CB Asset Swaps and CB Options: Structure and Pricing

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Abstract

This paper investigates deal structure of the stripping of convertible bonds into credit component and equity component, i.e., CB Asset Swap and CB Option. We provide pricing models for both credit component and option component for CB Stripping structured products. We show that CB Asset Swap can be priced as American installment option. Our results indicate that a higher Asset Swap spread paid by the dealer could lead to early exercise of the CB option. Based on a Monte Carlo simulation procedure proposed by Longstaff and Schwartz (2001), our simulation concludes that the CB call option will be mostly affected by (1) issuer credit, (2) put price and (3) interest rate level.

1. Introduction

Convertible Bond (CB) has become popular investment tool in recent years because of its fixed income floor and rich equity option value. It provides an alternative funding channel for enterprises comparing to traditional bonds. Recently, investment banks have developed a sophisticate technique to strip CB into credit component and option component to arbitrage the preferences between different investor groups. The credit component is commonly referred as CB Asset Swap transaction and the option component is referred as a Call on CB or CB option. For those dealer who create and market swaps involving convertible bonds, they benefit from judicious pricing due to high stock volatility and a swap house can end up owning potentially valuable equity options at negligible cost. In addition, most commercial banks and insurance companies can demand higher credit premium on the Asset Swap side and share the low premium benefit from the CB option holders.

In a CB Stripping transaction, CB is stripped into two structured products: the asset swap (credit component) for fixed income investors and the CB option (equity component) for common equity investors. While bond investor generally received extra spread over benchmark rate (i.e., Libor or Treasury), equity investor pays an option premium to get a CB option. To avoid position risk, dealer sometimes simultaneously match the asset swap trade with the CB option trade. In other words, dealer will exercise its right to call CB and cancel an Asset Swap transaction when option investor exercises the CB call option. The equity component and credit component should cancel each other and leave dealer with an arbitrage profit. Figure 1 shows the structure for a CB Stripping transaction for both option and credit components.

[Insert Figure 1 here]

To our best knowledge, there is no in-depth academic analysis on CB Stripping transaction. Practitioners come out with different calculation procedures and pricing models for Asset Swap and CB option (see Bloomberg (1998)). A common pricing methodology used by practitioners can be summarized as an ad hoc Two-Step Method: First, the equity-option premium is estimated and the Fixed Income value shows the effective price after taking the equity option premium away from the current market CB price. Next, use an Asset Swap calculation procedure to estimate the swap spread that can be achieved with the equity option stripped.

However, those commercial models ignore the American call feature of CB Asset Swap. In our view, the credit component of a CB Asset Swap can be treated as an American installment option to take into account the right to cancel the Swap and stop paying future interest payments before maturity. We will explain our pricing model in detail later.

The paper is organized as follows: We first introduce a complete CB Stripping structure and corresponding transaction contracts in Section 2. Section 3 shows the valuation and sensitivity analysis for CB Asset Swap using the concept of American installment option. We apply a Monte Carlo procedure proposed by Longstaff and Schwartz (2001) to evaluation CB option in Section 4 with an example to illustrate the pricing method. Section 5 concludes the paper.

2. CB Stripping Structure: TCC Convertible Bond

As an example, we show the Term Sheets and framework of CB Asset Swap transaction and Call option transaction on CB issued by Taiwan Cellular Corp (TCC) in October 2001. TCC CB Stripping structure is shown in Table 1:

[Insert Table 1 here]

There are three parts for a CB Asset Swap transaction:

(1) Outright Sales of CB: CB Stripping transaction begins with an outright sale of CB from dealer to credit investor with a call on CB attached. While there are various ways to determine the selling price, it is a common practice to sell the CB at par value.

(2) Interest Rate Swap: The Interest Rate Swap refers to a cash flow exchange between the dealer and the credit investor. Most likely, dealer will pay Libor plus a spread agreed upon to the credit investor in exchange for a fixed payment of CB coupon, if any, and put yield at put day. Again, market practices differ but the most common term is that the Swap will be terminated if the dealer calls the CB back.

(3) Call Option on CB: The structure of TCC CB Option transaction is shown in Figure 2. Note that the strike price sometimes is adjusted by a term called Reference Hedge. A Reference Hedge is the mark to market value of the Interest Rate Swap as mentioned above.

[Insert Figure 2 here]

In case of a CB with high put yield, the CB call option is similar to a default swap mainly to protect the credit risk. If there is no default risk, the issuer should redeem CB at put price which is higher than the call price. As a result, the CB option should be similar to a CB holding position. However, if the CB issuer goes bankrupt, the option holder will not call the CB and protect the investment from the down side risk.

3. Valuation Framework for CB Asset Swap Transaction

We first apply American installment option pricing model to CB Asset Swap pricing. A simple lattice approach is used here to compare installment option model with traditional model mentioned before.

3.1. Assumptions

The Numerical technique of pricing model in this section is by lattice approach to highlight the installment option value. Cox, Ross, and Rubinstein (1979) multiplicative binomial model showed that options can be valued by discounting their terminal expected value in a world of risk neutrality. We assume the market to trade at discrete times. At each interval, the stock can move up or down, the interest rate can move up, unchanged, or down. After one period, the two-dimension lattice has 6 node points.

For the interest rate tree, the stochastic short rate process is followed the general tree-building procedure proposed by Hull and White (1994) which is a trinomial tree for interest rates. The Hull-White (extended-Vasicek) model for the instantaneous short rate r is $dr = [\theta(t) - ar] + \sigma_r dz_r$, where θ(t) is the slope of the forward curve at time zero that is chosen to make the model consistent with the initial term structure; a is mean-reverting spread, σ_r is the instantaneous standard derivation of the short rate; dz_r is the standard Wiener process.

Let CB(r, s, t) be the value at time t of a contingent claim with an underlying stock whose value is s and short rate r at time t. The payoff of CB(r, s, t) at any node before maturity is the maximum value of conversion value and holding value. More precisely, the payoffs of CB during the time interval are listed as following:

3.2 Valuation Procedures for CB Asset Swap Transaction

Similar to an installment option, the periodical interest payments (LIBOR plus spread) can be treated as installment for option premium of the CB Option. Most importantly, CB Asset Swap can be regarded as an American installment option because the dealer can call the CB and terminate the Asset Swap transaction before maturity. As a result, an early call on CB could reduce the future interest payments (i.e., option premium installment) significantly. To incorporate the installment payment structure into the pricing model, we conduct our calculation procedure in the following manner.

