PRICING CONVERTIBLE BONDS

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Abstract. Convertible bonds are a developing segment of the corporate bond market. Nonetheless, the pricing of convertible bonds has not been addressed extensively due to the complicated optionality and the links between valuation and the underlying risk factors. Mixed results of mispricing have been reported. Our study clarifies this by a unique sample that consists of pure convertible bonds to control for complex optionality in these securities such as the call option. We examine the pricing of the real-time trade prices of the US convertible bonds. Least squares Monte Carlo simulation approach is used to solve a pricing model that includes stochastic volatility and credit risk. On average, an underpricing of 6.31% is observed from daily data covering from October 26, 2004 to June 30, 2011. Stochastic volatility is found to significantly affect the convertible bond pricing. Furthermore, illiquidity is an important explanatory variable that explain the mispricing of convertible bonds.

JEL Classification: G13, G15

Keywords: Convertible bonds, pricing, stochastic volatility, real-time trade prices

1. Introduction

Convertible bonds are an increasing segment of the corporate hybrid market with global outstanding market value of US$233 billion, as at 2011. A convertible bond is a typical example of path-dependent derivative structure that is equivalent to a bond with an embedded call option on the firm's stock whereby the fixed-income component acts as a cushion to the effect of a declining stock price. Convertible arbitrage hedge funds are the major market players that purchase more than 70% of convertible bonds in the primary market (Choi, Getmansky, and Tookes, 2009; Mitchell, Pedersen, and Pulvino, 2007). As at the first quarter of 2008, hedge funds are reported to purchase approximately 80% of the investments in the privately-placed convertible bonds (Brown, Grundy, Lewis, and Verwijmeren, 2012).

Pricing models are important tools in setting up investment strategies, including arbitrage, hedging and asset allocation as well as financing decision such as deciding the issuance price (Ho and Pfeffer, 1996). Convertible bonds are claimed to sell at discount from the theoretical values (Ammann, Kind, and Wilde, 2003; Loncarski, ter Horst, and Veld, 2009; Rotaru, 2006). The underpricing is found to remain present over a longer period of time after the issuance, though it decreases (Loncarski, et al., 2009). Therefore, market participants specifically the hedge funds actively search for mispricing in convertible bonds and exploit it usually by buying underpriced convertible bond and taking a short position in the equity (Ammann, Kind, and Seiz, 2010).

However, existing literature on the pricing of convertible bonds have reported mixed results from an underpricing of 12.9% (Carayannopoulos, 1996) to an overpricing of approximately 5% (Barone-Adesi, Bermudez, and Hatgioannides, 2003). In our paper, we clarify this by a unique sample, consisting of pure convertible bonds that control for complex optionality in these securities such as the call option. The call feature is valuable to the issuers but not the investors because it will redistribute wealth between convertible bondholders and stockholders (Brown, et al., 2012) at any time prior to the maturity, subject to call provisions such as call protection period, call notice period, and call trigger. Theoretically, issuers are assumed to call back the convertible bonds when it guarantees conversion but practically issuer do not act optimally[1] that leads to biases in the valuation process (Carayannopoulos and Kalimipalli, 2003). Also, the convertible arbitrage long-and-hedge strategy becomes complicated with the call feature, thus the hedge funds involvement in callable convertible bonds is significantly lower (Brown, et al., 2012)[2].

Our research fill this gap by highlighting the importance of identifying the option features present in a convertible bond since it affects the efficiency of a pricing model. Importantly, former empirical evidence on the convertible bond pricing is generated mainly from convertibles with complex option features[3] such as the call and put. In this paper, we examine the pricing of real-time trade prices of pure convertible bonds identified from TRACE-FINRA[4] which exclude callable and puttable features. Convertible bonds with sinking fund, mandatory, exchangeable, reset and reverse clauses are also excluded; so as to have a sample of pure convertible bonds. To our best knowledge, this is the first study to examine the pricing efficiency of the convertible bond real-time trade prices. The dissemination of real-time trade data is meant to increase the transparency level and to enable the regulators to monitor the market, pricing and execution quality.

We apply the least squared Monte Carlo simulation (LSM) approach (Longstaff and Schwartz, 2001) to solve for a pricing model that accounts for stochastic volatility and credit risk. The LSM offers significant gains in computational speed and efficiency in handling multiple state variables and path dependencies (Longstaff and Schwartz, 2001), thus is popular among the practitioners (Clément, Lamberton, and Protter, 2002). In the context of convertible bonds, the empirical evidence on stochastic volatility is still limited. It is impractical to assume constant volatility for two main reasons. Firstly, the payoff structures of convertible bonds are contingent on the performance of the underlying stocks. Secondly, convertible bonds tend to be issued by either unrated or non-investment grade firms (Huang and Ramírez, 2010), hence are likely to have greater stock volatility. We control for this

[1] Refer the recent paper by King and Mauer (2012) for further discussion on the determinants of call policy of convertible bonds.
[2] Choi, et. al. (2009) find that the absence of put and call options on a particular stock is associated with greater convertible bond arbitrage activity.
[3] For example, 103 callable convertible bonds in King (1986) 30 callable convertible bonds in Carayannopoulos (1996), 1 zero-coupon, callable and puttable convertible bond or LYON in McConnell and Schwartz (1986), 7 callable convertibles in Ho and Pfeffer (Ho and Pfeffer, 1996), 1 callable convertible in Barone-Adesi, et. al. (Barone-Adesi, et al., 2003), 21 callable and puttable convertibles in Ammann, et. al.(2003), 25 callable convertibles in Carayannopoulos and Kalimipalli (2003), 233 callable convertibles in Rotaru (2006) and 32 callable convertibles in Ammann, Kind and Wilde (2008).
[4] Financial Industry Regulatory Authority (FINRA) is the largest independent regulator for all securities firms doing business in the US. FINRA disseminates the information through Trade Reporting and Compliance Engine (TRACE) that was officially launched in July 2002.

using the constant elasticity of variance (CEV) model. The CEV is considered the simplest way to extend the Black Scholes model to include the observed inverse dependence of volatility and the stock price that also associated to the leverage effect (Cox, 1975, 1996). As for the credit risk, we follow the argument of Tsiveriotis and Fernandes (1998) to keep the pricing model simple. The fixed-income component of a convertible bond is discounted at a risk-adjusted interest rate whereas the stock component is discounted at a risk-free interest rate.

