Investor Behavior and Financial Innovation: A Study of Callable Bull / Bear Contracts*

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Investor Behavior and Financial Innovation: A Case Study on Callable Bull/Bear Contracts

Abstract

This paper draws on behavioral finance to propose a new explanation for financial innovations. We propose that such innovations might be successful because they cater to investors' behavioral biases. Specifically, we consider the popularity of knockout barrier options termed callable bull/bear contracts (CBBCs). Our analysis of prices and trading activity indicates that investors treat CBBCs in a manner similar to lottery tickets in that they prefer CBBCs with low prices, high volatilities, and high levels of positive skewness. We find that based on conservative estimates, during the year 2012, investors lost 1.39 billion HKD in trading CBBCs written on the Hang Seng Index. Our findings are consistent with the hypothesis that financial intermediaries cater to investors' preference by engineering products that meet investors' needs, but might generate negative investment returns. In particular, our analysis highlights the importance of cumulative prospect theory in financial innovation.

Keywords: Lotteries; Gambling; Financial Innovation; Cumulative Prospect Theory; Callable Bull/Bear Contract (CBBC); Turbo Warrant

JEL Classification: D03, D81, G02, G12, G23

> *"...investors are not fully rational... This opens up the possibility, however, for rational investors to take advantage of arbitrage opportunities created by the misperceptions of irrational investors."*
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> — Economic Sciences Nobel Prize Committee (2013)

1 Introduction

Behavioral finance literature has grown by leaps and bounds in recent years. In this paper, we consider the underexplored role of behavioral finance in financial engineering, and propose that new financial products might be structured in order to appeal to the behavioral biases of retail investors. More specifically, we analyze the popularity of Callable Bull / Bear Contracts (CBBCs), known as turbo warrants[1] in Europe. These derivatives are a type of structured product with a call price and a mandatory call feature. Essentially, a CBBC is a knockout barrier option; if the price of the underlying asset reaches the call price at any time prior to its maturity date, the CBBC is called back by its issuer, and trading of the CBBC is terminated immediately. If a callback does not occur, the payoff of a bull / bear contract at maturity is that of a vanilla European call / put option. Such CBBCs are extremely popular among investors in Europe and Hong Kong. In some European countries, the turnover value of turbo warrants constitutes more than 50% of all derivative trading (see Wong and Chan 2008 and RCD-HKEx 2009, Section 2). In Hong Kong, the market share of CBBCs in the turnover of HKEx's Main Board increased from 0.2% in 2006 to 11.6% in 2012. In fact, the corresponding turnover value increased more than 100 times from 11.34 billion HKD in 2006 to 1533.15 billion HKD in

[1] These contracts can be dated back to late 2001, when they first appeared in Germany.

2012. Moreover, in 2009 there were 8072 newly listed CBBCs, and their market share (10.9%) surpassed that of derivative warrants (10.7%).

The popularity of CBBCs is an intriguing stylized fact. In the spheres of practitioners and academia, different explanations prevail to account for this phenomenon. In the field, it has been claimed that some investors prefer CBBCs because they believe that CBBCs are much cheaper than their vanilla counterparts,[2] they are much less sensitive to volatility (Huang 2008, page 10), and because they can closely mimic price changes of the underlying asset (i.e., their Delta is close to one,) which offers investors higher price transparency (see HKEx 2006, page 1). Josen (2010) claims that "... although the CBBC appears to be cheaper and more transparent than normal warrants, they are in fact, rather complex. Investors may see their investment suddenly lost if the product is terminated upon the call event."[3] Lee (2011) attributes the popularity of CBBCs to the stagnancy and unpredictability of the stock market. Tsoi (2012), a global equity flow strategist at Societe Generale, opines that it is the high leverage of CBBCs that attracts investors.

Academic researchers disagree on whether CBBCs are sensitive to volatilities. For instance, Eriksson (2006) claims that a turbo warrant is not insensitive to changes in volatility. Wong and Chan (2008) extend the analysis of Eriksson (2006) to three more general models, and document that "whether CBBCs are sensitive to implied volatility or not" is actually model-dependent. Specifically, the statement,

[2] Since CBBCs are essentially barrier options, their vanilla counterparts are European options and derivative warrants with similar contractual terms.

[3] Similar viewpoints also appear in many CBBC investment guides. (HKEx, 2006, page 5) clearly notifies the potential investors that "When the underlying asset is trading close to the call price, the price of a CBBC may be quite volatile with wider spreads and uncertain liquidity". See also (Barclays, 2010, page 16) and (Credit Suisse, 2013, item 5.36); Credit Suisse (2013) is also used by UBS as its FAQs.

"implied volatility is insignificant to turbo warrant pricing", is only true under the Black-Scholes assumptions. In Wong and Lau (2008), the authors claim that "turbo warrants" are less sensitive to jump risks than a vanilla option, but jump risk nonetheless has a material effect on the pricing of turbo warrants. Recently, Liu and Zhang (2011) find a very interesting model-free property: newly issued CBBCs are almost equivalent to leveraged positions on their underlying asset in a low interest rate environment. Based on their analysis, the authors assert that the newly issued CBBCs are much less sensitive to volatility than warrants and regular European options, which, they argue, could explain the popularity of CBBCs after the recent financial crisis that they document.[4]

To date, there is no generally accepted framework that accounts for the popularity of CBBCs. We conjecture that the sparse literature is consistent with the notion that many financial phenomena are hard to understand using traditional finance theoretical frameworks that are based on the expected utility paradigm. We instead propose a behavioral explanation in this paper. We find that investors prefer to trade and hold CBBCs with the three characteristics of lottery-type securities found by Kumar (2009), i.e., low price, high volatility, and high positive skewness. Specifically, CBBCs near their call prices[5] are preferred by investors, because when the underlying price is close to their call levels, CBBCs have very low but volatile prices, and their payoffs are positively skewed. According to cumulative prospect

[4]It is relevant to note here that the trading volume of CBBCs on their issue dates is almost negligible.

[5]Throughout this paper, "a contract is near (or close to) its call level" means the underlying asset's day-end closing price is near (or close to) the call level stated in the contract. Similarly, "a contract's distance to call level" means the distance between the underlying asset's day-end closing price and the contract's call level.

theory, investors prefer such contracts, which provide them with a high potential payoff: if the contract eventually matures without being called back, the payoff is several times larger than the cost. That is, investors like such a large reward to cost ratio, even though the probability of a reward may be small. Thus, our evidence suggests that it is the investors' preference for lottery-type securities that drives the popularity of CBBCs, and that CBBC-type products are closely related to the behavioral finance idea of security issuance catering to investor demand.[6] Indeed, based on portfolio analyses, we find a negative relationship between skewness and average CBBC returns.

Investors' preference for lottery-type securities have been studied in many recent papers. Kumar (2009) shows that individual investors prefer stocks with lottery features. Bali, Cakici and Whitelaw (2011) find that both portfolio-level analyses and firm-level cross-sectional regressions indicate a negative and significant relation between the maximum daily return over the past one month and expected future stock returns. Green and Hwang (2012) find that initial public offerings with high expected skewness experience significantly greater first-day returns, but earn negative abnormal returns in the following one to five years. In addition to the negative correlation between skewness and returns found by Boyer, Mitton and Vorkink (2010), Conrad, Dittmar and Ghysels (2013) also find a negative (positive) relation between ex-ante volatility (kurtosis) and subsequent returns. Recently, Boyer and Vorkink (2013) find a strong and negative relationship between skewness and average option returns. All these empirical findings, including ours,

[6] Gennaioli, Shleifer and Vishny (2012) find that a market in which financial intermediaries cater to investors' preferences and beliefs by engineering securities perceived to be safe but exposed to neglected risks, could result in excessive security issuance.

are consistent with the theoretical prediction in Barberis and Huang (2008), who claim that securities with high skewness should earn low average returns, since investors with cumulative prospect theory (see Tversky and Kahneman 1992) utility tend to prefer opportunities with tiny probabilities of making large gains.

We find that, based on a conservative estimation, investors lost 1.39 billion HKD in trading CBBCs written on the Hang Seng Index during the year 2012.[7] Empirical findings also reveal that, other than investor preferences for lottery-type securities, the pricing formula (see (2.1)-(2.2) below) in CBBC prospectuses provided by HKEx as well as many issuers may be another reason for investors' big losses: investors follow the prospectus pricing formula closely and trade heavily near the call level, whereas (as we argue later) the price determined by the aforementioned prospectus pricing formula is positively biased. In fact, when CBBCs are close to their call levels, we show that the relative pricing error of the prospectus price over the estimate of the corresponding fair market value may be as high as hundreds of percentage points.

Our findings in this paper are consistent with the recent hypothesis that issuers may cater to investors' preferences by engineering products that, nonetheless, can generate negative investment returns (see, e.g., Bernard, Boyle and Gornall 2009 and Henderson and Pearson 2011).[8] From this point of view, CBBCs may not be as transparent as previously understood by investors. Issuers know that investors

[7] In our sample, more than three-quarters of CBBCs are called back by their issuers, so it is hard to believe that CBBCs are good hedging instruments. Several traders and retail investors working in Hong Kong also hold the opinion that CBBCs are speculative products rather than hedging instruments.

[8] For more information about debates on financial innovation, readers may refer to Frame and White (2004), Gabaix and Laibson (2006) and Carlin (2009).

like to trade CBBCs when they are very likely to be called back shortly and, more importantly, that investors tend to overprice these CBBCs. Thus issuers can issue CBBCs at prices higher than rational fundamental value and yet make profits. Overall, CBBC markets in Hong Kong allow us to highlight the joint effects of rational expectations and cumulative prospect theory in financial innovation.

The next section of the paper briefly introduces CBBCs and their market structure in Hong Kong. An empirical study on the trading behavior of CBBC investors is presented in Section 3. Lottery-like characteristics of CBBCs as well as portfolio returns are studied in this section. We also estimate how much investors lose by trading CBBCs. In Section 4, we discuss the implications of our findings and conclude the paper.

2 CBBC Market in Hong Kong

2.1 What are Callable Bull/Bear Contracts?

Callable Bull/Bear Contracts (CBBCs), first listed in Hong Kong Exchange and Clearing Limited (hereafter, HKEx) in June 2006, are a type of structured product that allow investors to track the performance of an underlying asset without paying the full price of the actual asset. They are listed either as "bull" or as "bear" contracts with a fixed maturity.

Essentially, CBBCs are knock-out barrier options. To characterize a CBBC, at least five ingredients need to be specified: an underlying asset, a strike price, a call price, a maturity date, and its entitlement ratio. Specifically, each bull/bear CBBC has a call price, which is equal to or above/below the strike price. If the price of the underlying asset reaches the call price at any time prior to its maturity date, the CBBC is called back by its issuer, trading of the CBBC is terminated immediately, and the contract matures in advance. Such an event is termed a Mandatory Call Event (hereafter, MCE). If a MCE does not occur, the payoff of a bull/bear contract at maturity is similar to that of a vanilla European call/put option with the settlement level being the same level for settling a contemporaneously expiring futures contract.[9] The entitlement ratio is the number of CBBCs needed to buy (or sell) one unit of the underlying asset, and represents the CBBC's exposure to the underlying asset; see (2.1)-(2.2) below.

According to the values received by the investors after a MCE, CBBCs are classified into two categories: Category R and Category N. A Category R CBBC has a call price that is different from its strike price, and its holder may receive a small amount of cash payment (called the residual value) when a MCE occurs. A category N CBBC has a call price that is equal to its strike price, and its holder will receive nothing if a MCE occurs. Most of the CBBCs in Hong Kong are Category R. In HKEx, the settlement price of residual value for a bull/bear contract is the minimum/maximum trading price of the underlying asset during the *settlement period*, which lasts from right after the MCE and up to and including the next trading session.[10] For this purpose, the pre-opening session and the morning session are considered as one trading session. In our study, the settlement price needs to

[9] In Hong Kong, the settlement price of futures is the arithmetic average of 5-minute quotes of the underlying on the last trading day.

[10] Unless the following session does not contain any continuous period of an hour during which trading in HSI is permitted on the Exchange, the MCE valuation period shall be extended to the subsequent trading session.

be imputed. For this purpose, we collect 1-min data on HSI from Bloomberg. The data includes opening price, highest price, lowest price, and closing price in each minute.[11]

Even though the MCE makes CBBCs look complicated, the theoretical issue price provided by many issuers as well as (HKEx, 2006, pages 3-4) is simple (The following content is standard and available in many CBBC manuals):

$$\begin{aligned} &\text{Theoretical Price of Bull Contract} \\ &\qquad = \frac{(\text{Spot Price} - \text{Strike Price}) + \text{Funding Cost}}{\text{Entitlement Ratio}}, \qquad (2.1) \\ &\text{Theoretical Price of Bear Contract} \\ &\qquad = \frac{(\text{Strike Price} - \text{Spot Price}) + \text{Funding Cost}}{\text{Entitlement Ratio}}, \qquad (2.2) \end{aligned}$$

where Funding Cost $=$ Strike Price $\times$ Annual BorrowingRate $\times$ Tenor of CBBC. Funding costs, also called financial costs, are the fees which issuers charge investors to cover their marketing and financing costs. These costs are usually adjusted according to benchmark borrowing rates in the market. For instance, using the HIBOR as a reference, issuers may add a certain percentage on top of the rate to derive the funding costs.

It will shortly be clear that, although the above formulae (2.1)-(2.2), excluding the funding cost, are appropriate and useful for deciding the trading prices of CBBCs that are deep in the money (and thus far away from their call levels), they

[11] In 2012, there were 247 trading dates in total. There was no afternoon trading session on December 24 (Christmas Eve) and December 31 (New Year's Eve). The morning session on July 24 was canceled due to the typhoon Vicente. Parenthetically, after March 4, 2012, the afternoon session started 30 minutes earlier at 1:00 p.m.

are misleading, however, when CBBCs are close to their call levels.

2.2 The Structure of the CBBC Market in HKEx during 2012

We collect day-end closing data on CBBC from HKEx (the data on most recent year are publicly available). There were 6952 CBBCs listed on HKEx during 2012. We use data on CBBCs that are listed in HKEx on or after January 1, 2012, and delisted on or before December 31, 2012. After ignoring contracts with zero trading volumes, the final data set consists of 2943 issues. Table 1 reports data on the issuance activity of CBBCs by issuer. In 2012 there were 12 issuers who issued 2943 different CBBCs, among which 1383 issues, or 47% were bull contracts. Their total trading volume was more than 14.8 trillion, and the aggregate turnover value was HK$1,163,621 million. UBS AG and Credit Suisse AG were the two most active issuers. Their issues made up almost half of the total issues, and nearly two-thirds of the total trading volume. The Bank of East Asia only issued 3 CBBCs with negligible trading volume. Among those 2943 CBBCs, 2297 issues, or 78.1% were called back before their maturity dates.