The fixed income investor pays the bond dealer on the settlement date the full face value plus accrued interest for the bond. It is important to note that the difference between the par and the market value of CB is the up-front premium payment in our model. A fair valuation on the CB Asset Swap transaction is to determine a spread over Libor to equate the theoretical up-front premium equal to the market-par difference. A recursive procedure is required to determine the spread.

The valuation procedure is a standard backward recursive pricing method. If the call option is held until maturity, the payoff should be the value of CB at that time deducts the strike price. On each decision node, the option holder make the decision based on the following considerations: First, the seller has the right to decide whether to keep the call or to early exercise it. If the decision is to keep the option, then the dealer has to pay Libor plus spread for one more period. In other words, the interest payment is treated as sequential premium installment of the CB Option. If the dealer decides to call CB back, the Asset Swap is terminated automatically and no more future payment is required. Thus the holding value of a CB Option with strike price at par needs to be further deducted by one-period discounted floating payment.

The holding value of CB Option is the discounted future cash flow at each node. The conversion value is the theoretical value of CB minus the strike price. The payoff of each node is obtained by repeating the procedure described above. The spread is determined when the call value at contract day is equal to the difference between CB theoretical value and the initial exchange amount.

We apply the American installment option for pricing the spread for a CB Asset Swap transaction of TCC CB as an example used before. The two underlying variables of the model are stock price and the spot interest rate. Following Hull and White (1994), we have the following assumptions:

The t-year zero coupon rate function $0.08\text{-}0.05e^{-0.18t}$; The mean-reverting spread and volatility of interest rate are 0.1 and 0.01, respectively. Time step is by quarter and we assume the option holder has the right to convert the bond to equity at every three month.

In order to demonstrate the significant difference of premium installment between American style and European style, we show the relationship between the spread charged and the theoretical up-front fee in Figure 3. For installment options, the value of American type at the beginning of the Swap transaction can be shown much higher than the value of European style because the dealer has the right to early exercise before maturity and does not required to pay further premium anymore. We see a negative relationship between up-front fee and spread charged since the spreads are part of premium to be paid in the future. Higher spread reduces the holding value of option and this effect is more significant for European type. It is interesting to note that the gap between two lines widens as the spread increases.

[insert Figure 3 here]

3.3 Discussion

As mentioned before, practitioners are using an ad hoc Two-Step Model to determine the level of the spread in a CB Asset Swap transaction. Since the Two-Step Model does not consider the early call feature, the spread will be under-estimated in an European style valuation model. However, the magnitude of the mispricing depends on the possibility of the dealer early exercising CB option and cancel the Asset Swap. If the underlying CB is deep-in-the-money, the early exercising possibility increases and the American style spread should be much higher. On the other hand, if the underlying CB is deep-out-of-money or the put price is high, the dealer is more likely to wait until the expiration day and the American style spread should be similar to the European style spread. One way to fix the pricing problem is to adjust the strike price with a term called Reference Hedge. In other words, the contract of CB Asset Swap sometimes specifies that the strike price for CB option should be adjusted by the mark to market value based on future Asset Swap payments to maturity. However, due to the calculation complexity and lack of benchmark for the term structure of CB Asset Swap, dealer tends to use a fixed strike price unless requested by a sophisticated credit investor.

4. The Pricing Model of CB Option

This section describes the evaluation procedure of CB Option transaction. There are some assumptions imposed in the model should be discussed.

4.1 Pricing Model and Assumptions

The numerical method we used here follows the least-square approach proposed by Longstaff and Schwartz (2001). The least-square approach is applied to derivatives pricing that not only depend on multiple factors but also have path-dependent and American-exercise features.

The process of the short-term riskless rate r at time t is assumed to follow CIR (1985) model and given by

$$dr = \kappa(\theta_r - r)dt + \sigma_r \sqrt{r} dZ_r \text{ ……………………………….. (1)}$$

The value of the underlying stock (S) of the issuing firm follows the lognormal diffusion process and ln S follows a generalized Wiener process as

$$d\ln S = (r - \frac{\sigma_s^2}{2})dt + \sigma_s \rho dz_r + \sigma_s \sqrt{1-\rho^2} dz_s \text{ ,} \qquad (2)$$

where σ_s is the standard derivation of stock price. ρ is the correlation coefficient between changes in firm value and changes in the short rate.

As to the credit risk of CB, we extend the concepts of intensity models and adopt credit ratings as classification of different credit spreads in our model. Based on Jarrow, Lando and Turnbull (1997), the credit spread depends on the recovery rate (δ) and the transition matrix for credit classes Q. In practice, we can observe credit spreads from markets, which reflect default risk in accordance with credit ratings. As a result, we assume credit spreads in credit market represent the expected values of compensation for taking default risk. The corresponding credit spreads are defined in table 2. With credit transition matrix and the assumption that default probability follows uniform distribution, then we can simulate credit path.

[Insert Table 2 here]

4.2 Simulation Results

We illustrate the pricing methodology by a simplified numerical example. Considering an American call option on one unit of zero-coupon CB with par value

100, it can be converted to two shares of stocks at conversion price of 50. Put price of CB at the end of period is 15% of notional amount. For the sake of convenience, the spread of floating interest rate in CB asset swap is set to 0. The call option on CB can be exercised at times 1, 2, and 3 at a strike price of 100 plus reference hedge. Time 3 is the expiration date of call option. The initial risk-free rate, the initial price of the stock and the initial credit rating of issuing firm are 5%, 48 and Rank A, respectively. For simplicity, we illustrate the algorithm using eight sampled paths and are shown in Table 3.

[Insert Table 3 here]

Our objective is to find the stopping rule that maximizes the value of CB and the value of call option on CB at each point along each path. We adopt the backward approach to decide the optimal strategy of investor. At time 3 as shown in Panel A of Table 4, the value of CB is the maximum value of put price and conversion value or 115 and 2 times market price of stock at time 3.

