank Ning Li and Yang Wang for their assistance in preparing the data. I acknowledge the financial support from Early Career Scheme PolyU254712 of the Hong Kong Research Grants Council. All remaining errors are author's responsibility.

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Abstract

In this study, we examine whether the counterparty credit risk is priced in options using the derivative warrant and option data in the Hong Kong market from 2005 to 2012. Derivative warrants are similar to options except that they are issued by financial institutions, and subject to the credit risk of issuers. We find that the credit risk of warrant issuers is priced in the derivative warrants only after the global financial crisis started in fall 2008. On average, a one percentage point increase in the CDS spreads of warrant issuers leads to a 1.9 percent decrease in the prices of derivative warrants during this period, and the effect of the credit risk is stronger for in-the-money put warrants. The results suggest that the counterparty credit risk has become an important factor in determining the prices of derivative securities since the global financial crisis.

1. Introduction

A counterparty credit risk refers to the risk that a counterparty will not pay as obligated in a contract. In the recent years, the counterparty credit risk has become one important dimension of risks faced by market participants. Since mid-2007, large and unexpected losses from mortgage-backed securities by many financial institutions all over the world eventually led to the global credit crisis. The fears of systemic default were extremely high shortly after the bankruptcy of the Lehman Brothers in September 2008. Large holdings of deteriorating sovereign debt by European financial institutions further exacerbated solvency problems of these financial institutions during the European sovereign debt crisis. The counteparty credit risk of many European financial institutions was unprecedentedly high in late 2011.

Despite the importance of the counterparty credit risk in the financial market, the empirical studies on the pricing of counterparty credit risk in derivative securities are few. The early studies almost exclusively focus on the interest rate swap market. The studies typically find that the effect of counterparty credit risk on the swap rate in interest rate swaps is extremely small.[1] A recent study by Arora, Gandhi and Longstaff (2012) examines how the credit risk of the credit default swap (CDS) dealers affects the CDS spreads they quote. The authors find that the counterparty credit risk is priced in the CDS spreads, but the magnitude is vanishingly small. Some of the studies find very limited roles of counterparty credit risk in determining the prices of derivative securities even in the crisis periods, during which market participants concern the counterparty credit risk the most. One key reason why these studies fail to identify a strong effect of counterparty credit risk is the credit risk mitigating mechanism required for the over-

[1] A partial list of the studies on the effects of counterparty credit risk on the interest rate swaps include Cooper and Mello (1991), Litzenberger (1992), Sun, Sundarensan and Wang (1993), Sorensen and Bollier (1994), Duffie and Huang (1996), Duffie and Singleton (1997), Mitton (1997), Eom, Subrahmanyam and Uno (2000, 2002), Bomfim (2002) and Liu, Longstaff and Mandell (2006). Cossin and Pirotte (1997) examine both currency swaps and interest rate swaps.

the-counter (OTC) transactions, such as collateral and netting. This mechanism reduces the counterparty credit risk, and makes the actual credit risk involved in the transactions difficult to measure.

This paper investigates the effects of counterparty credit risk on the pricing of options. Theoretical studies on the options market include Johnson and Stulz (1987), Hull and White (1995), Jarrow and Turnbull(1995), and Klein (1996), however, there is little empirical research. This paper uses the derivative warrants and options data in the Hong Kong market. The call and put derivative warrants traded in Hong Kong are like the usual call and put options traded in the U.S. and elsewhere, except that they can be issued, i.e., sold short, only by certain financial institutions approved by regulators.[2]

Some important features of the Hong Kong derivative warrant and option data make them an ideal sample to examine the effects of the counterparty credit risk on options pricing. Our sample of derivative warrants and options are both traded on the Hong Kong Stock Exchange (HKEx). Exchange trade options bear virtually no credit risk because margins are required for writing options and they are settled through a central cleaning house. However, derivative warrants are subject to the credit risk of their issuers. In our sample, a large number of matched pairs of derivative warrants and options with the same contract specifications are available so that other factors affecting option prices unrelated to credit risk are controlled for. Derivative warrant issuers are not required to put up collateral against the warrants they issue, whereas for the OTC derivatives, collateral is required. In case of a default on the OTC derivatives by one of the counterparties, all contracts between the counterparties are netted. The credit risk mitigation mechanism effectively reduces the counterparty credit risk involved in these OTC transactions. In addition, for derivative warrants, the liability is only on the issuer's side, which is dif-

[2]Derivative warrants are also traded in Germany, Switzerland, Italy, Britain, Australia, Singapore, Korea, and some other countries under different names. Derivative warrant is the term used in Hong Kong. The Hong Kong derivative warrant market was the largest in the world in terms of trading volume in 2007-2009, 2011 and 2012.

ferent from the forward-type of derivatives, such as the interest rate swaps and credit default swaps, examined in early studies, where the credit risk exists on both sides of the counterparties. The actual credit risk involved in buying the derivative warrants can be identified much more easily. The sample period is from 2005 to 2012, which covers a relatively quiet period and periods of crises, including the U.S. financial crisis and the European sovereign debt crisis, when the credit quality of the U.S. and European financial institutions deteriorated. The effects of the counterparty credit risk on the derivative warrant prices can be compared across different periods.

The counterparty credit risk of the derivative warrant issuers are measured by the CDS spreads of the issuers. We regress the price differences between derivative warrants and options on the CDS spreads of issuers to quantify the effects of credit risk of issuers on the prices of derivative warrants they issue. The empirical results show that only since fall 2008, is the counterparty credit risk of warrant issuers priced in the cross-section of derivative warrants. In this period, the credit quality of warrant issuing banks is much poorer on average, and there is a much larger cross-sectional variation in the credit quality of warrant issuing banks than before. The relation between the CDS spread and the price of the derivative warrant is economically significant. A one percentage point increase in the CDS spread leads to a 1.9 percent decrease in the price of the derivative warrant. There is also an evidence that in-the-money put warrants are more affected by the counterparty credit risk since fall 2008. The results suggest that the counterparty credit risk has become an important factor in determining the prices of derivative securities since the global financial crisis.