Table 2 lists the stocks or indexes that formed the underlying assets for the CBBCs. There were 37 underlyings in total, of which Hang Seng Index (HSI) is the most common reference and accounted for 2184 issues, or roughly three-fourths of the total sample. Moreover, both the average trading volume per issue and the average turnover value per issue for CBBCs written on HSI were much higher than those for issues written on other underlyings. As a result, the trading volume of CBBCs written on HSI made up 14.62 trillion, or roughly 98.7% of the total volume! The corresponding turnover value accounted for more than 98% of the total! Kunlun Energy, Lenovo Group, Minsheng Bank, and Boc Hong Kong were the four least common references, and their market share was almost negligible. Based on the above observations, we concentrate on the CBBCs written on HSI in the remaining empirical analyses. Such an approach also helps us circumvent the cumbersome issues in dealing with different underlying assets.

Table 3 shows the first 30 most actively (in terms of trading volumes) traded CBBCs in our sample. Fourteen of them were issued by UBS, twelve by Credit Suisse, and the remaining four were issued by HSBC. Among those 30 contracts, 16 were bull, and two-thirds were called back by their respective issuers. The distance between strike level and call level was no less than 200, while only 4 issues' distances were strictly greater than 200, whose entitlement ratios were also strictly higher than those for the others. The contract 60146 had the highest trading volume, which was about 71 billion. The highest turnover value, 8.6 billion HKD, belonged to CBBC 69884.

3 Trading Behavior of CBBC Investors

To ascertain the key influences that drive the popularity of CBBCs in Hong Kong, in this section, we first report some pertinent stylized facts about the trading behavior of CBBC investors. Then we relate their activity to some recent theoretical developments in behavioral finance. At the end of this section, we demonstrate / examine how much investors lose by trading CBBCs.

3.1 What Kind of CBBCs Are Most Preferred?

Figure 1 shows the histograms of outstanding ratios[12] on all trading days for two CBBCs during their lifespan. Reported data also include the closing prices, the distances to call levels (re-scaled by their respective entitlement ratio[13]), and the 11-day ($T-5$ to $T+5$) CBBC return[14] volatility (annualized) on each trading day. Both contracts are bull ones; CBBC 60172 is called back before expiration, and the other (60638) is not. We find that, for both contracts, the outstanding ratio and Distance to Call Level (defined as the distance between the HSI's day-end closing price and the contract's call level; hereafter, DtCL) are strongly negatively correlated: the correlation coefficients between outstanding ratio and DtCL for issues 60172 and 60638 are -0.742 and -0.790 (both p-values are less than 0.001), respectively. Interestingly, the correlation coefficients between the outstanding ratio and return volatility for issues 60172 and 60638 are 0.708 and 0.753 (again, both p-values are less than 0.001), respectively. Specifically, on the last trading day of issue 60172, when it is called back, the outstanding ratio is greater than 30%, while the outstanding ratio for issue 60638 almost vanishes as the contract approaches its maturity. From these two plots, it appears that investors prefer to hold highly volatile CBBCs, and those that are closer to their call levels.

To see whether the behavior found from individual CBBCs generalizes across all 2184 contracts written on HSI, Figure 2 reports the average trading volumes, the average turnover values, and the average outstanding ratios against the DtCL. We

[12] Outstanding ratio is equal to outstanding quantity divided by issue size.

[13] The entitlement ratio is the number of CBBCs needed to buy (or sell) one unit of the underlying asset, and represents the CBBC's exposure to the underlying asset. See also (2.1)-(2.2).

[14] Throughout this paper, returns are calculated by using day-end closing prices.

can see that investors like to trade and hold CBBCs with small DtCL: on average, the most preferred CBBCs for trading are those with DtCL lying in $[400, 500]$; the most preferred contracts for holding are those with DtCL less than 500; there were no investor trades or holds CBBCs with DtCL greater than 7000. As a matter of fact, the trading volume when DtCL is less than 1000 accounts for more than 90% of the total volume, the turnover value accounts for nearly 83% of the total turnover, and the outstanding ratio accounts for almost two-thirds. This confirms the findings from the two plots for single CBBCs reported in Figure 1 that investors like to hold CBBCs near their call levels. It is also important to note that, taking all 2184 contracts written on HSI as a whole, investors like to hold CBBCs with high return volatility as well.

We next report the trading behavior in called CBBCs and non-called ones separately. For called contracts, Figure 3 depicts a clear pattern that the average price decreases as the last trading day approaches. Meanwhile their average trading volume, average turnover value and average outstanding ratio increase dramatically as the last trading day approaches, and all three statistics are more than doubled in the last fifteen trading days. Specifically, the trading volume gradually increases from about 100 million when there are 50 trading days remaining to over 500 million with a peak of about 750 million when there are three trading days remaining. The turnover value also increases from 6 million HKD to about 50 million HKD — the highest level — when there are three trading days remaining. In the last three trading days, both trading volume and turnover value drop quickly to the similar levels as those when there are 50 trading days remaining. Accordingly, the outstanding ratio maintains a relatively stable level around 12% in the last four trading days.

Figure 4 depicts the counterparts of Figure 3 for CBBCs without MCE. Very differently from those observed for called CBBCs, the average price of non-called CBBCs hovers around the level of 0.25 HKD. In contrast to the increasing pattern for called CBBCs, the trading volume and turnover value for non-called CBBCs gradually decrease and arrive at their minimum on the last trading day. Accordingly, their outstanding ratio first increases slowly until there are thirteen trading days remaining and then slightly declines during the last twelve trading days. Thus, Figures 3 and 4 show completely different patterns for called and non-called CBBCs, in closing price, trading volume, turnover value, and outstanding ratio, as their last trading days approach. We can also observe from these two figures that, on average, the trading volume, the turnover value, and the outstanding ratio for called contracts are higher than those for non-called contracts, especially during trading days close to the last trading day. Table 4 reports summary statistics for all contracts, called contracts, and non-called ones. The results in Table 4 show that the called contracts are much more popular than the non-called ones: although the lifespan of called contract is shorter, their average daily trading volume is more than eight times of that for non-called ones, and their average turnover value is more than six times of that for non-called contracts. These results are consistent with our earlier findings in this paper after noting that the called CBBCs are close to their call levels during the several trading days immediately before MCE.

While the trading prices of CBBCs when they are close to their call levels are very low (actually significantly higher than their fundamental values), and their leverage levels are very high, it does not mean that investors can make money by holding and trading these contracts. The left panel of Figure 5 shows the proportion of CBBCs being called back against the number of trading days lapsed after CBBC' DtCL declined to some pre-specified levels. We can see that, among those contracts that experienced DtCL less than 200, nearly one half were called back by their respective issuers in the next two trading days, and more than 93% were called back before maturity. The right panel of Figure 5 depicts the histogram of residual values for all 1759 issues that were called back by their issuers. It is clear that most of residual values were less than two cents, and that more than 300 issues had nothing left after being called back. The sample mean of these residual values is 0.97 cent with a standard deviation of 0.68 cent.

To sum up, investors like to hold contracts near their call levels, which are prone to being called back very shortly and leave them with only a tiny residual value. As a matter of fact, as we will demonstrate, this leads to significant investment losses. One reasonable way to understand this seemingly irrational phenomenon is to adopt the cumulative prospect theory pioneered by Tversky and Kahneman (1992). One of the most important experimental findings of prospect theory is that people evaluate risk using so-called transformed probabilities, wherein investors overweight the tails of the objective distribution. By buying CBBCs near their call levels, investors are giving themselves a chance — in reality only a tiny chance — of achieving a very *large rate of return*: Figure 6 shows that if an investor buys a CBBC with DtCL$\leq$ 200 which survives from being called back, the payoff can be more than 40 cents, and the corresponding rate of return can be as high as hundreds of percentage points. Investors overweight this chance and thus overestimate the values of CBBCs near their call levels. In other words, investors seem to be treating CBBCs like lottery tickets.

3.2 Do Investors Treat CBBCs as Lottery Tickets?

To further investigate if investors treat CBBCs as lottery tickets, we conduct some empirical studies taking into account the characteristics of lottery-type securities presented in Kumar (2009): low price, high (positive) skewness, and high volatility. The results are reported in the last eight columns of Table 3, which include the skewness coefficient of daily CBBC returns, the correlation coefficient between daily outstanding ratio and closing price, the correlation coefficient between daily outstanding ratio and 11-day ($T-5$ to $T+5$) CBBC return volatility (annualized), as well as the correlation coefficient between daily outstanding ratio and the so-called Ex-Ante Skewness, which is a total skewness measure used in Boyer and Vorkink (2013). As can be seen, the daily returns for all contracts were positively skewed, with half contracts having a p-value less than 1% and 90% of the total sample having a p-value less than 10%. On average, the skewness was 1.090 with a significant p-value of 0.045, which confirms that the daily returns of CBBCs exhibit relatively strong positive skewness. Table 3 also shows that typically, the outstanding ratio is negatively correlated with closing price, but positively correlated with return volatility and ex-ante skewness. Note that, for a large portion of these issues, the corresponding p-values are very small, indicating that the reported correlations are quite strong. All these observations suggest that investors prefer CBBCs with characteristics of lottery-type stocks used in Kumar (2009) and Kumar, Page and Spalt (2011).

In a recent paper, Boyer and Vorkink (2013) find that total skewness exhibits a strong and negative relationship with average option returns. The authors use an "ex-ante skewness" measure to measure the total skewness. Next, we adopt their measure to study the relationship between skewness and average returns of CBBCs. The definition and computation of the ex-ante skewness measure are given in Appendix C, where the details for both bull and bear contracts are provided under the log normal assumption. We adopt the log normal assumption in this paper because it allows for closed-form expressions for both ex-ante skewness of CBBC returns and CBBC prices.[15]

Figures 7 and 8 plot the ex-ante skewness measure given by (C.1)-(C.2) and (C.8)-(C.9) against various CBBC characteristics including distance to call level, volatility of underlying asset, and time-to-maturity. Both bull and bear contracts are considered in this analysis. We find from Figure 7 that ex-ante skewness hits its peak when distance to call level is very small. Figure 8 shows that skewness increases as volatility or time-to-maturity increases. Both plots show that ex-ante skewness is more sensitive to distance to call level and volatility of underlying asset for contracts with long maturity. We can see that CBBCs closer to their call levels offer substantially higher skewness, especially as maturity increases. With the same characteristics, a bull contract generally demonstrates higher skewness

[15] Henderson and Pearson (2011) and Boyer and Vorkink (2013) rationalize the choice of log normal assumption along similar lines.

than a bear contract. For a bull contract with maturity of one year, its ex-ante skewness can be well over 20 when the distance to call level is small.

In order to study the relationship between skewness[16] and return, we create CBBC portfolios on each Monday from January 9, 2012 through November 26, 2012. There are 43 portfolio formation days in total. On each portfolio formation day, we first collect all listed CBBCs with a last trading day later than the portfolio formation day and group them by maturity,[17] then in each group with the same maturity we sort CBBCs into 3 ex-ante skewness terciles. Finally, three portfolios on the day are created by merging all CBBCs with the same skewness tercile but with different maturities. We omit portfolios consisting of less than six contracts. Table 5 reports various portfolio characteristics for different skewness terciles. The last two rows of each panel show the differences in averages between the high and low skewness tertiles, as well as the Newey and West (1987) t-statistics for testing whether these differences are equal to zero. Our sample contains on average 73 CBBCs per ex-ante skewness tercile, and 36 of them matured without being called back. The differences in the average ex-ante skewness, the average differ-

[16] Among all of the model parameters needed in computing the ex-ante skewness for a real contract, there are four parameters which are not explicitly specified in CBBC contracts: the first is the asset volatility σ; the second is the risk-free interest rate r; the third is the settlement period T_0, and the fourth is the settlement price. For asset volatility, we collect the implied volatility for options written on HSI with time-to-maturity 1-month, 2-month, 3-month, 6-month, 12-month, 18-month, and 24-month, and with moneyness (defined by strike/spot) 80%, 90%, 95%, 97.5%, 100%, 102.5%, 105%, 110%, and 120% from Bloomberg. Then implied volatilities for other time-to-maturities or moneynesses wee obtained by standard interpolation algorithm. For risk-free interest rate, we collect HIBOR from Yahoo Finance Service, which includes offered rates for Overnight, 1-week, 1-month, 3-month, 6-month, 9-month, and 12-month. Risk-free rates for other tenors werre calculated through a standard interpolation algorithm (see, e.g., Longstaff, Mithal and Neis 2005). Recalling the contract details introduced in Subsection 2.1, the settlement period and the settlement price can be obtained from the 1-min high frequency data of HSI.

[17] Since time-to-maturity has a material effect on ex-ante skewness (see Figures 7-8), we first group CBBCs by maturity before sorting them into ex-ante skewness bins (see also Boyer and Vorkink 2013). CBBCs written on HSI mature on the penultimate trading day of each month. In our sample, there were 24 different maturity dates in total.

ence of day high and day low, the average daily trading volume, the average daily turnover value, and the average outstanding ratio between the top tercile and the bottom tercile are highly significant. The results show that intra-day prices are more volatile when ex-ante skewness is higher, and that investors like to trade and hold CBBCs with high ex-ante skewness.

Table 6 shows the time-series averages of portfolio returns for each ex-ante skewness tercile. We re-scale the returns to be weekly so that the returns for different holding periods are comparable. The last two rows present the differences in average returns between the high and low skewness terciles, together with the Newey and West (1987) t-statistics for testing whether these differences are equal to zero. We can see that the returns of portfolios including all contracts decrease remarkably as the skewness increases. For example, if we hold the portfolio for 5 trading days, the average weekly return decreases from -1.22 percent for the low skewness tercile to -14.29 percent for the high skewness tercile. The corresponding t-statistic for the difference is -2.05. We find even more dramatic changes for CBBCs that were called back by their issuers. If a portfolio consisting of CBBCs that will be called back[18] before maturity is held for 5 trading days, the average weekly return decreases from -13.70 percent for the low skewness bin to -33.07 percent for the high skewness bin. The t-statistic for this difference was -4.72. In contrast, the case for CBBCs without MCE is totally different: when a portfolio consisting of CBBCs that won't be called back until maturity is held for 5 trading days, the returns of portfolios increase dramatically as skewness increases, from

[18] Reported in Panels B and C of Table 6 are posterior conditional estimations, since we don't know whether CBBCs will be called back or not on portfolio formation date.