[Insert Table 4 here]

If the conversion value of CB is in the money at time 2, the option holder will decide whether to exercise the option immediately or continue the option's life until the final expiration date at time 3. According to Longstaff and Schwartz (2001), we use only in-the-money paths since it allows us to better estimate the conditional expectation function in the region where exercise is relevant and significantly improves the efficiency of the algorithm.

Except path 8, all paths are sampled into our regression. Let X denote the stock prices, R denote the risk-free interest rate, C denote credit spread at time 2 for those paths, and Y denote the corresponding discounted cash flows received at time

3. To reflect the default risk, we use the sum of interest rate and credit spreads in prior period as our discount rate. On the first path, Y is 150.9434 (= 160/(1+5.5%+0.5%)).

We regress Y on a constant, X, R, and C in order to estimate the expected cash flow from continuing the CB's life conditional on the CB value relative factors. The resulting conditional expectation function of CB is

$$E[Y|X, R, C] = -674.662 + 9.76127X + 2949.85R + 3348.52C \quad (3)$$

We now compare the conversion value of immediate exercise at time 2 with the value from continuation in terms of this conditional expectation function.

$$\text{CB value at time 2} = \max(\text{Conversion value}, \text{Continue value}) \quad (4)$$

The decision rule specified above implies that it is optimal to convert the CB into stocks at time 2 for the third, fourth, and fifth paths. On the other hand, the conversion value of CB is out of money for the eighth path. The following matrix shows the cash flows received by the CB investor conditional on no exercise prior to time 2. Note that the cash flow in the final column becomes zero when the option is exercised at time 2. This result accounts for the conversion option can only be exercised once. We next examine whether the CB should be converted at time 1. To repeat the same approach to estimate the value of CB, there are five paths where the conversion options are in the money at time 1. Cash flows received at time 2 are discounted back one period to time 1, and any cash flows received at time 3 are discounted back two periods to time 1. Similarly X, R, C, and Y represent as previously mentioned at time 3, we get the estimated conditional expectation function,

$$E [Y| X, R, C] = 147.196 - 0.5564 X + 564.504 R - 3426.49 C \ldots (12)$$

We compare conversion choices and the result is shown in Panel A of Table 5.

[Insert Table 5 here]

Having identified the exercise strategy at time 1,2, and 3, the cash flows received by CB investors under the stopping rule are represented in Panel B of Table 5.

After discounting all the future expected cash flows into the initial period, we can get that the average present value of CB is 108.8533.

Similar to the procedure of simulation of CB value, we have to consider Reference Hedge more in our strike price when we simulate the value of call option on CB.

CB Option = max (Conversion value - Strike price, 0)

= max (Conversion value – 100 – Reference Hedge , 0)

Reference hedge is defined as the difference of future cash flows from the exchange of CASH Flow payments between the Asset Swap parties. For the first path at time 3, take an example, fixed interest rate payments is 15 (=100×15 %) while floating rate payments is 5.5 (=100* (5.5% + 0%)). So reference hedge is 9.5 for that point and corresponsive exercise value of call option on CB is 50.5 (= 2×80-100-9.5). The reference hedge matrix is in Panel A of Table 6

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[Insert Table 6 here]

To estimate conditional expectation function of CB Option, we use the same approach using CB value as underlying security. Let X denote the stock prices, R denote the risk-free interest rate, C denote credit spread, CB denote CB value at time 2 for those paths, and Y denote the corresponding discounted cash flows of CB Option received at time 3. The resulting conditional expectation function of CB Option at time 2 is

$$E[Y|X, R, C] = -1136.04 + 16.2191X - 1.13453RB + 4638.84R + 5060.85C \quad (13)$$

The matrix of comparison of early exercise with holding the option is showed as Panel B in Table 6.

Continuing this procedure previously mentioned, we observe the value of CB Option on each path of all periods under the optimal stopping rules. As a result, the value of CB Option at initial point is 21.326 and is shown in Panel C in Table 6.

4.2. Sensitivity Analysis

We investigate the sensitivity of each variable on the pricing model in the section. We test the sensitivity of the stock price volatility, the interest rate volatility, initial stock price, correlation coefficient between stock price and risk-free interest rate, initial interest rate, and initial credit rating.

(1) Effect of the volatility of stock price

We show the simulation results of CB Option and CB value in excess of strike price 100, which we define as Intrinsic Value. Both values are shown in figure 4. We observe that (1) Both the simulated values of CB Option and Intrinsic Value increase as the volatility of stock price increases; (2) Since the theoretical CB value is deep in the money, CB Option is not much higher than Intrinsic Value and these two lines are very close. The time value of CB Option is slightly higher in the case of smaller volatility.

[Insert Figure 4 here]

(2) Effect of interest rate volatility

The simulation results of CB Option as well as intrinsic value are showed in figure 5. We observe that (1) Both the simulated values increase as the volatility of interest rate increases; (2) The scales of the both values increase in an oscillating rate as the volatility increase.

.

[Insert Figure 5 here]

(3) Effect of Initial Stock Price

The following figure shows the simulation results for different initial stock prices. We observe in Figure 6 that (1) Both simulated values for CB Option and Intrinsic Value rise as the initial stock price increases; (2) The shape is upward slopping as initial stock price increases; (3) The value of CB Option is higher when initial stock price is low, which indicates that equity investors prefer buying a CB Option than holding a CB in a low stock price case.

[Insert Figure 6 here]

(4) Effect of initial risk-free interest rate

Figure 7 shows the effect of different risk-free interest rate on CB Option valuation. Since the value of underlying asset is negatively related to interest rate, we observe that the CB Option valuation decreases as the risk-free interest rate increases. Most importantly, we can observe that value of CB Option decreases in a diminishing rate as the interest rate level increases. Comparing with Intrinsic Value, CB Option is more valuable when higher interest rate leads to lower CB value.