We document an average underpricing of 6.31% from daily observations, estimated from a sample of 96 pure convertible bonds, covering from October 26, 2004 to June 30, 2011. Consistently, we report underpricing throughout our observation period similar to Ammann, et. al. (2003), Carayannopoulos (1996), Guschin and Curien (2008), King (1986) and Rotaru (2006). Equity-like convertible bonds are less underpriced, 0.56%, by the market than the debt-like convertibles, 10.7%. Excluding the most intense stage of the crisis period that is during the collapse of Lehman Brothers (September 15, 2008 to March 15, 2009)[5], on average we also document an underpricing of 3.14%. Similarly, the underpricing observed from the equity-like convertibles is smaller than debt-like convertibles, to be specific 0.27% and 5.56%, respectively. Equity-like convertibles bonds are less risky and more attractive to investors because of the higher value of conversion option. On the other hand, debt-like convertibles are of higher credit risk because the option component is less likely to be exercised. If the issuing firm is approaching default, the straight bond value of the convertible could also fall substantially. Furthermore, the pricing of debt-like convertibles are more challenging than equity-like convertibles. Debt-like convertibles are sensitive to model inputs and specifications such as the credit spread, default probability and recovery rate.

During the crisis, on average the convertible bonds trade at a deep discount with a moneyess ratio of 0.543. Therefore, we observe a huge underpricing of 42.97%, in which the debt-like convertibles are underpriced by 48.271% whereas the equity-like convertibles are underpriced by 11.122%. During this period, the financial market fell into a period of extreme volatility with higher probability of default risk. The US Securities and Exchange Commission (SEC) imposed a temporary ban on short selling[6] that adds to the massive

[5] We define this period with reference to the 79th annual report of Bank for International Settlements (BIS).

[6] SEC bans the short selling for 799 financial companies for three weeks, i.e. from September 19, 2008 to October 2, 2008 as an effort to stabilise these firms and to restore equilibrium to the markets (SEC press release 2008-211, retrieved from http://www.sec.gov/news/press/2008/2008-211.htm).

selling pressure from the arbitrageurs. The ban restricted convertible arbitrage opportunities that cause the arbitrageurs to become liquidity demanders instead of natural liquidity providers to the market (Choi, Getmansky, Henderson, and Tookes, 2010). Furthermore, Hedge Fund Research Inc. reported that its convertible arbitrage index realised losses of 34% in 2008, which is mainly driven by the extreme event from September to November 2008 (Mitchell and Pulvino, 2012).

In addition, we find that stochastic volatility does have a significant effect on the efficiency of convertible bond pricing. The impact is relatively greater for convertible bonds with higher underlying stock return volatility. The degree of underpricing decreases monotonically from 7.34% for the third quintile to 12.26% for the fifth quintile of volatility. But there are no significant decreases in the underpricing for the first and second quintiles of volatility. These findings add to the importance of incorporating time-varying effect of volatility, particularly in the pricing of convertible bonds with substantial fluctuation in underlying stock returns. Note that the effect of stochastic interest rate is not included in the subsequent pricing mode. From the preliminary test, we observe insignificant mean difference in the mispricing between the constant interest rate model and the stochastic interest rate model. Therefore, interest rate is assumed to be constant, which is consistent with Ammann, et al. (2008) and Brennan and Schwartz (1980).

In fact, the convertible bond market is relatively illiquid in comparison to equity and straight bond markets. Therefore, some of the mispricing may be attributable to the illiquidity of convertible bonds (Ammann, et al., 2003; Loncarski, et al., 2009). In general, illiquidity may cause significant pricing discrepancies and difficulty to sell an investment or financial security quickly to meet unexpected cash flow needs. This issue has become increasingly important to regulators, rating agencies, security exchanges, and institutional investors (Chordia, Sarkar, and Subrahmanyam, 2005; Longstaff, 1995). To answer this question, we perform a regression analysis. We find that illiquidity has significant effect on the mispricing of convertible bonds. Illiquid convertibles tend to be underpriced by the market, as measured by the convertible bond issuance size and oversubscription of the convertibles at issuance. Also, riskier convertible bonds, those with longer time to maturity, higher rating code and greater uncertainty, are more likely to be underpriced. Consistent with Ammann, et al. (2003), Carayannopoulos (1996), King (1986), Zabolotnyuk, Jones, and Veld (2010), we find debt-like/out-of-money (OTM) convertible bonds tend to be underpriced whereas equity-like/in-the-money (ITM) convertible bonds are more likely to be overpriced. Importantly, trades that are executed during the extreme crisis period are significantly underpriced with a higher degree of mispricing that is consistent with the highly uncertain market condition. This result also supports our earlier finding of deep underpricing during the collapse of Lehman Brothers.

The paper is structured as follows. Section 2 reviews the related literature of the convertible bond pricing models. Section 3 describes the market, data set and the specific characteristics of the identified convertible bonds, in addition to the valuation framework including the estimations of parameters and mispricing. Section 3 also describes the testable predictions that analyse the mispricing of convertible bonds. Section 4 reports and discusses the results of pricing efficiency. Section 5 concludes.

