Investor Behavior and Financial Innovation: Callable Bull/Bear Contracts

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Abstract

We examine the notion that financial innovations cater to investors’ behavioral biases. Specifically, we analyze the popularity of callable bull/bear contracts (CBBCs), which are options that can be called back when underlying prices reach a threshold. Investors treat CBBCs like lotteries in that they prefer CBBCs with low prices, high volatilities, and high skewness, and prefer trading them when underlying prices are near callback thresholds. During 2012, issuers gained (investors lost) 1.82 billion HKD (US$235 million) by trading CBBCs written on the Hang Seng Index. 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.”

— Economic Sciences Nobel Prize Committee (2013)

In traditional finance, financial innovations are desirable because they cover additional contingencies (i.e., enable market completeness) or mitigate financial frictions (Ross 1989, Allen and Gale 1991, and Duffie and Rahi 1995). In a complementary view, we consider the role of behavioral finance in financial engineering. We 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) in Hong Kong, which are also known as turbo warrants¹ 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 prior to its maturity date, the CBBC is called back by its issuer, and trading of the CBBC is terminated. If a callback does not occur, the payoff of a bull/bear contract at maturity is that of a vanilla European call/put option.

CBBCs are extremely popular among investors in Europe and Hong Kong. Indeed, in some European countries, the turnover value of turbo warrants constitutes more than 50% of all derivative trading (Wong and Chan 2008; 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. The corresponding turnover value increased more than 100 times from 11.34 billion HKD in 2006 to 1,533.15 billion HKD in 2012. Moreover,

¹These contracts can be dated back to late 2001, when they first appeared in Germany.
in 2009 there were 8,072 newly listed CBBCs, and their market share (10.9%) surpassed that of derivative warrants (10.7%).

The popularity of CBBCs is intriguing. Different explanations have been proposed to account for this phenomenon. It has been claimed that some investors prefer CBBCs because they believe that CBBCs are much cheaper than their vanilla counterparts, they are much less sensitive to volatility (Huang 2008, page 10), and because they can closely mimic price changes in the underlying asset (i.e., their delta is close to one,) which offers investors higher price transparency (see HKEx 2006, page 1). Josen (2010), however, clarifies that “... although the CBBC appears to be cheaper and more transparent than normal warrants...Investors may see their investment suddenly lost if the product is terminated upon the call event.”

In an article by Lam (2011), Edmond Lee of SG Securities attributes the popularity of CBBCs to the unpredictability (volatility) of the stock market. Eva Tsoi, a global equity flow strategist at Société Générale, opines in Ngan (2012) that it is the high leverage of CBBCs that attracts investors.

Existing literature does not seem to have reached agreement on the success of CBBCs.

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

3Similar 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, 2014, item 5.36); Credit Suisse (2014) is also used by UBS as its FAQs.

4There is a debate on whether the theoretical prices of 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 this analysis to three more general models, and document that “whether CBBCs are sensitive to implied volatility or not” is actually model-dependent. Specifically, the statement, “implied volatility is insignificant to turbo warrant pricing”, is only true under the Black-Scholes assumptions. Wong and Lau (2008) 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, Luo, 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. The authors assert that the newly issued CBBCs are much less sensitive to volatility than warrants and regular European options, which could explain the popularity of CBBCs after the recent financial crisis.
In this paper, we propose a behavioral explanation for the popularity of these contracts. We find that investors prefer to trade and hold CBBCs with the three characteristics of lottery-type securities proposed by Kumar (2009): low average price, high volatility, and high positive skewness. Specifically, CBBCs near their call prices 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. 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, we suggest 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 concept of security issuance and financial marketing catering to the demands of investors with limited sophistication. Indeed, we find a negative relationship between skewness and average CBBC returns, which is consistent with Barberis and Huang (2008), who argue that securities with high skewness should earn low average returns, since investors with cumulative prospect theory utility (see Tversky and Kahneman 1992) tend to prefer lottery-type opportunities.

Of course, investors’ preferences for lottery-type securities have been examined in

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5Throughout this paper, a contract being near (or close to) its call level means that 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.

6Gennaioli, 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. Shefrin and Statman (1993) propose that the appeal of strategies such as covered call writing to investors might depend on how the strategies are framed by their brokers, e.g., as loss avoidance or as a possible profit opportunity.
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 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. Bali and Murray (2013) find a strong and negative relation between risk-neutral skewness and the returns of “skewness assets,” where the latter consist of a combination of option and underlying stock positions that are designed to gain exposure to skewness. Recently, Boyer and Vorkink (2014) find a strong and negative relationship between a measure of \textit{ex ante} skewness and average option returns.

Most of the preceding studies rely on an empirical relationship between skewness and realized returns to motivate preferences for lottery-type investments. In contrast, CBBCs offer a unique window for directly studying investors’ preferences for structured products that resemble lotteries. This is because CBBCs are simpler than many other financial products, and their mandatory call feature together with their issuers’ monopoly power makes them very similar to state lotteries. Specifically, if CBBCs are called back, they may incur finite (usually small) losses; otherwise, they can generate arbitrarily high rates of return (with tiny probability).
Our findings are consistent with the recent hypothesis that issuers may cater to investors by engineering products that are either too complex or that appeal to behavioral biases (see, e.g., Bernard, Boyle, and Gornall 2009 and Henderson and Pearson 2011). Unlike other papers on financial innovation, however, we explicitly estimate gains and losses to issuers and investors. Our dataset facilitates this calculation because markets in CBBCs are mostly made by the issuing firm, and short-selling is not permitted. We are thus able to estimate investor profits (i.e., the negative of issuer profits) by calculating the differential between monetary values of sales and purchases on a daily basis. We estimate that investors lost 1.82 billion HKD (US$235 million) in trading CBBCs written on the Hang Seng Index during 2012. Empirical findings also reveal that, other than investor preferences for lottery-type securities, a simplistic pricing formula (see (1)-(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 when the contract is near the call level, while the price determined by the aforementioned prospectus pricing formula is positively biased in this situation. In fact, when CBBCs are close to their call levels, we show that the relative pricing error of

7Bernard, Boyle, and Gornall (2009) show that securities termed locally-capped globally-floored contracts (LCGFCs, a class of index-linked notes) are preferred by investors because they overweight tail probabilities. Henderson and Pearson (2011) analyze a popular structured equity product termed Stock Participation Accreting Redemption Quarterly-pay Securities (SPARQS). SPARQS have a payoff similar to that of a covered call except that SPARQS are callable by the issuer via a schedule of call prices, and are terminated early if the underlying stock price drops too low. Henderson and Pearson (2011) show that the initial offering prices of SPARQS in their sample are about 8% higher than estimates of the product’s fair market values. The authors claim that it is difficult to rationalize purchases of SPARQS by informed rational investors. Both LCGFCs and SPARQS are more complex than CBBCs, and their returns are capped by their contract provisions. In contrast, as pointed out earlier, CBBCs are simpler and can generate arbitrarily high return (with tiny probability) in an easily understandable way, which likely appeals to investors with gambling preferences.

8In 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 (the mandatory call feature of CBBCs and the minimum tick size of HKEx can both result in relatively large basis risk). Several traders and retail investors working in Hong Kong also hold the opinion that CBBCs are speculative products rather than hedging instruments.
the prospectus price over the estimate of the corresponding fair market value may be as high as hundreds of percentage points.

Overall, our evidence indicates that CBBCs are popular principally because investors like the lottery-like feature of CBBCs that are likely to be called back. Investors also tend to price these CBBCs high,\(^9\) which leads to gains for the issuer. We thus highlight the impact of cumulative prospect theory in financial innovation.

The CBBCs we analyze, of course, are specialized contracts traded in Hong Kong. So, a natural issue that arises is the relevance of the CBBC setting for the typical finance researcher trying to understand financial innovations. To recapitulate, there are at least three reasons why this setting has unique but general appeal. First, the CBBC contract has lottery-like features that are easy to comprehend, which allows us to clearly consider the appeal of lottery-type securities to investors. There also is a time-series element to the lottery feature; contracts far from call-back are not like lotteries in the short-term, but contracts close to call-back are. This allows an analysis of whether investors clamor for these contracts precisely during periods where they behave as lotteries.\(^{10}\) Finally, and most importantly, liquidity in CBBC markets is provided by the issuing firms themselves, and short-selling is not permitted, allowing for the computation of estimated profits and losses to issuers. This allows us to examine a hitherto unexplored issue: how

\(^9\)Li and Zhang (2011) find that derivative warrants — a class of structured products — typically have higher prices than do otherwise identical options, and show that the price difference can be explained by liquidity premium. Using a unique transactions dataset from Hong Kong, Chang, Tang, and Zhang (2014) show that households tend to accept lower risk-adjusted returns for structured products whose suitability for these investments is left unchecked by issuers or policymakers.

\(^{10}\)Out-of-the-money (OTM) options also can potentially have high skewness. However, OTM options have low deltas, whereas the deltas of CBBC contracts typically close to unity (see Figure 1). So the CBBC contract not only behaves like a lottery but is also extremely sensitive to fluctuations in the underlying price when the distance to call is small, thus considerably enhancing its appeal as a speculative instrument.
the issuance of lottery-type securities earns economic rents for issuers by appealing to
the gambling tendencies of investors.

The next section of the paper briefly introduces CBBCs and their market structure in
Hong Kong. We present an empirical study on the trading behavior of CBBC investors
in Section 2, where we also study lottery-like characteristics of CBBCs, and estimate
issuers’ profits (and investors’ losses). In Section 3, we discuss the implications of our
findings and conclude the paper.

1 CBBCs: Definition and Market Structure

In this section, we define CBBCs, describe the market environment in which these con-
tracts are traded, and also discuss the nature of our data.