3.60 percent for the low skewness tercile to 19.58 percent for the high skewness bin. The paired t-statistic for this difference is 4.36. We believe that the latter observation—the high return when issues are not being called back—is the charm of CBBCs. These findings verify the theoretical prediction / finding in Barberis and Huang (2008), which suggests that “a positive skewed security can be ’overpriced’ and can earn a negative average excess return”, and are consistent with the empirical findings on stock option market in Boyer and Vorkink (2013).

3.3 Issuers’ Profit: Prospectus Price vs. Fundamental Value

In a recent working paper, Liu and Zhang (2011) show that when the underlying asset follows a continuous stochastic process and the risk-free rate vanishes, the price of a Vanilla[19] Bull CBBC is equal to spot price minus strike price. Similarly, under the same setting, it is easy to show that the price of a Vanilla Bear CBBC is equal to strike price minus spot price. These results are consistent with the pricing formulae (2.1) and (2.2) in CBBC prospectuses provided by many issuers (e.g., UBS, Credit Suisse, and HSBC). However, when the risk-free rate is positive and / or the CBBC is Exotic (like most of the CBBCs traded in HKEx) rather than a Vanilla-type CBBC, these formulas are invalid. For ease of exposition, define[20]

$$\text{Prospectus Price of Bull Contract} = \frac{\text{Spot Price} - \text{Strike Price}}{\text{Entitlement Ratio}}, \quad (3.1)$$

$$\text{Prospectus Price of Bear Contract} = \frac{\text{Strike Price} - \text{Spot Price}}{\text{Entitlement Ratio}}. \quad (3.2)$$

[19] A Vanilla CBBC’s settlement price given MCE equals to its call level. See Appendix A.

[20] The prospectus prices below are the theoretical prices in (2.1)-(2.2) minus the funding cost.

The issue of interest now is the deviation between the prospectus prices in (3.1)-(3.2) and the fundamental value. In this paper, we use the theoretical prices under the log normal assumption (see Black and Scholes 1973 and Merton 1974), as proxies for fundamental values. Explicit pricing formulae of CBBCs are given in Appendix D.

Figure 9 depicts the relative error of prospectus prices over the Black-Scholes-Merton based prices. The relative errors are heavily dependent on the distance to call level and the volatility of underlying asset. When the distance to call level is greater than 2000, the relative error is economically negligible. However, when the price of an underlying asset approaches the call level, the relative pricing error increases dramatically. The errors are amplified when the underlying asset is more volatile. When the volatility of an underlying asset is 0.5, the relative errors can be higher than 200% when the contract is close to its call level. Unfortunately, Table 7 shows that investors follow the prospectus price closely, and Figure 2 reveals that investors trade heavily when the prospectus prices are positively biased. This is likely an important way by which the issuers make money.

We now examine issuers' profit/loss patterns in CBBCs. We compute the profit on the issuance day as the product of issue price and issue volume. For each intermediate trading day, if the day-end outstanding quantity is greater than or equal to that of the previous trading day, we estimate the profit as the product of the mean selling price of the current trading day and the growth (comparing with the previous trading day) in day-end outstanding quantity; if its day-end outstanding quantity is less than that of the previous trading day, we estimate the loss as the product of the mean buying price of the current trading day and the fall in day-end outstanding quantity relative to that on the previous day. The final loss for called contracts is computed using residual values. The settlement prices for computing residual values as per Footnote 16, i.e., obtained from the 1-min high frequency data of HSI. The overall profit/loss nets out the preceding computations.

Figure 10 reports, from the issuers' perspective, the profit/loss pattern, against the number of trading days remaining, the distance to call level, and the daily closing price, for CBBCs that are called back by issuers. The first plot shows that most of the profit is earned near the MCE. The profit in the last five trading days immediately before MCE accounted for 49.0%, and the profit in the last fifteen trading days accounted for 82.8% of the total. The second plot tells us that the issuers make money mainly by trading[21] CBBCs that are near their call levels. The profit when distance to call level is less than or equal to 500 made 51.1% of the total, and that when distance to call level is less than 800 accounted for 94.9%. There is a clearer pattern when the profit is plotted against the daily closing price. In fact, more than 97 percent profit was made when the daily closing price was less than 9 cents! Figure 11 depicts the counterparts of those in Figure 10 for non-called CBBCs. The issuers lose 1.13 billion HKD in trading CBBCs that are not called back. There is no specific pattern against the number of trading days remaining. Interestingly, even though the profit was relatively small, there is still a clear pattern varying with the distance to call level and the daily closing price, especially the

[21] In general, CBBC's issuer itself is the only liquidity provider, who is also the only market participant that is allowed to short sell the respective CBBC. In our sample, there are two exceptions: Bank of East Asia and Rabobank, who assign third parties as liquidity providers.

latter. Issuers can make a profit when the distance to call level is small or the price is very low: By trading non-called CBBCs with distance to call level less than 800, issuers earn 267.5 million HKD; By trading non-called CBBCs with daily closing price lower than 10 cents, issuers earn 467.9 million HKD.

Overall, the profit for trading both called and non-called CBBCs amounts to 1.39 billion HKD.[22] We report profits for all issuers in Table 8. The two biggest winners were UBS and Credit Suisse, who earned 510.4 million HKD[23] and 503.5 million HKD, respectively. The net profit for each of them makes up more than one-third of the total net profit. The biggest loser, Citigroup, lost 45.7 million HKD. On average, issuers earned 1.44 million HKD from each called contract, and lost 2.66 million HKD due to each non-called contract. Overall they gained an average of 0.64 million HKD by trading each CBBC. UBS was the most efficient trader of called issues in that it earned 2.57 million HKD from each called contract. Its profit dominated over its loss in non-called issue, and made it the biggest winner. Citigroup did not do well with non-called issues: it lost 6.7 million HKD for each issuance of contract without MCE, which also left it as the biggest loser. Overall Citigroup lost nearly 1 million HKD on each issue.

[22] We believe that our estimation here is conservative in that the trading volume is usually higher than the changes of outstanding quantities, and more importantly, since the issuer itself is usually the only liquidity provider, it has initiative when taking prices.

[23] About 61.7 million CHF (the mean of daily HKD/CHF FX rate is 0.1209 in 2012), which accounted for 2.5% of the net loss attributable to UBS shareholders in 2012, which was 2510 million CHF.

4 Discussion and Conclusion

We propose that the design of financial innovations, in part, might be motivated by their appeal to investors' behavioral biases. We present evidence that investors' preference for knockout barrier options known as callable bull / bear contracts (CBBCs) is mainly due to gambling-like behavior: Investors prefer CBBCs with the three most important characteristics of lottery-type securities documented in Kumar (2009): low price, high positive skewness, and high return volatility. Our findings are consistent with the theoretical idea proposed in Barberis and Huang (2008), which states that "a positively skewed security can be 'overpriced' and can earn a negative average excess return."

Our findings also are consistent with the recent hypothesis that issuers may cater to investors' preferences by engineering products that can generate negative investment returns (Gennaioli, Shleifer and Vishny 2012). CBBC cater to investor preferences by issuing many CBBCs, are close to their call levels on their issue date, and these CBBCs generate negative average returns. A conservative estimation shows that, during the year 2012, investors trading CBBCs written on Hang Seng Index lost 1.39 billion HKD! Note that since each issuer of CBBC is the sole liquidity provider and short-selling is not possible, issuers have great power in setting the prices of CBBCs. This is consistent with a recent finding by Ruf (2011), who shows that issuers use their monopoly power to extract wealth from investors.

The launch of CBBCs may be termed an *"advanced" dark-side* of financial innovation. Interestingly, both issuers and HKEx try to make CBBCs and their trading as transparent as possible. A CBBC leaflet provided by HKEx clearly states the risks involved in trading CBBC (see HKEx 2006, 2009). Specifically, it says "When the underlying asset is trading close to the Call Price, the price of a CBBC may be more volatile with wider spreads and uncertain liquidity. CBBC may be called at any time and trading will terminate as a result." This seemingly friendly reminder may in fact be a trap in that issuers can take advantage of the gambling behavior by notifying investors when they can bet, because wordings such as "volatile" may in fact stimulate gambling behavior. Moreover, all CBBC prospectuses provide a theoretical pricing formula which is in fact used to determine the initial offering price. This theoretical price is misleading, especially when the underlying asset is trading close to the call price. Unfortunately, we find that investors trade CBBCs heavily when the prices of these contracts are near the call level, where the aforementioned theoretical price is severely positively biased, and this is a primary source of investors' big losses.

Our analysis of issuers' profit patterns indicates that unsophisticated investor behavior can create wealth for issuers. Specifically, our work is consistent with the notion that issuers rationally market positively skewed securities to retail investors; and these latter investors price these securities under cumulative prospect theory, which can result in overpriced securities from the perspective of rational agents. As a result, issuers may be able to sell those securities at prices higher than their rational levels. CBBC markets in Hong Kong provide us a vivid example of how financial companies might profit by catering to the behavioral biases of investors.

Appendices

A Risk-Neutral Pricing Formula of CBBCs

Recall the introduction of CBBCs in Section 2. By virtue of the risk-neutral valuation formula (see, e.g., Harrison and Pliska 1981), the price of a bull contract at $t \leqslant T_b$ is given by

$$P_t^{\text{bull}}(T-t) = e^{-r(T-t)}\mathbb{E}_t\left[(S_T-K)\,1_{\{T_b>T\}}\right] + \mathbb{E}_t\left[e^{-r(T_b+T_0-t)}1_{\{T_b\leqslant T\}}\left(\min_{T_b\leqslant u\leqslant T_b+T_0} S_u - K\right)^+\right], \tag{A.1}$$

where $r>0$ is the constant risk-free rate, T is the maturity date, $S := (S_t)_{t\geqslant 0}$ is the price process of the underlying asset, K is the strike price, and $T_b := \inf\{t \geqslant 0; S_t \leqslant S_b\}$ is the first time that the price process S crosses the call level S_b. T_0 is the settlement period given the call level is hit. Here $(x)^+ := \max(x,0)$, and $\mathbb{E}_t[\cdot]$ is the expectation under the risk-neutral measure given information known at time t. Similarly, the price of a bear contract can be expressed as

$$P_t^{\text{bear}}(T-t) = e^{-r(T-t)}\mathbb{E}_t\left[(K-S_T)\,1_{\{\widetilde{T}_b>T\}}\right] + \mathbb{E}_t\left[e^{-r(\widetilde{T}_b+T_0-t)}1_{\{\widetilde{T}_b\leqslant T\}}\left(K-\max_{\widetilde{T}_b\leqslant u\leqslant \widetilde{T}_b+T_0} S_u\right)^+\right], \tag{A.2}$$

with $\widetilde{T}_b := \inf\{t \geqslant 0; S_t \geqslant S_b\}$. Intuitively speaking, if the asset price S hits the call level S_b before the maturity date T, the investor loses the value of the first expectation in (A.1) or (A.2) which is just a down-and-out option and, meanwhile, enters into a *Exotic* option with a short maturity T_0. Thus this type of CBBC is also known as an *Exotic* CBBC.

A CBBC is called *Vanilla*, if its settlement price given MCE equals its call level and the length of its settlement period is equal to zero. Accordingly, the residual values of *Vanilla* bull / bear contracts are given by $\mathbb{E}_t\left[e^{-r(T_b-t)}1_{\{T_b\leqslant T\}}\left(S_b-K\right)^+\right]$ and $E_t\left[e^{-r(\widetilde{T}_b-t)}1_{\{\widetilde{T}_b\leqslant T\}}\left(K-S_b\right)^+\right]$, respectively. Here T_b and $\widetilde{T}_b$ are the same as those in (A.1) and (A.2).

B Brownian Motion with Drift, First Passage Time, and its Running Minimum (Maximum)

In this appendix, we present some theoretical results related to Brownian motion with drift, its first passage time, and its running minimum (maximum). These results facilitate the derivation of closed-form formulae for ex-ante skewness and price of CBBC in the next two appendices.

Assume W is a standard Brownian motion (Wiener process). For any $\sigma > 0$, $\mu \in \mathbb{R}$ and $b \in \mathbb{R}$, define $\tau_b := \inf\{t \geq 0 : \mu t + \sigma W_t = b\}$, then for any $a \in \mathbb{R}$ such that $b(b-a) \geq 0$, we have (see, e.g., Karatzas and Shreve 1991, Sections 2.8.A and 3.5.C),

$$\begin{aligned}
&\mathbb{P}(\mu t+\sigma W_t \in da, \tau_b > t)\\
=\;& \frac{1}{\sqrt{2\pi t}\,\sigma}\exp\left(\frac{\mu a}{\sigma^2}-\frac{\mu^2 t}{2\sigma^2}\right)\left(\exp\left(-\frac{a^2}{2\sigma^2 t}\right)-\exp\left(-\frac{(2b-a)^2}{2\sigma^2 t}\right)\right)da,
\end{aligned}$$

which yields

$$
\begin{aligned}
f(\lambda,\mu,\sigma,b,t) &:= \mathbb{E}\left[e^{\lambda(\mu t+\sigma W_t)}1_{\{\tau_b>t\}}\right] \\
&= \begin{cases} \int_{-\infty}^{b} e^{\lambda a}\mathbb{P}(\mu t+\sigma W_t\in da, \tau_b>t), & b\geqslant 0, \\ \int_{b}^{\infty} e^{\lambda a}\mathbb{P}(\mu t+\sigma W_t\in da, \tau_b>t), & b\leqslant 0, \end{cases} \\
&= \begin{cases} e^{\frac{1}{2}\lambda t\left(\lambda\sigma^2+2\mu\right)}\left(N\left(d_1\right)-e^{2b\lambda+\frac{2b\mu}{\sigma^2}}N\left(-d_2\right)\right), & b\geqslant 0, \\ e^{\frac{1}{2}\lambda t\left(\lambda\sigma^2+2\mu\right)}\left(N\left(-d_1\right)-e^{2b\lambda+\frac{2b\mu}{\sigma^2}}N\left(d_2\right)\right), & b\leqslant 0, \end{cases}
\end{aligned} \tag{B.1}
$$

with $N(\cdot)$ being the cumulative distribution function (cdf) of a standard normal distribution, and

$$
d_1=\frac{b-\mu t-\lambda\sigma^2 t}{\sigma\sqrt{t}}, \quad d_2=\frac{b+t\mu+\lambda\sigma^2 t}{\sigma\sqrt{t}}.
$$