2. Review of Literature

The theoretical framework for the pricing of contingent claim assets is established with the well-known publication of Black-Scholes (1973) and Merton's (1973, 1974) options pricing model that is further divided into the structural approach (firm-value approach) and the reduced-form approach (stock-value approach). Ingersoll (1977) views the value of a convertible bond as a contingent claim on the firm-value. In the initial work, the firm-value is assumed to consist only of convertible bonds and common stock (Brennan and Schwartz, 1977; Ingersoll, 1977) but is further extended to include senior debt (Brennan and Schwartz, 1980; Nyborg, 1996) and multiple classes of convertible bonds (Lewis, 1991).

The literature on the structural approach of convertible bond pricing is relatively limited because of its drawbacks. Firstly, the firm-value is neither directly tradable nor observable in the market, thus it is difficult to estimate the volatility of the underlying asset (McConnell and Schwartz, 1986; Nyborg, 1996). Secondly, the solution to the partial differential equation (PDE) of the contingent-claim becomes complicated when the model considers more complex capital structure (Takahashi, Kobayashi, and Nakagawa, 2001; Zabolotnyuk, et al., 2010). Consequently, the reduced-form approach is introduced by McConnell and Schwartz (1986) to price convertible bonds that view the security as a contingent claim of the underlying common stock.

Either a closed-form or a numerical solution can be applied to solve the value of convertible bonds, depending on the underlying assumptions governing each pricing model.

Closed-form solution is restricted to perfect market assumptions and continuous time factor so it is unlikely to generalise the solution (Ingersoll, 1977; Lewis, 1991) Market imperfections, path-dependent payoff structures and boundary conditions could not be integrated in the pricing model (Nyborg, 1996; Wilde and Kind, 2005). Therefore, numerical solutions such as the (1) finite difference method (Ayache, Forsyth, and Vetzal, 2003; Brennan and Schwartz, 1977, 1980; Takahashi, et al., 2001; Tsiveriotis and Fernandes, 1998; Yigitbasioglu, 2002), (2) finite element method, (3) tree model (Chambers and Lu, 2007; Hung and Wang, 2002; Yagi and Sawaki, 2010) and (4) simulation model (Lvov, Yigitbasioglu, and El Bachir, 2004; Wilde and Kind, 2005) are suggested.

A simulation method is usually recommended in solving the valuation of high-dimensional derivative securities because the convergence rate is independent of the number of state variables (Fu, Laprise, Madan, Su, and Wu, 2001; Ibáñez and Zapatero, 2004). Though, both finite difference and lattice-based methods are appropriate in solving early exercise features, these methods are still lacking in terms of the speed of computation. These methods are efficient to solve for pricing models with one or two sources of uncertainty (Broadie and Glasserman, 1997; Longstaff and Schwartz, 2001) because the convergence rate is exponential in the number of state variables. As a result, simulation is claimed to be increasingly attractive in handling multiple state variables and path dependencies (Broadie and Glasserman, 1997; Ibáñez and Zapatero, 2004; Longstaff and Schwartz, 2001).

Brennan and Schwartz (1980) allow for two stochastic state variables, particularly the firm-value and interest rate. But the differences generated by the one-factor model and the two-factor model are relatively small. Therefore, Brennan and Schwartz (1980) conclude that it is more computational efficient to assume a flat term structure. Amman, et. al. (2008) and Carayannopoulos (1996) support the claim but Barone-Adesi, et. al. (2003) and Ho and Pfeffer (1996) claim otherwise. Credit risk has been an important consideration in the pricing model. In the structural approach, the possibility of bankruptcy is determined endogenously. A company would fall into bankruptcy when the total firm-value (Brennan and Schwartz, 1977; Ingersoll, 1977; Lewis, 1991) or the net total firm value[7] (Brennan and Schwartz, 1980; Nyborg, 1996) falls below the total redemption value of the convertible bonds. On the contrary, the reduced-form approach precludes the possibility of bankruptcy, thus overestimating the value of convertible bonds. In the reduced-form approach, credit risk has

[7] Net total firm value equals to the total firm value minus total senior debt.

to be estimated exogenously. For example, McConnell and Schwartz (1986) add a constant credit spread to the risk-free rate to capture the credit risk.

Tsiveriotis and Fernandes (1998) refute the credit risk claim of McConnell and Schwartz (1986), claiming that a convertible bond can be decomposed into two components. The fixed income component of a convertible bond[8] is exposed to credit risk, whereas the stock component has zero default risk because the issuer can always deliver its own stock. For these reasons, the fixed income component is discounted at a risk-adjusted rate and the stock component is discounted at the risk-free rate. Then, the credit risk consideration is extended to include the probability of default, hazard rate, fractional loss as well as recovery upon bankruptcy (Ayache, et al., 2003; Takahashi, et al., 2001). In practice, there is limited market credit information when pricing convertible bonds, particularly in modelling the hazard rate and the fractional loss, which are not observable. As a result, practitioners are more likely to use the Tsiveriotis and Fernandes (1998)'s model in setting up investment and hedging strategies because this model only requires the estimation of credit spreads.

As for the equity risk, conventionally, the underlying asset of a convertible bond is assumed to follow a lognormal distribution with constant volatility, which is impractical when the payoff structure is dependent on the stock price. Moreover, the life of a convertible bond is typically longer, thus the variance of stock return may change substantially. Practitioners also recognise the drawback of assuming constant volatility. Therefore, they have to constantly adjust the variance rate estimated in the model (Macbeth and Merville, 1980). In brief, the subject of stochastic volatility in convertible bond pricing has not been studied extensively. For example, the implied volatility (Barone-Adesi, et al., 2003), local volatility (Yigitbasioglu, 2002), multiple levels of historical volatility (Lvov, et al., 2004), the CEV model (Das and Sundaram, 2007), and the GARCH model (Ammann, et al., 2008).

