Original Article

Valuing primary issue convertible bonds: Evidence from China

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ABSTRACT This study examines the valuation of primary issue convertible bonds (CBs) in China. It proposes and tests a valuation model based on partial least squares regression, by using data from the Chinese stock markets. The study finds the model to be effective, and identifies six important determinants for valuing primary issue CBs in Chinese stock markets.

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INTRODUCTION

Convertible bonds (CBs) are coupon-paying corporate bonds that can be converted into company stock at the discretion of the holder. They are typically listed securities issued by

companies and traded on secondary markets. Companies issue them for two main reasons (see, for example, Davis and Lischka¹). First, they enable companies to lower their costs of debt funding by implicitly selling an option on

their stock. This helps to resolve the problem of asymmetric information on the risk of the underlying assets, and reduces agency costs. Second, they can be used as an indirect and delayed equity issue, which can reduce dilution and circumvent regulatory hindrances.

As a result of their complexity, the valuation of CBs is challenging, and may involve option valuation, yield curve modeling and credit risk modeling. Their valuation has been extensively studied during the past several decades. Many earlier studies, including those by Brigham,² Walter and Que,³ Ingersoll,⁴ and Brennan and Schwartz,^{5,6} are based on the so-called structural approach, in which the value of the firm is used as the basic underlying state variable. Nyborg⁷ provides an overview of this approach. The estimation of parameters in pricing CBs using this approach is extremely difficult, for two reasons. First, the firm's value is neither tradable nor observable. Second, any other claims that are senior to CBs must be valued simultaneously. To circumvent these problems, some pricing models using stock price (in some cases with additional random variables such as interest rates) as the basic underlying variable have been developed. This makes the estimation of the parameters simpler, as the firm's stocks are tradable and therefore the stock price is observable; further, there is no need to estimate the value of other senior claims. Examples of this approach can be found in studies by McConnell and Schwartz,⁸ Cheung and Nelken,⁹ and Ho and Pfeffer.¹⁰ However, these studies simply use a risky discount rate, and ignore bankruptcy risk.

Another approach, known as reduced form, is based on the valuation of risky debt (see, for example, Jarrow and Turnbull,¹¹ Duffie and Singleton,¹² and Madan and Unal¹³). Studies using this approach include those of McConnell

and Schwartz,⁷ Cheung and Nelken,⁹ Bardhan *et al*,¹⁴ Ho and Pfeffer,⁹ Tsiveriotis and Fernandes,¹⁵ Davis and Lischka,¹ Takahashi *et al*,¹⁶ Hung and Wang,¹⁷ and Andersen and Buffum.¹⁸

CBs have existed for a long time in developed economies such as the United States. Most of the convertible bond pricing literature described above is based on the arbitrage theory, that is, the no-arbitrage condition. However, this approach may be invalid in China, where the CBs market is still in the early development stage – the first issue was in 1992 – and is characterized by market illiquidity and regulatory constraints. Thus, a non-standard approach to studying primary issue CBs in China is needed.

A few studies exist on the valuation of primary issue CBs. Billingsley *et al*¹⁹ calculate the relative contribution of debt and implicit warrant to the value of initial public offering (IPO) CBs. Their approach provides a way to assess the relationship between the value of implicit warrant and its determinants by isolating individual components of the value of CBs. Based on a sample of 260 IPOs listed on the Korean Stock Exchange from January 1985 to March 1990, Kim *et al*²⁰ examine the role of information disclosure through the prospectus in the primary issue market. Their results reveal that the market price is significantly affected by financial variables such as earnings per share, industry-wide prospects, and offer size and type. In addition, they find that the inclusion of potential signaling variables does not increase the explanatory power and predictability of the model. Kim and Ritter²¹ find that the use of accounting information in association with comparable firm multiples is important in valuing primary issue CBs. Liu and Chen²² find that the price/earnings (P/E), market-to-book

and price-to-sales multiples of comparable firms have significant power of predictability. It is generally accepted that stochastic interest rate, dividend, credit risk, transaction cost, call provisions, put provisions, re-fixed clauses, volatility of stock price, coupon rate and P/E have significant impacts on the value of CBs.