[Insert Figure 7 here]

(5) Effect of correlation coefficient

Since the process of stock price and the risk-free interest rate are stochastic, we are curious about whether similar fluctuation make obvious influence on simulation results. By changing the number of the correlation coefficient, we show the results through the figure 8. We observe that there is a negative relation but small influence for the estimated values with the setting of the correlation coefficient between stock price and risk-free interest rate. This is because the effect of interest rate as the discount factor will partly counterbalance the effect of stock price, even though higher interest rate should lead to higher stock price under the settings of positive correlation coefficient.

[Insert Figure 8 here]

(6) Effect of initial credit rating

In order to reflect the credit risk of CB, we use corresponding credit spreads of credit rating in our pricing model. We assume big credit spreads for the CBs under investment grade (BBB) to reflect higher possibility of bankruptcy. Figure 9 shows the effect of different initial credit rating on the valuation of CB Option and Intrinsic Value. In figure 9, we observe that the simulated value dramatically decreases as credit rating getting lower. It is important to note that, comparing to holding a CB position (i.e., Intrinsic Value), a CB Option is relatively valuable as credit rating deteriorating because option holder can give up the exercise right to call the CB in case of bankruptcy.

[Insert Figure 9 here]

(7) Effect of put price

Figure 10 shows the effect of put price on the CB option valuation. It is important to note that lower put price make CB option more attractive than CB holding value. In other words, we see CB Option has a much higher value then Intrinsic Value in a low put price case.

[Insert Figure 10 here]

5. Comments and Conclusions

This paper investigates deal structure of the stripping of convertible bonds into credit component and equity component, i.e., CB Asset Swap and CB Option. We provide pricing models for both credit component and option component for CB Stripping structured products. We show that CB Asset Swap can be priced as American installment option. Our results indicate that a higher Asset Swap spread paid by the dealer could lead to early exercise of the CB option. Comparing to the ad hoc Two-Stage Model used by practitioners, the estimated spread based on American installment option model should be higher to take into account the early exercise premium.

Based on a Monte Carlo simulation procedure proposed by Longstaff and Schwartz (2001), we can simulate a three-factor CB Option model with early exercise feature. Holding interest rate and credit rating constant, we find that CB Option is slightly more expensive than CB holding position, defined as Intrinsic Value. Most importantly, our simulation concludes that, comparing to CB holding position, the CB call option will be mostly affected by (1) issuer credit, and (2) interest rate level and (3) put price. In a high credit grade and high put price situation, the valuation of CB option and Intrinsic Value should be similar. In other words, CB option investor should not pay much higher premium than Intrinsic Value. On the other hand, if the CB is belong to non-investment grade (lower than BBB) and interest rate (comparing to put yield) is high, equity investor should pay a much higher premium for a CB Option than CB Intrinsic Value.

References:

Bloomberg, 1998, "A Derivative for Asia's Season of Financial Discontent," *Bloomberg Magazine*, May.

Cox, J. C., J. E. Ingresoll, and S.A. Ross (1985): "A Theory of the Term Structure of Interest Rates", Econometrica, Vol. 36(7), 385-407.

Deutsche Bank Group, 2001, *Yageo Corp. Stripped Convertible Asset Swap -Indicative Terms and Conditions.*

Hull J. and A. White (1994). "Numerical Procedures for Implementing Term Structure Models I: Single Factor Models." *Journal of Derivatives,* Vol. 2, NO. 1, 7-16.

Jarrow, R. A., D. Lando, and S. M. Turnbull (1997): "A Markov Model for the Term Structure of Credit Risk Spreads," *Review of Financial Studies,* Vol. 10(2), 481-523.

Longstaff, F. A.,and E.S. Schwartz (2001): "Valuing American Options by Simulation: A Simple Least-Square Approach," *The Review of Financial Studies,* Vol. 14(1),113-147.

MONIS, 2002, "Structuring Convertible Bonds," MONIS Convertible XL V4.00 User Guide.

Table 1

Term Sheet of CB Asset Swap

Contract Terms of Initial Bond Purchase: (Seller: Party A, Buyer: Party B)

Bond	Zero Coupon rate, Convertible Bond
Maturity	6 years
Trade Date	October [ ],2001
Termination Date	October [ ],2007
Notional Amount	$ 100
Purchase Price	100 % flat of accrued Interest ($100)
Yield to Put	15 % of notional amount on October [ ],2004
Conversion Price	$ 50 per stock

Contract Terms of CB Asset Swap Transaction

Transaction Maturity	3 years
Trade Date	October [ ],2001
Termination Date	October [ ],2004
Floating Rate Payment (Party A)	Semi-yearly, 6-months LIBOR + spread as floating rate option in accordance with notional amount.
Designated Maturity	6 months
Spread	200 bps
Fixed Rate Payment (Party B)	15 % (Yield to Put) flat of the Notional on termination date
Early Termination	If call option investor exercises his call option, Party A must buy CB back with 100% of notional amount from Party B. And the asset swap will be early terminated immediately.
Exercise Date	Any Business Day up to and including Expiration Date.

Contract Terms of Call Option on CB Transaction

Call type	American call
Underlying Asset	The bonds, as described above
Transaction Maturity	3 years
Seller	Party A (Dealer)
Buyer	Equity investor
Trade Date	October [ ],2001
Expiration Date	October [ ],2004
Premium	10 % flat of national amount
Strike Price	The sum of (1) 100% of the National Amount (2) The net present value of the REFERENCE HEDGE (3) Accrued Interest (4) Early Exercise Fee
Reference Hedge	The differences of future cash flows from the exchange of interest rate payments between the asset swap parties

Table 2

Credit Spreads

Definition of Credit Spreads corresponding to the credit rating of underlying bond

Credit	AAA	AA	A	BBB	BB	B	C
Spread(bps)	10	50	100	150	300	1000	5000

Table 3

Sample Paths for Interest Rate, Stock Price, and Credit Rating

Eight sample paths for three state variables-interest rate, stock, and credit rating, are sampled to illustrate the pricing procedure of Call on CB.