Empirically, the results are found to be mixed. An average underpricing between 1.94% (Landskroner and Raviv, 2008) and 12.9% (Carayannopoulos, 1996) to an average overpricing between 0.36% (Ammann, et al., 2008) and approximately 5% (Barone-Adesi, et al., 2003) have been reported. Out-of-money (OTM) convertible bonds tend to be underpriced whereas in-the-money (ITM) convertible bonds are more likely to be overpriced (Ammann, et al., 2003; Carayannopoulos, 1996; King, 1986; Zabolotnyuk, et al., 2010). But

[8] The fixed-income component includes of periodic coupon payments, final redemption payment and any call or put provisions which are dependent on the issuer's timely access to the required cash amount.

interestingly, Ammann, et. al. (2008) and Landskroner and Raviv (2008) find evidence of underpricing in the ITM convertible bonds. The relation between the mispricing and term to maturity is also found to be inconsistent. King (1986) claims that convertible bonds with shorter term to maturity are more likely to be underpriced by the market but Ammann, et. al. (2003) and Landskroner and Raviv (2008) claim otherwise. The value of a convertible bond is also sensitive to the underlying assumption of dividend yield/payment (Ammann, et al., 2008; McConnell and Schwartz, 1986), coupon payment (Ammann, et al., 2008; Lau and Kwok, 2004; Rotaru, 2006), and the conversion ratio (Lau and Kwok, 2004; Rotaru, 2006).

In addition to the model-related risk factors (interest rate risk, equity risk, and credit risk) and the issue-specific factors (moneyness, maturity, coupon, conversion ratio, and dividend), boundary conditions, in particular the call provisions, do affect the pricing of convertible bonds. Theoretically, issuers are assumed to act optimally by calling the convertible bonds when it guarantees conversion. But in practice the convertible bonds are not called immediately even though the conversion price equals the call price because of the prespecified call restrictions that leads to estimation biases. Existing empirical studies have been focusing on examining the pricing of convertible bonds with complex option features, such as the call and put. For example, 21 callable and puttable convertibles in Ammann, et. al.(2003), 25 callable convertibles in Carayannopoulos and Kalimipalli (2003), 233 callable convertibles in Rotaru (2006) and 32 callable convertibles in Ammann, Kind and Wilde (2008).

In brief, reported inconsistencies are generally attributable to the limitations and differences of the model specifications. There are also concerns with the length of the study, or the statistical limitations due to few observations and relatively small sample size. These limitations may generate estimation biases and limit the ability to generalise the results and models used. In a nutshell, there remains scope for further examination of the question of convertible bond valuation.

3. Data and Methodology

3.1 Market

This study examines the US convertible bond market for two main reasons. Firstly, the US market has the largest convertible bond market, evidenced by the highest market share followed by Europe, Japan and Asia-Pacific (refer Table 1). Throughout the observed period (year 2000 to 2011), US holds more than half of the convertible bond market share, with the highest market share of 73.25% in 2007. In 2011, the market share has slightly decreased to 63.64%. Secondly, the real-time trade data of convertible bonds are disseminated by the Financial Industry Regulatory Authority (FINRA), the largest non-governmental regulator for all securities firms doing business with the US public. In July 2002, FINRA officially launched Trade Reporting and Compliance Engine (TRACE) to disseminate over-the-counter[9] (OTC) corporate bond real-time trade data and trade volume information to the public. For the investors, the real-time trade data are meant to better gauge the quality of the execution they are receiving from their broker-dealers. The dissemination of the information not only increases the levels of transparency but is also intended to enable the regulators to monitor the market, pricing and execution quality.

(INSERT TABLE 1 ABOUT HERE)

(INSERT TABLE 2 ABOUT HERE)

TRACE was implemented in three phases (refer Table 2). Phase I was implemented on July 1, 2002 to disseminate the trade information for (1) investment grade securities with an initial issue size of US$1 billion or greater and (2) 50 non-investment grade (high yield) securities disseminated under FIPS2[10] that are transferred to TRACE. Thus, by the end of 2002, FINRA disseminated the transaction information for approximately 520 securities. Subsequently, phase II was implemented on April 14, 2003 to further disseminate (1) all investment grade securities of at least US$100 million par value (original issue size) or greater rated A3/A- or higher, (2) a group of 120 investment grade securities rated Baa/BBB, and (3) 50 non-investment grade bonds. In total, the number of disseminated bonds increased to approximately 4,650 bonds. Eventually, it was fully phased in by January 2006, offering real-time, public dissemination of transaction and price data for all publicly traded corporate bond, including convertible bonds. Nonetheless, any transactions pursuant to Rule 144A[11] are not disseminated.

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[9]National Association of Securities Dealers, NASD (2004) estimates that 99% of the US corporate bond trading is transacted over-the-counter.

[10]Before the launching of TRACE, the dissemination of real-time trade data for high yield bonds was collected by NASD under the Fixed Income Pricing System (FIPS).

[11] Rule 144A, adopted by the Security and Exchange Commission of US (SEC) came into effect on April 30, 1990 to provide a safe harbour exemption from the registration requirements of the Securities Act (1933) for resale of restricted securities among 'qualified institutional buyers'(QIBs) (http://www.sec.gov/)..

3.2 Sample Selection

This study examines the pricing of real-time trade data of the US convertible bonds that are disseminated by TRACE of FINRA (TRACE-FINRA). Initially, we identified 511 convertible bonds that are offered before June 30, 2011. June 30, 2011 is selected as the end date for the study because at that time, the US government temporarily stopped issuing 5- and 7- year bonds (refer Figure 1). The mean maturity of our sample is 5.927 years (refer Table 3), which is between the US government 5- and 7- year bonds. When the issuance of the US government bonds recommenced, the bonds' credit rating had reduced. Therefore, including convertible bonds after June 30, 2011 could cause bias.