1.1 What are CBBCs?

Callable Bull/Bear Contracts (CBBCs), first listed on the HKEx in June 2006, are a type
of structured product that allows investors to non-linearly track the performance of an
underlying 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. 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, trad-
ing 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.\textsuperscript{11} 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.\textsuperscript{12}

Depending on 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; 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; its holder receives nothing if a MCE occurs. Most of the
CBBCs in Hong Kong fall in Category R. The residual value for a Category R contract
is computed as the difference between a “settlement” price and strike price for a bull
contract and that between the strike price and the settlement price for a bear contract.
On the HKEx, the settlement price for the 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.\textsuperscript{13}

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 be imputed. For this purpose,
\textsuperscript{11}In Hong Kong, the settlement price of futures is the arithmetic average of 5-minute quotes of the
underlying on the last trading day.
\textsuperscript{12}This ratio varies across contracts. Quoted CBBC prices are scaled by the entitlement ratio.
\textsuperscript{13}Unless the following session does not contain any continuous period of an hour during which trading
in the Hang Seng Index is permitted on the Exchange, the MCE valuation period shall be extended to the
subsequent trading session.
we collect 1-min data on the Hang Seng Index (HSI) from Bloomberg. The data include opening price, highest price, lowest price, and closing price in each minute.\(^{14}\)

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

\[
\text{Theoretical Price of Bull Contract} = \frac{\text{Spot Price} - \text{Strike Price} + \text{Funding Cost}}{\text{Entitlement Ratio}},
\]

\[
\text{Theoretical Price of Bear Contract} = \frac{\text{Strike Price} - \text{Spot Price} + \text{Funding Cost}}{\text{Entitlement Ratio}},
\]

where \(\text{Funding Cost} = \text{Strike Price} \times \text{Annual Borrowing Rate} \times \text{Tenor of CBBC}\). Funding costs, also called financial costs, are the fees that 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 Hong Kong Interbank Borrowing Rate (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 (1)-(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 are misleading when CBBCs are close to their call levels.

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\(^{14}\)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.
We conclude this subsection by a brief comparison of CBBCs and vanilla options. Most trading of vanilla options occurs when options’ underlyings are close to option strikes (or close to at the money). The main attractiveness of a vanilla option is the convexity when the option is close to at the money. While, as we argue later in this paper, the main value the CBBC adds over the stock when the CBBC is close to being called (where most of the CBBC trading occurs) is the high skewness. Actually, the convexity when CBBC is close to being called is very small; the convexity of a CBBC is “concentrated” on a single point, namely the call level, which is what differentiates CBBCs from vanilla options. We refer the reader to Figure 1 for details. Note that CBBC prices are *almost* parallel to the 45-degree line when underlying price is higher than call level.

1.2 Structure of the CBBC Market in HKEx during 2012

We collect day-end closing data on CBBC from HKEx for the year 2012. There were 6,952 CBBCs listed on HKEx during this year.\(^\text{15}\) We use data on CBBCs that are listed on the 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 2,943 issues, among which 1,383 were bull contracts.

Table 1 reports data on the issuance activity of CBBCs by issuer. In 2012, there were 12 issuers and their total trading volume was more than 14.8 trillion, and the aggregate turnover value was HK$1,164 billion (about US$150 billion). UBS AG and Credit Suisse

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\(^{15}\)To identify a CBBC listed on HKEx, we need a five-digit CBBC code (starting with 6) as well as its issue date (or listing date), since CBBC codes are recycled.
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 three CBBCs with negligible total trading volume. Among the 2,943 CBBCs, 2,297 issues were called back before their maturity dates.\footnote{For very active CBBCs, issuers sometimes increase the supply of these contracts subsequent to the initial trading date. In our sample, only fourteen of 2,943 issues saw their supply increase in this fashion, so the impact of this phenomenon on our results is negligible.}

When CBBC contracts are issued, the issuing firm assigns a sole market maker/liquidity provider to these contracts. As reported in Table 1, the major CBBC issuers assign their own subcompanies to act as liquidity providers. Only the Bank of East Asia and Rabobank, who issue trivial quantities of CBBCs, assign third-party brokers as liquidity providers. Thus, profits from providing liquidity in CBBCs largely accrue to the issuing parent company.

Table 2 lists the stocks or indexes that formed the underlying assets for the CBBCs. There were 37 underlyings in total, of which HSI is the most common reference and accounted for 2,184 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 underlyings, 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. This approach also helps us circumvent the cumbersome
issues in dealing with different underlying assets.\textsuperscript{17}

Table 3 shows the top 30 most actively traded CBBCs in our sample. Fourteen were issued by UBS, 12 by Credit Suisse, and the remaining 4 were issued by HSBC. Among those 30 contracts, 16 were bull; 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. Contract 60146 (listed on Jan. 30, 2012) had the highest trading volume, which was about 71 billion. The highest turnover value, 8.6 billion HKD, belonged to CBBC 69884 (listed on Jan. 11, 2012).

2 Trading Behavior of CBBC Investors

To investigate the key influences that drive the popularity of CBBCs in Hong Kong, 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. We then demonstrate/examine how much investors lose by trading CBBCs.

2.1 Investors’ Preferences for Called Vs. Non-Called CBBCs

To illustrate the differences between CBBCs that are called back and those that are not, Figure 2 shows the histograms of outstanding ratios, defined as outstanding quantity divided by issue size, across all trading days for a called and an uncalled CBBC (respectively 60172 and 60638) during their lifespan. The reported data also include the closing

\textsuperscript{17}Our central results continue to hold when we expand the sample to cover all of the underlyings. The related analyses are available upon request.
prices, the distances to call levels (re-scaled by their respective entitlement ratio), and the 11-day \((T - 5 \text{ to } T + 5)\) CBBC return\(^{18}\) volatility (annualized) on each trading day. Both 60172 and 60638 are bull contracts; 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 2,184 contracts written on HSI, in Figure 3 we report the average trading volumes, the average turnover values, and the average outstanding ratios as functions of the DtCL. We can see that investors like to trade and hold CBBCs with small DtCL. On average, the most traded CBBCs are those with DtCL lying in the range \([400, 500]\); the most preferred contracts for holding are those with DtCL less than 500; there were no investor trades and no documented cases of investors holding CBBCs with DtCL greater than 7,000. The trading volume when DtCL is less than 1,000 accounts for more than 90% of the

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\(^{18}\)Throughout this paper, returns are calculated from day-end closing prices.
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 Figure 2 that investors prefer to hold CBBCs near their call levels. It is also relevant to note that, considering all 2,184 contracts written on the HSI, investors appear to prefer CBBCs with high return volatility as well.

Panel A of Figure 4 depicts a clear pattern for called contracts, in that the average price decreases as the last trading day approaches. Further, their average trading volume, average turnover value, and average outstanding ratio increase dramatically as the last trading day approaches, and all three statistics more than double in the last 15 trading days. Specifically, the average 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 average 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.

Panel B of Figure 4 presents the counterparts of Panel A for CBBCs without a M-CE. In contrast to called CBBCs, the average price of non-called CBBCs hovers around 0.27 HKD. Trading volume and turnover for non-called CBBCs gradually decrease and reach their minimum on the last trading day. Accordingly, their outstanding ratio hovers around 2.2% during the last 50 trading days. Thus, Panels A and B of Figure 4 show
distinctively different patterns for called and non-called CBBCs as their last trading days approach. We also observe 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. In Panel C, we consolidate the results in Panels A and B. We can see that, for all 2184 issues, the patterns are very similar to those for called contracts.

Table 4 reports summary statistics for all contracts, and separately for called and non-called ones. The results show that 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 that for non-called ones, and their average turnover value is more than six times that for non-called contracts. These results show high statistical significance (as documented in the last row of Table 4), and are consistent with our earlier findings upon noting that called CBBCs are close to their call levels during the several trading days immediately before MCE.

While the prices of CBBCs when they are close to their call levels are very low, and their leverage levels are very high, these observations do not imply 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 as a function of the number of trading days lapsed following a DtCL decline to various levels. Among those contracts that experienced DtCLs 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 histogram in the right panel of Figure 5 depicts residual values for all 1,758 issues that
were called back by their issuers. Most residual values were less than two cents, and more than 300 issues had no value 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. This can lead to significant investment losses (as we show later). One reasonable way to understand this seemingly irrational phenomenon is to consider cumulative prospect theory, pioneered by Tversky and Kahneman (1992). An implication of prospect theory is that people evaluate risk using so-called transformed probabilities, wherein investors overweight the tails of the objective distribution. Azevedo and Gottlieb (2012) show that, under some mild conditions, consumers with prospect theory preferences can sustain unbounded losses and yet obtain positive utility. In our case, 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 CB-BC with $DtCL \leq 200$ which survives being called back, the payoff can be more than 40 cents. The corresponding rate of return can be as high as hundreds of percentage points. Investors can overweight this chance and thus overestimate the values of CBBCs near their call levels. In other words, investors might be treating CBBCs as lottery tickets. We shed more light on this observation below.

2.2 Do Investors Treat CBBCs as Lottery-Type Securities?

Kumar (2009) proposes three characteristics for lottery-type stocks: low price, high (pos-
itive) skewness, and high volatility. To understand the extent to which investors prefer CBBCs because of these features, the last few columns of Table 3 present the skewness coefficient of daily CBBC returns, the correlation coefficient between the daily outstanding ratio and the closing price, and the correlation coefficient between the daily outstanding ratio and the annualized 11-day ($T - 5$ to $T + 5$) CBBC return volatility. We also compute the correlation between the outstanding ratio and an “ex ante skewness” measure first proposed by Boyer and Vorkink (2014); details of our corresponding measure for CBBCs are provided in Appendix C.\textsuperscript{19}

As can be seen in Table 3, the daily returns for all contracts are positively skewed, with half the 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 is 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, as characterized in Kumar (2009) and Kumar, Page, and Spalt (2011).