This study, therefore, aims to assess the importance of financial variables contained in prospectuses in valuing primary issue CBs by using the partial least squares regression (PLSR) method. It contributes to the literature in two ways: it provides a new approach based on PLSR, which can overcome the multicollinearity problem, and it extends the existing literature (for example Ingersoll,⁴ Brennan and Schwartz⁵) by including more financial variables.

This article is organized as follows. The next section describes the methodology; the subsequent section presents the model and data used in the study; the penultimate section gives the empirical results and analysis; and the final section is a summary.

METHODOLOGY

PLSR is a multivariate regression model originally developed by Wold²³ that has been used extensively in applied sciences such as social science and chemometrics. Its theoretical foundation is the canonical correlation analysis. PLSR incorporates not only information of regressors, but also dependent variables in extracting components. PLSR does not estimate each regressor one by one, but decomposes and re-combines the information, efficiently extracting that which is most important and excluding the redundant or meaningless. PLSR has proved useful in explaining a set of dependent variables from a very large set of regressors with

a small number of observations. Therefore, PLSR is suitable for our study, as we have a large number of variables. It overcomes the multicollinearity problem that occurs when using the classical multiple linear regression, which may lead to estimation bias.

PLSR can be used with one dependent variable or multidependent variables. This study uses the single dependent variable, which is described below.

Partial least squares regression

PLSR works by extracting one component at a time. Given a dependent variable y , m regressors $X = [x_1, x_2, \dots, x_m]$ and n observations, we can construct an $n \times m$ observation matrix $X = [x_1, x_2, \dots, x_m]_{n \times m}$. We assume that all data are centered and scaled with a mean of zero and standard deviation of one. The centered regressors and dependent variable ensure that the selection of successive components is based on how much variation they explain, in either regressors or dependent variable, or both. Scaling is used to place all regressors and dependent variables on an equal footing as compared to their variations in the data. With PLSR, we can estimate a new matrix $T = [t_1, t_2, \dots, t_K]$ with dimension $n \times K$ (where $K \leq m$), whose columns are linear combinations of columns of X . By using the notation of Höskuldsson,²⁴ $X = \sum t_i p_i^T = TP^T$ where $P = [p_1, p_2, \dots, p_K]$ is a matrix with the dimension of $m \times K$. The algorithm of PLSR can be described as follows:

1. Consider a multilinear regression model

$$y = X\beta + \varepsilon \quad (1)$$

where X is the observed matrix of dimension $n \times m$, β is the coefficient vector of

dimension $m \times 1$, ε is the error term and γ is the dependent variable.

- Suppose that K is a constant and known value and the initial values are set as

$$k = 1, E_1 = X, \text{ and } f_1 = \gamma. \quad (2)$$

- Estimate the loading vector ω_k and the corresponding component vector t_k :

$$\begin{aligned} \omega_k &\propto E_k^T f_k, \quad \|\omega_k\| = 1 \\ t_k &= E_k \omega_k \end{aligned} \quad (3)$$

where $\|\cdot\|$ is the norm of a vector, and ω_k is a weighting vector reflecting the weight assigned to each variable x_j in forming a component vector t_k . In this article ω_k is called a loading vector.

- Estimate the following $m + 1$ simple regressions:

$$\begin{aligned} f_k &= \alpha_k t_k + e_{f_k}, \\ E_{k,j} &= p_{k,j} t_k + e_{E_{k,j}}, \quad j = 1, 2, \dots, m \end{aligned} \quad (4)$$

or

$$\begin{aligned} f_k &= \alpha_k t_k + e_{f_k}, \\ E_k &= t_k P_k^T + e_{E_k} \end{aligned} \quad (5)$$

As t_k is a linear combination of the columns of X , it also has a mean of zero. Thus, the regressions do not have intercept terms.