(INSERT FIGURE 1 ABOUT HERE)

301 convertible bonds are found to be attached with callable feature. These convertible bonds have to be excluded from our sample selection to control for the impact of non-optimal call on pricing efficiency[12], thus reducing the sample to 211 convertible bonds. The sample also excludes convertible bonds that are attached with puttable, sinking fund or mandatory[13] features. In addition, our selection criteria require the convertible bonds to be public bonds issued by the US local firms, to have prospectus in EDGAR[14] and with active underlying common stock of the issuer. Therefore, exchangeable convertible bonds[15] and convertible bonds with delisted underlying stock or have filed for Chapter 11 are also excluded to ensure our sample consists only of pure convertible bonds. These criteria further reduce the sample size to 177 convertible bonds.

Furthermore, the sample requires the convertible bonds to have credit ratings to account for credit risk. Only 33 convertible bonds are found to be rated. In view of that, we

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[12] The valuation process also becomes very complicated if all the features of convertible bonds are taken into consideration (Lau and Kwok, 2004). Nonetheless, the pricing model can be extended to incorporate these features into the valuation of convertible bonds in the future study.

[13] A mandatory convertible bond is a bond that has to be converted mandatorily into equity at maturity.

[14] EDGAR, the Electronic Data Gathering, Analysis, and Retrieval system, performs automated collection, validation, indexing, acceptance, and forwarding of submissions by companies and others who are required by law to file forms with the U.S. Securities and Exchange Commission (SEC). Its primary purpose is to increase the efficiency and fairness of the securities market for the benefit of investors, corporations, and the economy by accelerating the receipt, acceptance, dissemination, and analysis of time-sensitive corporate information filed with the agency.

[15] An exchangeable bond has approximately the same features as the conventional convertible bond but the payoff of an exchangeable bond depends on the underlying stock of another company. In brief, the bondholder is granted an option to exchange the bond for shares of another company.

take the credit rating of the issuer when the convertible bond is not rated, which is consistent with existing studies (Ammann, et al., 2008; Rotaru, 2006). Rating information for the convertible bonds is also disseminated by TRACE-FINRA whereas rating information for the issuer is obtained from Moody's. After imposing these selection criteria, we have a unique sample consisting of 96 issues of pure convertible bonds. A pure convertible bond is defined as a bond embedded with only the conversion provision.

The observation period covers from the first trade date disseminated by TRACE-FINRA for the selected sample, i.e., from October 26, 2004 through June 30, 2011. This study examines the pricing efficiency on daily observation, thus we have to calculate the intraday average price from the disseminated real-time data. Trades that are cancelled are excluded to avoid repetition in the data. From the beginning of November 2008, TRACE-FINRA identifies the reporting party for each real-time data. TRACE-FINRA disseminates three reporting party indicators – B, S and D for the real-time data. B and S represent the customer trade whereas D represents the inter-dealer trade which is always a sell. B is where reporting party (dealer) bought from a customer and S is where reporting party (dealer) sold to a customer.

We have four types of real-time intraday average price for comparison, with the total number of daily observations in the parentheses for the whole sample, i.e. the *MPAll* (41,774), *MPBuyer* (26,756), *MPSeller* (24,720), and *MPDealer* (19,634). *MPAll* represents the daily intraday average trade prices from October 26, 2004 through June 30, 2011 without distinguishing the reporting parties. But from November 2008 onwards, we have *MPBuyer*, and *MPSeller* to represent the retail trade prices and *MPDealer* that represent the wholesale trade prices.The convertible bond specific data such as the maturity at issuance, coupon rate, conversion price, conversion premium at offering, amount of issuance and credit rating are collected from TRACE-FINRA and Thomson Reuters EIKON. Any inconsistent data found between TRACE-FINRA and EIKON is verified against the issuers' prospectus or official filings to the US Securities and Exchange Commission (SEC) that are publicly accessible via EDGAR. On the other hand, the corresponding synchronous stock prices are collected from Datastream.

3.3 Sample Descriptions

Table 3 reports the summary statistics for the overall sample of 96 convertible bonds. The mean maturity at issuance is 5.927 years with the longest maturity of 20 years. Average coupon rate is at 3.75%. The range for the coupon rate is wide – from as low as 0.375% to a high rate of 15%. On average, the convertible bond can be converted at a conversion price of US$32.105 per share and a conversion premium at offering of 31.059%. Conversion premium measures the excess of the conversion price over the stock price at issuance as a percentage of the stock price $\left(\frac{Conversion\ Price-Stock\ Price}{Stock\ Price}\right)$. A relatively low conversion premium indicates a more equity-like convertible bond and vice-versa (Brown, et al., 2012). The mean total issuance is approximately US$425 million with an average overallotment of US$16 million. On average, the Moody's rating is between Ba2 and Ba3. According to the rating definition, securities rated Ba are judged to have speculative elements and are subject to substantial credit risk.

(INSERT TABLE 3 ABOUT HERE)

This is of no surprise because access to the convertible bond market is more flexible for issuers who have difficulty entering the traditional bond market due to restrictive rating requirements. A good example is the growth firm. A growth firm is reluctant to issue a significant amount of straight bond because the higher fixed income obligation tends to increase the expected cost of financial distress of a firm. Besides, a growth firm does not favour issuing common stock if the current stock price does not reflect the firm's growth opportunities. So, the issuance of equity is expected to cause excessive dilution on existing stockholders' claims (Chang, Chen, and Liu, 2004; Stein, 1992).