There are other studies of derivative warrants in the Hong Kong market unrelated to the counterparty credit risk. Duan and Yan (1999) use a semiparametric approach to pricing derivative warrants that substantially improves upon the Black-Scholes (1973) model. Chan and Wei (2001), Chen and Wu (2001), and Draper, Mak, and Tang (2001) focus on the effect of the introduction of derivative warrants on the price and trading volume of the underlying securities. Chow, Li, and Liu (2009) examine the trading records of market makers in the Hong Kong derivative warrants market to understand their inventory management. Li and Zhang (2011) show derivative warrants are overpriced relative to options, and the price difference between derivative warrants and options reflects the liquidity premium of derivative warrants over options.

The remainder of this paper is organized as follows. Section 2 provides a brief introduction to the derivative warrants and options markets in Hong Kong. Section 3 describes the data. Section 4 examines the effects of the credit risk of derivative warrant issuers on the price of derivative warrants they issue, and presents some robustness checks of the main results. Section 5 concludes the paper.

2. Hong Kong Derivative Warrants and Options Markets

Trading of derivative warrants and options in Hong Kong is conducted on the HKEx, which is divided into the securities market, the derivatives market, and the base metals market. Stocks and derivative warrants, among others, are traded on the securities market.[3] Futures and options on indexes and individual stocks, interest rate futures, current futures, and gold futures are traded on the derivative market. The London Metal Exchange acquired in 2012 forms the base metals market of the HKEx.

There are two types of warrants in Hong Kong, equity warrants and derivative warrants. In recent years, most of the warrants traded on the HKEx are derivative warrants. Equity warrants are issued by a listed company and give holders the right to subscribe for equity securities of the issuer. When these warrants are exercised, the listed company

[3]The derivative warrants account for about 17% of the total volume traded in the securities market in 2005 to 2012.

will issue new shares to their holders and collect extra capital. Derivative warrants are structured products, issued by a third party, generally an investment bank, independent of issuer of the underlying asset. Both call and put derivative warrants exist. The underlying assets can be a single security or a basket of securities, stock indices, currencies, commodities or futures contracts. When a call derivative warrant on a single stock is exercised, no new shares of the underlying company will be issued. Almost all derivative warrants currently traded in Hong Kong are European style and cash-settled. The issuers of derivative warrants include several major U.S., European and Australian banks, such as Goldman Sachs, Citigroup, J.P. Morgan, Lehman Brothers, Société Générale, KBC, Deutsche Bank, BNP Paribas, and Macquarie Bank etc. Each underlying asset may have multiple issuers who compete with each other to offer popular contract specifications, lower prices and better liquidity.

It is important to note that derivative warrants are not secured on any of issuers' or their guarantors' assets or collateral. Derivative warrants represent issuers' or guarantors' general contractual obligations and rank equally with other general unsecured obligations of issuers or guarantors. Thus, derivative warrants are subject to the credit risk of issuers or guarantors. One important case regarding the counterparty credit risk of the derivative warrant issuer is the collapse of Lehman Brothers. Lehman Brothers had 134 derivative warrants outstanding when filed for bankruptcy on 15 September 2008. All these derivative warrants were suspended from trading since then. The market value of Lehman Brothers warrants held by investors at the market close before the suspension was HKD 21.7 million.

The index options in Hong Kong are of European style and settled by cash, while the stock options are of American style with physical delivery of the underlying assets upon exercise. The contract specifications of the options are set by the exchange. To trade on the option market in Hong Kong, a client can either open a cash account or a margin account with a broker registered at the HKEx. Where a client maintains a cash account with the broker, the client can carry long option positions only and is not subject to paying margins. Where a client maintains a margin account with the broker, the client will be required to pay margin on both long and short positions based on the Standard Portfolio Analysis of Risk (SPAN) margin methodology. SPAN is a risk-based, portfolio approach for calculating the daily margin requirement which has been developed by the Chicago Mercantile Exchange. It constructs scenarios of futures price movements and volatility changes to evaluates what the entire portfolio might lose in the following trading day, and computes the margin requirement to cover that risk.

3. Data Description

We focus on derivative warrants and options written on the Hang Seng Index (HSI) in this paper. A comparison between derivative warrants and options on the index is clean, as they are both of European style and cash settled. The HSI is the benchmark index in the Hong Kong stock market, and the derivatives written on it are the most liquid ones. For the rest of the paper, we will refer to derivative warrants on the HSI as just warrants because the underlying is an index and there is no confusion.

The data on warrants and options on the HSI are obtained from the HKEx. The warrants data include daily closing bid and ask prices, trading share volume, dollar volume, and other contract specifications such as maturity and strike price. The options data include intraday bid and ask quotes, daily trading volume, maturity and strike price of the options. The options market is closed at 4:15 PM, and the warrants market is closed at 4:00 PM. We select the intraday bid and ask quotes of options that are the closest to 4:00 PM, and match them with the closing prices of warrants. We use a sample of warrants and options matched with the same maturity and strike price so that the prices of warrants and options can be compared.[4] The closing HSI level is from Yahoo! Finance.