Specifically, for $t\geq 0$, explicit formulae for the tail probability and the density of the first passage time τ_b can be expressed as

$$
\begin{aligned}
\mathbb{P}\left(\tau_b>t\right) &= f(0,\mu,\sigma,b,t)=\begin{cases} N\left(\frac{b-\mu t}{\sigma\sqrt{t}}\right)-e^{\frac{2b\mu}{\sigma^2}}N\left(-\frac{b+t\mu}{\sigma\sqrt{t}}\right), & b\geqslant 0, \\ N\left(-\frac{b-\mu t}{\sigma\sqrt{t}}\right)-e^{\frac{2b\mu}{\sigma^2}}N\left(\frac{b+t\mu}{\sigma\sqrt{t}}\right), & b\leqslant 0, \end{cases} \\
\mathbb{P}(\tau_b\in dt) &= -\frac{\partial\mathbb{P}\left(\tau_b>t\right)}{\partial t}dt=\frac{|b|}{\sqrt{2\pi t^3}\sigma}\exp\left(-\frac{(b-\mu t)^2}{2t\sigma^2}\right)dt.
\end{aligned}
$$

Furthermore, substituting the expression of $\mathbb{P}(\tau_b\in dt)$ into the next integral, we can obtain

$$
\eta(\lambda,\mu,\sigma,b,T) := \mathbb{E}\left[e^{-\lambda\tau_b}1_{\{\tau_b\leqslant T\}}\right]=\int_0^T e^{-\lambda t}\mathbb{P}(\tau_b\in dt)
$$

$$= \begin{cases} e^{\frac{b(\mu+\mu_1)}{\sigma^2}} N(-d_3) + e^{\frac{b(\mu-\mu_1)}{\sigma^2}} N(-d_4), & b \geqslant 0, \\ e^{\frac{b(\mu+\mu_1)}{\sigma^2}} N(d_3) + e^{\frac{b(\mu-\mu_1)}{\sigma^2}} N(d_4), & b \leqslant 0, \end{cases} \tag{B.2}$$

where $d_3 = \frac{b+T\mu_1}{\sigma\sqrt{T}}$, $d_4 = \frac{b-T\mu_1}{\sigma\sqrt{T}}$ with $\mu_1 := \sqrt{2\lambda\sigma^2+\mu^2}$. As by products, we also have, for $\mu = 0$,

$$\theta(0,\sigma,b,T) = Tf(0,0,\sigma,b,T) + \frac{|b|}{\sigma^2}\left(\sqrt{\frac{2}{\pi}}\sigma\sqrt{T}e^{-\frac{b^2}{2\sigma^2 T}} - 2|b|N\left(-\frac{|b|}{\sigma\sqrt{T}}\right)\right),$$

and, for $\mu \neq 0$,

$$\theta(\mu,\sigma,b,T) := \mathbb{E}\left[\tau_b \wedge T\right] = T\mathbb{P}(\tau_b > T) + \mathbb{E}\left[\tau_b 1_{\{\tau_b \leqslant T\}}\right]$$
$$= Tf(0,\mu,\sigma,b,T) + \begin{cases} \frac{b}{|\mu|}\left(e^{\frac{b(\mu-|\mu|)}{\sigma^2}} N\left(-\frac{b-|\mu|T}{\sigma\sqrt{T}}\right) - e^{\frac{b(\mu+|\mu|)}{\sigma^2}} N\left(-\frac{b+|\mu|T}{\sigma\sqrt{T}}\right)\right), & b \geqslant 0, \\ \frac{b}{|\mu|}\left(e^{\frac{b(\mu-|\mu|)}{\sigma^2}} N\left(\frac{b-|\mu|T}{\sigma\sqrt{T}}\right) - e^{\frac{b(\mu+|\mu|)}{\sigma^2}} N\left(\frac{b+|\mu|T}{\sigma\sqrt{T}}\right)\right), & b \leqslant 0. \end{cases}$$

To derive the analytic formula of ex-ante skewness and price for CBBCs, we have to study the running minimum (maximum) of Brownian motion with drift. Define

$$\text{Inf}(t) := \inf_{0 \le s \le t} (\mu s + \sigma W_s), \quad \text{Sup}(t) := \sup_{0 \le s \le t} (\mu s + \sigma W_s),$$

then it is easy to see that (see also Borodin and Salminen 2002, formulae (2.1.1.4) and (2.1.2.4)):

$$\mathbb{P}\left(\text{Sup}(t) < b\right) = \mathbb{P}(\tau_b > t), \quad b \geqslant 0,$$

$$\mathbb{P}\left(\mathrm{Inf}(t) > b\right) \;=\; \mathbb{P}(\tau_b > t), \quad b \leqslant 0.$$

By virtue of the above formulas, we have

$$\begin{aligned}
& g(\lambda, \mu, \sigma, k, t) := \mathbb{E}\left[e^{\lambda \mathrm{Inf}(t)} 1_{\{\mathrm{Inf}(t) > k\}}\right] \\
&= \int_k^0 e^{\lambda b} \frac{-\partial \mathbb{P}\left(\mathrm{Inf}(t) > b\right)}{\partial b} \mathrm{d}b = \int_k^0 e^{\lambda b} \frac{-\partial \mathbb{P}\left(\tau_b > t\right)}{\partial b} \mathrm{d}b \\
&= \frac{2}{\mu + \mu_2}\left[-\mu_2 e^{\frac{1}{2}\lambda(\mu+\mu_2)t}\left(N\left(d_5\right) - N\left(d_6\right)\right) + \mu N\left(d_7\right) - \mu e^{k\lambda + \frac{2k\mu}{\sigma^2}} N\left(d_8\right)\right],
\end{aligned}$$

for $k \leqslant 0$, and

$$\begin{aligned}
& h(\lambda, \mu, \sigma, k, t) := \mathbb{E}\left[e^{\lambda \mathrm{Sup}(t)} 1_{\{\mathrm{Sup}(t) < k\}}\right] \\
&= \int_0^k e^{\lambda b} \frac{\partial \mathbb{P}\left(\mathrm{Sup}(t) < b\right)}{\partial b} \mathrm{d}b = \int_0^k e^{\lambda b} \frac{\partial \mathbb{P}\left(\tau_b > t\right)}{\partial b} \mathrm{d}b \\
&= \frac{2}{\mu + \mu_2}\left[\mu_2 e^{\frac{1}{2}\lambda(\mu+\mu_2)t}\left(N\left(d_5\right) - N\left(d_6\right)\right) + \mu N\left(-d_7\right) - \mu e^{k\lambda + \frac{2k\mu}{\sigma^2}} N\left(-d_8\right)\right],
\end{aligned}$$

for $k \geqslant 0$, where $d_5 = \frac{k-\mu_2 t}{\sigma\sqrt{t}},\ d_6 = -\frac{\mu_2 t}{\sigma\sqrt{t}},\ d_7 = \frac{\mu t}{\sigma\sqrt{t}},\ d_8 = \frac{k+\mu t}{\sigma\sqrt{t}}$ with $\mu_2 := \mu + \lambda\sigma^2$. The above functions $f(\cdots)$, $g(\cdots)$, $h(\cdots)$ and $\eta(\cdots)$ are key ingredients of the closed-form expressions for ex-ante skewness and price of CBBCs presented in the next two appendices.

C Explicit Formulae of Ex-Ante Skewness

Following Boyer and Vorkink (2013), we define the measure of ex-ante skewness for a CBBC over horizon t to T as

$$\text{SKEW}_t(\tau) := \frac{\mathbb{E}_t\left[R_t(\tau) - \mu_t(\tau)\right]^3}{\left[\sigma_t(\tau)\right]^3}, \qquad \tau := T - t, \tag{C.1}$$

where $\mu_t(\tau) = \mathbb{E}_t[R_t(\tau)]$, $\sigma_t(\tau) = \left(\mathbb{E}_t\left[R_t^2(\tau)\right] - \mu_t^2(\tau)\right)^{1/2}$, and $R_t(\tau)$ denotes CBBC's return, . In terms of the return's raw moments, (C.1) can be expressed as

$$\text{SKEW}_t(\tau) = \frac{\mathbb{E}_t\left[R_t^3(\tau)\right] - 3\mathbb{E}_t\left[R_t^2(\tau)\right]\mu_t(\tau) + 2\mu_t^3(\tau)}{\left(\mathbb{E}_t\left[R_t^2(\tau)\right] - \mu_t^2(\tau)\right)^{3/2}}, \tag{C.2}$$

which indicates that only the first three raw moments of CBBC return are required to compute the ex-ante skewness. Recalling the introduction of CBBCs presented in Section 2.1, the return from holding a bull contract to maturity, $R_t^{\text{bull}}(\tau)$ is

$$R_t^{\text{bull}}(\tau) = \frac{(S_T - K)\,1_{\{T_b > T\}} + 1_{\{T_b \leqslant T\}}\left(\min\limits_{T_b \leqslant t \leqslant T_b + T_0} S_t - K\right)^+}{\hat{P}_t^{\text{bull}}(\tau)}, \tag{C.3}$$

where T is the maturity date, $S := (S_t)_{t \geqslant 0}$ is the price process of HSI, K is the strike price, $\hat{P}_t^{\text{bull}}(\tau)$ is the market price of the bull contract, and $T_b := \inf\{t \geqslant 0; S_t \leqslant S_b\}$ is the first time that the price process S crosses the call level S_b. Here $(x)^+ := \max(x, 0)$, and T_0 is the settlement period given the call level is hit. Define

$$M_{x,\theta} := \min_{0 \leqslant t \leqslant \theta} S_t, \text{ given } S_0 = x,$$

then from (C.3) we can rewrite the j-th raw moment of $R_t^{\text{bull}}(\tau)$ as

$$\begin{aligned}&\mathbb{E}_t\left[\left(R_t^{\text{bull}}(\tau)\right)^j\right] \\ =\ &\frac{\mathbb{E}_t\left[(S_T-K)^j\,1_{\{T_b>T\}}\right]+\mathbb{E}\left[\left(M_{S_b,T_0}-K\right)^j\,1_{\{M_{S_b,T_0}>K\}}\right]\mathbb{P}_t(T_b\leqslant T)}{\left(\hat{P}_t^{\text{bull}}(\tau)\right)^j},\end{aligned} \tag{C.4}$$

where $\mathbb{P}_t$ is the probability given information as of time t. Noting that, at time t, $T_b > T$ is equivalent to $M_{S_t,T-t} > S_b$, Equation (C.4) shows that, in order to compute the raw moments for a bull contract, we need the joint distribution of the underlying asset price and its running minimum.

In the remaining part of this appendix, by virtue of the results presented in Appendix B, we derive explicit formulae for ex-ante skewness defined by (C.1)-(C.2) under the log normal assumption. For ease of exposition, we introduce the following notations

$$\Theta_1 := (r-\sigma^2/2, \sigma, s_b, T-t), \qquad \Theta_2 := (r-\sigma^2/2, \sigma, k_b, T_0), \tag{C.5}$$

where $s_b := \ln(S_b/S_t)$ and $k_b := \ln(K/S_b)$. To compute the ex-ante skewness, we need (C.4) for $j = 1, 2, 3$, which consists of the following three components:

$$\mathbb{E}_t\left[(S_T-K)^j\,1_{\{T_b>T\}}\right],\ \mathbb{E}_0\left[\left(M_{S_b,T_0}-K\right)^j\,1_{\{M_{S_b,T_0}>K\}}\right],\ \mathbb{P}_t(T_b\leqslant T). \tag{C.6}$$

Under the log normal setting, the risk-neutral dynamics of the underlying asset is given by $S := (S_0\exp((r-\sigma^2/2)t+\sigma W_t)_{t\geq 0}$ with $(W_t)_{t\geq 0}$ being a standard Brownian motion. The first hitting time of S on call level S_b is identical to the first hitting time of $(rt - \sigma^2 t/2 + \sigma W_t)_{t \geq 0}$ on the level $\ln(S_b/S_0)$. Thus, by (B.1) and the definition of τ_b, we have

$$\mathbb{P}_t(T_b \leqslant T) = 1 - \mathbb{P}_t(T_b > T) = 1 - f(0, \Theta_1). \tag{C.7}$$

We next concentrate on the computation of the first two components in (C.6). When $j = 1$, we have

$$\begin{aligned}
& \mathbb{E}_t\left[(S_T - K)1_{\{T_b > T\}}\right] \\
= \; & \mathbb{E}_t\left[S_T 1_{\{T_b > T\}}\right] - K\mathbb{P}_t(T_b > T) \\
= \; & \mathbb{E}_t\left[S_t \exp\left(\int_t^T (r - \sigma^2/2)dt + \int_t^T \sigma dW_t\right) 1_{\{T_b > T\}}\right] - K\mathbb{P}_t(T_b > T) \\
= \; & S_t \mathbb{E}_0\left[e^{(r-\sigma^2/2)(T-t) + \sigma W_{T-t}} 1_{\{\tau_1 > T-t\}}\right] - K\mathbb{P}(\tau_1 > T - t),
\end{aligned}$$

where $\tau_1 := \inf\{t \geq 0 : (r - \sigma^2/2)t + \sigma W_t = s_b\}$ with $s_b := \ln(S_b/S_t) < 0$. By virtue of (B.1), we have

$$\mathbb{E}_t\left[(S_T - K)1_{\{T_b > T\}}\right] = S_t f(1, \Theta_1) - K f(0, \Theta_1).$$

Similarly,

$$\begin{aligned}
\mathbb{E}_t\left[(S_T - K)^j 1_{\{T_b > T\}}\right] &= \sum_{k=0}^{j} C_j^k (-K)^k S_t^{j-k} f(j - k, \Theta_1), \\
\mathbb{E}_0\left[\left(M_{S_b, T_0} - K\right)^j 1_{\{M_{S_b, T_0} > K\}}\right] &= \sum_{k=0}^{j} C_j^k (-K)^k S_b^{j-k} g(j - k, \Theta_2),
\end{aligned}$$

where $k_b := \ln(K/S_b) < 0$, and $C_j^k := \frac{j!}{k!(j-k)!}$ is the binomial coefficient. Recall that $\mathbb{P}_t(T_b \leqslant T) = 1 - f(0, \Theta_1)$. The raw moments are given by

$$\mathbb{E}_t\left[\left(R_t^{\text{bull}}(\tau)\right)^j\right] = \frac{\sum_{k=0}^{j} C_j^k (-K)^k \left[S_t^{j-k} f(j-k, \Theta_1) + [1 - f(0, \Theta_1)] S_b^{j-k} g(j-k, \Theta_2)\right]}{\left(P_t^{\text{bull}}(\tau)\right)^j}, \tag{C.8}$$

where $P_t^{\text{bear}}(\tau)$ is the market price of a bear contract. Similarly,

$$\begin{aligned}
\mathbb{E}_t\left[(K - S_T)^j 1_{\{T_b > T\}}\right] &= \sum_{k=0}^{j} C_j^k K^k (-S_t)^{j-k} f(j-k, \Theta_1), \\
\mathbb{E}_0\left[\left(K - \widetilde{M}_{S_b, T_0}\right)^j 1_{\{\widetilde{M}_{S_b, T_0} < K\}}\right] &= \sum_{k=0}^{j} C_j^k K^k (-S_b)^{j-k} h(j-k, \Theta_2),
\end{aligned}$$

where $\widetilde{M}_{x,\theta} := \left(\max_{0 \leqslant t \leqslant \theta} S_t \,\middle|\, S_0 = x\right)$, and Θ_1 and Θ_2 are given in (C.5) with $s_b := \ln(S_b / S_t) > 0$, $k_b := \ln(K / S_b) > 0$. The raw moments for bear contracts can be given by

$$\mathbb{E}_t\left[\left(R_t^{\text{bear}}(\tau)\right)^j\right] = \frac{\sum_{k=0}^{j} C_j^k K^k \left[(-S_t)^{j-k} f(j-k, \Theta_1) + (1 - f(0, \Theta_1))(-S_b)^{j-k} h(j-k, \Theta_2)\right]}{\left(P_t^{\text{bear}}(\tau)\right)^j}, \tag{C.9}$$

where $P_t^{\text{bear}}(\tau)$ is the market price of a bear contract. Substituting (C.8) and (C.9) into (C.2), we are able to obtain the explicit formulae of ex-ante skewness for both bull and bear contracts.