Path	T=0	T=1	T=2	T=3
Panel A: Risk-free Interest Rate Paths				
1	5%	6%	5.50%	5.5%
2	5%	6.50%	7.50%	6%
3	5%	4%	5.50%	5%
4	5%	6%	6%	6.5%
5	5%	5.50%	6.50%	6%
6	5%	7%	6%	6%
7	5%	4.50%	6%	5.5%
8	5%	5%	4%	4.5%
Panel B: Stock Price Paths				
1	48	55	65	80
2	48	40	54	60
3	48	53	59	62
4	48	42	58	55
5	48	52	60	53
6	48	30	53	65
7	48	58	66	75
8	48	55	48	46
Panel C: Credit Rating Paths				
1	A	A	AA	AA
2	A	BBB	BBB	A
3	A	A	BBB	BBB
4	A	AA	A	BBB
5	A	A	AAA	AA
6	A	BBB	BB	C
7	A	A	A	A
8	A	A	AA	BBB

Table 4

Optimal Exercise Strategy At Time 2

The theoretical value of CB at time 3 CB(3) is the maximum value of CB put value and conversion value. Y is discounted cash flows received at time 3 which is CB(3) divided by discounted rate or (1+R+C), where R is risk-free interest rate and C is credit spread at time 2. Regress Y on X, R, and C for in-the-money paths (all but 8th paths) at time 2 and the regression equation is E [Y| X, R, C] = -674.662 + 9.76127 X+2949.85R+3348.52C, where X is stock price at time 2. Panel B shows the optimal conversion strategy. The optimal early conversion decision for each path at time 2 is to compare the conversion value of CB at time 2 to the continue value. CB(2) is the maximum value of conversion value and continue value which is the conditional expectation of regression function at time 2 described above The conversion value is conversion ratio which is 2 multiplied by the stock price at time 2. In Panel C, the optimal early conversion decision for each path is obtained from comparing discounted CB(3) to time 2 or Y in Panel A to CB(2) in panel B. Since CB can only be converted once, future cash flows occur at either time 2 or time 3.

Panel A: The value of Variables in Regression Equation at Time 2

Path	CB(3)	Y	X	R	C
1	160	150.9434	65	5.50%	0.50%
2	120	110.59908	54	7.00%	1.50%
3	124	115.88785	59	5.50%	1.50%
4	110	102.80374	58	6.00%	1.00%
5	106	99.437148	60	6.50%	0.10%
6	130	119.26606	53	6.00%	3.00%
7	150	141.50943	66	5.00%	1.00%
8	115	—	—	—	—

Panel B: The Value of CB at Time 2

Path	Conversion Value	Continue Value	CB(2)
1	130	138.8049	138.8049
2	108	109.16388	109.16388
3	118	113.72248	118
4	116	101.96786	116
5	120	106.10297	120
6	106	120.13191	120.13191
7	132	150.55952	150.55952
8	—	—	—

Panel C: Optimal Exercise Strategy at Time 2 and Time 3

Path	t = 1	t = 2	t=3
1	—	0	160
2	—	0	120
3	—	118	0
4	—	116	0
5	—	120	0
6	—	0	130
7	—	0	150
8	—	0	115

Table 5

The Strategy Decision and Cash Flows

CB(1) is the maximum value of conversion value and continue value which is the conditional expectation of regression equation described above. The conversion value is conversion ratio which is 2 multiplied by the stock price at time 1. Stopping cash flows for each path are showed after having identified the optimal exercise strategy at time 1,2, and 3. In Panel B, the optimal early conversion decision for each path is obtained from comparing discounted CB(2) to time 1 or CB(3) discounted to time 1 in panel C of Table 4 to CB(1) in panel A.

Panel A: Optimal early conversion decision at time 1

Path	Conversion	Continue	CB(1)
1	**110.0000**	**116.196755**	**116.1968**
2	**—**	**—**	**—**
3	**106.0000**	**106.019569**	**106.01957**
4	**—**	**—**	**—**
5	**104.0000**	**115.043576**	**115.04358**
6	**—**	**—**	**—**
7	**116.0000**	**135.1067**	**135.1067**
8	**110.0000**	**110.551715**	**110.55172**

Panel B: Stopping Cash Flows

Path	t = 1	t = 2	t=3
1	0	0	**160**
2	0	0	**120**
3	0	118	**0**
4	0	116	**0**
5	0	120	**0**
6	0	0	**130**
7	0	0	**150**
8	0	0	**115**

Table 6

The Cash Flows at Each Path with Reference Hedge

The continue value is the conditional expectation obtained from above regression equation. The value of CB Option at time 2 is the maximum value between exercise value and continue value. Panel C shows the cash flow of Call on CB at each path. .

Panel A: Reference Hedge

Path	t = 1	t = 2	t=3
1	-1.66	3.00	9.5
2	-2.60	0.48	7.5
3	2.15	5.00	9.5
4	-1.66	2.49	9
5	-0.71	2.48	8.5
6	-3.54	1.49	9
7	1.19	3.99	9
8	0.24	5.58	11

Panel B: The value of call on CB at time 2

Path	Exercise Value	Continue	Call on CB
1	30.7358	41.16363	41.1636
2	11.9630	16.57325	16.5733
3	18.8505	18.06131	18.8505
4	17.8505	2.00122	17.8505
5	—	—	—
6	8.0734	17.43494	17.4349
7	31.7358	46.15681	46.1568
8	—	—	—

Panel C: Value of call on CB under the optimal stopping rules

Path	t = 1	t = 2	t=3
1	0	0	52.5
2	0	0	14
3	10.1134	0	0
4	0	17.8505	0
5	0	22.8049	0
6	0	0	23
7	0	0	42
8	17.3168	0	0

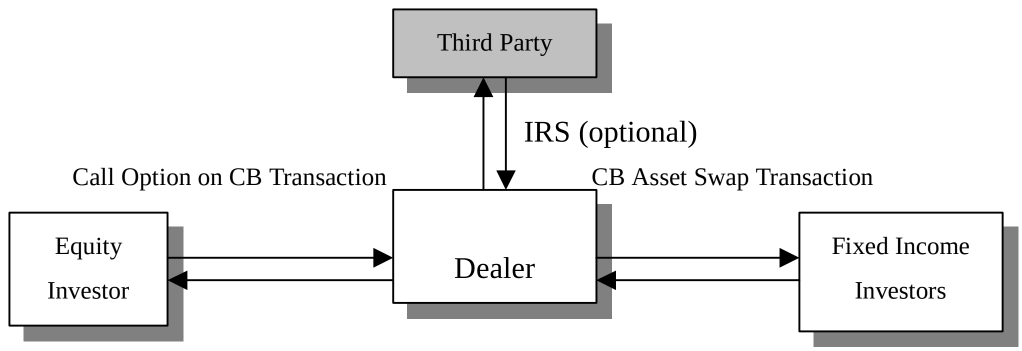

Figure 1. The Structure of CB Asset Swap Business

CB Asset Swap transaction mainly consists of CB asset swap transaction and call option on CB transaction. Third party may also involve in this structures for IRS (Interest Rate Swap).