- Update the residual matrices by using the residuals calculated in the previous steps as the new column vectors,

$$\begin{aligned} f_{k+1} &= e_{f_k}, \\ E_{k+1} &= [e_{E_{k,1}}, e_{E_{k,2}}, \dots, e_{E_{k,m}}] = e_{E_k} \end{aligned} \quad (6)$$

Combining (4) and (6), we have:

$$\begin{aligned} t_1 &= E_1 \omega_1 = X h_1 \\ t_i &= E_i \omega_i = E_{i-1} (I - \omega_{i-1} p_{i-1}^T) \omega_i \\ &\vdots \\ &= E_1 \omega_i \prod_{\tau=1}^{i-1} (I - \omega_{\tau} p_{\tau}^T) \\ &= E_1 h_i \\ &= X h_i \end{aligned} \quad (7)$$

where $h_1 = \omega_1$ and $h_i = \omega_i \prod_{\tau=1}^{i-1} (I - \omega_{\tau} p_{\tau}^T)$ for $i \geq 2$. Let $H = [h_1, h_2, \dots, h_K]$. Using this notation, we have

$$T = XH. \quad (8)$$

- If k is less than K , increase its value by one and return to Step 3. If k is equal to K , the process stops and the estimated vector γ is

$$\hat{\gamma}_K = \hat{\alpha}_1 t_1 + \hat{\alpha}_2 t_2 + \dots + \hat{\alpha}_K t_K = T \hat{\alpha} \quad (9)$$

where $\hat{\alpha} = [\hat{\alpha}_1, \hat{\alpha}_2, \dots, \hat{\alpha}_K]$ is an estimated coefficient vector. Combining equations (1), (9) and (6), we have

$$\hat{\gamma} = T \hat{\alpha} = XH \hat{\alpha} = X \hat{\beta}. \quad (10)$$

Thus, the coefficient vector of PLSR, $\hat{\beta}_{PLSR}$ is given by

$$\hat{\beta}_{PLSR} = H \hat{\alpha} = H(T^T T)^{-1} T^T \gamma. \quad (11)$$

Note that the above procedure requires that K is known. However, it is unknown in practice, and needs to be estimated through cross-validation methods, which are discussed below.

- Because the data above are scaled and centered, we can obtain the estimated

coefficients of the original data through

$$\gamma = \frac{\bar{y} - \bar{\gamma}}{\sigma_{\bar{y}}},$$

$$x_i = \frac{\bar{x}_i - \bar{x}_i}{\sigma_{\bar{x}_i}}, \quad i = 1, 2, \dots, m \quad (12)$$

where $\bar{y}(\bar{\gamma})$ and $\bar{x}_i(\bar{x}_i)$ are original data (means) of y and x_i , respectively, and $\sigma_{\bar{y}}$ and $\sigma_{\bar{x}_i}$ are standard deviations of $\bar{y}$ and $\bar{x}_i$, respectively. By inserting equation (12) into equation (9), we can obtain the coefficients of the original data.

Estimation of the number of PLSR components

Cross-validation can be used to estimate the number of PLSR components. This method has many variations, including one-at-a-time, split-sample, blocked and random sample. We use the common one-at-a-time cross-validation, which obtains the number of PLSR components by minimizing the predicted residual sum of squares (PRESS). That is,

$$PRESS(k^*) = \min_{1 \leq k^* \leq q} \left[\sum_{i=1}^n (y_i - \hat{y}_{k(-i)})^2 \right] \quad (13)$$

where $\hat{y}_{k(-i)}$ is the predicted value estimated by using the data set with the i th observation removed, y_i is the y value of the i th sample, and k^* is the number of PLSR components obtained through one-at-a-time cross-validation.

ESTIMATION OF THE VARIABLE IMPORTANCE FOR PROJECT (VIP)