D Closed-form Pricing Formulae of CBBCs

In this appendix, we provide pricing formulae for CBBCs under the log normal assumption. Recall (A.1). The time-t price of a bull contract with time-to-maturity $\tau = T - t$ can be written as

$$P_t^{\text{bull}}(\tau) \;=\; C_1^{\text{bull}} + C_2^{\text{bull}}, \tag{D.1}$$

where

$$\begin{aligned} C_1^{\text{bull}} &= \mathbb{E}_t\left[e^{-r(T-t)}\left(S_T - K\right)1_{\{T_b > T\}}\right], \\ C_2^{\text{bull}} &= \mathbb{E}_t\left[e^{-r(T_b+T_0-t)}\left(M_{S_b,T_0} - K\right)^+ 1_{\{T_b \le T\}}\right]. \end{aligned}$$

Noting from Appendix C that $\mathbb{E}_t\left[\left(S_T - K\right)1_{\{T_b > T\}}\right] = S_t f(1, \Theta_1) - K f(0, \Theta_1)$, the explicit formula of C_1^{bull} is given by

$$C_1^{\text{bull}} = e^{-r(T-t)}\left[S_t f(1, \Theta_1) - K f(0, \Theta_1)\right].$$

By virtue of the law of iterated expectations (also known as the tower rule) and the strong Markov property of BS model,

$$C_2^{\text{bull}} = \mathbb{E}\left[e^{-rT_0}\left(M_{S_b,T_0} - K\right)1_{\{M_{S_b,T_0} > K\}}\right]\mathbb{E}_t\left[e^{-r\tau_1}1_{\{\tau_1 \leqslant T-t\}}\right],$$

where $\tau_1 := \inf\{t \geq 0 : (r - \sigma^2/2)t + \sigma W_t = s_b\}$ with $s_b := \ln(S_b/S_t) < 0$. Assume the settlement period T_0 is known. Noting from Appendix C that

$\mathbb{E}_t\left[e^{-r\tau_1}1_{\{\tau_1\leqslant T-t\}}\right] = \eta(r,\Theta_1)$, and $\mathbb{E}\left[\left(M_{S_b,T_0}-K\right)1_{\{M_{S_b,T_0}>K\}}\right] = S_b g(1,\Theta_2) - Kg(0,\Theta_2)$, we have

$$C_2^{\text{bull}} = e^{-rT_0}\left[S_b g(1,\Theta_2) - Kg(0,\Theta_2)\right]\eta(r,\Theta_1),$$

where the function $\eta(\cdots)$ is given by (B.2). Substituting C_1^{bull} and C_2^{bull} into (D.1), we obtain the explicit pricing formula for a bull contract. Similarly, the pricing formula for a bear contract can be expressed as

$$P_t^{\text{bear}}(\tau) = C_1^{\text{bear}} + C_2^{\text{bear}}, \tag{D.2}$$

where

$$\begin{aligned} C_1^{\text{bear}} &= e^{-r(T-t)}[Kf(0,\Theta_1) - S_t f(1,\Theta_1)], \\ C_2^{\text{bear}} &= e^{-rT_0}\left[Kh(0,\Theta_2) - S_b h(1,\Theta_2)\right]\eta(r,\Theta_1). \end{aligned}$$

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Table 1: CBBC issues on HKEx in 2012 by issuer. The first column reports the HKEx ticker for each issuer. Here and hereafter we omit the issues with zero trading volumes. Volume and Turnover are measured in million. Percentage contributions to the total sample are reported in parentheses. NoI is the number of issues, VpI is the averaged trading volume per issue, and TpI represents the averaged turnover value per issue.

Ticker	Issuer	NoI	Volume	VpI	Turnover	TpI
BP	BNP Paribas	249 (0.0846)	308820 (0.0208)	1240.2	26254 (0.0226)	105.4
CS	Credit Suisse	687 (0.2334)	4901497 (0.3307)	7134.6	347111 (0.2983)	505.3
CT	Citigroup	47 (0.0160)	97310 (0.0066)	2070.4	11691 (0.0100)	248.7
DC	Daiwa Capital	170 (0.0578)	680613 (0.0459)	4003.6	59458 (0.0511)	349.8
EA	Bank of East Asia	3 (0.0010)	144 (0.0000)	48.1	28 (0.0000)	9.5
GS	Goldman Sachs	150 (0.0510)	209745 (0.0142)	1398.3	15856 (0.0136)	105.7
HS	HSBC	268 (0.0911)	875765 (0.0591)	3267.8	116699 (0.1003)	435.4
JP	J.P. Morgan	136 (0.0462)	503275 (0.0340)	3700.6	52033 (0.0447)	382.6
ML	Merrill Lynch	81 (0.0275)	127736 (0.0086)	1577.0	9258 (0.0080)	114.3
RB	Rabobank	5 (0.0017)	1624 (0.0001)	324.7	231 (0.0002)	46.1
SG	Societe Generale	394 (0.1339)	2212981 (0.1493)	5616.7	180438 (0.1551)	458.0
UB	UBS	753 (0.2559)	4901815 (0.3307)	6509.7	344564 (0.2961)	457.6
	Bull	1383 (0.4699)	6734212 (0.4544)	4869.3	491991 (0.4228)	355.7
	Bear	1560 (0.5301)	8087113 (0.5456)	5184.0	671630 (0.5772)	430.5
	Called	2297 (0.7805)	12090017 (0.8157)	5263.4	889384 (0.7643)	387.2
	Non-Called	646 (0.2195)	2731308 (0.1843)	4228.0	274237 (0.2357)	424.5
	Total	2943 (1.0000)	14821325 (1.0000)	5036.1	1163621 (1.0000)	395.4

Table 2: CBBC issues on HKEx in 2012 by underlying. The first column reports the HKEx ticker for each underlying. All the issues with zero trading volumes are excluded. Volumes and Turnovers are measured in millions. Percentage contributions to the total sample are reported in parentheses. NoI is the number of issues, VpI is the averaged trading volume per issue, and TpI represents the averaged turnover value per issue.

Ticker	Underlying	NoI	Volume	VpI	Turnover	TpI
1	CHEUNG KONG	14 (0.0048)	1162 (0.0001)	83.0	205 (0.0002)	14.7
5	HSBC HOLDINGS	21 (0.0071)	8240 (0.0006)	392.4	845 (0.0007)	40.2
13	HUTCHISON	41 (0.0139)	5906 (0.0004)	144.0	600 (0.0005)	14.6
16	SHK PPT	14 (0.0048)	819 (0.0001)	58.5	117 (0.0001)	8.4
27	GALAXY ENT	10 (0.0034)	163 (0.0000)	16.3	43 (0.0000)	4.3
135	KUNLUN ENERGY	1 (0.0003)	37 (0.0000)	37.0	9 (0.0000)	9.4
358	JIANGXI COPPER	4 (0.0014)	33 (0.0000)	8.3	14 (0.0000)	3.5
386	SINOPEC CORP	29 (0.0099)	2220 (0.0001)	76.6	240 (0.0002)	8.3
388	HKEX	57 (0.0194)	5150 (0.0003)	90.3	901 (0.0008)	15.8
494	LI and FUNG	6 (0.0020)	177 (0.0000)	29.5	37 (0.0000)	6.2
688	CHINA OVERSEAS	7 (0.0024)	115 (0.0000)	16.4	34 (0.0000)	4.9
700	TENCENT	100 (0.0340)	10220 (0.0007)	102.2	2342 (0.0020)	23.4
728	CHINA TELECOM	5 (0.0017)	182 (0.0000)	36.3	18 (0.0000)	3.5
762	CHINA UNICOM	10 (0.0034)	489 (0.0000)	48.9	118 (0.0001)	11.8
857	PETROCHINA	12 (0.0041)	1125 (0.0001)	93.8	193 (0.0002)	16.1
883	CNOOC	20 (0.0068)	3122 (0.0002)	156.1	726 (0.0006)	36.3
914	ANHUI CONCH	4 (0.0014)	8 (0.0000)	1.9	3 (0.0000)	0.8
939	CCB	28 (0.0095)	5460 (0.0004)	195.0	516 (0.0004)	18.4
941	CHINA MOBILE	41 (0.0139)	14212 (0.0010)	346.6	1443 (0.0012)	35.2
992	LENOVO GROUP	1 (0.0003)	83 (0.0000)	82.5	11 (0.0000)	11.2
1088	CHINA SHENHUA	5 (0.0017)	295 (0.0000)	59.1	61 (0.0001)	12.1
1288	ABC	12 (0.0041)	578 (0.0000)	48.1	51 (0.0000)	4.2
1299	AIA	13 (0.0044)	366 (0.0000)	28.1	161 (0.0001)	12.3
1398	ICBC	30 (0.0102)	11157 (0.0008)	371.9	1040 (0.0009)	34.7
1928	SANDS CHINA LTD	7 (0.0024)	131 (0.0000)	18.7	72 (0.0001)	10.3
1988	MINSHENG BANK	1 (0.0003)	48 (0.0000)	47.5	9 (0.0000)	9.1
2318	PING AN	17 (0.0058)	1605 (0.0001)	94.4	266 (0.0002)	15.6
2388	BOC HONG KONG	1 (0.0003)	40 (0.0000)	40.3	12 (0.0000)	11.7
2601	CPIC	2 (0.0007)	22 (0.0000)	11.0	8 (0.0000)	4.2
2628	CHINA LIFE	55 (0.0187)	3508 (0.0002)	63.8	1041 (0.0009)	18.9
2823	X ISHARES A50	100 (0.0340)	31250 (0.0021)	312.5	3441 (0.0030)	34.4
3323	CNBM	7 (0.0024)	427 (0.0000)	61.0	79 (0.0001)	11.3
3333	EVERGRANDE	6 (0.0020)	235 (0.0000)	39.1	25 (0.0000)	4.1
3968	CM BANK	2 (0.0007)	40 (0.0000)	19.8	14 (0.0000)	7.1
3988	BANK OF CHINA	10 (0.0034)	631 (0.0000)	63.1	46 (0.0000)	4.6
HSCEI	Hang Seng China Enterprises Index	66 (0.0224)	88584 (0.0060)	1342.2	7767 (0.0067)	117.7
HSI	Hang Seng Index	2184 (0.7421)	14623486 (0.9867)	6695.7	1141112 (0.9807)	522.5

Table 3: Descriptive statistics for 30 most active (in terms of trading volume) CBBCs written on HSI during 2012. We report, for each CBBC, its codes, contract style (Bull/Bear), issuer, strike level, call level, entitlement (or conversion) ratio, listing date, maturity date, delisting date, Time-to-Maturity (TtM, i.e. number of days between listing date and maturity date), the survival time (SCD, i.e., number of calendar days between listing date and the last trading day). Trading volumes and turnover values are measured in millions. MCE equal to 1 means MCE occurs, and equals 0 otherwise. The skewness of daily returns, the correlation between outstanding ratio and closing price, the correlation between outstanding ratio and 11-day ($T-5$ to $T+5$) CBBC return volatility (ReV), as well as the correlation between outstanding ratio and ex-ante skewness (ExS) are also reported. The p-value for the null hypothesis of zero skewness is computed through the Pearson Type VII curve approximation proposed in D'Agostino and Tietjen (1973). The ex-ante skewness is computed by using (C.1)-(C.2) and (C.8)-(C.9) under the log normal assumption. The differences between the averages of the bull and bear contracts, as well as those between the averages of the called and non-called issues are reported along with p-values for testing the null hypothesis of no difference.