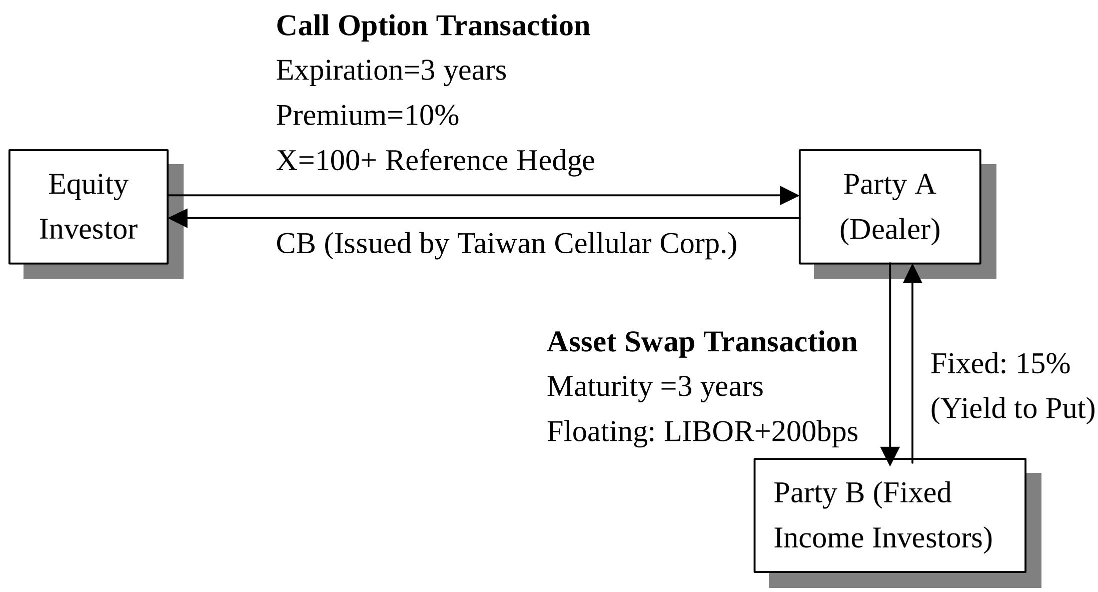

Figure 2. Asset Swap Business Structure of Taiwan Cellular Corp.

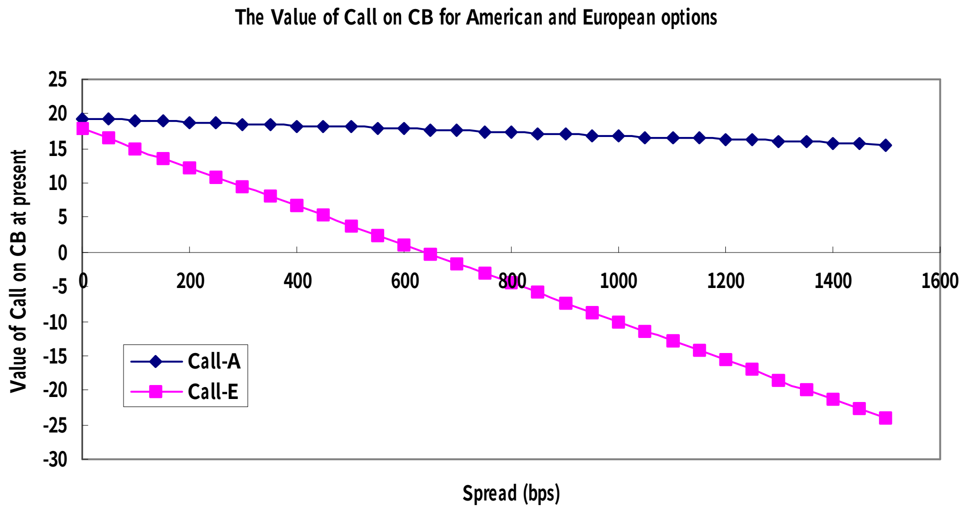

Figure 3. Value comparison for call on CB of American and European options

The CB asset swap is based on the TCC contract terms. To highlight the value of early exercise for installment option, the value of call on CB for two types of option, American and European, are calculated. The payoff of American option=max(HV - (FP + Spread), CV), where HV is Holding Value of Option, and FP is Floating Payment at each coupon date. The payoff of European option is discounted future cash flow that is HV- (FP + Spread).

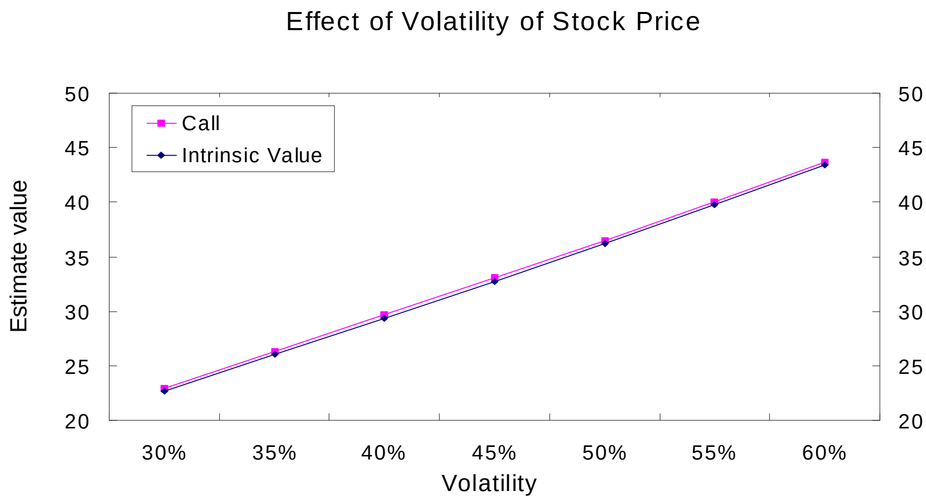

Figure 4. Effect of volatility of stock price

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7 except we vary the volatility of stock price. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.