To eliminate unimportant regressors from the analysis, we need to consider the regression coefficients for the standardized data. Regressors with small coefficients (in absolute value) make a

small contribution to explaining the dependent variables. VIP, developed by Wold,²⁵ is a statistic that represents the contribution made by each variable. The VIP for each variable reflects its importance in the PLSR model. If a variable has a relatively small coefficient (in absolute value) and a small value of VIP, it is a prime candidate to be eliminated. Based on the work of Wold,²⁵ a VIP value of less than 0.8 is considered to be small. VIP is estimated as:

$$VIP_j = \sqrt{\frac{m}{Rd(y; t_1 \sim t_K)} \sum_{i=1}^K Rd(y; t_i) \omega_{ij}^2} \quad (14)$$

where VIP_j is the VIP of the j th regressor x_j ; $Rd(y; t_1 \sim t_K)$ and $Rd(y; t_i)$ are degree of response by PLSR components $t_1 \sim t_K$ and t_i , respectively; and $Rd(y; t_i) = r^2(y, t_i)$, m , K are the number of regressors and the number of extracting PLSR components, respectively; ω_{ij} is the j th weight of axis ω_i , which reflects the marginal contribution of x_j in constructing PLSR component t_j , and there holds $\sum_{j=1}^m \omega_{ij}^2 = 1$, for any $i = 1, 2, \dots, K$.

Estimation of the mean squared error of prediction (MSEP)

To assess the fitness of the proposed model we use the MSEP, which is given by:

$$MSEP = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2 \quad (15)$$

where $\hat{y}_i$ is the predicted value of the i th observation of the data, and n is the size of the test set.

In summary, we can follow the above procedures to carry out PLSR and assess the fitness of the PLSR model. All estimates are conducted with SAS (Version 8.02).

MODEL AND DATA

The PLSR model

Because this article involves with valuing primary issue CBs, it uses the IPO price of a CB as the dependent variable, which is defined as:

CBP = Convertible bond price, which is the IPO price of a convertible bond, that is, the close of market price on the first trading day after listing.

Next, we need to select the explanatory (independent) variables for PLSR. Based on the financial theories and previous studies (Mehta and Khan,²⁶ Datta *et al.*,²⁷ Kang and Lee²⁸), we propose the following 27 variables that can have an impact on the value of primary issue CBs:

1. *SP* = stock price. The closing price of the underlying stock.
2. *ICP* = initial conversion price, at which the bond-holder has the option of exchanging the bond for the firm's common stock over the life of the bond. The higher the ICP, the smaller the probability that the bond holder will exchange the bond for the underlying stock.²⁹
3. *ConP* = conversion premium. The difference between the initial conversion price of a CB and the average stock price over 30 trading days before the prospectus release. The initial conversion premium ranges from 0.1 per cent to 10 per cent in China.
4. *RDL* = ratio of drawing lots. A ratio of total amount used to purchase CBs to total amount applied for CBs.
5. *ISSE* = index of Shanghai Stock Exchange, one of the two major market indicators in Chinese stock markets.
6. *ADISSE* = a dummy variable, which is 1 when *ISSE* increases on the previous day, and 0 otherwise.
7. *DRLS* = dilution ratio in tradable stocks.³⁰ A ratio of converted stocks to tradable stocks.
8. *DRTS* = dilution ratio in total stocks. A ratio of converted stocks to total stocks (tradable stocks plus non-tradable stocks).
9. *OS* = offering size. The amount of CBs being issued at par value.
10. *RTP* = ratio of trigger put, at which a firm's stock price remains continuously under conversion price for a specified period of time (for example 30 days) and the bond-holders are precluded from exercising put options during this time. This ratio is usually about 60–90 per cent in Chinese stock markets.
11. *PP* = put price, at which bond-holders have the right to sell CBs back to the issuer when put provisions are satisfied. The put price ranges from 101 to 108 in China.
12. *T* = time to maturity. A period of time from issuing date to maturity.
13. *ACR* = average coupon rate. The sum of coupon rates divided by the life of the CBs.
14. *AI* = accrued interest. The amount of interest owed from the date of the last coupon payment to the present. Any accrued interest will be lost on conversion.
15. *RRC* = ratio of re-fixed conversion. A fraction of time (for example 20 days out of a consecutive 30 trading days) in the total bond life when the closing price of underlying stock has been continuously lower than the original conversion price, and the firm is forced to lower the conversion price by a certain percentage. This ratio is usually about 70–95 per cent in Chinese stock markets.
16. *RE* = re-fixed extent. A percentage at which an issuer reduces the conversion price.