[4]Warrant issuers can choose the specifications of warrants to issue. However, they tend to issue

To measure the credit risk of warrant issuers, we use the senior 5-year CDS spreads provided by CMA. A CDS is a derivative security to insure against the risk of a default by a particular entity. The buyer of the CDS makes periodic payments, known as the CDS spreads, to the seller until the end of the life the of CDS or until the default of the entity, in which the buyer has the right to sell the bond issued by the entity for their face value to the seller. The CDS spread is approximately equal to the excess of the par yield on the bond over the par yield on the risk-free bond with the same maturity. Thus, a higher CDS spread indicates a higher credit risk of the warrant issuer. The end-of-day average closing bid and ask quotes of CDS spreads are downloaded from Datastream and Bloomberg. To account for the time difference between the CDS data and Hong Kong data, the warrants and options prices are matched one-day lag CDS spreads. The sample period is from January 1, 2005 to December 31, 2012.

3.1. Warrants Issuers

Table 1 reports the names of issuers and the number of warrants issued in the sample period. European banks, including Société Générale, KBC, Deutsche Bank, and BNP Paribas, are the most active issuers. Some American and Australian banks, such as Goldman Sachs and Macquarie Bank, are also important issuers in the warrants market. The numbers of call warrants and of put warrants are roughly the same. Issuers tend to issue calls and puts with the same strike price and maturity for hedging purpose. In our sample, there are 3312 different warrants and 175007 warrant-day observations matched with options.[5]

Table 1 here

warrants with the same specifications as available options. About 28% HSI warrants cannot be matched with options of the same maturity and strike price, and they are excluded from our sample.

[5]Lehman Brothers issued 4 call warrants and 4 put warrants on the HSI in the sample period, but none of them can be matched with options because they have different strike prices from options.

Figure 1 shows the time-series plots of the minimum, median, and maximum of the distribution of the CDS spreads in percentage point of warrants issuers. The CDS spreads are low and stable from 2005 to the first half of 2007, and there is a very little dispersion of CDS spreads across different issuers. Since the second half of 2007, the CDS spreads have started to go up, and stay high in the remaining sample period. The cross-sectional differences in the CDS spreads are also large in the second half of the sample period. The first pike in the time series corresponds to the collapse of Bear Stearns in early 2008. The CDS spreads increase to the highest level around the bankruptcy of Lehman Brothers in September 2008. After a relative quite period from late 2009 to early 2011, the CDS spreads go up again in the second half of 2011 amid the European sovereign debt crisis.

Figure 1 here

The time-series mean and standard deviation of the CDS spreads for each individual issuer are tabulated in Table 2. Some American and Australia banks, such as Morgan Stanley, Macquarie Bank, Merrill Lynch, and Citigroup, are among the banks with the highest CDS spreads during the sample period. The volatility of CDS spreads tends to increase with the level of CDS spreads. HSBC and Rabobank have the lowest CDS spreads. We further divide the sample period into two subperiods by the month when the Lehman Brothers declared the bankruptcy. On average, the level and volatility of CDS spreads in the second subperiod are about 5 and 2 times as high as those in the first subperiod, respectively. The U.S. banks tend to have a higher credit risk than European banks do in the second subperiod.

Table 2 here

3.2. Summary Statistics

We denote the value of the HSI on day t as $H(t)$ and the strike price of a warrant or an option as K. Let $p_w^b(i,t,\kappa,m)$ and $p_w^a(i,t,\kappa,m)$ be the closing bid and ask prices, respectively, of a warrant (either a call or a put) on day t with moneyness, $\kappa = 1 - K/H(t)$ for a call and $\kappa = K/H(t) - 1$ for a put, maturity, m, measured by the number of days, and issued by issuer i. Similarly, let $p_o^b(t,\kappa,m)$ and $p_o^a(t,\kappa,m)$ be the closing bid and ask prices, respectively, of the option (either a call or a put) on day t with moneyness, κ, and maturity, m. For each day t, warrants with the same (κ, m) issued by different issuers are matched with the same option. For simplicity, the dependence of κ on t is suppressed unless it is necessary.

The moneyness, κ, and maturity, m, for the matched pairs of warrants and options are shown in the first two rows of Table 3. The numbers reported are the time-series averages of the percentiles of the cross-sectional distribution for each day. If less than ten pairs of matched warrants and options or less than two issuers in a day are available, we regard the day as a missing day. The sample of warrants and options are near-the-money with the moneyness of majority between $\pm 15\%$. A typical maturity of warrants when issued is 6-month, although issuers are allowed to issue warrants with maturity up to 5-year. The bid-ask average price of warrants, $\bar{P}_w = 100(p_w^a + p_w^b)/2H$, and of options, $\bar{P}_o = 100(p_o^a + p_o^b)/2H$, are reported in next two rows in Table 3. The reason for normalizing by H is to make the price data comparable across time. Defined this way, the prices of warrants or options are expressed in terms of the percentage of the HSI level. The results suggest that prices of warrants are generally higher than those of options. The next row reports the distribution of the price difference between warrants and options, $D_{\bar{P}} = \bar{P}_w - \bar{P}_o$. The results show a large cross-sectional variation in $D_{\bar{P}} = \bar{P}_w - \bar{P}_o$. Although for the majority of warrant-option pairs, the prices of warrants are higher, quite some warrants are traded at lower prices than options are. Li and Zhang (2011) attribute the price difference between warrants and options to the liquidity premium of warrants over options. In this paper, we focus on explaining the cross-sectional variation in the prices of warrants rather than the price difference between warrants and options as two groups. The CDS spread, C, is reported on the next row. The CDS spreads are about 1% on average and slightly skewed to the right. The next a few rows report the summary statistics of liquidity variables, including the normalized trading volume, $V_w = \tilde{V}_w/1000H$ and $V_o = \tilde{V}_o/1000H$, where $\tilde{V}_w$ and $\tilde{V}_o$ are the daily dollar trading volume for warrants and options, respectively, the difference in the transformed trading volume, $D_V = \log(\tilde{V}_w/H+1) - \log(\tilde{V}_o/H+1)$, the bid-ask spreads, $\bar{P}_w = 100(p_w^a - p_w^b)/H$ and $\bar{P}_o = 100(p_o^a - p_o^b)/H$, and the difference in the bid-ask spreads of warrants and options, $D_S = S_w - S_o$. The reason to define a transformed trading volume is that V is skewed to the right as shown here. The difference in the transformed trading volume is used in the regression analysis that follows. The results show that warrants have higher volumes and lower bid-ask spreads than options have, suggesting the better liquidity of warrants than options.