														Skew. (return)		Corr(out, price)		Corr(out, ReV)		Corr(out, ExS)	
Code	Style	Issuer	Strike	CallL	Ratio	Listed	Matu.	Deli.	TtM	SCD	Volu.	Turn.	MCE	Skew.	p-value	Corr.	p-value	Corr.	p-value	Corr.	p-value
60146	Bear	UB	22000	21800	10000	01/30/12	08/30/12	08/31/12	213.0	213.0	70962	5345	0	1.794	0.000	-0.403	0.000	0.669	0.000	0.673	0.000
60258	Bull	CS	20100	20300	10000	02/02/12	08/30/12	04/11/12	210.0	69.0	68197	4868	1	4.142	0.000	-0.393	0.007	0.235	0.116	0.353	0.017
60235	Bull	UB	19800	20000	10000	02/01/12	08/30/12	05/14/12	211.0	103.0	66071	4950	1	3.347	0.000	-0.814	0.000	0.658	0.000	0.530	0.000
60301	Bull	UB	20200	20400	10000	02/02/12	09/27/12	04/02/12	238.0	60.0	63984	4182	1	0.548	0.138	-0.649	0.000	0.410	0.007	0.485	0.001
60300	Bull	UB	20000	20200	10000	02/02/12	07/30/12	04/12/12	179.0	70.0	57460	4032	1	3.389	0.000	-0.677	0.000	0.412	0.004	0.649	0.000
69884	Bull	HS	17488	17888	15000	01/11/12	09/27/12	09/28/12	260.0	260.0	56898	8619	0	1.281	0.000	-0.733	0.000	0.741	0.000	0.487	0.000
60280	Bull	CS	20238	20438	10000	02/02/12	08/30/12	04/02/12	210.0	60.0	54854	3601	1	0.367	0.312	-0.566	0.000	0.384	0.012	0.330	0.035
61891	Bear	UB	20800	20600	10000	05/14/12	09/27/12	09/17/12	136.0	126.0	53533	4367	1	7.422	0.000	-0.676	0.000	0.419	0.000	0.292	0.006
61172	Bear	CS	21400	21200	10000	03/20/12	06/28/12	05/03/12	100.0	44.0	53360	3873	1	1.944	0.000	-0.710	0.000	0.442	0.019	0.660	0.000
61173	Bear	CS	21550	21350	10000	03/20/12	06/28/12	05/03/12	100.0	44.0	49805	3955	1	3.502	0.000	-0.771	0.000	0.360	0.060	0.776	0.000
60172	Bull	CS	19700	19900	10000	01/31/12	07/30/12	05/15/12	181.0	105.0	49504	3622	1	3.021	0.000	-0.776	0.000	0.556	0.000	0.473	0.000
62970	Bull	CS	18490	18690	10000	06/20/12	11/29/12	11/30/12	162.0	162.0	49480	3134	0	2.018	0.000	-0.406	0.000	0.532	0.000	0.541	0.000
60145	Bear	UB	22300	22100	10000	01/30/12	09/27/12	09/28/12	241.0	241.0	48823	4622	0	0.412	0.036	-0.512	0.000	0.618	0.000	0.641	0.000
60179	Bull	UB	19700	19900	10000	01/31/12	08/30/12	05/15/12	212.0	105.0	48053	3218	1	3.083	0.000	-0.757	0.000	0.618	0.000	0.761	0.000
60337	Bull	UB	20100	20300	10000	02/03/12	08/30/12	04/11/12	209.0	68.0	46617	3290	1	3.020	0.000	-0.743	0.000	0.583	0.000	0.723	0.000
67682	Bear	CS	20750	20550	10000	08/01/12	12/28/12	09/17/12	149.0	47.0	44895	3180	1	4.563	0.000	-0.665	0.000	0.442	0.010	0.473	0.006
60845	Bear	CS	21950	21750	10000	02/29/12	06/28/12	06/29/12	120.0	120.0	44513	3920	0	0.505	0.061	0.100	0.366	-0.165	0.137	0.009	0.937
62058	Bull	UB	17800	18000	10000	05/18/12	11/29/12	11/30/12	195.0	195.0	43935	3339	0	5.006	0.000	-0.467	0.000	0.788	0.000	0.721	0.000
60325	Bull	CS	20000	20200	10000	02/03/12	08/30/12	04/12/12	209.0	69.0	42626	3148	1	3.002	0.000	-0.626	0.000	0.624	0.000	0.492	0.001
62177	Bear	UB	20100	19900	10000	05/22/12	09/27/12	08/07/12	128.0	77.0	40854	2724	1	3.621	0.000	-0.644	0.000	0.830	0.000	0.416	0.002
60218	Bear	HS	24188	23888	25000	02/01/12	10/30/12	10/31/12	272.0	272.0	40475	7072	0	0.174	0.325	-0.330	0.000	0.552	0.000	0.703	0.000
60217	Bear	HS	23388	23088	15000	02/01/12	08/30/12	08/31/12	211.0	211.0	39807	7245	0	0.332	0.100	-0.624	0.000	0.727	0.000	0.815	0.000
60236	Bull	UB	19600	19800	10000	02/01/12	09/27/12	05/15/12	239.0	104.0	39510	2552	1	2.334	0.000	-0.702	0.000	0.647	0.000	0.710	0.000
60049	Bear	CS	22300	22100	10000	01/27/12	08/30/12	08/31/12	216.0	216.0	39154	3674	0	1.112	0.000	-0.541	0.000	0.655	0.000	0.681	0.000
60173	Bull	CS	19500	19700	10000	01/31/12	08/30/12	05/16/12	212.0	106.0	38827	2949	1	2.963	0.000	-0.752	0.000	0.743	0.000	0.608	0.000
63392	Bear	UB	22900	22700	10000	10/10/12	01/30/13	12/28/12	112.0	79.0	38690	2275	1	0.770	0.033	-0.835	0.000	0.813	0.000	0.830	0.000
61282	Bear	CS	21300	21100	10000	03/27/12	06/28/12	05/02/12	93.0	36.0	38672	2839	1	2.443	0.000	-0.604	0.003	0.833	0.000	0.091	0.695
60638	Bull	HS	16788	17188	20000	02/21/12	12/28/12	12/31/12	311.0	311.0	38294	5501	0	0.552	0.003	-0.755	0.000	0.776	0.000	0.661	0.000
62057	Bear	UB	20200	20000	10000	05/18/12	08/30/12	08/07/12	104.0	81.0	38268	3424	1	4.649	0.000	-0.696	0.000	0.351	0.008	0.382	0.004
60486	Bull	UB	20400	20600	10000	02/10/12	08/30/12	03/08/12	202.0	27.0	37606	2698	1	2.620	0.000	-0.521	0.022	0.226	0.352	0.227	0.366
Average									187.8	122.7	48124	4074	0.667	2.464	0.034	-0.608	0.013	0.549	0.024	0.540	0.069
Average (bull)									215.0	117.1	50120	3981	0.750	2.543	0.028	-0.646	0.002	0.558	0.031	0.547	0.026
Average (bear)									156.8	129.1	45844	4180	0.571	2.374	0.040	-0.565	0.026	0.539	0.017	0.532	0.118
Difference									58.2	-11.9	4276	-198		0.169		-0.081		0.019		0.015	
p-value									0.005	0.691	0.233	0.720		0.800		0.270		0.819		0.850	
Average (called)									171.7	74.0	48569	3487	1.000	3.037	0.024	-0.679	0.002	0.529	0.029	0.513	0.057
Average (non-called)									220.1	220.1	47234	5247	0.000	1.318	0.052	-0.467	0.037	0.589	0.014	0.593	0.094
Difference									-48.4	-146.1	1335	-1760		1.719		-0.212		-0.060		-0.080	
p-value									0.032	0.000	0.735	0.016		0.007		0.024		0.551		0.353	

Table 4: Descriptive statistics for CBBCs listed on HKEx in 2012. TtM is the Time-to-Maturity (calendar days), SCD is the Survival Calendar Days, STD is the Survival Trading Days, NoTD is the Number of Trading Days with non-zero trading volumes, VpSTD is the average trading volume per STD, and TpSTD is the average turnover value per STD. In this table, the statistics for trading volume and turnover value are computed based on cumulative values for each contract. All of the general holidays for 2012 stated in the website of Hong Kong government are excluded in calculation of the number of trading days. Trading volumes are measured in million and turnover values in million HKD. The differences between the averages of the called and non-called issues are reported along with *p*-values for testing the null hypothesis of no difference between the called and non-called issues.

	TtM	SCD	STD	NoTD	Volume	VpSTD	Turnover	TpSTD
Panel A: Statistics for 2184 issues written on HSI								
Mean	168.8	57.7	39.6	21.3	6695.7	430.5	522.5	28.9
Std	59.8	67.5	46.4	24.5	9551.4	680.1	817.3	46.2
Min	91.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
Med	158.5	25.0	17.0	12.0	2624.6	137.0	194.4	9.5
Max	396.0	329.0	225.0	196.0	70961.7	4320.3	8619.3	394.2
Panel B: Statistics for 1758 called issues written on HSI								
Mean	169.2	31.7	21.7	16.6	6792.9	520.7	497.3	34.5
Std	61.0	38.9	26.4	19.9	9393.6	728.7	732.9	49.7
Min	91.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
Med	158.0	16.0	11.0	9.0	2866.0	203.8	194.4	13.9
Max	396.0	289.0	197.0	169.0	68197.2	4320.3	5623.2	394.2
Panel C: Statistics for 426 non-called issues written on HSI								
Mean	167.3	167.3	113.5	40.8	6294.8	58.3	626.4	5.6
Std	54.9	54.9	36.8	31.1	10178.8	90.1	1094.1	8.6
Min	91.0	91.0	61.0	1.0	0.0	0.0	0.0	0.0
Med	162.0	162.0	108.0	38.0	1665.3	16.1	194.5	1.9
Max	329.0	329.0	225.0	196.0	70961.7	542.8	8619.3	49.6
Difference	1.9	-135.5	-91.8	-24.2	498.1	462.4	-129.1	28.9
p-value	0.528	0.000	0.000	0.000	0.358	0.000	0.021	0.000

Table 5: The table reports the average number of contracts (NoC), average ex-ante skewness (EAS), average high-low difference (HLD) of intra-day trading prices (in cent), average daily trading volume per contract (in million), average daily turnover value per contract (in million HKD), and average outstanding ratio (in percent) across each ex-ante skewness tercile. The ex-ante skewness is computed by using (C.1)-(C.2) and (C.8)-(C.9) under the log normal assumption. The last row in each panel reports the differences between the high and low skewness terciles. Newey and West (1987) *t*-statistics are computed for testing whether these differences are equal to zero. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Skewness Terciles	NoC	EAS	HLD	Vol.	Turn.	Outs.
	Panel A: All Contracts					
1	73	0.59	1.30	43.21	7.14	3.85
2	73	1.34	1.61	164.48	16.18	4.88
3	73	2.75	2.01	537.16	38.29	10.59
3-1	—	2.16 ***	0.72 ***	493.95 ***	31.14 ***	6.73 ***
(t-stat)		(23.53)	(9.67)	(7.82)	(5.98)	(10.84)
	Panel B: Called Contracts					
1	38	1.13	1.61	99.29	11.11	3.64
2	38	1.93	1.83	409.87	33.58	6.75
3	37	3.40	2.22	649.32	44.37	12.18
3-1	—	2.27 ***	0.61 ***	550.03 ***	33.27 ***	8.53 ***
(t-stat)		(18.04)	(6.63)	(10.49)	(7.45)	(9.81)
	Panel C: Non-Called Contracts					
1	35	0.47	1.11	40.77	6.76	3.76
2	36	0.99	1.53	74.50	8.65	4.12
3	36	1.60	1.88	295.79	25.03	6.75
3-1	—	1.13 ***	0.77 ***	255.01 ***	18.27 ***	2.99 ***
(t-stat)		(10.06)	(6.99)	(5.99)	(5.38)	(5.65)

Table 6: Average weekly (5 trading day) returns for CBBCs portfolios in 2012. On each portfolio formation day CBBCs are first grouped by maturity, then in each group with the same maturity, we sort CBBCs into ex-ante skewness terciles, where ex-ante skewness is defined as in equations (C.1), and is evaluated under the log normal assumption. Finally, we average the returns across all maturity to create returns for each skewness tercile. We use the closing prices as the proxy for price. The last row reports the differences in average returns between the high and low skewness terciles. Newey and West (1987) *t*-statistics are computed for testing whether these differences are equal to zero. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

	Panel A: All Contracts			Panel B: Called			Panel C: Non-Called		
Skew.	Holding Periods			Holding Periods			Holding Periods		
Terciles	5	10	20	5	10	20	5	10	20
1	-1.22	-1.45	-1.09	-13.70 ***	-12.97 ***	-11.23 ***	3.60 **	3.22 ***	2.43 ***
2	-2.10 **	-1.98 ***	-1.49 ***	-22.94 ***	-19.21 ***	-14.19 ***	10.16 ***	9.76 ***	7.13 ***
3	-14.29 **	-8.51 ***	-5.90 ***	-33.07 ***	-23.59 ***	-15.39 ***	19.58 ***	18.65 ***	14.21 ***
3-1	-13.07 **	-7.06 *	-4.81 *	-19.37 ***	-10.61 ***	-4.16 *	15.98 ***	15.43 ***	11.78 ***
(t-stat)	(-2.05)	(-1.67)	(-1.89)	(-4.72)	(-2.94)	(-1.79)	(4.36)	(5.00)	(6.09)

Table 7: The accumulative trading volumes and the accumulative turnover values for some ranges of *Distance* ($= |\text{Closing Price} - \text{Prospectus Price}|$) between the daily closing price and the prospectus price. Here the prospectus price is defined by (3.1)-(3.2) with the daily closing price of Hang Seng Index as the Spot Price therein. Reported are the percentage contributions to the respective sample. For example, for all issues called by issuers, the accumulative trading volume when *Distance* is less than one cent accounts for 75.5% of the total trading volume of all called issues.

Distance (in cent)	≤ 0.5	≤ 1	≤ 1.5	≤ 2
Panel A: Trading Volume				
called contracts	45.236	75.503	88.847	95.151
non-called contracts	24.899	51.466	66.369	78.331
overall	41.488	71.073	84.705	92.051
Panel B: Turnover Value				
called contracts	40.061	68.922	83.746	91.858
non-called contracts	20.824	41.695	54.721	67.279
overall	36.516	63.905	78.397	87.329

Table 8: This table reports, for each issuer, the profit (in million HKD) by trading CBBCs written on HSI. PPI represents the profit per issue, NoI the number of issues, NoCI the number of called issues, and PoCI the percentage of called issues. Percentage contributions to the total are reported in parenthesis. The Bank of East Asia did not issue any CBBC written on HSI in the year 2012.