17. *SSV* = stock-return volatility. A standard deviation of the continuously compounded equity return (based on the daily closing price) 20–40 trading days before the issuing date.
 18. *RTC* = ratio of trigger call. A ratio at which a firm's stock price has been continuously higher than the conversion price for a specified period of time (for example 20 days of a continuous 30 trading days) and an issuer has the right to call CBs. This ratio is usually about 120–150 per cent in Chinese stock markets.
 19. *CP* = call price, at which an issuer has the right to redeem CBs when call provisions are satisfied. Based on studies by Ingersoll⁴ and Brennan and Schwartz⁵, the call price in the prospectus is positively correlated to the value of CBs.
 20. *PE* = price/earnings, which is calculated as market price per share divided by earnings per share. Firms with low price/earnings ratios face high financial distress costs (see McConnell and Servaes³¹). In contrast, firms with high price/earnings ratios or growth potential prefer convertible debt financing.
 21. *YRCB* = yield rate of corporate (straight) bond, which is equal to the rate of return on a corporate bond issued by the same firm with similar maturity.³²
 22. *RFR* = risk-free rate. An interest rate of time deposit with similar maturity in China, representing the external financing cost of listed firms.
 23. *EPS* = earnings per share. Total earnings divided by the number of shares in the prospectus.
 24. *NTAPS* = net tangible assets per share. Total net tangible assets divided by the number of shares in the prospectus.
 25. *GOR* = growth of operating revenue, which is the difference between operating revenue this year and last year, divided by that of last year.
 26. *GNP* = growth of net profit, which is the difference between net profits this year and last year, divided by that of last year. *GNP* is a proxy for the growth potential of a listed company.
 27. *RCFS* = running cash flow per share, which is equal to cash flow divided by the numbers of shares.
- Using these independent variables, the following PLSR model is proposed to identify the determinants of primary issue CBs in Chinese stock markets:
- $$\begin{aligned}
 CBP_i = & \beta_1 SP_i + \beta_2 ICP_i + \beta_3 ConP_i + \beta_4 RDL_i \\
 & + \beta_5 ISSE_i + \beta_6 ADISSE_i + \beta_7 DRLS_i \\
 & + \beta_8 DRTS_i + \beta_9 OS_i + \beta_{10} RTP_i \\
 & + \beta_{11} PP_i + \beta_{12} T_i + \beta_{13} ACR_i + \beta_{14} AI_i \\
 & + \beta_{15} RRC_i + \beta_{16} RE_i + \beta_{17} RTC_i \\
 & + \beta_{18} CP_i + \beta_{19} PE_i + \beta_{20} SSV_i \\
 & + \beta_{21} YRCB_i + \beta_{22} RFR_i + \beta_{23} EPS_i \\
 & + \beta_{24} NTAPS_i + \beta_{25} GOR_i \\
 & + \beta_{26} GNP_i + \beta_{27} RCFS_i + \varepsilon_i. \quad (16)
 \end{aligned}$$

Sample and data

The sample contains 25 primary issue CBs in Chinese stock markets between 16 March 2000 and 3 June 2004. The 25 primary issue CBs are from the following listed companies: Fuxing, Fengyuan, Guiguan, Gangfan, Huaxi, Guodian, Jichang, Hangang, Longdian, Minsheng, Qiaocheng, Shougang, Shanying, Shuiyun, Sichou-2, Wanke, Tongdu, Xigang, Yangguang, Yanjing, Yage, Yunhua, Jianghuai, Gehua and Yinggang.

We use cross-section market trading data and financial data from the Wind Information and Financial database³³ and *Security Times* in China. Summary statistics of the variables in the PLSR model (16) are presented in Table 1.