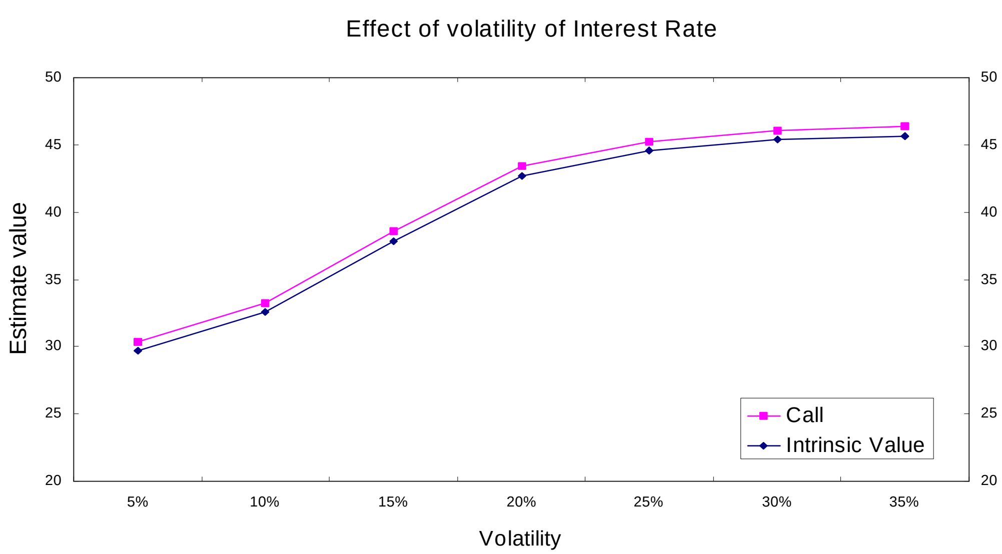

Figure 5. Effect of Volatility of Interest Rate

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7 except we vary the volatility of interest rate. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach. The lower line is intrinsic value which is obtained by value difference of CB value and strike price by various volatility of interest rate.

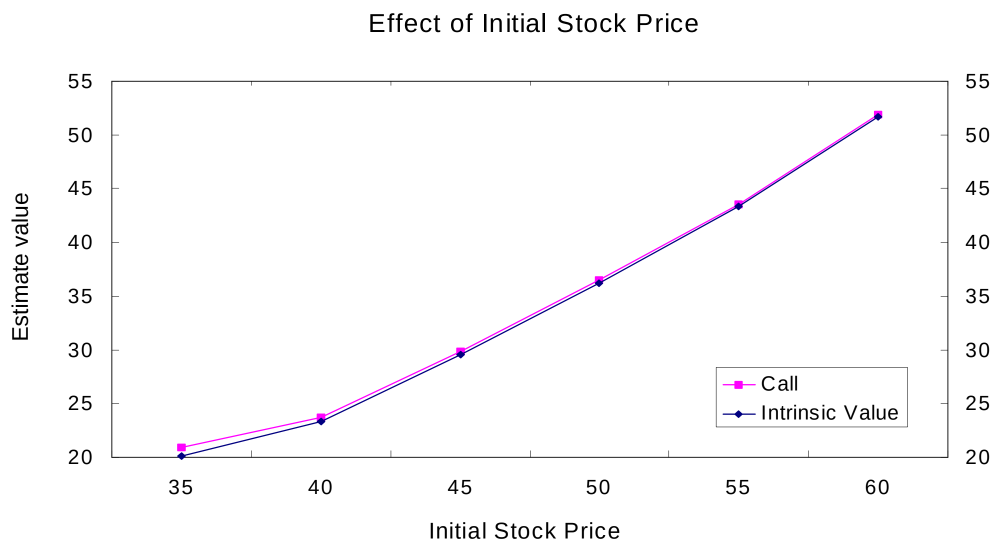

Figure 6. Effect of Initial Stock Price

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7 except we vary the initial stock price. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.

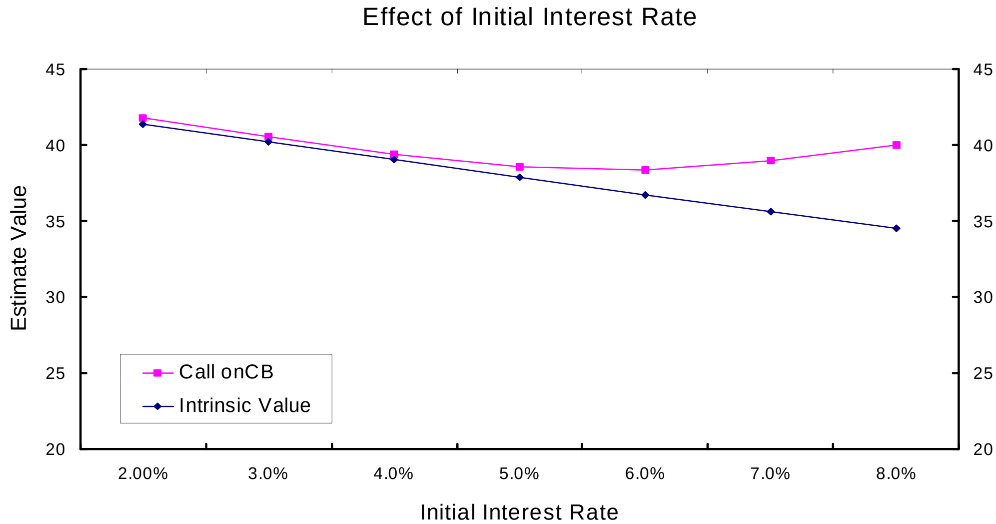

Figure 7. Effect of initial Interest Rate

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7 except we vary the initial interest rate. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.