	Called Issues		Non-Called Issues		All Issues		Distribution		
Issuer	Profit	PPI	Profit	PPI	Profit	PPI	NoI	NoCI	PoCI
BP	167.2 (0.066)	0.84	-25.5 (0.022)	-0.88	141.8 (0.102)	0.62	227	198	0.872
CS	815.6 (0.323)	1.96	-312.1 (0.275)	-3.12	503.5 (0.362)	0.97	517	417	0.807
CT	14.6 (0.006)	0.38	-60.3 (0.053)	-6.70	-45.7 (0.033)	-0.97	47	38	0.809
DC	11.3 (0.004)	0.11	-53.6 (0.047)	-1.17	-42.3 (0.030)	-0.29	146	100	0.685
GS	14.6 (0.006)	0.14	-18.6 (0.016)	-0.44	-4.0 (0.003)	-0.03	150	108	0.720
HS	117.4 (0.046)	2.06	-22.6 (0.020)	-2.26	94.8 (0.068)	1.41	67	57	0.851
JP	121.7 (0.048)	1.12	-20.1 (0.018)	-0.74	101.7 (0.073)	0.75	136	109	0.801
ML	6.6 (0.003)	0.09	-2.1 (0.002)	-0.21	4.5 (0.003)	0.06	81	71	0.877
RB	0.7 (0.000)	0.14	0.0 (0.000)	0.00	0.7 (0.000)	0.14	5	5	1.000
SG	348.2 (0.138)	1.16	-220.7 (0.195)	-2.48	127.5 (0.092)	0.33	390	301	0.772
UB	908.5 (0.360)	2.57	-398.2 (0.351)	-6.22	510.4 (0.366)	1.22	418	354	0.847
Overall	2526.4 (1.000)	1.44	-1133.8 (1.000)	-2.66	1392.6 (1.000)	0.64	2184	1758	0.805

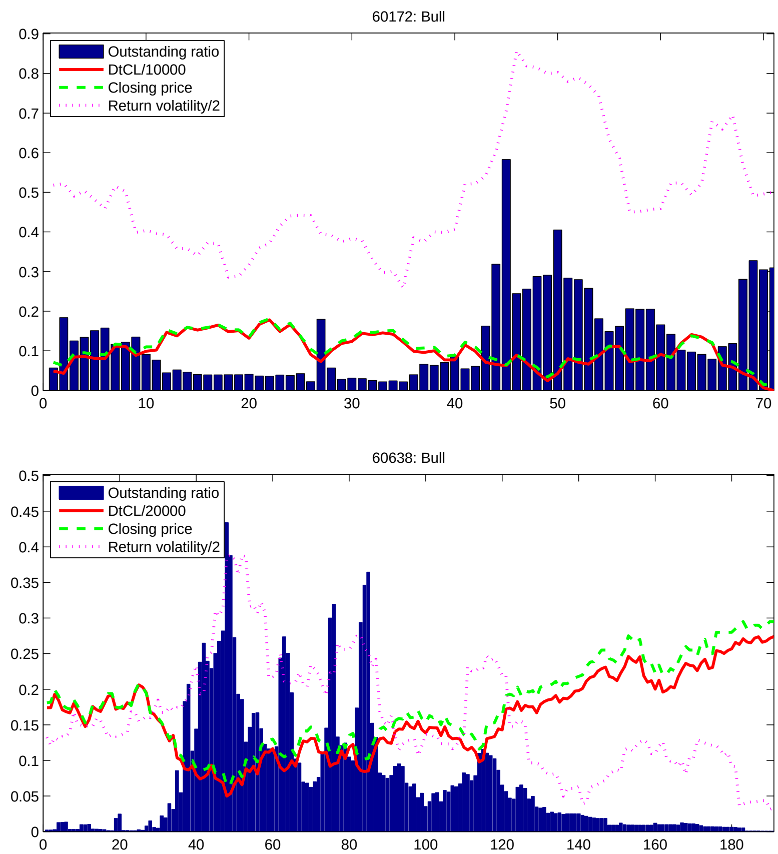

Figure 1: We provide the outstanding ratio (outstanding quantity divided by issue size), the distance to call level (DtCL, re-scaled by entitlement ratio), the closing prices, and the 11-day ($T-5$ to $T+5$) CBBC return volatility (annualized) for two bull CBBC issuances numbered 60172 and 60638. The correlation between outstanding ratio and DtCL for issues 60172 and 60638 are -0.742 and -0.790, respectively. The correlation between outstanding ratio and return volatility for issues 60172 and 60638 are 0.708 and 0.753, respectively. We re-scaled these quantities into the same order of magnitudes.

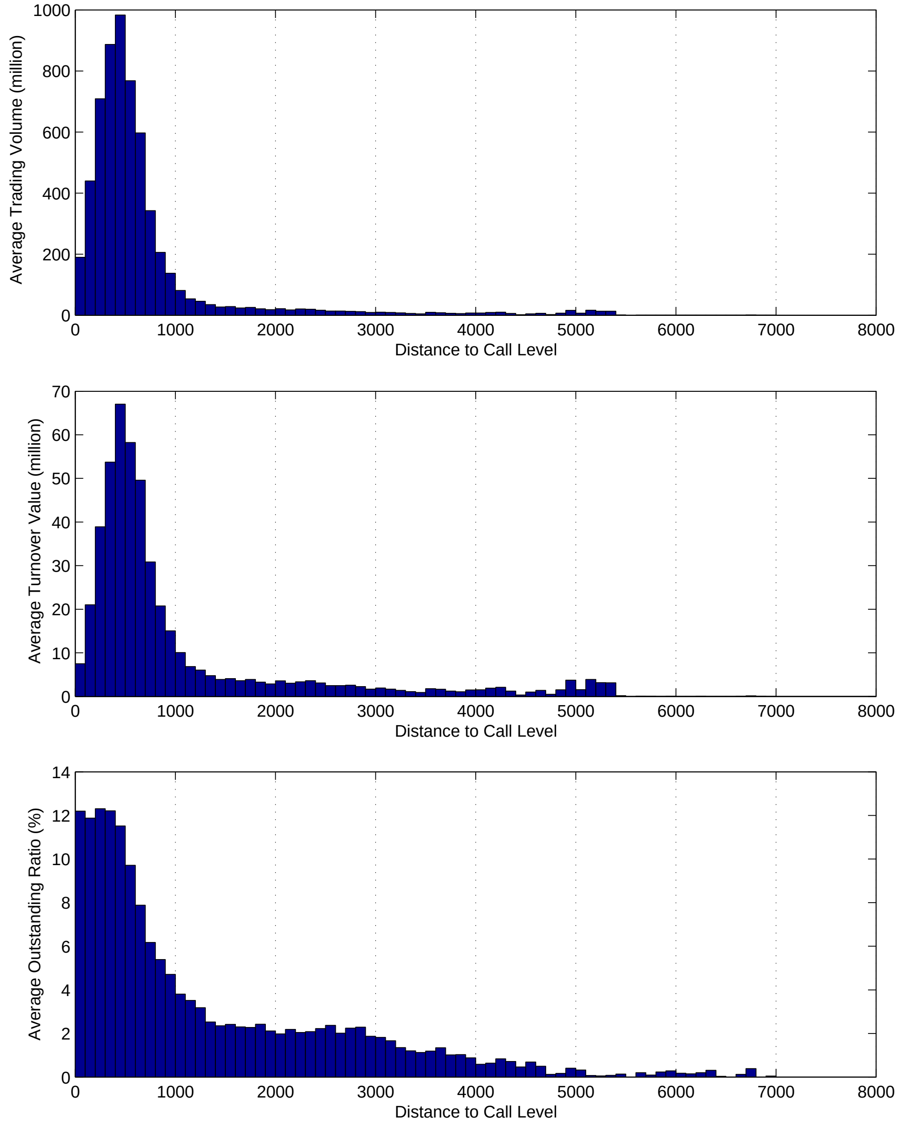

Figure 2: Average trading volumes, average turnover values, and average outstanding ratios with different distance to call level (DtCL) for all contracts on all trading days. The bin size is 100. Reported are averaged values of daily trading records lying in each bin. The trading volume when DtCL less than 1000 accounts for 91.3%, the turnover value accounts for 82.9%, and the outstanding ratio accounts for 66.1%. On each day, the distance to call level is defined as the absolute difference between contract's call level and the closing price of HSI on that day.

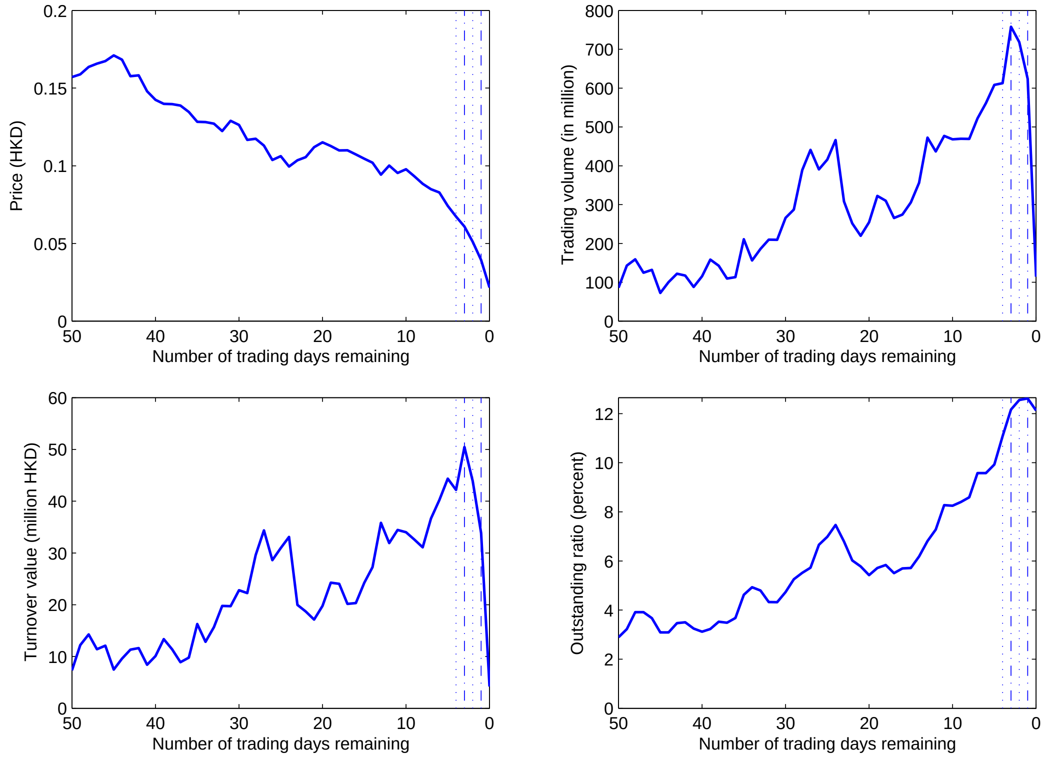

Figure 3: The average CBBC price, the average daily trading volume, the average daily turnover value, and the average outstanding ratio against the number of trading days remaining for the 1758 CBBCs that are called by issuers. The averaging is across all CBBCs with a given number of trading days remaining.

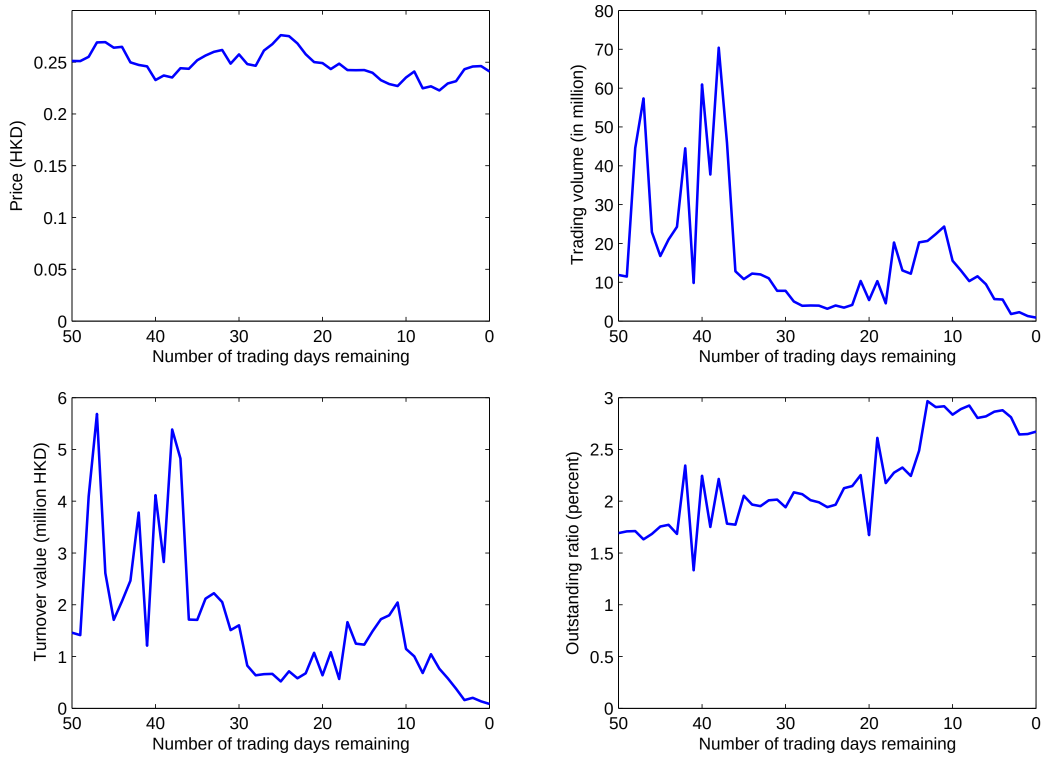

Figure 4: The average CBBC price, the average daily trading volume, the average daily turnover value, and the average outstanding ratio against the number of trading days remaining for the 426 CBBCs without MCE. The averaging is across all CBBCs with a given number of trading days remaining.

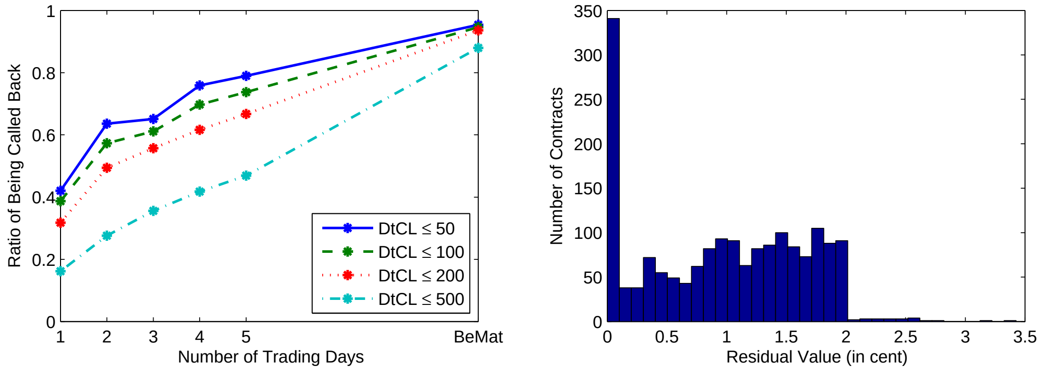

Figure 5: LEFT: The ratio of being called back against the number of trading days lapsed after CBBC' day-end distance to call level (DtCL) declines to some pre-specified levels. BeMat means before maturity. RIGHT: Histogram of residual values for all 1758 CBBCs that are called back by issuers. The sample mean is 0.97 cent with a standard deviation of 0.68 cent.

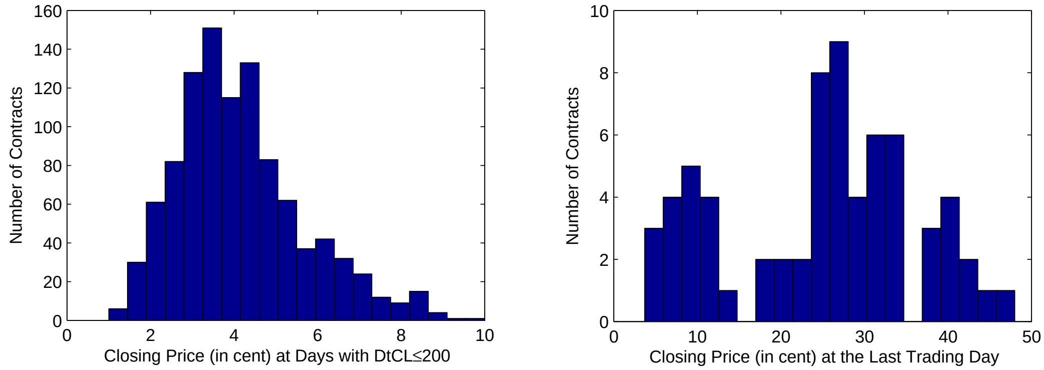

Figure 6: LEFT: Histogram of the CBBC closing prices at days with distance to call level (DtCL) less than 200 for all issues written on HSI. The sample mean is 4.2 cent with a standard deviation 1.5 cent. RIGHT: Histogram of closing prices at the last trading day for all contracts that survive from a DtCL$\leq$ 200. The sample mean is 24.8 cent with a standard deviation of 11.4 cent.