EMPIRICAL RESULTS

First, we note that the conditional number of the matrix $X^T X$ is more than 20 for our sample. This indicates a high level of collinearity among the impendent variables. Therefore, as suggested earlier, PLSR rather than traditional ordinary

Table 1: Summary statistics for the variables

<i>Variable</i>	<i>Mean</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>
<i>CBP</i>	103.24	4.1	0.4	2.03
<i>SP</i>	9.59	3.52	1.56	5.95
<i>ICP</i>	9.96	3.82	1.51	6.11
<i>ConP</i>	0.02	0.02	2.05	7.14
<i>RDL</i>	21.87	34.04	1.44	3.49
<i>ISSE</i>	1538.92	126.01	1	4.94
<i>ADISSE</i>	0.64	0.49	0.58	1.34
<i>DRLS</i>	35.01	8.07	0.3	2.69
<i>DRTS</i>	14.6	4.48	0.21	1.9
<i>OS</i>	10.75	8.09	2.02	7.83
<i>RTP</i>	0.76	0.09	1.43	4.42
<i>PP</i>	104.33	2.34	0.22	1.64
<i>T</i>	4.68	0.75	1.85	4.44
<i>ACR</i>	1.68	0.4	0.68	2.61
<i>AI</i>	2.1	3.03	1.33	3.59
<i>RRC</i>	85.2	6.69	-0.07	2.21
<i>RE</i>	15.2	6.84	-0.07	2.04
<i>SSV</i>	0.28	0.06	-0.13	1.63
<i>RTC</i>	132.8	7.37	1.43	4.35
<i>CP</i>	103.1	1.54	0.27	1.48
<i>PE</i>	22.18	14.08	1.75	6.56
<i>YRCB</i>	3.68	0.66	1.35	3.92
<i>RFR</i>	1.99	0.05	4.69	23.04
<i>EPS</i>	0.41	0.18	0.98	3.57
<i>NTAPS</i>	3.62	1.07	-0.05	2.43
<i>GOR</i>	25.38	30.92	0.52	3.68
<i>GNP</i>	22.78	29.69	0.69	4.64
<i>RCFS</i>	1.12	2.7	4.22	20.49

least squares regression should be used in this study.

PLSR components

The one-at-a-time cross-validation is employed for this study as a result of the small sample size. The results are reported in Table 2, which shows that the PRESS reaches its absolute minimum of 0.153 when $K^* = 11$ (represented in bold).

Therefore, we choose 11 PLSR components:

$t_1, t_2, \dots, t_{11}$.

The selection of the PLSR components is based on its power in explaining the variation in both the regressors and the dependent variable. The proportions of the variation explained by the selected components through PLSR are

shown in Table 3. According to this table, 80.6 per cent of the variation in the regressors and 96.1 per cent of the variation in the dependent variable can be explained by the 11 selected components. As these proportions are quite high, the selection of 11 components is satisfactory.

Model estimation

This sub-section reports and analyzes the empirical results for the PLSR model (16). The results are summarized in Table 4, followed by detailed discussions.

The first thing to notice is the sign of the coefficient estimates. A positive coefficient indicates that an increase in this variable will lead to an increase in the IPO price of CBs, whereas a negative coefficient indicates that an increase in this variable will lead to a decrease in the IPO price of CBs. Table 4 shows that the coefficients of *SP*, *ISSE*, *DRTS*, *OS*, *AI*, *RTC*, *CP*, *PE*, *YRCB*, *NTAPS* and *GNP* are positive. Of these, *GNP* (0.6992) has the largest normalized coefficient and *DRTS* (0.0931) the smallest. In contrast, the coefficients of *ICP*, *ConP*, *RDL*, *ADISSE*, *DRLS*, *RTP*, *PP*, *T*, *ACR*, *RRC*, *RE*, *SSV*, *RFR*, *EPS*, *GOR* and *RCFS* are negative. Of these, *RCFS* (−0.0189) has the largest normalized coefficient and *SSV* (−0.5679) the smallest.