Table 3 here

4. Empirical Analysis

4.1. Counterparty Credit Risk and the Price Difference Between Warrants and Options

In section, we use regression analysis to examine the effects of counterparty credit risk of warrant issuers on the prices of warrants they issue. The regression model is given as

$$D_P = \beta_0 + \beta_1 C + \beta_2 D_V + \beta_3 D_S + \varepsilon, \tag{1}$$

where D_P is the price difference between matched warrants and options, and C is the CDS spread, which measures the counterparty credit risk of warrant issuers. If the counterparty credit risk is priced in warrants, the coefficient on C is negative. We include, D_V and D_S, the differences in the transformed trading volume and the bid-ask spread between warrants and options, respectively, in the specification to control for the liquidity premium of warrants over options. The regressions are run for each day, the coefficient estimates are averaged across days, and the t-statistics are adjusted for 30-day lags of autocorrelation using the Newey-West (1987) procedure.

The results for the entire sample period are shown in the Panel A of Table 4. C is negatively related to D_P, however, the relation is not statistically significant. Since the market conditions in the first and the second half of the sample period are significantly different, the counterparty credit risk may be priced differently in these two periods. We report the results for the two subperiods, January 2005 to August 2008, and September 2008 to December 2012, in Panel B and C of Table 4, separately. The results suggest that in the first subperiod when the credit quality of warrants issuing banks is generally good, the credit risk is not a major concern of warrant investors. The small cross-sectional variation of the CDS spreads among issuers also contributes to the failure to identify the effects of credit risk accurately. Only in the second subperiod, is the counterparty credit risk of the warrant issuers priced. In this period, the level and the dispersion of the credit risk of the issuers are both high, and the credit risk becomes an important factor in determining warrants prices. The results are little changed when the liquidity differences between warrants and options are controlled for. Coefficients on liquidity variables also have the expected signs, positive on D_V and negative on D_S, consistent with the results reported in Li and Zhang (2011).

Table 4 here

Given that the average value of $\bar{P}_w$ is about 6.37 in the second subperiod, the coefficient on C in the univariate regression, -0.1212, indicates that on average, a one percentage point increase in the CDS spread of a warrant issuer leads to a 1.9 percent decrease in the value of the warrant. To understand the magnitude of the estimate, we compare it with what theoretical models predict. Under the assumption that the credit risk of the option writer and the value of the underlying asset of the option are independent, Hull and White (1995) show that

$$P^* = Pe^{-(y^*-y)T} \tag{2}$$

where P^* is the value of the option sold by the writer with maturity in T-year, P is the value of the same option without credit risk, y^* is the yield on a zero-coupon bond with maturity T and with the same seniority as the option written, and y is the yield on a risk-free zero-coupon bond with maturity T. Given that the average time-to-maturity of the warrants in our sample is about 1/4 year, i.e., $T = 1/4$, and if C is a good approximation of y^*-y, according to Hull and White (1995), one percentage point increase in C translates into a 1/4 percent decline in the value of the warrant. Our estimate is about 8 times as large as what the model predicts

Our results are also in contrast to those reported in Arora, Gandhi and Longstaff (2012) for the CDS market. They find that a 645 basis points increase in the credit spread of a CDS dealer only translates into a one basis point decline in the dealers spread for selling credit protection. They argue that such a small effect of the counterparty credit risk is due to the credit risk mitigation mechanism, such as collateral and netting, in the OTC market. In our case, the warrant issuers are not required to put up any collateral, and as a result, the strong effects of counterparty credit risk on the pricing of warrants are identified.

4.2. Which Warrants are More Affected by the Counterparty Credit Risk

When the value of the underlying asset of a warrant is positively (negatively) related to the counterparty credit risk of the warrant issuer, the counterparty credit risk is expected to be more important for call (put) warrant. This is so because when such a warrant has the highest value, the warrant issuer is mostly like to default on the obligation from issuing the warrant. In this subsection, we empirically examine which types of warrants are more affected by the counterparty credit risk.

We first examine the correlation between the monthly changes in CDS spreads of warrant issuers and the contemporaneous monthly return on the HSI, the underlying asset of the warrants. The correlation is calculated at monthly frequency rather than at higher frequency to reduce the effects from the non-synchronicity of the CDS and the HSI data and possible stale quotes of CDS spreads in early period of the sample. The results in Table 5 show that for all issuers, their CDS spreads are highly and negatively correlated with the HSI. The magnitudes of the correlations are higher for some Asian banks, such as Bank of China, Daiwa, and Nomura. The CDS spreads of HSBC and Standard Chartered Bank are also strongly correlated with the HSI because of their important roles in the financial market in Hong Kong. We also calculate the correlations between CDS spreads and the HSI for the two subperiods. The results show that the correlations are about the same for these two subperiods. Overall, the results suggest a strong, stable, and negative relation between the credit risk of warrant issuers and the return on the HSI.