To provide some in-depth description, we subsample the convertible bonds by the observed conversion provision and the type of placement when the securities are first issued. Summary statistics of the subsamples are discussed in turn. From the sample, 34 convertible bonds (subsample 1) are identified to be issued without any conversion restriction, in which the convertible bonds can be converted at any time prior to the maturity. Conversely, 62 convertible bonds (subsample 2) are attached with conversion restrictions. The restrictions are identified from the issuer's prospectus, stating that the conversion option can only be exercised within the prespecified conversion timeframe, the conversion is only allowed if the prevailing stock price exceeds the conversion price for at least a certain percentage (for example, more than 130% of the conversion price per share) and for a certain period of time (for example, at least 20 trading days in a period of 30 consecutive trading days). These provisions restrict the bondholders from immediate conversion though the prevailing stock price exceeds the conversion price.

(INSERT TABLE 4 ABOUT HERE)

Panels A and B of Table 4 describes the summary statistics for subsamples 1 and 2, respectively. Then, Panel C reports the test of mean differences for the observed characteristics. Statistical evidence claims that there are significant differences at 1% level, in the coupon rate and conversion price between the two subsamples. Subsample 1 is issued at a higher coupon rate, with a mean of 4.86% and a wider range from 1.25% and 15%, but subsample 2 is issued at a lower coupon rate, with a mean of 3.141% and a range from 0.375% to 6.5%. This finding possibly explains the reason for issuing convertible bonds with conditional conversion. Lower coupon rates expose the issuers (in subsample 2) to relatively lower fixed-income obligation, thus the conversion restrictions enable the issuers to take advantage of the lower interest rate environment. The mean conversion price for subsample 2 is significantly lower than subsample 1 at 1% level by US$13.113 per share but no statistical difference is found for the conversion premium at offering. As for the other observed characteristics the mean differences are found to be statistically insignificant.

Next, we discuss the characteristics of the sample, grouped by the type of placement when the convertible bonds are first issued. The type of placement can be identified from Datastream and is confirmed against the issuer's prospectus in EDGAR. Equally, there are 48 convertible bonds in each subsample. Subsample A includes of convertible bonds that are first issued via private placement pursuant to Rule 144A that are subsequently registered with the US Securities and Exchange Commission (SEC) to be public issues[16] whereas subsample B consists of convertible bonds that are issued via public placement. Existing studies (Fenn, 2000; Huang and Ramírez, 2010; Livingston and Zhou, 2002) have reported tremendous increase in the size of 144A debt market, ever since the rule came into effect on April 30, 1990. Specifically, Huang and Ramírez (2010) document that the total offering of convertible bonds in the 144A market increased from US$1.4 billion in 1991 to US$22.4 billion in 2004.

[16] Huang and Ramírez (2010) found that approximately 88% of the convertible debts and 91% of the straight debts issued via Rule 144A are subsequently registered with the SEC. For over 80% of these issues, the registration is found to be filed within three months of issuance but Fenn (2000) found a longer period, ranging from three to seven months for high-yield bonds. Huang and Ramírez (2010) further claim the difference is because they use the date of registration with SEC instead of the time of completion of the exchange offer used to complete the registration.

On contrary, the total offering via the public placement decreased from US$9.7 billion in 1991 to US$4.8 billion in 2004.

Below-investment grade issuers are claimed to be more likely to issue bonds via the 144A market with options to register the securities with the SEC (Fenn, 2000). The 144A market provides a leeway for the low credit rating firms to issue securities quickly in order to meet their urgent financing needs because the disclosure requirements are less stringent (Fenn, 2000; Huang and Ramírez, 2010; Livingston and Zhou, 2002). Therefore, the speed of issuance hypothesis significantly explains the growth of the 144A market (Fenn, 2000; Huang and Ramírez, 2010). In addition, Huang and Ramírez (2010) find that QIBs[17] have advantages over public lenders in dealing with firms with high credit risk and information asymmetry, supporting the lender specialisation hypothesis.

(INSERT TABLE 5 ABOUT HERE)

Panels A and B of Table 5 describe the summary statistics for subsample A and subsample B, respectively whereas Panel C reports the test of mean differences of the observed characteristics. Credit rating is found to be insignificant, possibly because of the nature of the available data used in our study, which may affect the convertible bonds in subsample A. The ratings are the bonds' rating when they have become public issues. Furthermore, issuers in the 144A market have the options to get credit ratings for their securities between the offering and the subsequent registration dates for two main reasons. Firstly, the QIBs are less dependent on credit ratings than the public investors and secondly the application for credit ratings would delay the issuance process of 144A securities (Huang and Ramírez, 2010).

Statistically, the convertible bonds in subsample A are issued with longer maturity at issuance with a mean difference of 0.729 years, significant at 10% level, similar to Huang and Ramírez (2010)[18]. Conversely, the mean coupon rate for subsample A is significantly lower than subsample B, at 1% level, with a mean difference of 1.166%. Rule 144A is meant

[17]QIBs are defined as institutions that own or have investment discretion over $100 million or more in assets. In addition to the $100 million requirement, banks and savings and loan associations must also have at least $25 million of net worth to qualify as QIBs. For registered broker-dealers, $10 million investment in securities would meet the requirement (Livingston and Zhou, 2002).Hedge funds are found to be one of the major group of QIBs, in which 73.4% of the financing of newly-issued convertibles is provided by hedge funds (Brown, et al., 2012).

[18] Huang and Ramírez (2010) reports a higher mean maturity at issuance of 12.74 years for 554 convertible bonds that were first issued via Rule 144A and 9.68 years for 188 convertible bonds that were issued via non-shelf public placement.

to encourage speedy issuance because debt issuers are not required to file pre-issued registration with the SEC. Therefore, timely issuance enables the firms to take advantage of favourable market conditions, such as lower interest rates (Huang and Ramírez, 2010). The mean conversion price for subsample A is significantly higher than subsample B at 5% level by US$10.891 per share. Nonetheless, there is no statistical difference in mean, found for the conversion premium at offering.