These observations are largely consistent with our expectations. *GNP* and *ISSE* have a positive impact on the value of primary issue CBs because they reflect growth potential for listed firms. *CP* also has a positive impact on the value of primary issue CBs because it indicates a high probability of conversion. In addition, *AI* plays an important role in valuing CBs in Chinese stock markets because bond

Table 2: PRESS statistics for the selection of PLSR components

Number of Extracted components	PRESS(k^*)
0	0.889
1	0.653
2	0.656
3	0.784
4	0.751
5	0.629
6	0.326
7	0.197
8	0.232
9	0.253
10	0.172
11	0.153
12	0.304
13	0.499
14	0.535
15	0.507

Table 3: Proportion (%) of variation explained by PLSR components

Number of Extracted Components	Regressors (%)		Dependent Variable (%)	
	Current	Accumulative	Current	Accumulative
1	14.3150	14.3150	51.2889	51.2889
2	10.2919	24.6069	16.8356	68.1245
3	10.5849	35.1918	7.8522	75.9767
4	10.5252	45.7170	5.3889	81.3656
5	5.1670	50.8840	6.9413	88.3069
6	7.5455	58.4295	2.0850	90.3919
7	4.8373	63.2668	2.5380	92.9300
8	7.6691	70.9359	1.0903	94.0202
9	2.8359	73.7718	0.9202	94.9405
10	2.7511	76.5229	0.7674	95.7079
11	4.1061	80.6290	0.4036	

buyers usually pay accrued interest to bond holders, who hold CBs from issuing date to last coupon date. Similarly, *SSV* and *RRC* have a negative impact on IPO pricing of CBs as they represent high financing cost and a low probability of conversion.

In assessing the importance of the independent variables for the PLSR model, note that the VIP estimates for *DRLS*, *DRTS*, *RRC* and *RE* are less than 0.8, which means that they make a relatively small contribution to explaining the variation in both the regressors and the dependent variable. However, they cannot be eliminated from the model because the normalized coefficients for these regressors appear to be significantly different from zero (at -0.4980 , 0.0931 , -0.5120 and -0.2619 , respectively).

Based on the normalized coefficients in absolute value and in descending order, the ranking of the variables in terms of their importance in valuing primary issue

CBs is: *GNP*, *CP*, *ISSE*, *SSV*, *AI*, *RRC*, *DRLS*, *ICP*, *RTP*, *NTAPS*, *RDL*, *PE*, *OS*, *RE*, *T*, *ConP*, *RTC*, *EPS*, *SP*, *PP*, *DRTS*, *GOR*, *YRCB*, *ADISSE*, *ACR*, *RCFS* and *RFR*. Further, *GNP*, *CP*, *ISSE*, *SSV*, *AI* and *RRC* are the most important variables because the absolute value of their normalized coefficients is greater than 0.5.

Compared with the literature, our findings for growth of net profit and call price are consistent with Ingersoll⁴ and Brennan and Schwartz,⁵ as the growth of net profits is an important indicator of a firm's value and growth potential, and call price is positively correlated to the price of primary issue CBs in China. Brennan and Schwartz⁶ extend their model by including stochastic interest rates; however, they conclude that the effect of a stochastic term structure on the price of CBs is so small that it can be neglected for empirical purposes. This study finds that *AI* (the amount of interest owed from the date of the last coupon payment to the

Table 4: Estimation results of the PLSR model

<i>Independent Variable</i>	<i>Coefficient</i>		<i>Independent Variable</i>	<i>Coefficient</i>	
	<i>Normalized</i>	<i>Original</i>		<i>Normalized</i>	<i>Original</i>
<i>Constant</i>	0.0	−26.5550			
<i>SP</i>	0.1464 (1.490)★	0.1703	<i>RRC</i>	−0.5120 (0.789)	−31.3663
<i>ICP</i>	−0.4530 (1.100)★	−0.4860	<i>RE</i>	−0.2619 (0.535)	−15.6844
<i>ConP</i>	−0.1796 (1.614)★	−30.5166	<i>SSV</i>	−0.5679 (0.962)★	−38.3837
<i>RDL</i>	−0.2813 (2.350)★	−0.0339	<i>RTC</i>	0.1704 (1.174)★	9.4725
<i>ISSE</i>	0.5807 (1.241)★	0.0189	<i>CP</i>	0.6024 (1.572)★	1.6079
<i>ADISSE</i>	−0.0478 (1.192)★	−0.4001	<i>PE</i>	0.2806 (1.089)★	0.0817
<i>DRLS</i>	−0.4980 (0.728)	−0.2529	<i>YRCB</i>	0.0539 (1.100)★	0.3354
<i>DRTS</i>	0.0931 (0.790)	0.0852	<i>RFR</i>	−0.0116 (0.806)★	−0.8796
<i>OS</i>	0.2735 (1.124)★	0.1386	<i>EPS</i>	−0.1621 (0.880)★	−3.6769
<i>RTP</i>	−0.3359 (1.360)★	−15.3670	<i>NTAPS</i>	0.3060 (0.961)★	1.1771
<i>PP</i>	−0.0938 (1.173)★	−0.1641	<i>GOR</i>	−0.0821 (1.481)★	−1.0880
<i>T</i>	−0.1977 (1.135)★	−1.0828	<i>GNP</i>	0.6992 (0.936)★	9.6516
<i>ACR</i>	−0.0350 (1.463)★	−35.4604	<i>RCFS</i>	−0.0189 (1.193)★	−0.0287
<i>AI</i>	0.5205 (1.669)★	0.7046			