Table 5 here

The negative correlation between the credit risk of warrant issuers and the HSI indicates that the prices of put warrants are expected to be more sensitive to the CDS spreads. This is especially the case for in-the-money put warrants because investors will suffer a large amount of loss from in-the-money put warrants upon the bankruptcy of warrant issuers. We empirically test whether in-the-money put warrants are affected by the counterparty credit risk of warrant issuers by running the following regression,

$$D_P = \beta_0 + \beta_1 C + \beta_2 D_V + \beta_3 D_S + \beta_4 I + \beta_5 I \times C + \varepsilon, \tag{3}$$

where D_P is the price difference between matched warrants and options, C is the CDS spread, D_V and D_S, are the differences in the transformed trading volume and the bid-ask spread between warrants and options, respectively, and I is the indicator for an in-the-money put. The sign on the interaction term, $I \times C$, is negative if the in-the-money put is more sensitive to the counterparty credit risk.

Similar to (1), the regressions are run for each day. To avoid the multicollinearity problem in the cross-sectional regressions, we remove the days without the in-the-money put observations, which account for about 10% of days in our sample. Table 6 reports the coefficient estimates averaged across days, and the t-statistics adjusted for 30-day lags of autocorrelation using the Newey-West (1987) procedure in the parentheses. For the entire sample period, C has a negative sign, and the magnitude is greater than that reported in Table 4. The difference is due to a large decrease in the coefficient estimation for C in the first subperiod. However, the coefficient is still not statistically significant. The coefficient is estimated with large errors because of the small cross-sectional variation in C in this subperiod. In the second subperiod, the coefficient on C has a similar magnitude to that reported in Table 4. Both D_V and D_S have the expected signs, accounting for the liquidity premium of warrants over options. The coefficient on I is positive, suggesting that other thing being equal, the price differences between the in-the-money put warrants and options tend to be higher than other types of warrants and options. However, I is not statistically significant for the first subperiod. The coefficient on $I \times C$ is negative, but only statistically significant in the second subperiod. The results indicate that in-the-money put warrants are more sensitive to the credit risk of issuers in the second subperiod.

Table 6 here

4.3. Robustness Checks

In this subsection, we conduct some robustness checks of the main results. We focus on the second subperiod because the effects of the counterparty credit risk on the prices of warrants cannot be estimated accurately due to the small cross-sectional variation of C in the first subperiod.

Newly issued warrants typically have a maturity of 6 months, so the spread of a short maturity CDS may be a better measure of the counterparty credit risk of warrant issuers than the commonly used 5-year CDS spread does. In the first robustness check, we use the 1-year CDS spreads as C in the regression specification. There is an evidence that the term structure of the CDS spreads vary a lot across time. In the periods of crisis, the term structure of the CDS spreads is usually downward sloping with the longer maturity CDS spreads being lower than shorter maturity ones, whereas in the quite periods, the term structure of the CDS spreads tends to be upward sloping. The results for the same regression as (3) are reported in the Panel A of Table 7. Note that for the regression specification with terms I and $I \times C$, the days without the in-the-money put observations are removed. The magnitudes and statistical significance of the coefficient estimates on C and $I \times C$ are greater than those reported in Table 4 and Table 6, suggesting that the 1-year CDS spreads measure the counterparty credit risk faced by warrant investors better than the 5-year ones do.

Table 7 here

The results reported earlier are based on the closing bid and ask quotes of warrants and options. In the second robustness check, we redo the analysis using a subset of the original sample by requiring both warrants and options pairs with positive trading volume. In do so, we remove those extreme illiquid warrant and option observations, and lessen the concern of possible stale quotes, which do not represent the actual prices. About 60% of the warrants and options pairs are removed in this sample. The results reported in the Panel B of Table 7 are essentially the same as those in Table 4 and Table 6. The magnitudes of coefficients estimates on C and $I \times C$ are slightly smaller, however. Overall, the results suggest a robust effect of the counterparty credit risk on the warrants pricing, and the effect is stronger for in-the-money put warrants.

5. Conclusion

In this paper, we examine whether the counterparty credit risk is priced in options. We conduct the analysis using the derivative warrant and option data in the Hong Kong market from 2005 to 2012. The derivative warrants are option-like structured products issued by financial institutions, including some major U.S., European and Australia banks. The derivative warrants are subject to the counterparty credit risk of the issuing banks, and the exchange traded options are not affected by the credit risk due to margin requirements. We examine the cross-sectional relation between the counterparty credit risk of warrant issuers, measured by their CDS spreads, and the price differences of matched derivative warrant and option pairs on the HSI. We find that the CDS spreads are strongly and negatively related to the price differences only after the global financial crisis since fall 2008. During this period, the level and the cross-sectional variation of the CDS spreads of warrant issuers are much greater than those before. The magnitude is economically significant. On average, a one percentage point increase in the CDS spread of a warrant issuer leads to a 1.9 percent decrease in the warrant price. The results also indicate that the changes in the CDS spreads of warrant issuers are all negatively correlated with the HSI, and in-the-money put warrants are more sensitive to the counterparty credit risk of warrant issuers. This is so because in-the-money put warrants tend to have the highest value when the credit risk of the warrant issuers is the highest.

The use of the derivative warrants data in this study provides a fresh perspective to the understanding of the counterparty credit risk on derivatives pricing. The derivative warrants are exchange traded, and not subject to the credit mitigation mechanism, such as collateral and netting, required in the OTC market. The counterparty credit risk related to the derivative warrants is always on the issuers' side, different from forward-type of derivatives, for which the counterparty credit risk exists on both sides of the transaction. These features make the credit risk of derivative warrants easily identified. The results of the paper highlight the importance of the counterparty credit risk on the pricing of derivative securities.