Figures 7 and 8 plot the ex ante skewness measure as a function of various CB-BC characteristics including $DtCL$, the volatility of underlying asset, and the time-to-maturity. Both bull and bear contracts are considered in this analysis. We find from

\textsuperscript{19}We compute this measure under the log-normal assumption because it allows for closed-form expressions. Henderson and Pearson (2011) and Boyer and Vorkink (2014) rationalize the choice of log-normal assumption along similar lines.
Figure 7 that ex ante skewness hits its peak when DtCL is very small. Figure 8 shows that skewness increases as volatility or time-to-maturity increases. Both figures show that ex ante skewness is more sensitive to DtCL and the volatility of underlying asset for contracts with long maturities. 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 than a bear contract. For a bull contract with a 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 and return, we create CBBC-based portfolios for each Monday from January 9, 2012 through November 26, 2012. There are 43 portfolio formation days in total. For 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, then in each group with the same maturity we sort CBBCs into ex ante skewness terciles. Finally, we form three skewness-based portfolios.

Among all of the model parameters needed for computing the ex ante skewness for a real contract, there are five parameters that are not explicitly specified in CBBC contracts: the first is the asset volatility \( \sigma \); the second is the risk-free interest rate \( r \); the third is the dividend yield \( d \), the fourth is the settlement period \( T_0 \), and the fifth is the settlement price. For measuring asset volatility, we collect the implied volatility for options written on HSI with times to maturity of 1 month, 2 months, 3 months, 6 months, 12 months, 18 months, and 24 months, and with moneyness (defined by strike/spot) 80%, 90%, 95%, 97.5%, 100%, 102.5%, 105%, 110%, and 120% from a Bloomberg terminal. Then, implied volatilities for other times to maturity or moneyness are obtained by a standard interpolation algorithm. For the risk-free interest rate, we collect the 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 are calculated through a standard interpolation algorithm (see, e.g., Longstaff, Mithal, and Neis 2005). The dividend yield \( d \) of HSI is estimated by

\[
\frac{1}{3} \sum_{i=2009}^{2011} \log \left( \frac{\text{HSI}_i + \text{HSIDPI}_i}{\text{HSI}_{i-1}} \right) = 2.97%,
\]

where \( \text{HSI}_i \) and \( \text{HSIDPI}_i \) are the respective closing prices of HSI and HSIDPI (HSI Dividend Point Index) on the second-to-last trading day of year \( i \) (the Dividend Point Index is reset once a year after the market close on the second-to-last trading day of each year). Recalling the contract details introduced in Subsection 1.1, the settlement period and the settlement price can be obtained from HSI high frequency data.

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 2014). CBBCs written on HSI mature on the penultimate trading day of each month. In our sample, there were 24 different maturity dates in total.
by merging all CBBCs within 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 terciles, 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; 36 of them matured without being called back.

We find in Table 5 that the differences in the average ex ante skewness, the average difference 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.

Panel A of Table 6 shows the time-series averages of equally weighted portfolio returns for each ex ante skewness tercile. We scale all returns to weekly units, so that the returns for different holding periods are comparable. The last two rows of the panel 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 five trading days, the average weekly return decreases from $-1.94\%$ for the low skewness tercile to $-14.03\%$ for the high skewness tercile. The corresponding $t$-statistic for
the difference is $-1.82$. As supplementary analysis, we also create portfolios sorted by another characteristic of lottery-type securities, the \( \text{MAX} \) variable (maximum daily return within the previous month) proposed by Bali, Cakici, and Whitelaw (2011). The results are similar and are reported in Panel B of Table 6.

We find even more dramatic spreads between the extreme skewness terciles for CB-BCs that were called back by their issuers. If a portfolio consisting of CBBCs that will be called back before maturity is held for 5 trading days, the average weekly return decreases from $-14.02\%$ for the low skewness bin to $-33.00\%$ for the high skewness bin. The \( t \)-statistic for this difference is $-4.02$. The situation for CBBCs without a MCE is completely different: when a portfolio consisting of CBBCs that are not called back until maturity is held for five trading days, the returns of portfolios increase dramatically as skewness increases, from $3.60\%$ for the low skewness tercile to $19.71\%$ for the high skewness bin. The paired \( t \)-statistic for this difference is $4.44$. We believe that the latter observation—the high return when issues are not being called back—forms the basis of the attraction of CBBCs for retail investors.

---

22The results here are not due to outliers. Taking Panel A1 of Table 6 as an example: in 19 (30) weeks, CBBCs with low (high) skewness generate higher (lower) 5-day average returns; the number of the 2-week periods that CBBCs with low (high) skewness generate higher (lower) 10-day average returns is 20 (25).

23We refrain from using the \( \text{MAX} \) variable in further analyses since more than one half of CBBCs have life-spans shorter than one month (see Table 4).

24We report posterior conditional estimations in middle panels and right panels of Table 6, since we do not know whether CBBCs will be called back or not on portfolio formation date.

25Though the HKEx Fact Book does not provide concrete statistics on the clientele for CBBCs, these contracts are listed under the \textit{Individuals} section at \url{http://www.bnparibas.com.hk}, and the \textit{Private Banking} section at \url{https://www.credit-suisse.com/hk}. We sent email queries to HKEx and all CBBC issuers on the topic of investor types that prefer these contracts, and obtained three replies. SGA Societe Generale’s Warrant and CBBC Team stated that “We do not have the concrete statistics regarding to your question. But roughly speaking, the participants in HK CBBCs market are retail investors.” The other two respondents simply claimed that they do not have the breakdown of CBBC investors types. We also called HKEx and four CBBC liquidity providers, among which, the customer service representatives of UBS and J.P. Morgan claimed that retail investors dominate the market, while those of HSBC, BNP Paribas and HKEx said that they did not have the relevant statistics. Hon (2013) investigates the investment preferences and
of Barberis and Huang (2008) that “a positive skewed security can be ‘overpriced’ and can earn a negative average excess return”, and are consistent with Boyer and Vorkink (2014). Specifically, using data for common stock options, Boyer and Vorkink (2014) show that investors are willing to forego returns of as much as 50% per week in order to gain exposure to options with the greatest lottery potential relative to options with the lowest lottery potential, which is much higher than the corresponding number in equity markets documented by Boyer, Mitton, and Vorkink (2010). The authors attribute this difference to higher skewness opportunities offered by options and risk compensation demanded by intermediaries for bearing unhedgable risk.

We next attempt to ascertain if the results in Panel A of 6 are due to liquidity, rather than ex ante skewness. Specifically, we address the concern that high skewness CBBCs may be more liquid, so that the negative relation of skewness to returns captures a liquidity premium (Amihud and Mendelson 1986). Thus, in Panel C of Table 6, we redo the exercise in Panel A with ex ante skewness replaced by the turnover ratio (a proxy for liquidity, viz. Datar, Naik, and Radcliffe 1998), defined as trading volume over issue size. We see that again, returns decrease with turnover for all contracts, and for contracts experiencing a MCE. However, the opposite pattern holds for contracts that are not called back. In Panel D1 of Table 6, we perform a double sort, first by turnover, then by skewness. We see the same pattern as in Panel A1 of Table 6 for ex ante skewness terciles, i.e., returns decrease in skewness. The pattern for turnover sort is much weaker and not consistently significant. In Panel D2 of Table 6, we double sort by return volatil-

behavior of small investors in Hong Kong using data from a questionnaire-based survey. The author finds that the CBBC is the most popular product among small investors.
ity and ex ante skewness. Again, average portfolio returns decrease in skewness, and the pattern for return volatility is much weaker and not consistently significant. The results in Panel D indicate that the skewness results are not proxying for liquidity and return volatility of CBBCs.

In the next two subsections, we aim to shed light on the relation between CBBC issuers and investors, and consequently on the incentives for issuers to innovate using CBBCs.

### 2.3 Prospectus Price vs. Fundamental Value

We compare the prospectus price advertised in CBBC marketing material to actual theoretical values of CBBCs, since the price in the prospectus may be an important reference point for unsophisticated investors. Liu, Luo, and Zhang (2011) show that when the underlying asset follows a continuous stochastic process, pays no dividend, and the risk-free rate vanishes, the price of a vanilla 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\(^{28}\) 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 vanil-

---

\(^{26}\)Similar results hold when we perform independent sorts on ex ante skewness and turnover, or on ex ante skewness and volatility.

\(^{27}\)Another issue of interest is that whether the pattern in average CBBC returns can be explained by co-skewness (or systematic skewness) (see, e.g., Kraus and Litzenberger 1976 and Harvey and Siddique 2000) within a rational asset pricing setting. A standard way to obtain co-skewness and idiosyncratic skewness would be to run time-series regressions of CBBC returns on market returns and squared market returns (see Regression (10) in Bali, Cakici, and Whitelaw 2011, Appendix). However, since the lifespans for many CBBCs are shorter than one month, it is not feasible to implement the regression for individual contracts without losing many data points. To address this issue, we follow the portfolio approach of (Boyer and Vorkink, 2014, Table VIII): on each portfolio formation day, we construct 20 portfolios (forming more portfolios is not feasible due to the small cross-section of individual CBBCs) by sorting CBBCs on ex ante skewness, and conduct Fama and MacBeth (1973) regressions of these portfolio returns on ex ante skewness rank and a set of controls including co-skewness, idiosyncratic skewness, 10-day trailing CBBC return volatility, turnover ratio, and outstanding ratio. The results indicate that co-skewness does not account for the return pattern found in Table 6, so that our results are more consistent with preferences for total skewness; see Mitton and Vorkink (2007) among others.

\(^{28}\)A vanilla CBBC’s settlement price given MCE equals to its call level. See Appendix A.
The bear CBBC is equal to strike price minus spot price. These results are consistent with the pricing formulae (1) and (2) in CBBC prospectuses provided by many issuers (e.g., UBS, Credit Suisse, and HSBC). However, in general, when the risk-free rate does not equal the dividend yield and/or the CBBC is exotic (like most of the CBBCs traded on HKEx) rather than a vanilla type, these formulas are invalid. For ease of exposition, define:

\[
\text{Prospectus Price of Bull Contract} = \frac{\text{Spot Price} - \text{Strike Price}}{\text{Entitlement Ratio}}, \tag{3}
\]

\[
\text{Prospectus Price of Bear Contract} = \frac{\text{Strike Price} - \text{Spot Price}}{\text{Entitlement Ratio}}. \tag{4}
\]

The quantity of interest is the deviation between the prospectus prices in (3)-(4) 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 the underlying asset. When the distance to call level is greater than 2000 and the time-to-maturity is small, 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. With a value of 0.5 for the volatility of the underlying asset, the relative errors can be higher than 200% when the contract is close to its call level.