In addition, the total issuance for subsample A is significantly higher with a mean difference of US$177.263 million, at 5% level but significantly lower amount of overallotment at 1% level. The mean difference of the subsamples for overallotment is US$30.475 million. In general, debt issued via Rule 144A have smaller base of potential buyers (only the QIBs), less stringent disclosure requirements and weaker legal protection. Because of these, the 144A debt are claimed to be less liquid and have considerable risk, thus producing yield premium over public issues (Fenn, 2000; Livingston and Zhou, 2002). As a result, issuers in the 144A market are more likely to issue larger bond size because investors are more likely to ask for lower rate of return for larger issues that are usually more liquid than small issues (Fenn, 2000; Livingston and Zhou, 2002)[19]. Furthermore, there is evidence of negative relation between gross underwriter spread and size of issuance, explained by the economies of scale (Livingston and Zhou, 2002). For subsequent test, we only provide subsamples by the terms of conversion because rationally, once these convertible bonds are registered to become public issues, type of placement is assumed not to have significant on the pricing efficiency.

(INSERT TABLE 6 ABOUT HERE)

(INSERT TABLE 7 ABOUT HERE)

Next, Table 6 reports the characteristics of the real-time trade prices disseminated by TRACE-FINRA and the moneyness of the convertible bonds. The daily trade price is calculated by taking the average of the real-time intraday price, which is reported at US$100 when trading at par, though the actual face value of each convertible bond is US$1,000. Averaging from October 26, 2004 through June 30, 2011, the daily real-time trade price (*MPAll*) is US$110.972. Retail trades denoted by *MPBuyer* and *MPSeller* are recorded at

[19] Huang and Ramírez (2010) also reports a higher mean gross proceeds US$259 million for 554 convertible bonds that were first issued via Rule 144A and US$182 million for 188 convertible bonds that were issued via non-shelf public placement.

US$112.035 and US$111.824, respectively, whereas the wholesale trade denoted by *MPDealer* is recorded at US$110.031. The moneyness[20] is calculated by taking the ratio of the prevailing underlying stock price over the prespecified conversion price. The mean moneyness is 0.84, and with reference to Mitchell and Pulvino (2012)[21] we define convertible bonds with moneyness less than 0.84 as debt-like (credit-sensitive), whereas convertible bonds with moneyness greater than 0.84 as equity-like (equity-sensitive). Table 7 reports statistically insignificant mean difference between the retail trade prices. But the retail trade prices are found to be significantly higher than the wholesale trade prices, at 1% level probably due to lower trade frequency.

(INSERT TABLE 8 ABOUT HERE)

We also report the market data by terms of conversion. From Panel C of Table 8, convertible bonds that are issued without conditional conversion are priced significantly higher than the convertible bonds that are issued with conditional conversion, at 1% level and the results are consistent for all types of trade prices. On average, subsample 1 consists of equity-like convertible bonds, whereby subsample 2 consists of debt-like convertible bonds with moneyness ratios of 0.974 and 0.797, respectively. Convertible bonds in subsample 1 offer better flexibility to the bondholders than subsample 2 because the bondholders are not restricted to convert the convertible bonds at any time prior to maturity whenever the condition guarantees conversion. Therefore, rationally bondholders are more likely to pay higher value for non-conditional convertibles[22] as compared to those in subsample 2 that limit the bondholders from taking immediate advantage of the favourable market condition.

We examine the characteristics of real-time trade prices, and moneyness by subperiods for two reasons. First of all, the observed market data are time varying and secondly, our observation period includes the extreme period of financial instability. The subperiods are defined with reference to the 79th annual report of Bank for International

[20] To be consistent with literature on convertible bond pricing, we choose to report the moneyness instead of conversion premium.

[21] Mitchell and Pulvino (2012) sort their sample by the median of moneyness. Similarly, we sort our sample by the median of moneyness (0.77) and we find the results for the subsequent tests are indifferent whether the sample is sorted by the mean or median of moneyness.

[22] The justification is related to the value between non-callable and callable convertible bonds. The value of a plain vanilla convertible bond is higher than the value of a callable convertible bond but the difference decreases as the default risk increases (Das and Sundaram, 2007). An investor is more likely to pay higher value for a callable convertible bond with better call protection such as more stringent hard call and/or soft call provisions that makes it more difficult for the issuer to initiate a call (Gong and Meng, 2007; Lau and Kwok, 2004).

Settlements (BIS)[23], but with slight changes to fit our sample periods. We define six subperiods for our sample. *Subperiod 1* starts prior to the subprime-mortgage-related turmoil (prior to mid-August 2007); *Subperiod 2* covers the subprime-mortgage-related turmoil (from mid-August 2007 to mid-September 2008); *Subperiod 3* includes the most intense stage of the crisis (from the collapse of Lehman Brothers, i.e. September 15, 2008 to mid-March 2009); *Subperiods 4, 5* and *6* are the recovery stages. The recovery stage is further divided into three subperiods with the intention of examining the gradual recovery, i.e., from mid-March 2009 to December 2009, 2010, and the first six month of 2011.

(INSERT TABLE 9 ABOUT HERE)

(INSERT TABLE 10 ABOUT HERE)

Panel A of Table 9 summarises the statistics of the sample, whereas Panels B and C are for the subsamples by conversion terms. Table 9 only reports the real-time trade price measured by *MPAll* because it provides an inclusive observation for the identified subperiods, including the pre and post crisis periods. *MPAll* and moneyness shows a statistically significant decreasing trend from *Subperiod 1* to *Subperiod 3* and a gradual increasing trend from *Subperiod 4* to *Subperiod 6*, at 1% level (refer Table 10). Statistically, greater significant mean differences are found when every subperiod is compared against the most intense period (*Subperiod 3*). During the extreme crisis period, the US Federal Reserve responded by lowering interest rates, whereas the US Securities and Exchange Commission (SEC) imposed temporary ban on short selling within a week of Lehman's collapse. The ban restricted convertible arbitrage opportunities that causes the arbitrageurs to become liquidity demanders instead of natural liquidity providers to the market (Choi, et al., 2010). Furthermore, Hedge Fund Research Inc. reports that its convertible arbitrage index realised losses of 34% in 2008, which is mainly driven by the extreme event from September to November (Mitchell and Pulvino, 2012)