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Table 1
Summary Statistics of Derivative Warrants Issuers
This table reports the names of warrant issuers and the numbers of derivative warrants on the Hang Seng Index issued by each issuer. The second to the fifth columns are, respectively, the numbers of call, put, all derivative warrants, and the proportion of derivative warrants out of the entire sample, issued by each issuer. The last column is the number of daily observations. The sample period is January 2005 to December 2012.

Issuer	Call	Put	Total	Prop (%)	Obs
ABN AMRO	22	25	47	1.42	1753
Barclays	51	38	89	2.69	5029
Bank of China	19	16	35	1.06	2348
BNP Paribas	142	146	288	8.70	16111
Credit Suisse	52	44	96	2.90	4362
Citigroup	10	10	20	0.60	1241
Deutsche Bank	206	207	413	12.47	19762
Daiwa	26	25	51	1.54	2573
Goldman Sachs	116	133	249	7.52	12197
HSBC	96	81	177	5.34	12134
JP Morgan	24	20	44	1.33	2293
KBC	228	231	459	13.86	26469
Macquarie Bank	138	127	265	8.00	16398
Merrill Lynch	66	62	128	3.86	6574
Morgan Stanley	9	16	25	0.75	998
Nomura	20	12	32	0.97	1938
Rabobank	39	32	71	2.14	4247
Royal Bank of Scotland	31	32	63	1.90	2450
Standard Chartered Bank	16	16	32	0.97	2008
Societe Generale	296	269	565	17.06	29551
UBS	86	77	163	4.92	4571
All	1693	1619	3312	100.00	175007

Table 2
Summary Statistics of CDS Spreads
This table reports the mean and the standard deviation (std) of the CDS spreads in percentage point of each derivative warrant issuer. The summary statistics are reported for the entire sample period, January 2005 to December 2012, and for two subperiods, January 2005 to August 2008 and September 2008 to December 2012.

	Jan 05 - Dec 12		Jan 05 - Aug 08		Sep 08 - Dec 12	
Issuer	mean	std	mean	std	mean	std
ABN AMRO	0.8671	0.7012	0.2640	0.3269	1.3763	0.5001
Barclays	0.9469	0.7489	0.2845	0.3581	1.5063	0.4926
Bank of China	1.1762	0.9266	0.4412	0.3932	1.7968	0.7821
BNP Paribas	0.8067	0.7940	0.1960	0.2100	1.3224	0.7380
Credit Suisse	0.8123	0.5838	0.3216	0.3154	1.2266	0.4118
Citigroup	1.3954	1.2249	0.3937	0.4776	2.2411	1.0059
Deutsche Bank	0.8292	0.6104	0.2916	0.2726	1.2831	0.4176
Daiwa	1.2574	1.1439	0.2943	0.2307	2.0706	0.9610
Goldman Sachs	1.2978	1.0144	0.4865	0.4108	1.9828	0.8545
HSBC	0.6353	0.4744	0.2237	0.2527	0.9829	0.3118
JP Morgan	0.7419	0.4668	0.3712	0.2922	1.0550	0.3401
KBC	1.3675	1.2072	0.3002	0.3362	2.2687	0.9044
Macquarie Bank	1.6106	1.5148	0.5335	0.7027	2.5200	1.4173
Merrill Lynch	1.5629	1.2310	0.6775	0.7828	2.3105	1.0281
Morgan Stanley	1.7047	1.5075	0.5981	0.6125	2.6391	1.4027
Nomura	1.3616	1.2835	0.2837	0.2670	2.2717	1.0810
Rabobank	0.6001	0.4810	0.1668	0.1973	0.9660	0.3185
Royal Bank of Scotland	1.0453	0.9573	0.2642	0.3299	1.7050	0.8048
Standard Chartered Bank	0.8384	0.6553	0.2787	0.2827	1.2640	0.5252
Societe Generale	1.0366	1.0206	0.2406	0.2856	1.7086	0.9303
UBS	0.9080	0.7475	0.2851	0.3925	1.4339	0.5442
Average	1.0858	0.9188	0.3427	0.3681	1.7110	0.7510

Table 3
Summary Statistics of Prices of Derivative Warrants and Options, CDS Spreads, and Liquidity Variables
This table reports the 5th, 25th, 50th, 75th, and 95th percentiles of the cross-sectional distributions of prices of derivative warrants and options, CDS spreads, and liquidity variables. Subscripts w and o stand for derivative warrants and options, respectively. The variables include moneyness, κ, maturity in days, m, the bid-ask average, $\bar{P} = 100(p^a + p^b)/2H$, where H is the Hang Seng Index level, and p^a and p^b are the closing ask and bid prices, the bid-ask spread, $S = 100(p^a - p^b)/H$, the normalized daily dollar trading volume, $V = \tilde{V}/1000H$, where $\tilde{V}$ is the daily dollar trading volume, the difference in the prices of derivative warrants and options, $D_{\bar{P}} = \bar{P}_w - \bar{P}_o$, the difference in the transformed daily dollar volume of derivative warrants and options, $D_V = \log(\tilde{V}_w/H + 1) - \log(\tilde{V}_o/H + 1)$, the difference in the bid-ask spreads of derivative warrants and options, $D_S = S_w - S_o$, and the CDS spread, C. The numbers reported are the time-series averages of the daily percentiles. The sample period is January 2005 to December 2012.