\footnote{The prospectus prices below are the theoretical prices determined by (1)-(2) exclusive of the funding cost.}
Table 7, which documents trading volume and turnover for various levels of the absolute distance between closing prices and the prospectus prices for called and non-called CBBCs, shows that investors follow the prospectus price closely, by trading heavily when the distance is small. Specifically, total turnover and volume are statistically higher when closing prices are close to the prospectus price, than when these prices are far apart. Volume and turnover also are statistically higher for called contracts relative to non-called ones. Figure 3 reveals that investors trade heavily when the prospectus prices are positively biased. These are likely important phenomena by which the issuers earn profits from CBBC issuance.

2.4 Issuers’ Profit

We now examine issuers’ profit/loss patterns in CBBCs. For each trading day, we estimate the profit/loss as

\[
\text{Number of CBBCs Sold} \times \text{Average Price per CBBC Sold} - \text{Number of CBBCs Bought} \times \text{Average Price per CBBC Bought},
\]

(5)

where the daily trading summaries of the Number of CBBCs Sold, the Average Price per CBBC Sold, the Number of CBBCs Bought, and the Average Price per CBBC Bought are collected by the HKEx directly from the respective issuers.\textsuperscript{30} The final profit/loss for called contracts is computed using residual values. The settlement prices for computing

\textsuperscript{30}The Average Price per CBBC sold reported to the exchange by issuers is defined as the total revenue from selling CBBCs divided by the number of CBBCs sold, and analogously for the buy side.
residual values are obtained as per Footnote 20 (i.e., from one-minute high frequency data for the HSI). The overall profit/loss nets out all of the preceding computations. In our data, the quantities of CBBCs bought or sold only account for trading by the respective issuers, and not for trades between other institutions and/or individuals. Thus, the estimation (5) of issuers’ daily profit/loss is exact.

The left column of Figure 10 reports, from the issuers’ perspective, the profit/loss pattern, as functions of the number of trading days remaining to callback, DtCL, 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 a MCE accounts for 49.6%, while the profit in the last 15 trading days comprises 78.9% of the total. The second plot shows that the issuers make money mainly by trading 31 CBBCs that are near their call levels. The profit when DtCL is less than or equal to 500 comprises 53.6% of the total, and that when DtCL is less than 800 accounts for 94.5%. There is a clearer pattern when the profit is plotted as a function of the daily closing price. In fact, nearly 97% of the profit is made when the daily closing price is less than 9 cents. The right column of Figure 10 depicts the counterparts of those in the left column for non-called CBBCs. The issuers lose 1.22 billion HKD in trading CBBCs that are not called back. There is no specific pattern for profits as a function of the number of trading days remaining to callback. Interestingly, however, there is a clear pattern for profits as a function of DtCL and the daily closing price, especially the latter. Issuers can make a modest profit when the distance to call level is small or the price is

---

31 As noted in Subsection 1.2, the CBBC’s issuer is the only liquidity provider in the vast majority of cases, with two exceptions that issue trivial amounts of CBBCs.
very low; specifically, by trading non-called CBBCs with distance to call level less than 700, issuers earn 188.2 million HKD, and by trading non-called CBBCs with daily closing price lower than 9 cents, they earn 430.1 million HKD.

Overall, issuers’ profits from trading both called and non-called CBBCs amount to 1.82 billion HKD.\textsuperscript{32} We report profits by issuer in Table 8. As can be seen, estimated profits on called contracts are significantly positive and those on non-called contracts are significantly negative for all but two issuers, and the overall profits are significantly positive. These findings indicate that CBBCs are profitable for issuers mainly due to high investor interest in called contracts. The two biggest winners were Credit Suisse and UBS, who earned 696.8 million HKD and 604.7 million HKD,\textsuperscript{33} respectively. The net profit for each of them makes up more than 30% of the total net profit. The biggest loser, Daiwa Capital, lost 23.2 million HKD. On average, issuers earned 1.73 million HKD from each called contract, and lost 2.86 million HKD due to each non-called contract. Overall they gained an average of 0.84 million HKD by trading each CBBC. UBS was the most efficient trader of called issues in that it earned 2.93 million HKD from each called contract. However, UBS did not do well with non-called issues: it lost 6.76 million HKD on contracts without MCE. Overall, UBS earned 1.45 million HKD on each issue, since 84.7% of UBS issued CBBCs were called back.

Overall, the evidence accords with the view that CBBCs are profitable to issuers. The

\textsuperscript{32}Similar to the case of writing vanilla options, the main risk exposure of selling CBBCs is that these contracts could mature deep in the money, at which time the issuers would have large cash outlays due to their short position. As documented in Chapter 10 of CBBC Handbook provided by BNP Paribas (see also Item 5.20 of Credit Suisse 2014), issuers may hedge their risks by trading the underlying asset or warrants and options written on the asset. The ability of banks to lay off their risk exposure by conducting appropriate hedging strategies would lend a boost to the risk-adjusted rents from issuing CBBCs.

\textsuperscript{33}About 73.1 million CHF (the mean of daily HKD/CHF FX rate is 0.1209 in 2012), which accounted for 2.9% of the net loss attributable to UBS shareholders in 2012, which was 2,510 million CHF.
profits mainly accrue from called CBBCs, and that such CBBCs are heavily right-skewed ex ante. These observations together indicate that issuer profits from CBBCs stem from investor preference for lottery-type securities.

3 Conclusion

Traditional motives for financial innovation rely on market completeness and reduction of transaction costs. We take an alternative view and provide evidence that the design of financial innovations can be motivated by their appeal to investors’ behavioral biases. We show 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. These tend to be CBBCs that are particularly prone to being called back.

In a recent paper, Gennaioli, Shleifer, and Vishny (2012) suggest that issuers may cater to investors’ tastes in the short run by engineering products that can nonetheless generate negative investment returns in the longer term. We complement this study by arguing that new products may generate negative returns because agents with behavioral biases are willing to pay high prices for such products. Thus, issuing banks cater to investor preferences for lottery-type, positively skewed, products, by issuing many CBBCs that are close to their call levels on their issue date, and these CBBCs generate negative average returns. We show that, during 2012, investors trading CBBCs written

34 It is debatable whether investors’ desire for positively skewed securities is reflective of naïveté since this phenomenon is consistent with cumulative prospect theory (CPT). Thus, we do not assert that in-
on Hang Seng Index lost 1.82 billion HKD (US$235 million). Our findings are consistent with the theoretical idea proposed by Barberis and Huang (2008), who state that “a positively skewed security can be ‘overpriced’ and can earn a negative average excess return.” Note that since each issuer of CBBCs is the sole liquidity provider and short-selling is not possible, issuers have great price-setting power in CBBC markets, and are thus able to garner rents. This is consistent with a recent finding by Ruf (2011), who shows using high-frequency data on German bank-issued warrants that security issuers who act as monopolistic liquidity suppliers are able to earn rents from retail investors.

An interesting observation is that CBBCs are not issued in an opaque environment. Indeed, HKEx tries to ensure transparency about the structure of CBBC contracts. For example, material provided by HKEx clearly states the risks involved in trading CBBC (see HKEx 2006): “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 an avenue by which issuers and exchanges can appeal to lottery preferences, because wordings such as “volatile” may in fact stimulate such behavior. Moreover, all CBBC prospectuses provide a theoretical pricing formula that is used to determine the initial offering price. 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 source of investor losses.

Our analysis of issuers’ profit patterns indicates that investor preferences for lottery-voters who trade CBBCs are naïve and thus are knowingly misled by issuers; merely that CBBCs are marketed to appeal to investors with CPT preferences.
like securities can create wealth for rational issuers. Our work is consistent with the no-
tion that issuers market positively skewed securities to retail investors with preferences
that find such securities appealing. As a result, issuers are able to sell these securities
at highly profitable prices. Overall, CBBC markets provide us with a vivid example of
how financial companies might profit by catering to the behavioral proclivities of retail
investors.
Appendices

A A Risk-neutral Pricing Formula for CBBCs

By virtue of the risk-neutral valuation formula (e.g., Harrison and Pliska 1981), the price of a bull contract at \( t \leq T_b \) is given by:

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

where \( r > 0 \) is the constant risk-free rate, \( T \) is the maturity date, \( S := (S_t)_{t \geq 0} \) is the price process of the underlying asset, \( K \) is the strike price, and \( T_b := \inf\{ t \geq 0; S_t \leq S_b \} \) 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:

\[
P_{t}^{\text{bear}}(T-t) = e^{-r(T-t)} \mathbb{E}_t \left[ (K - S_T) 1_{\{\bar{T}_b > T\}} \right] \\
+ \mathbb{E}_t \left[ e^{r(\bar{T}_b+T_0-t)} 1_{\{\bar{T}_b \leq T\}} \left( K - \max_{\bar{T}_b \leq u \leq \bar{T}_b+T_0} S_u \right)^+ \right],
\]

with \( \bar{T}_b := \inf\{ t \geq 0; S_t \geq S_b \} \). Intuitively, 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 (6) or (7), which is just a down-and-out option, and enters into an exotic option with a short
maturity $T_0$. These represent the formulae for “exotic” CBBCs.

For a vanilla CBBC, the 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:

$$
E_t \left[ e^{-r(T_b-t)} 1_{\{T_b \leq T\}} (S_b - K)^+ \right] \quad \text{and} \quad E_t \left[ e^{-r(\tilde{T}_b-t)} 1_{\{\tilde{T}_b \leq T\}} (K - S_b)^+ \right],
$$

respectively. Here $T_b$ and $\tilde{T}_b$ are the same as those in (6) and (7).