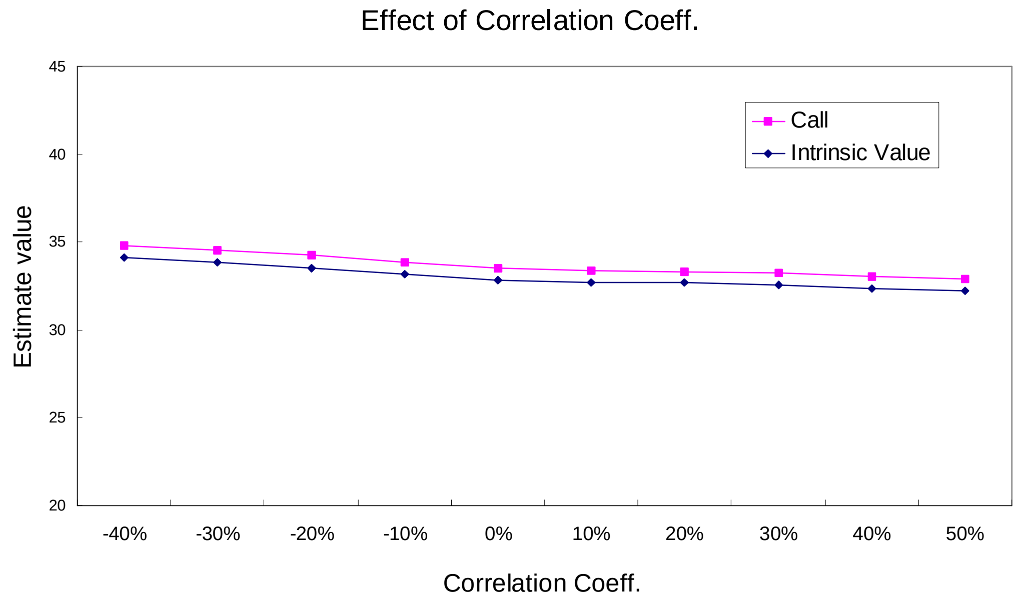

Figure 8. Effect of Correlation Coefficient

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7 except we vary the correlation coefficient. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.

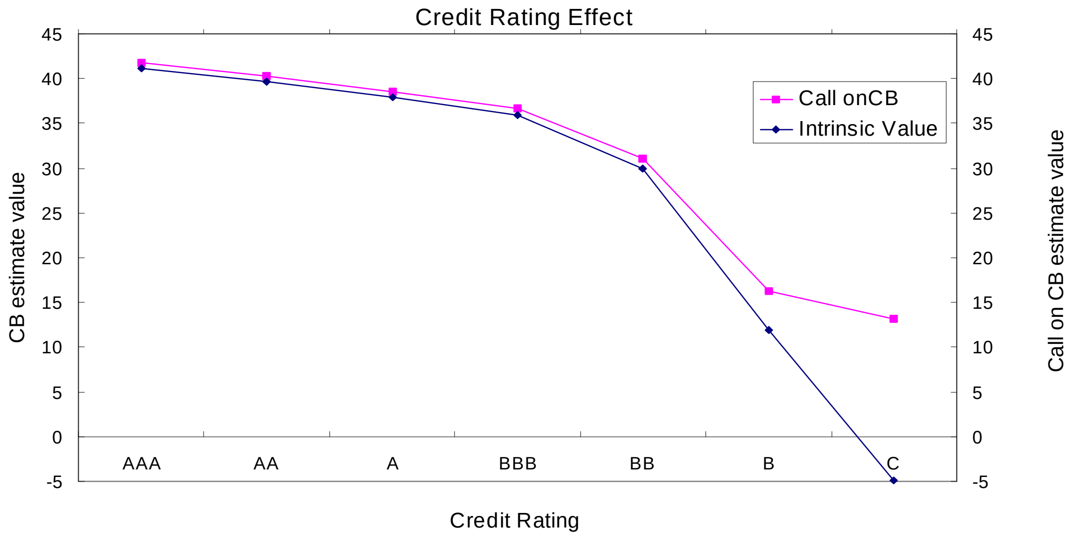

Figure 9. Effect of Initial Credit Rating

The call option transaction is based on contract terms of TCC. The model parameters are based on Table 7. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach with various initial credit rating. The initial credit spread is set according to Table 2. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.

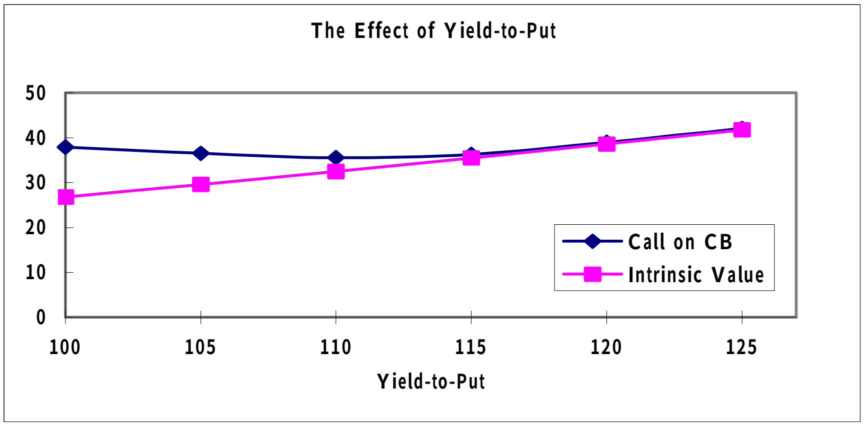

Figure 10. The Effect of Yield-to-Put

The call option transaction is based on contract terms of TCC but with various put price. The model parameters are based on Table 7. The numerical method follows the least-squares approach developed by Longstaff and Schwartz (2001). The upper line is the value of Call obtained by least-square approach with various yield-to-put. The lower line is intrinsic value which is obtained by value difference of CB value and strike price.