	P5	P25	P50	P75	P95
κ	-0.1636	-0.0875	-0.0220	0.0501	0.1407
m	27.39	55.05	86.70	137.75	178.42
$\bar{P}_w$	0.8532	2.4265	5.2219	9.0529	15.7133
$\bar{P}_o$	0.5806	1.9114	4.4715	8.2875	15.0787
$D_{\bar{P}}$	-0.1961	0.1959	0.5017	0.9523	1.7944
C	0.5804	0.7175	0.9616	1.2404	1.6482
V_w	0.0001	0.0010	0.0134	0.1693	4.0557
V_o	0.0000	0.0003	0.0057	0.0497	0.4237
D_V	-3.7992	-1.0992	0.2906	2.1414	6.6299
S_w	0.0389	0.0663	0.1515	0.3750	1.5414
S_o	0.0531	0.1197	0.2214	0.4034	0.7095
D_S	-0.5873	-0.2330	-0.0364	0.1791	1.2900

Table 4
Counterparty Credit Risk and the Price Difference Between Derivative Warrants and Options
This table reports the coefficient estimates of the following regression,

$$D_P = \beta_0 + \beta_1 C + \beta_2 D_V + \beta_3 D_S + \varepsilon,$$

where D_P is the price difference between matched derivative warrants and options, C is the CDS spread, and D_V and D_S are the differences in the transformed trading volume and the bid-ask spread of derivative warrants and options, respectively. The regressions are run for each day, and the coefficient estimates reported are averaged across days. The t-statistics in parentheses are adjusted for 30-day lags of autocorrelation using the Newey-West procedure. The $\bar{R}^2$ is the average of the R^2s across days. Panel A is for the entire sample period, January 2005 to December 2012, Panel B is for January 2005 to August 2008, and Panel C is for September 2008 to December 2012.

A. Jan 05 - Dec 12				
Const	C	D_V	D_S	$\bar{R}^2$
0.6733	-0.0540			0.0355
(12.5)	(-0.6)			
0.6238	-0.0689	0.0122	-0.3093	0.2003
(11.8)	(-0.7)	(3.5)	(-8.9)	
B. Jan 05 - Aug 08				
Const	C	D_V	D_S	$\bar{R}^2$
0.4718	0.0258			0.0332
(7.8)	(0.1)			
0.4190	-0.0083	0.0080	-0.3037	0.1834
(7.4)	(-0.0)	(1.9)	(-5.1)	
C. Sep 08 - Dec 12				
Const	C	D_V	D_S	$\bar{R}^2$
0.8428	-0.1212			0.0374
(11.5)	(-2.8)			
0.7961	-0.1199	0.0158	-0.3140	0.2146
(11.0)	(-3.0)	(3.1)	(-8.0)	

Table 5
Correlations Between Changes in CDS Spreads and the Hang Seng Index Returns

This table reports the correlations between monthly changes in CDS spreads and monthly returns on the Hang Seng Index for each derivative warrant issuer. The summary statistics are reported for the entire sample period, January 2005 to December 2012, and for two subperiods, January 2005 to August 2008 and September 2008 to December 2012.

Issuer	Jan 05 - Dec 12	Jan 05 - Aug 08	Sep 08 - Dec 12
ABN AMRO	-0.3165	-0.4133	-0.3010
Barclays	-0.2746	-0.4724	-0.2536
Bank of China	-0.7711	-0.6352	-0.8357
BNP Paribas	-0.4670	-0.5732	-0.4637
Credit Suisse	-0.4677	-0.4081	-0.4961
Citigroup	-0.4505	-0.3617	-0.5014
Deutsche Bank	-0.4091	-0.5057	-0.3947
Daiwa	-0.5899	-0.5572	-0.6320
Goldman Sachs	-0.4839	-0.4518	-0.5204
HSBC	-0.5824	-0.4837	-0.6265
JP Morgan	-0.5503	-0.5167	-0.5770
KBC	-0.3483	-0.1686	-0.4077
Macquarie Bank	-0.4007	-0.5037	-0.4110
Merrill Lynch	-0.4223	-0.5148	-0.4270
Morgan Stanley	-0.2319	-0.3714	-0.2462
Nomura	-0.5845	-0.5975	-0.6261
Rabobank	-0.4101	-0.4835	-0.4024
Royal Bank of Scotland	-0.3421	-0.4350	-0.3308
Standard Chartered Bank	-0.5927	-0.4411	-0.6534
Societe Generale	-0.4641	-0.5800	-0.4626
UBS	-0.3366	-0.4127	-0.3285
Average	-0.4522	-0.4708	-0.4713

Table 6
Counterparty Credit Risk and the Pricing of In-the-Money Put Derivative Warrants
This table reports the coefficient estimates of the following regression,

$$D_P = \beta_0 + \beta_1 C + \beta_2 D_V + \beta_3 D_S + \beta_4 I + \beta_5 I \times C + \varepsilon,$$

where D_P is the price difference between matched derivative warrants and options, C is the CDS spread, D_V and D_S are the differences in the transformed trading volume and the bid-ask spread of derivative warrants and options, respectively, and I is the indicator of in-the-money put. The regressions are run for each day, and the coefficient estimates reported are averaged across days. The t-statistics in parentheses are adjusted for 30-day lags of autocorrelation using the Newey-West procedure. The $\bar{R}^2$ is the average of the R^2s across days. Panel A is for the entire sample period, January 2005 to December 2012, Panel B is for January 2005 to August 2008, and Panel C is for September 2008 to December 2012.