## 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 the ex ante skewness and values 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 (e.g., Karatzas and Shreve 1991, Sections 2.8.A and 3.5.C):

$$
\mathbb{P}(\mu t + \sigma W_t \in da, \tau_b > t) = \frac{1}{\sqrt{2\pi t} \sigma} \exp \left( \frac{\mu a}{\sigma^2} - \frac{\mu^2 t}{2\sigma^2} \right) \left( \exp \left( -\frac{a^2}{2\sigma^2 t} \right) - \exp \left( -\frac{(2b-a)^2}{2\sigma^2 t} \right) \right) da,
$$
which yields:

\[
f(\lambda, \mu, \sigma, b, t) := \mathbb{E} \left[ e^{\lambda(\mu t + \sigma W_t)} 1_{\{\tau_b > t\}} \right] = \begin{cases} 
\int_{-\infty}^{b} e^{\lambda a} \mathbb{P}(\mu t + \sigma W_t \in da, \tau_b > t), & b \geq 0, \\
\int_{b}^{\infty} e^{\lambda a} \mathbb{P}(\mu t + \sigma W_t \in da, \tau_b > t), & b \leq 0,
\end{cases}
\]

\[
e^\frac{\lambda}{2} \left( \frac{\lambda \sigma^2 + 2\mu}{\sigma^2} \right) \left( N(d_1) - e^{2b\lambda + \frac{2b\mu}{\sigma^2}} N(-d_2) \right), & b \geq 0,
\]

\[
e^\frac{\lambda}{2} \left( \frac{\lambda \sigma^2 + 2\mu}{\sigma^2} \right) \left( N(-d_1) - e^{2b\lambda + \frac{2b\mu}{\sigma^2}} N(d_2) \right), & b \leq 0,
\]

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 \(\tau_b\) can be expressed as:

\[
\mathbb{P}(\tau_b > t) = f(0, \mu, \sigma, b, t) = \begin{cases} 
N \left( \frac{b - \mu t}{\sigma \sqrt{t}} \right) - e^{2b\mu} \left( -e^{2b\lambda + \frac{2b\mu}{\sigma^2}} N \left( \frac{b + t\mu}{\sigma \sqrt{t}} \right) \right), & b \geq 0,
\\
N \left( -\frac{b - \mu t}{\sigma \sqrt{t}} \right) - e^{2b\lambda} \left( -e^{\frac{2b\mu}{\sigma^2}} N \left( \frac{b + t\mu}{\sigma \sqrt{t}} \right) \right), & b \leq 0,
\end{cases}
\]

\[
\mathbb{P}(\tau_b \in dt) = -\frac{\partial \mathbb{P}(\tau_b > t)}{\partial t} dt = \frac{|b|}{\sqrt{2\pi t^3} \sigma} \exp \left( -\frac{(b - \mu t)^2}{2t\sigma^2} \right) dt.
\]

We then obtain:

\[
\eta(\lambda, \mu, \sigma, b, T) := \mathbb{E} \left[ e^{-\lambda \tau_b} 1_{\{\tau_b \leq T\}} \right] = \int_{0}^{T} e^{-\lambda t} \mathbb{P}(\tau_b \in dt)
\]

32
\[
\begin{aligned}
&= \begin{cases} 
\frac{b(\mu+\mu_1)}{\sigma^2} e^{\frac{b(\mu_1)}{\sigma^2}} N(-d_3) + e^{\frac{b(\mu_1)}{\sigma^2}} N(-d_4), & b \geq 0, \\
\frac{b(\mu-\mu_1)}{\sigma^2} e^{\frac{b(\mu)}{\sigma^2}} N(d_3) + e^{\frac{b(\mu_1)}{\sigma^2}} N(d_4), & b \leq 0,
\end{cases}
\end{aligned}
\] (9)

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 \(\mu \neq 0\),

\[\theta(\mu, \sigma, b, T) := \mathbb{E} [\tau_b \wedge T] = TP(\tau_b > T) + \mathbb{E} \left[ \tau_b 1_{\{\tau_b \leq T\}} \right] = Tf(0, \mu, \sigma, b, T) + \begin{cases} 
\frac{b}{|\mu|} \left( e^{\frac{b(\mu)}{\sigma^2}} N(\frac{-|b|\mu}{\sigma \sqrt{T}}) - e^{\frac{b(\mu_1)}{\sigma^2}} N(\frac{-b+|\mu|T}{\sigma \sqrt{T}}) \right), & b \geq 0, \\
\frac{b}{|\mu|} \left( e^{\frac{b(\mu)}{\sigma^2}} N(\frac{-|b|\mu}{\sigma \sqrt{T}}) - e^{\frac{b(\mu_1)}{\sigma^2}} N(\frac{b+|\mu|T}{\sigma \sqrt{T}}) \right), & b \leq 0.
\end{cases}\]

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

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

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

\[\mathbb{P}(\text{Sup}(t) < b) = \mathbb{P}(\tau_b > t), \quad b \geq 0,\]

\[\mathbb{P}(\text{Inf}(t) > b) = \mathbb{P}(\tau_b > t), \quad b \leq 0.\]
By virtue of the above formulas, we have:

\[
g(\lambda, \mu, \sigma, k, t) := \mathbb{E} \left[ e^{\lambda\text{Inf}(t)} I_{\{\text{Inf}(t) > k\}} \right] \\
= \int_k^0 e^{\lambda b} - \frac{\partial}{\partial b} \mathbb{P} (\text{Inf}(t) > b) \, db = \int_k^0 e^{\lambda b} - \frac{\partial}{\partial b} \mathbb{P} (\tau_b > t) \, db \\
= \frac{2}{\mu + \mu_2} \left[ -\mu_2 e^{\frac{1}{2} \lambda (\mu + \mu_2) t} (N(d_5) - N(d_6)) + \mu N(d_7) - \mu e^{k+\frac{2k}{\sigma^2} N(d_8)} \right],
\]

for \( k \leq 0 \), and

\[
h(\lambda, \mu, \sigma, k, t) := \mathbb{E} \left[ e^{\lambda\text{Sup}(t)} I_{\{\text{Sup}(t) < k\}} \right] \\
= \int_0^k e^{\lambda b} \frac{\partial}{\partial b} \mathbb{P} (\text{Sup}(t) < b) \, db = \int_0^k e^{\lambda b} \frac{\partial}{\partial b} \mathbb{P} (\tau_b > t) \, db \\
= \frac{2}{\mu + \mu_2} \left[ \mu_2 e^{\frac{1}{2} \lambda (\mu + \mu_2) t} (N(d_5) - N(d_6)) + \mu N(-d_7) - \mu e^{k+\frac{2k}{\sigma^2} N(-d_8)} \right],
\]

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

### C Explicit Formulae for Ex Ante Skewness

Following Boyer and Vorkink (2014), we define the measure of ex ante skewness for a CBBC over the horizon \( t \) to \( T \) as:

\[
\text{SKEW}_l(\tau) := \frac{\mathbb{E}_t [R_t(\tau) - \mu_t(\tau)]^3}{[\sigma_t(\tau)]^3}, \quad \tau := T - t,
\]
where $\mu_t(\tau) = \mathbb{E}_t[R_t(\tau)]$, $\sigma_t(\tau) = (\mathbb{E}_t[R_t^2(\tau)] - \mu_t^2(\tau))^{1/2}$, and $R_t(\tau)$ denotes CBBC’s return. In terms of the return’s raw moments, (10) can be expressed as:

$$\text{SKEW}_t(\tau) = \frac{\mathbb{E}_t[R_t^3(\tau)] - 3\mathbb{E}_t[R_t^2(\tau)]\mu_t(\tau) + 2\mu_t^3(\tau)}{(\mathbb{E}_t[R_t^2(\tau)] - \mu_t^2(\tau))^{3/2}}. \quad (11)$$

Recalling the introduction of CBBCs presented in Section 1.1, the return from holding a bull contract to maturity, $R_t^{\text{bull}}(\tau)$ is:

$$R_t^{\text{bull}}(\tau) = \frac{(S_T - K) \mathbf{1}_{\{T_b > T\}} + 1\{T_b \leq T\} \left( \min_{T_b \leq t \leq T_b + T_0} S_t - K \right)^+}{\hat{P}_t^{\text{bull}}(\tau)}, \quad (12)$$

where $T$ is the maturity date, $S := (S_t)_{t \geq 0}$ 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 $T_b := \inf\{t \geq 0; S_t \leq S_b\}$ 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

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

then from (12) we can rewrite the $j$-th raw moment of $R_t^{\text{bull}}(\tau)$ as:

$$\mathbb{E}_t \left[ (R_t^{\text{bull}}(\tau))^j \right] = \mathbb{E}_t \left[ (S_T - K)^j \mathbf{1}_{\{T_b > T\}} \right] + \mathbb{E} \left[ (M_{S_b, T_0} - K)^j \mathbf{1}_{M_{S_b, T_0} > K} \right] \mathbb{P}_t(T_b \leq T) \quad (\hat{P}_t^{\text{bull}}(\tau))^j, \quad (13)$$
where $\mathbb{P}_t$ is the probability given information as of time $t$. Noting that, at time $t$, $T_b > T$ is equivalent to $M_{S_b, T-t} > S_b$, Equation (13) 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 (10)-(11) under the log-normal assumption. For ease of exposition, we introduce the following notation:

$$
\Theta_1 := (r - d - \sigma^2/2, \sigma, s_b, T - t), \quad \Theta_2 := (r - d - \sigma^2/2, \sigma, k_b, T_0),
$$

where $s_b := \ln(S_b/S_t)$, $k_b := \ln(K/S_b)$, and $d$ denotes the dividend yield of the HSI. To compute the ex ante skewness, we need (13) for $j = 1, 2, 3$, which consists of the following three components:

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

Under the log-normal setting, the risk-neutral dynamics of the underlying asset is given by $S := (S_0 \exp((r - d - \sigma^2/2) t + \sigma W_t))_{t \geq 0}$ 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 (8) and the definition of $\tau_b$, we have:

$$
\mathbb{P}_t(T_b \leq T) = 1 - \mathbb{P}_t(T_b > T) = 1 - f(0, \Theta_1).
$$
We next concentrate on the computation of the first two components in (15). When \( j = 1 \), we have:

\[
\mathbb{E}_t \left[ (S_T - K)1\{T_b > T\} \right] = \mathbb{E}_t \left[ S_T 1\{T_b > T\} \right] - K \mathbb{P}_t(T_b > T)
\]

\[
= \mathbb{E}_t \left[ S_T \exp \left( \int_t^T (r - d - \sigma^2/2) dt + \int_t^T \sigma dW_t \right) 1\{T_b > T\} \right] - K \mathbb{P}_t(T_b > T)
\]

\[
= S_t \mathbb{E}_0 \left[ e^{(r-d-\sigma^2/2)(T-t) + \sigma W_{T-t} 1\{\tau_1 > T-t\}} \right] - K \mathbb{P}(\tau_1 > T - t),
\]

where \( \tau_1 := \inf\{t \geq 0 : (r - d - \sigma^2/2)t + \sigma W_t = s_b\} \) with \( s_b := \ln(S_b/S_t) < 0 \). From (8), 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,

\[
\mathbb{E}_t \left[ (S_T - K)^j 1\{T_b > T\} \right] = \sum_{k=0}^{j} C_j^k (-K)^k S_t^{j-k} f(j-k, \Theta_1),
\]

\[
\mathbb{E}_0 \left[ (M_{S_b, T_0} - K)^j 1\{M_{S_b, T_0} > K\} \right] = \sum_{k=0}^{j} C_j^k (-K)^k S_b^{j-k} g(j-k, \Theta_2),
\]

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

\[
\mathbb{E}_t \left[ \left( R_t^{\text{bull}}(\tau) \right)^j \right]
\]
\[
\sum_{k=0}^{j} C^k_j (-K)^k \left[ S^{j-k}_i f(j-k, \Theta_1) + [1 - f(0, \Theta_1)]S^{j-k}_b g(j-k, \Theta_2) \right] \frac{1}{(p^\text{bull}(\tau))^j},
\]

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

\[
\mathbb{E}_t \left[ (K - S_T)^j 1_{\{T_b > T\}} \right] = \sum_{k=0}^{j} C^k_j K^k (-S_t)^{j-k} f(j-k, \Theta_1),
\]

\[
\mathbb{E}_0 \left[ (K - \tilde{M}_{S_b, T_0})^j 1_{\{\tilde{M}_{S_b, T_0} < K\}} \right] = \sum_{k=0}^{j} C^k_j K^k (-S_b)^{j-k} h(j-k, \Theta_2),
\]

where \( \tilde{M}_{x, \theta} := \max_{0 \leq t \leq \theta} S_t = x \), and \( \Theta_1 \) and \( \Theta_2 \) are given in (14) 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:

\[
\mathbb{E}_t \left[ \left( R^\text{bear}_t(\tau) \right)^j \right] = \sum_{k=0}^{j} C^k_j K^k \left[ (-S_t)^{j-k} f(j-k, \Theta_1) + (1 - f(0, \Theta_1))(-S_b)^{j-k} h(j-k, \Theta_2) \right] \frac{1}{(p^\text{bear}_t(\tau))^j},
\]

where \( p^\text{bear}_t(\tau) \) is the market price of a bear contract. Substituting (17) and (18) into (11), we are able to obtain explicit formulae for ex ante skewness of CBBCs. Parenthetically, to the best of our knowledge, no work prior to ours provides explicit formulae for the ex ante skewness of CBBCs.
In this appendix, we provide explicit pricing formulae for CBBCs under the log normal assumption.\(^{35}\) Recall (6). The time-\(t\) price of a bull contract with time-to-maturity \(\tau = T - t\) can be written as:

\[
P_t^{\text{bull}}(\tau) = C_1^{\text{bull}} + C_2^{\text{bull}},
\]

where:

\[
C_1^{\text{bull}} = \mathbb{E}_t \left[ e^{-r(T-t)} (S_T - K)_1\{T_b > T\} \right],
\]

\[
C_2^{\text{bull}} = \mathbb{E}_t \left[ e^{-r(T_b+T_0-t)} (M_{S_{T_0},T_0} - K)_+ 1\{T_b \leq T\} \right].
\]

Noting from Equation (16) that \(\mathbb{E}_t \left[ (S_T - K)_1\{T_b > T\} \right] = S_t f(1, \Theta_1) - K f(0, \Theta_1)\), the explicit formula of \(C_1^{\text{bull}}\) is given by:

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

\(^{35}\)There do exist explicit pricing formulae for CBBCs elsewhere in the literature; see, e.g., Eriksson (2006) and (Liu, Luo, and Zhang, 2011, Appendix A). In the latter paper, the authors determine explicit formulae by decomposing a bull contract into three parts: a down-and-out option, a standard floating strike lookback option, and a one-touch option. In this paper, we present formulae based on Black and Scholes 1973 and Merton 1974) as developed in Appendix C, that is, using the functions \(f(\cdots), g(\cdots), h(\cdots)\) and \(\eta(\cdots)\) defined in Appendix B.
From the law of iterated expectations and the strong Markov property of the Black-
Scholes model,

\[ C_{2}^{\text{bull}} = \mathbb{E} \left[ e^{-rT_0} (M_{S_b,T_0} - K) 1_{\{M_{S_b,T_0} > K\}} \right] \mathbb{E}_t \left[ e^{-r\tau_1} 1_{\{\tau_1 \leq T-t\}} \right], \]

where \( \tau_1 := \inf\{ t \geq 0 : (r - d - \sigma^2/2)t + \sigma W_t = s_b \} \) with \( s_b := \ln(S_b/S_t) < 0 \). Assume the settlement period \( T_0 \) is known. Noting that \( \mathbb{E}_t \left[ e^{-r\tau_1} 1_{\{\tau_1 \leq T-t\}} \right] = \eta(r, \Theta_1) \), and \( \mathbb{E} \left[ (M_{S_b,T_0} - K) 1_{\{M_{S_b,T_0} > K\}} \right] = S_b g(1, \Theta_2) - Kg(0, \Theta_2) \), we have:

\[ C_{2}^{\text{bull}} = e^{-rT_0} [S_b g(1, \Theta_2) - Kg(0, \Theta_2)] \eta(r, \Theta_1), \]

and where the function \( \eta(\cdots) \) is given by (9). Substituting for \( C_{1}^{\text{bull}} \) and \( C_{2}^{\text{bull}} \) into (19), we obtain the explicit pricing formula for a bull contract. Similarly, the pricing formula for a bear contract can be expressed as:

\[ p_{I}^{\text{bear}}(\tau) = C_{1}^{\text{bear}} + C_{2}^{\text{bear}}, \]

where:

\[ C_{1}^{\text{bear}} = e^{-r(T-t)} [Kf(0, \Theta_1) - S_t f(1, \Theta_1)], \]
\[ C_{2}^{\text{bear}} = e^{-rT_0} [Kh(0, \Theta_2) - S_b h(1, \Theta_2)] \eta(r, \Theta_1). \]
References


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 issues with zero trading volumes. Volume and Turnover 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.

<table>
<thead>
<tr>
<th>Ticker</th>
<th>Issuer</th>
<th>Liquidity Provider†</th>
<th>NoI</th>
<th>Volume</th>
<th>VpI</th>
<th>Turnover</th>
<th>TpI</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP</td>
<td>BNP Paribas</td>
<td>BNP Paribas Securities (Asia) Ltd.</td>
<td>249 (0.0846)</td>
<td>308820 (0.0208)</td>
<td>1240.2</td>
<td>26254 (0.0226)</td>
<td>105.4</td>
</tr>
<tr>
<td>CS</td>
<td>Credit Suisse</td>
<td>Credit Suisse Securities (Hong Kong) Ltd.</td>
<td>687 (0.2334)</td>
<td>4901497 (0.3307)</td>
<td>7134.6</td>
<td>347111 (0.2983)</td>
<td>505.3</td>
</tr>
<tr>
<td>CT</td>
<td>Citigroup</td>
<td>Citigroup Global Markets Asia Ltd.</td>
<td>47 (0.0160)</td>
<td>97310 (0.0066)</td>
<td>2070.4</td>
<td>11691 (0.0100)</td>
<td>248.7</td>
</tr>
<tr>
<td>DC</td>
<td>Daiwa Capital</td>
<td>Daiwa Capital Markets Trading Hong Kong Ltd.</td>
<td>170 (0.0578)</td>
<td>680613 (0.0459)</td>
<td>4003.6</td>
<td>59458 (0.0511)</td>
<td>349.8</td>
</tr>
<tr>
<td>EA</td>
<td>Bank of East Asia</td>
<td>Kingsway Financial Services Group Ltd.</td>
<td>3 (0.0010)</td>
<td>144 (0.0000)</td>
<td>48.1</td>
<td>28 (0.0000)</td>
<td>9.5</td>
</tr>
<tr>
<td>GS</td>
<td>Goldman Sachs</td>
<td>Goldman Sachs (Asia) Securities Ltd.</td>
<td>150 (0.0510)</td>
<td>209745 (0.0142)</td>
<td>1398.3</td>
<td>15856 (0.0136)</td>
<td>105.7</td>
</tr>
<tr>
<td>HS</td>
<td>HSBC</td>
<td>HSBC Securities Brokers (Asia) Ltd.</td>
<td>268 (0.0911)</td>
<td>875765 (0.0591)</td>
<td>3267.8</td>
<td>116699 (0.1003)</td>
<td>435.4</td>
</tr>
<tr>
<td>JP</td>
<td>J.P. Morgan</td>
<td>J.P. Morgan Broking (Hong Kong) Ltd.</td>
<td>136 (0.0462)</td>
<td>503275 (0.0340)</td>
<td>3700.6</td>
<td>52033 (0.0447)</td>
<td>382.6</td>
</tr>
<tr>
<td>ML</td>
<td>Merrill Lynch</td>
<td>Merrill Lynch Far East Ltd.</td>
<td>81 (0.0275)</td>
<td>127736 (0.0086)</td>
<td>1577.0</td>
<td>9258 (0.0080)</td>
<td>114.3</td>
</tr>
<tr>
<td>RB</td>
<td>Rabobank</td>
<td>Rabo Brokerage Hong Kong Ltd.</td>
<td>5 (0.0017)</td>
<td>1624 (0.0011)</td>
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<td>231 (0.0002)</td>
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<tr>
<td>SG</td>
<td>Societe Generale</td>
<td>SG Securities (Hong Kong) Ltd.</td>
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<td>UB</td>
<td>UBS</td>
<td>UBS Securities Hong Kong Ltd.</td>
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<td>—</td>
<td>1383 (0.4699)</td>
<td>6734212 (0.4544)</td>
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<td>491991 (0.4228)</td>
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<tr>
<td>Bear</td>
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<td>—</td>
<td>1560 (0.5301)</td>
<td>8087113 (0.5456)</td>
<td>5184.0</td>
<td>671630 (0.5772)</td>
<td>430.5</td>
</tr>
<tr>
<td>Called</td>
<td>—</td>
<td>—</td>
<td>2297 (0.7805)</td>
<td>5263414 (0.3661)</td>
<td>5263.4</td>
<td>889384 (0.7643)</td>
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</tr>
<tr>
<td>Non-Called</td>
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<td>—</td>
<td>646 (0.2195)</td>
<td>2731308 (0.1843)</td>
<td>4228.0</td>
<td>274237 (0.2357)</td>
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<td>Total</td>
<td>—</td>
<td>—</td>
<td>2943 (1.0000)</td>
<td>14821325 (1.0000)</td>
<td>5036.1</td>
<td>1163621 (1.0000)</td>
<td>395.4</td>
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† On July 15, 2013, Bank of East Asia changed its CBBC liquidity provider to RHB OSK Securities Hong Kong Ltd. Similarly, on May 27, 2013, Rabobank altered its CBBC liquidity provider to Hui Kai Securities Ltd.
Table 2: CBBC issues on HKEx in 2012 by underlying asset. The first column reports the HKEx ticker for each underlying. All the issues with zero trading volumes are excluded. Volume and Turnover 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.