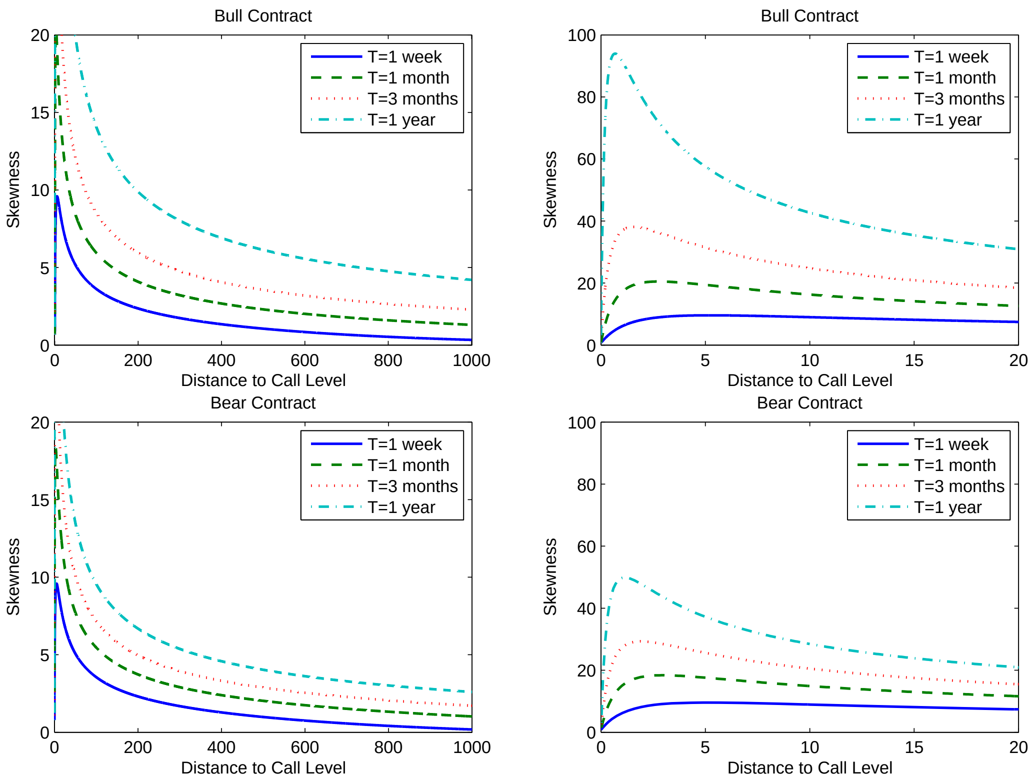

Figure 7: Ex-ante skewness against distance to call level. The ex-ante skewness is computed by using (C.1)-(C.2) and (C.8)-(C.9) under the log normal assumption. For bull contract $S_b = 19200$, $K = 19000$, and $S \in (19200, 20200)$. For bear contract $S_b = 20800$, $K = 21000$, and $S \in (19800, 20800)$. The other parameter values are $r = 0.006$, $\sigma = 0.3$, and $T_0 = 1/500$ (half a day).

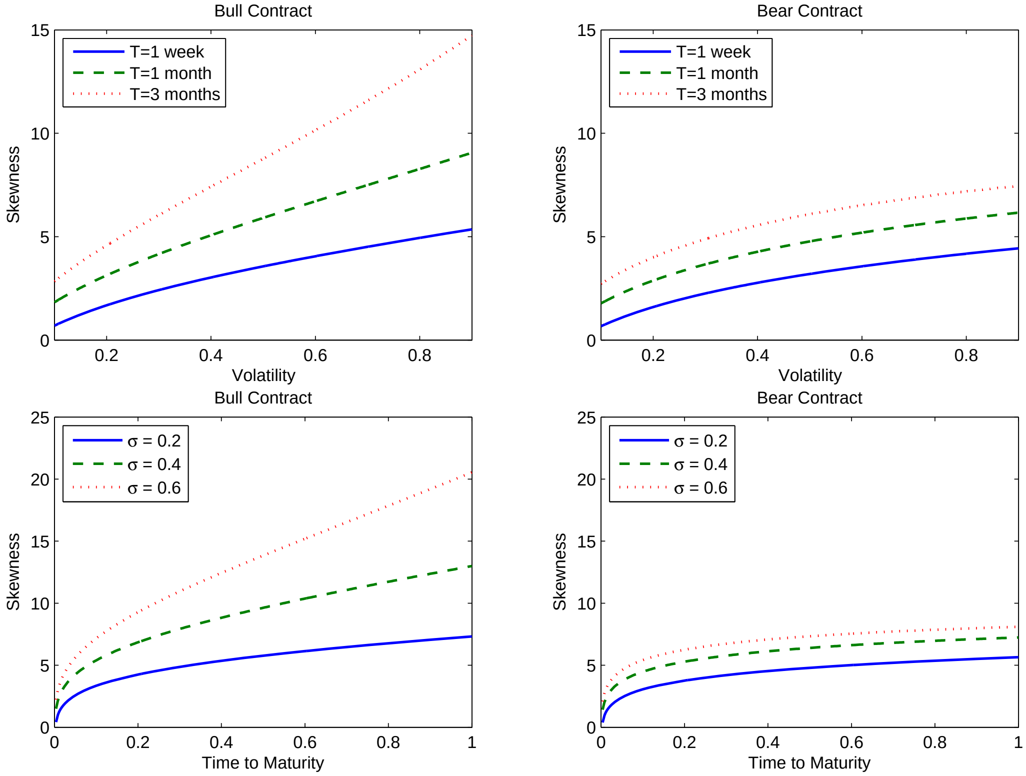

Figure 8: Ex-ante skewness against volatility and time-to-maturity. The ex-ante skewness is computed by using (C.1)-(C.2) and (C.8)-(C.9) under the log normal assumption. For bull contract $S = 20000$, $S_b = 19800$, $K = 19600$. For bear contract $S = 20000$, $S_b = 20200$, $K = 20400$. The other parameter values are $r = 0.006$, and $T_0 = 1/500$ (half a day).

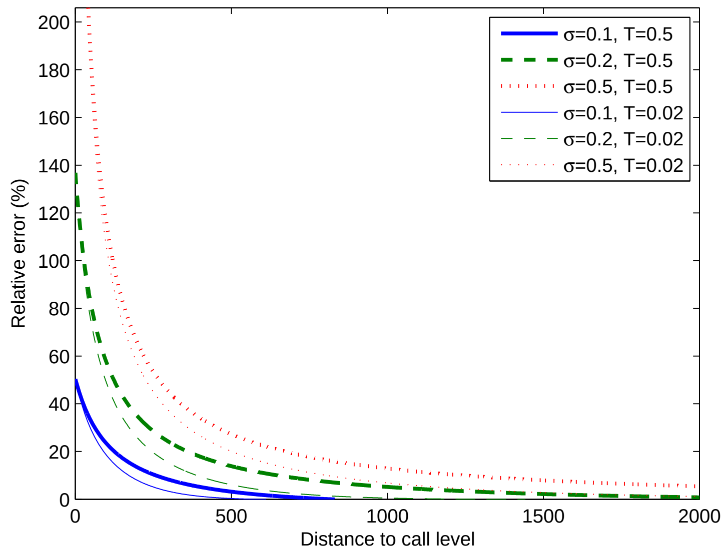

Figure 9: The relative error of the prospectus price defined in (3.1) over the price based on Black-Scholes-Merton model is plotted against the distance between underlying asset price and call level. Preferred parameter values are: strike price $K = 18800$, call level $S_b = 19000$, risk-free interest rate $r = 0.6\%$, spot price of underlying $S_0 = 20000$, time to maturity $T = 0.5$ (half a year), settlement period $T_0 = 0.002$ (half a day), and entitlement ratio $R = 10000$.

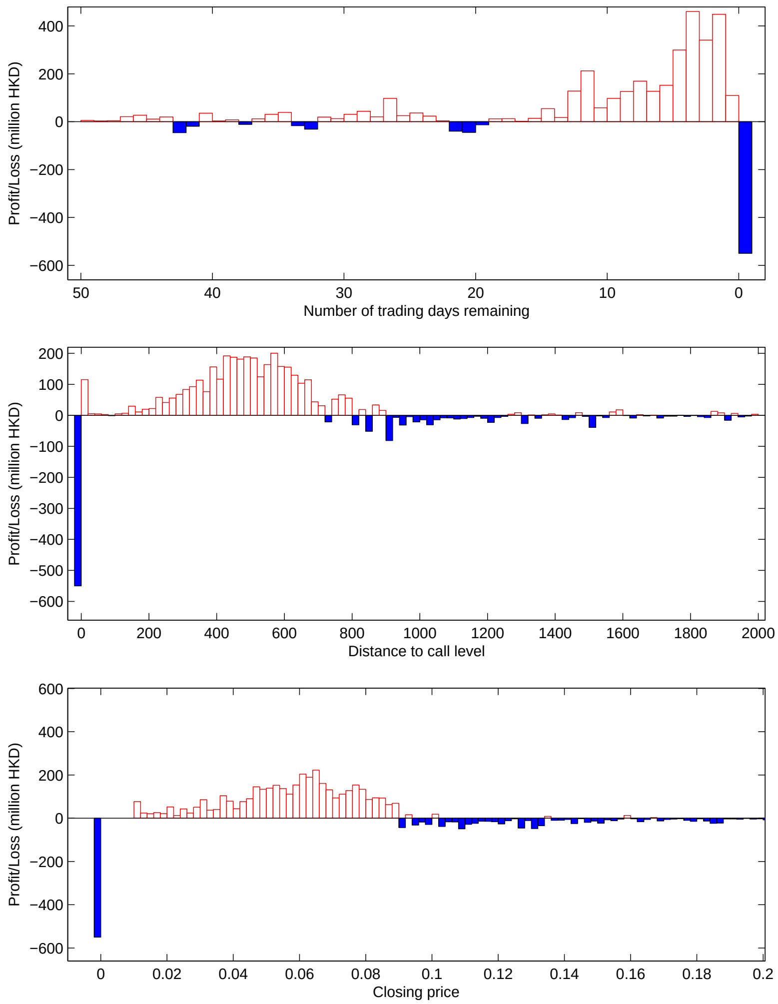

Figure 10: Profit / loss pattern for CBBCs called by issuers. Clear bars indicate profits, and shaded bars indicate losses. The profit on the issuance day is the product of issue price and issue volume. For a bull / bear contract, the settlement prices for computing residual values are obtained from high frequency data for HSI. For each intermediate trading day, if its day-end outstanding quantity is greater than or equal to that of the previous trading day, we estimate the profit as the product of the mean selling price of the current trading day and the growth (comparing with the previous trading day) in day-end outstanding quantity; if its day-end outstanding quantity is less than that of the previous trading day, we estimate the loss as the product of the mean buying price of the current trading day and the number of fall (comparing with the previous trading day) in day-end outstanding quantity. The profit due to the initial offer is 1.44 million HKD. The loss (the longest negative bar) due to final residual values is 550.0 million HKD. The total net profit is 2.53 billion HKD.

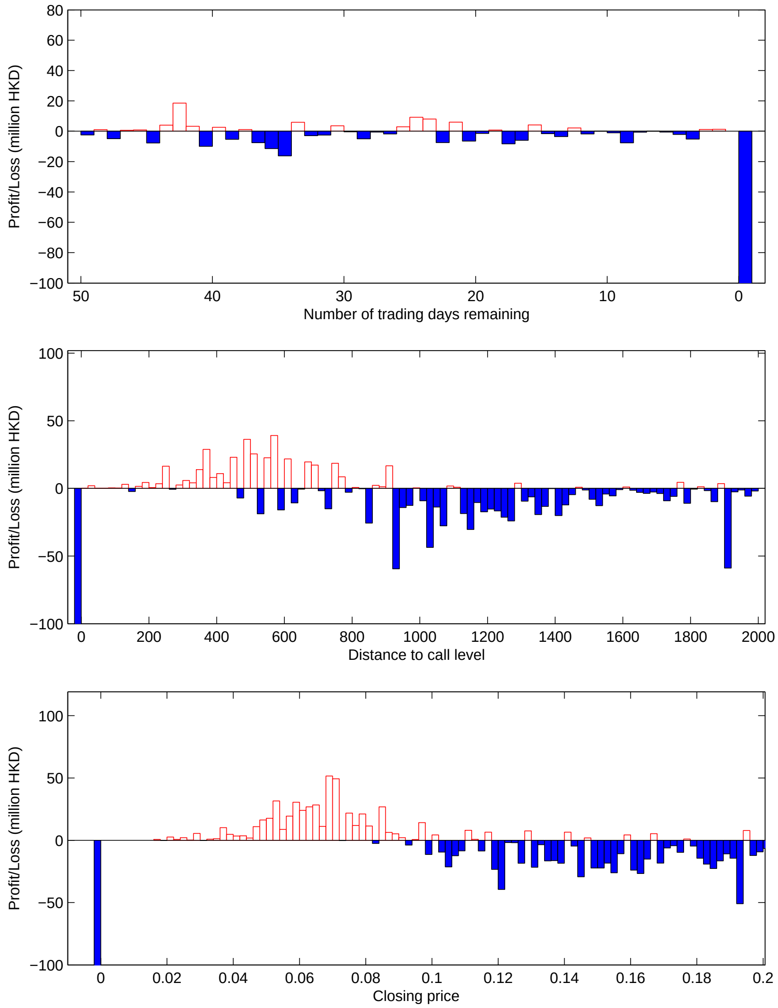

Figure 11: Profit/loss pattern for CBBCs without MCE. Clear bars indicate profits, and shaded bars indicate losses. Profit due to the initial offer is 0.33 million HKD. The loss (the longest negative bar) due to the final short position is 717.8 million HKD. In order to view the pattern more clearly, we do not plot the full vertical axis. The total net loss is 1.13 billion HKD. The profits/losses on issuance day and intermediate trading days are computed by the same method as that used in Figure 10. If the contracts mature without MCE, the settlement price is that used for settling a contemporaneously expiring HSI future contract.