A. Jan 05 - Dec 12						
Const	C	D_V	D_S	I	$I \times C$	$\bar{R}^2$
0.7271	-0.1616					0.0352
(12.9)	(-1.8)					
0.6736	-0.1700	0.0139	-0.3362			0.2013
(12.1)	(-2.0)	(3.8)	(-9.4)			
0.6544	-0.0940	0.0181	-0.3272	0.2119	-0.2459	0.2548
(11.6)	(-1.2)	(4.2)	(-8.3)	(2.6)	(-1.7)	
B. Jan 05 - Aug 08						
Const	C	D_V	D_S	I	$I \times C$	$\bar{R}^2$
0.5461	-0.2195					0.0310
(7.9)	(-1.0)					
0.4855	-0.2440	0.0113	-0.3577			0.1785
(7.4)	(-1.2)	(2.5)	(-5.4)			
0.4503	-0.0649	0.0134	-0.3598	0.1228	-0.2984	0.2396
(6.0)	(-0.3)	(2.6)	(-4.9)	(1.1)	(-0.9)	
C. Sep 08 - Dec 12						
Const	C	D_V	D_S	I	$I \times C$	$\bar{R}^2$
0.8467	-0.1234					0.0379
(11.4)	(-2.8)					
0.7978	-0.1211	0.0157	-0.3220			0.2163
(10.8)	(-3.0)	(3.0)	(-8.1)			
0.7891	-0.1133	0.0212	-0.3056	0.2708	-0.2112	0.2648
(11.2)	(-2.8)	(3.4)	(-7.1)	(2.4)	(-3.2)	

Table 7
Robustness Checks on the Effects of Counterparty Credit Risk on the Price Difference Between Derivative Warrants and Options
This table reports the coefficient estimates of the following regression,

$$D_P = \beta_0 + \beta_1 C + \beta_2 D_V + \beta_3 D_S + \beta_4 I + \beta_5 I \times C + \varepsilon,$$

where D_P is the price difference between matched derivative warrants and options, C is the CDS spread, D_V and D_S are the differences in the transformed trading volume and the bid-ask spread of derivative warrants and options, respectively, and I is the indicator of in-the-money put. The regressions are run for each day, and the coefficient estimates reported are averaged across days. The t-statistics in parentheses are adjusted for 30-day lags of autocorrelation using the Newey-West procedure. The $\bar{R}^2$ is the average of the R^2s across days. The sample period is September 2008 to December 2012. In Panel A, C is 1-year CDS spreads, and Panel B is for sample of derivative warrants and options with positive trading volumes.

A. 1-Year CDS Spreads						
Const	C	D_V	D_S	I	$I \times C$	$\bar{R}^2$
0.8089	-0.1496					0.0410
(13.2)	(-3.3)					
0.7651	-0.1495	0.0158	-0.3128			0.2171
(12.5)	(-3.6)	(3.1)	(-8.0)			
0.7589	-0.1498	0.0198	-0.3051	0.2585	-0.2430	0.2650
(13.0)	(-3.5)	(3.5)	(-7.3)	(2.9)	(-3.8)	
B. Derivative Warrants and Options with Positive Volumes						
Const	C	D_V	D_S	I	$I \times C$	$\bar{R}^2$
0.6374	-0.0983					0.0507
(12.3)	(-3.6)					
0.5958	-0.0914	0.0189	-0.4876			0.3034
(11.9)	(-3.1)	(5.7)	(-10.4)			
0.5872	-0.0895	0.0199	-0.4704	0.2135	-0.1685	0.3538
(12.1)	(-3.2)	(7.2)	(-9.9)	(3.0)	(-3.8)	

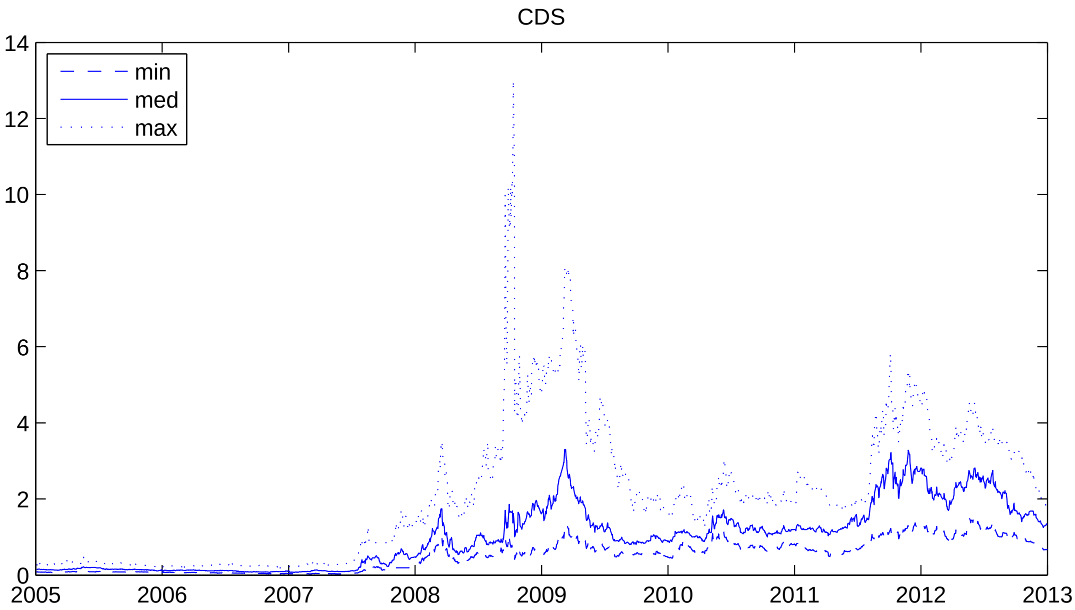

Figure 1. CDS Spreads

This figure shows the time-series plots of the minimum, median and maximum of the cross-sectional distribution of the CDS spreads in percentage point of derivative warrant issuers from January 2005 to December 2012.