<table>
<thead>
<tr>
<th>Ticker</th>
<th>Underlying</th>
<th>NoI</th>
<th>Volume</th>
<th>VpI</th>
<th>Turnover</th>
<th>TpI</th>
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<tr>
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<td>CHEUNG KONG</td>
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<td>1162</td>
<td>83.0</td>
<td>205</td>
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<td>5</td>
<td>HSBC HOLDINGS</td>
<td>21</td>
<td>8240</td>
<td>392.4</td>
<td>845</td>
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<td>13</td>
<td>HUTCHISON</td>
<td>41</td>
<td>5906</td>
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<td>600</td>
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<tr>
<td>16</td>
<td>SHK PPT</td>
<td>14</td>
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<td>58.5</td>
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<td>27</td>
<td>GALAXY ENT</td>
<td>10</td>
<td>163</td>
<td>16.3</td>
<td>43</td>
<td>4.3</td>
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48
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-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 \((T - 5 \text{ to } T + 5)\) 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 the expressions in Appendix C 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.

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Average (bull)  215.0  117.1  501.20  3981.0  0.750  2543.0  0.028  -0.646 0.002  0.558  0.011  0.345  0.027
Average (bear)  156.8  129.1  4584.4  4180.5  0.571  2374.0  0.040  -0.565 0.026  0.539  0.017  0.539  0.115
Difference  58.2  -19.2  4276.6  -198  0.169  -0.081  0.019  0.006
\(p\)-value  0.005  0.691  0.233  0.720  0.800  0.270  0.819  0.943
Average (called)  171.7  74.0  45869.0  3487.0  1.000  3157.0  0.024  -0.629 0.002  0.529  0.029  0.515  0.056
Average (non-called)  220.1  220.1  47234.5  5247.0  0.000  1318.0  0.052  -0.467 0.037  0.589  0.014  0.596  0.091
Difference  -48.4  -146.1  1335.0  -1760  1.719  -0.212  -0.060  -0.081
\(p\)-value  0.032  0.000  0.735  0.016  0.007  0.024  0.551  0.351
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. 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 the Hong Kong government are excluded in the calculation of the number of trading days. Trading volumes are measured in millions 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.

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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 cents), average daily trading volume per contract (in millions), 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 the expressions in Appendix C 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.

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<td>37</td>
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<td>(18.47)</td>
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<td>(9.67)</td>
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<td><strong>Panel C: Non-Called Contracts</strong></td>
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<td>36</td>
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<td>72.69</td>
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<td>0.73***</td>
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<td>(7.74)</td>
<td>(6.18)</td>
<td>(5.55)</td>
<td>(5.67)</td>
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Table 6: Average holding-period (measured in number of trading days) returns for CBBC portfolios in 2012. All returns are scaled to weekly units (10-day and 20-day returns are divided by 2 and 4, respectively). Panel A: 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 Appendix C, and is evaluated under the log-normal assumption. Finally, we average the returns across all maturities to create returns for each skewness tercile. We use daily closing prices to compute returns. The last row reports the differences in average returns between the high and low skewness terciles. Panel B: We redo the exercise in Panel A with ex ante skewness replaced by MAX (maximum daily CBBC return within the previous month). Panel C: We redo the exercise in Panel A with ex ante skewness replaced by Turnover Ratio (ToR, defined as trading volume divided by issuing size). In Panel D1, we further sort CBBCs in each turnover-ratio-sorted portfolio formed in Panel C1 into ex ante skewness terciles. Panel D2 reports results from the double sort by ReV (10-day trailing CBBC return volatility) and ex ante skewness. Reported in Panel D are the average holding-period returns over the next five trading days. Newey and West (1987) t-statistics are computed for testing whether return differences are equal to zero. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

<table>
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<th></th>
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<tr>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
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<td></td>
<td>(-1.94)</td>
<td>(-2.11)</td>
<td>(-1.54)</td>
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<tr>
<td>2</td>
<td>-1.66*</td>
<td>-1.51**</td>
<td>-1.25**</td>
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<tr>
<td>3</td>
<td>-14.03**</td>
<td>-8.34**</td>
<td>-5.74***</td>
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<tr>
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<tr>
<td>(t-stat)</td>
<td>(-1.82)</td>
<td>(-1.31)</td>
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<tr>
<th>MAX Terciles</th>
<th>Panel B1: All Contracts</th>
<th>Panel B2: Called</th>
<th>Panel B3: Non- Called</th>
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<td></td>
<td>(-2.99)</td>
<td>(-2.20*)</td>
<td>(-1.53***</td>
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<tr>
<td>2</td>
<td>-6.29**</td>
<td>-3.94**</td>
<td>-2.39**</td>
</tr>
<tr>
<td>3</td>
<td>-7.99***</td>
<td>-5.60***</td>
<td>-4.35***</td>
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<td>-3.40</td>
<td>-2.82*</td>
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<td>(-1.92)</td>
<td>(-1.26)</td>
<td>(-1.81)</td>
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<th>ToR Terciles</th>
<th>Panel C1: All Contracts</th>
<th>Panel C2: Called</th>
<th>Panel C3: Non- Called</th>
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<tr>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
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<tr>
<td></td>
<td>(-0.59)</td>
<td>(-0.56)</td>
<td>(-0.38)</td>
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<tr>
<td>2</td>
<td>-6.74***</td>
<td>-4.65***</td>
<td>-3.18***</td>
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<td>3</td>
<td>-10.26***</td>
<td>-6.71***</td>
<td>-4.91***</td>
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<td>3-1</td>
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<td>(t-stat)</td>
<td>(-2.93)</td>
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<tr>
<td>-2.38</td>
<td>0.94</td>
</tr>
<tr>
<td>-4.80</td>
<td>-3.56</td>
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<tr>
<td>-4.73</td>
<td>-12.42***</td>
</tr>
<tr>
<td>-2.36*</td>
<td>-13.35***</td>
</tr>
<tr>
<td>(t-stat)</td>
<td>(-1.80)</td>
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Table 7: Average percentage contributions in cumulative trading volumes and turnover values of different ranges of Distance (= |Closing Price−Prospectus Price|, in cents) between the daily closing price and the prospectus price. Here the prospectus price is defined by (3)-(4) with the daily closing price of Hang Seng Index being defined as the Spot Price therein. Reported are the percentage contributions to the respective samples. For example, across all issues called by issuers, the average percentage contribution in cumulative trading volume when Distance lies in (0.5, 1] is 28.3%. In the last three columns, we report the differences between the averages in two successive columns (ci − cj means column i minus column j). The last row in each panel reports the differences between the called and non-called samples. p-values 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.