Note: The statistics of VIP (in parentheses) are based on Wold (1994). ★ denotes that VIP for the coefficients is greater than 0.8.

Figure 1: The predicted value versus market value for primary issue convertible bonds in China.

present) has a positive impact on the value of primary issue CBs in China. Bardhan *et al*¹⁴ and Tsiveriotis and Fernandes¹⁵ split the value of a convertible bond into a stock component and a straight bond component. High stock-return volatility will lower the value of the stock component, and thus has a negative impact on the value of primary issue CBs. This study also incorporates some important variables that are not mentioned in other studies, such as stock price index and ratio of re-fixed conversion.

Based on the arbitrage-free pricing model (APT), a firm's value follows a diffusion process, and a convertible bond is considered a hybrid option. The effectiveness of the model depends on the appropriate specifications. Some important variables that affect the valuation of CBs may be neglected in the two-factor APT (Ho and Pfeffer,¹⁰ Takahashi *et al*,¹⁶ Giovanni *et al*³⁴) and three-factor APT (Davis and Lischka¹). This study sheds some light on this issue by incorporating more financial variables through PLSR.

Model fitness

The results of the above model are illustrated in Figure 1. The MSEF for this model is extremely small: an average of 0.63 per cent. The greatest MSEF is 2.22 per cent for the CBs issued by Guiguan, whereas the smallest MSEF is 0.08 per cent for those issued by Yunhua. Therefore, Figure 1 demonstrates that the PLSR pricing model is a good fit for valuing primary issue CBs. In addition, we use one-at-a-time cross-validation to prevent the potential problem of the data being over-fitted. Therefore, the PLSR pricing model is robust. In summary, the empirical results are supportive of the proposed PLSR model (16).

CONCLUSION

This study investigates the valuation of CBs by using PLSR and incorporating more financial variables than considered in previous literature. It prevents over-fitness of the model by applying one-at-a-time cross-validation to search for the number of PLSR components.

The empirical results reveal that our PLSR model accurately explains the cross-sectional differences in the pricing of primary issue CBs in China. The ranking of the variables according to their importance in valuing primary issue CBs in China is, in descending order, *GNP*, *CP*, *ISSE*, *SSV*, *AI*, *RRC*, *DRLS*, *ICP*, *RTP*, *NTAPS*, *RDL*, *PE*, *OS*, *RE*, *T*, *ConP*, *RTC*, *EPS*, *SP*, *PP*, *DRTS*, *GOR*, *YRCB*, *ADISSE*, *ACR*, *RCFS* and *RFR*. The six most important determinants are the growth of net profit (*GNP*), call price (*CP*), index of Shanghai Stock Exchange (*ISSE*), volatility of stock return (*SSV*), ratio of re-fixed conversion (*RRC*) and accrued interest (*AI*).

Overall, this article demonstrates that PLSR is an effective tool in valuing primary issue CBs in China.

The proposed new methodology based on the PLSR also has potential for valuing CBs in other emerging economies. Like those of China, the bond markets of many emerging economies are illiquid and subject to many restrictive regulations, which invalidates the no-arbitrage approach.

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