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<th>Distance</th>
<th>[0, 0.5]</th>
<th>(0.5, 1]</th>
<th>(1, 1.5]</th>
<th>(1.5, 2]</th>
<th>c2 − c3</th>
<th>c3 − c4</th>
<th>c4 − c5</th>
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<tr>
<td>Called</td>
<td>47.4</td>
<td>28.3</td>
<td>12.8</td>
<td>6.7</td>
<td>19.2***</td>
<td>15.4***</td>
<td>6.2***</td>
</tr>
<tr>
<td>Non-called</td>
<td>25.0</td>
<td>20.0</td>
<td>10.6</td>
<td>8.8</td>
<td>5.0**</td>
<td>9.4***</td>
<td>1.7</td>
</tr>
<tr>
<td>Overall</td>
<td>43.0</td>
<td>26.7</td>
<td>12.4</td>
<td>7.1</td>
<td>16.4***</td>
<td>14.3***</td>
<td>5.3***</td>
</tr>
<tr>
<td>Difference</td>
<td>22.4***</td>
<td>8.3***</td>
<td>2.2**</td>
<td>-2.2**</td>
<td>—</td>
<td>—</td>
<td>—</td>
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Panel A: Trading Volume

| Called | 45.7    | 28.0    | 13.2    | 7.3     | 17.7*** | 14.7*** | 5.9***  |
| Non-called | 24.5    | 19.3    | 10.1    | 8.6     | 5.3**   | 9.1***  | 1.5     |
| Overall  | 41.6    | 26.3    | 12.6    | 7.6     | 15.3*** | 13.6*** | 5.1***  |
| Difference | 21.1*** | 8.7***  | 3.1***  | -1.3    | —       | —       | —       |

Panel B: Turnover Value
Table 8: This table reports, for each issuer, the profit (in million HKD) by trading CBBCs written on the HSI. We exclude the Bank of East Asia since it did not issue any CBBC written on the HSI in the year 2012. PPI represents the averaged 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 parentheses. $p$-values are computed for testing whether these averages are equal to zero. Statistical significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

<table>
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<th>Issuer</th>
<th>Called Issues</th>
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<td>PPI</td>
<td>Profit</td>
<td>PPI</td>
<td>PPI</td>
<td>NoI</td>
<td>NoCI</td>
<td>PoCI</td>
<td>NoI</td>
<td>NoCI</td>
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<tr>
<td>BP</td>
<td>244.3 (0.080)</td>
<td>1.23***</td>
<td>−21.3 (0.017)</td>
<td>−0.73***</td>
<td>+223.0 (0.122)</td>
<td>+0.98***</td>
<td>227</td>
<td>198</td>
<td>0.872</td>
<td></td>
<td></td>
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<tr>
<td>CS</td>
<td>1019.3 (0.335)</td>
<td>2.44***</td>
<td>−322.5 (0.265)</td>
<td>−3.23***</td>
<td>+696.8 (0.382)</td>
<td>+1.35***</td>
<td>517</td>
<td>417</td>
<td>0.807</td>
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<tr>
<td>CT</td>
<td>17.0 (0.006)</td>
<td>0.45***</td>
<td>−33.8 (0.028)</td>
<td>−3.75</td>
<td>−16.8 (0.009)</td>
<td>−0.36</td>
<td>47</td>
<td>38</td>
<td>0.809</td>
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<tr>
<td>DC</td>
<td>38.3 (0.013)</td>
<td>0.38***</td>
<td>−61.5 (0.051)</td>
<td>−1.34**</td>
<td>−23.2 (0.013)</td>
<td>−0.16</td>
<td>146</td>
<td>100</td>
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<tr>
<td>GS</td>
<td>21.8 (0.007)</td>
<td>0.20***</td>
<td>−18.1 (0.015)</td>
<td>−0.43***</td>
<td>+3.7 (0.002)</td>
<td>+0.02</td>
<td>150</td>
<td>108</td>
<td>0.720</td>
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<tr>
<td>HS</td>
<td>109.2 (0.036)</td>
<td>1.92***</td>
<td>−29.2 (0.024)</td>
<td>−2.92**</td>
<td>+80.0 (0.044)</td>
<td>+1.19***</td>
<td>67</td>
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<td>0.851</td>
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<td>JP</td>
<td>146.3 (0.048)</td>
<td>1.34***</td>
<td>−26.6 (0.022)</td>
<td>−0.99***</td>
<td>+119.6 (0.066)</td>
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<td>109</td>
<td>0.801</td>
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<td>ML</td>
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<td>0.09***</td>
<td>−2.8 (0.002)</td>
<td>−0.28**</td>
<td>+3.5 (0.002)</td>
<td>+0.04</td>
<td>81</td>
<td>71</td>
<td>0.877</td>
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<tr>
<td>RB</td>
<td>0.6 (0.000)</td>
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<td>−0.0 (0.000)</td>
<td>−0.00</td>
<td>+0.6 (0.000)</td>
<td>+0.12</td>
<td>5</td>
<td>5</td>
<td>1.000</td>
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<td></td>
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<tr>
<td>SG</td>
<td>400.2 (0.132)</td>
<td>1.33***</td>
<td>−268.4 (0.221)</td>
<td>−3.02***</td>
<td>+131.8 (0.072)</td>
<td>+0.34</td>
<td>390</td>
<td>301</td>
<td>0.772</td>
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<tr>
<td>UB</td>
<td>1037.6 (0.341)</td>
<td>2.93***</td>
<td>−432.8 (0.356)</td>
<td>−6.76***</td>
<td>+604.7 (0.332)</td>
<td>+1.45***</td>
<td>418</td>
<td>354</td>
<td>0.847</td>
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<tr>
<td><strong>Overall</strong></td>
<td>**3040.8 (1.000)</td>
<td><strong>1.73</strong>*</td>
<td>**−1217.0 (1.000)</td>
<td><strong>−2.86</strong>*</td>
<td>**+1823.8 (1.000)</td>
<td><strong>+0.84</strong>*</td>
<td>**2184</td>
<td>**1758</td>
<td><strong>0.805</strong></td>
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Figure 1: Bull CBBC vs. vanilla call: Theoretical price, Delta, and Ex Ante Skewness. The ex ante skewness is computed by using the expressions in Appendix C under the log normal assumption. The parameter values for CBBC are: strike price $K = 19,000$, call level $S_b = 19,200$, risk-free interest rate $r = 0.6\%$, dividend yield $d = 3\%$, volatility $\sigma = 30\%$, time-to-maturity $T = 1/4$ (one quarter), settlement period $T_0 = 0.002$ (half a day). The vanilla call has the same strike price and time-to-maturity as CBBC.
Figure 2: This figure shows 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: 60172 (listed on Jan. 31, 2012) and 60638 (listed on Feb. 21, 2012). The correlations between outstanding ratio and DtCL for issues 60172 and 60638 are $-0.742$ and $-0.790$, respectively. The correlations between outstanding ratio and return volatility for issues 60172 and 60638 are $0.708$ and $0.753$, respectively.
Figure 3: 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 falling within 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.
Panel A: For the 1,758 CBBCs called by issuers

Panel B: For the 426 CBBCs without a MCE

Panel C: For all 2,184 CBBCs written on HSI

Figure 4: The average CBBC price, the average daily trading volume, the average daily turnover value, and the average outstanding ratio as functions of the number of trading days remaining. The averaging is across all CBBCs with a given number of trading days remaining.
Figure 5: **LEFT:** The proportion of contracts called back as a function of the number of trading days lapsed after CBBCs’ day-end distance to call level (DtCL) declines to four pre-specified levels (50, 100, 200, and 500). BeMat means before maturity. **RIGHT:** Histogram of residual values for all 1,758 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 CBBC closing prices on days with distance to call level (DtCL) less than 200 for all issues written on the HSI. The sample mean is 4.2 cents with a standard deviation of 1.5 cents. **RIGHT**: Histogram of closing prices on the last trading day for all contracts that survive from a DtCL ≤ 200. The sample mean is 24.8 cents with a standard deviation of 11.4 cents.
Figure 7: Ex ante skewness as a function of the distance to call level (DtCL). To display the behavior for small DtCL more clearly, the right panels limit the $x$-axes to $[0,20]$ and expand the $y$-axes to $[0,100]$. The ex ante skewness is computed by using the expressions in Appendix C under the log normal assumption. For the bull contract, $S_b = 19,200$, $K = 19,000$, and $S \in (19,200, 20,200)$. For the bear contract $S_b = 20,800$, $K = 21,000$, and $S \in (19,800, 20,800)$. The other parameter values are $r = 0.6\%$, $d = 3\%$, $\sigma = 0.3$, and $T_0 = 1/500$ (half a day).
Figure 8: Ex ante skewness as a function of, in turn, volatility and time-to-maturity. The ex ante skewness is computed by using the expressions in Appendix C under the log normal assumption. For a bull contract, $S = 20,000$, $S_b = 19,800$, $K = 19,600$. For a bear contract $S = 20,000$, $S_b = 20,200$, $K = 20,400$. The other parameter values are $r = 0.6\%$, $d = 3\%$, and $T_0 = 1/500$ (half a day).
Figure 9: The relative error of the prospectus price defined in (3) over the price based on the Black-Scholes-Merton model is plotted against the distance between underlying asset price and call level. The parameter values are: strike price $K = 18,800$, call level $S_b = 19,000$, risk-free interest rate $r = 0.6\%$, dividend yield $d = 3\%$, spot price of underlying $S_0 = 20,000$, time-to-maturity $T = 0.5$ (half a year), settlement period $T_0 = 0.002$ (half a day), and entitlement ratio $R = 10,000$. 
Figure 10: **LEFT COLUMN:** Profit/loss pattern for CBBCs called by issuers. Clear bars indicate profits, and shaded bars indicate losses. The profit/loss on each trading day is computed from Equation (5). For each called contract, the loss given an MCE is computed using residual values with settlement prices obtained as per Footnote 20 (i.e., from 1-min high frequency data for the HSI). The loss (the longest negative bar) due to final residual values is 550.0 million HKD. The total net profit is 3.04 billion HKD. **RIGHT COLUMN:** Profit/loss pattern for CBBCs without a MCE. Clear bars indicate profits, while shaded bars indicate losses. 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 1.22 billion HKD. The profit/loss on each trading day is computed from Equation (5). If the contracts mature without a MCE, the settlement price is that used for settling a contemporaneously expiring HSI futures contract.
Figure 11: Profit/loss pattern for all CBBCs written on HSI. Clear bars indicate profits, while shaded bars indicate losses. The profit/loss on each trading day is computed from Equation (5). For each called contract, the loss given an MCE is computed using residual values with settlement prices obtained as per Footnote 20 (i.e., from 1-min high frequency data for the HSI). If the contracts mature without a MCE, the settlement price is that used for settling a contemporaneously expiring HSI futures contract. In order to view the pattern more clearly, we do not plot the full vertical axis. The total net profit is 1.82 billion HKD. The plots in this figure are the sums of the corresponding plots in Figure 10.