Prior to the subprime-mortgage-related turmoil (*Subperiod 1*), on average the convertible bonds are equity-like, traded at US$112.119 that decreases to US$108.483 in *Subperiod 2*. The moneyness decrease to 0.543 during the collapse of Lehman Brothers

[23] BIS defines five stages of the global financial crisis, i.e. Stage 1 – Pre-march 2008: Prelude to the crisis, Stage 2 – Mid-March to mid-September 2008: Towards the Lehman bankruptcy, Stage 3 – 15 September 2008 to late October 2008: Global loss of confidence, Stage 4 – Late October 2008 to mid-March 2009: Global downturn and Stage 5 – Since mid-March 2009: Downturn deepens but loses speed ("79th Annual Report 1 April 2008 - 31 March 2009," 2009).

(*Subperiod 3*), traded at US$77.56. The relatively low moneyness confirms the debt-like feature of the convertible bonds. Thereafter, the *MPAll* increases to US$101.393 in the last three quarters of 2009, then to US$117.255 in 2010, and to US$130.162 in the first half of 2011. On average, the moneyness improves to 0.717, 0.863 and 0.997, respectively. The increase signifies a gradual change from debt-like to equity-like convertible bonds. Similar trends are observed in the subsamples.

Next, we examine the impact on the trade prices following the changes in the moneyness. Moneyness is measured as the ratio of stock price over conversion price. Since the conversion price stays relatively constant throughout the life of a convertible bond[24], the major driver of a change in the moneyness is the performance of the stock price that affects the value of a convertible bond. *MPAll* and moneyness are found to be positively related though moneyness is indifferent between *Subperiods 1* and *2* (refer Table 11). Moving from *Subperiods 2* to *3*, *MPAll* decreases by US$0.075[25] when moneyness decreases by one basis point. Once the market starts to pick up in *Subperiod 4*, consistently *MPAll* increases by US$0.074 for every one basis point increase in the moneyness. The momentum increases to US$0.077, from *Subperiods 4* to *5* and to US$0.083, from *Subperiods 5* to *6* for every one basis point increase in the moneyness.

3.4 Valuation Framework

This study employs Longstaff and Schwartz's (2001) stock-based least squares Monte Carlo simulation model (LSM) for the pricing of convertible bonds. LSM is selected because convertible bonds are subject to multiple sources of risk and path-dependent features. LSM provides a path-dependent approximation using information contained in a sample of simulated paths by means of simple regression. Following Longstaff and Schwartz (2001), this study assumes a finite time horizon $[0, T]$, where $t = 0$ indicates today and $t = T$ indicates the day of maturity for a convertible bond.

The probability space is defined as (Ω, F, P) and an equivalent martingale measure Q subject to assumption of no arbitrage opportunities. Ω is the set of all possible outcomes ω of the state variables for pricing convertible bonds between time 0 to T, F is the sigma field of

[24] But the conversion price (conversion ratio) is typically adjusted for stock split and stock dividends.
[25] The change in *MPAll* is calculated on the actual face value, US$1,000 of each convertible bond to provide a clear relation between the trade price and moneyness.

distinguishable events at time *T,* and *P* is the probability measure corresponding to *F*. Let $C(\omega, s;\ t, T), \omega \in \Omega, s \in (t, T)$ denote the payoff of a convertible bond, conditional on the convertible bond is being exercised after *t* and both the issuer and investor follow optimal exercise strategies for all stopping time *s*.

The point in time whereby the embedded option is executed, leading to premature exercise is termed as optimal stopping time τ^*. The convertible bond is terminated immediately and the bondholder is not entitled for any coupon payments and redemption value after τ^*. The total payoff for a convertible bond is different from an option. At τ^* the bondholder will also get the periodic coupon payments accumulated from the existence of the bond until τ* together with the payoff illustrated in Table 11. Some convertible bonds also contain accrued interest payments. As a result, the total payoff $C_{tot}(\omega, \tau^*;\ t_k, T)$ from a convertible bond at τ^*equals to

$$C_{tot}(\omega, \tau^*;\ t_k, T) = C(\omega, \tau^*, t_k, T) + c(\tau^*) \qquad (1)$$

where $C_{tot}(\omega, \tau^*; t_k, T)$ is the optimal payoff from the convertible bond subject to boundary conditions, at τ^* and $c(\tau^*)$ is the present value at $\tau^*$of all coupon and accrued interest payments arising during the period $[t_0, t^*]$. Once the optimal exercise decisions and corresponding payoffs are determined for each path, the value V_0 of convertible at t_0 is calculated by averaging the discounted payoff over all the simulated paths.

$$V_0 = \frac{1}{n}\sum_{i=1}^{n} exp^{\left(-\int_{t_0}^{t_i^*} r(\omega_i, s)ds\right)} C_{tot}(\omega_i, \tau_i^*; t_0, T) \qquad (2)$$

where τ_i^* are the optimal stopping times for each path *i*, $C_{tot}(.)$ are the corresponding total payoffs, and $r(\omega_i, s)$ is the instantaneous risk-free interest rate during the period $[t_0, t^*]$ in path *i*.

(INSERT TABLE 11 ABOUT HERE)

The valuation process considers discrete time, with daily frequency and time *t* belonging to a set of finite number of stopping times $t_0 \leq t_1 \leq t_2 \ldots \leq t_K$ with $t_0 = 0$ and $t_K = T$. Table 11 summarises the payoff $C(\omega, s;\ t, T)$ of a convertible bond when the state path ω is realised, at time *s*. At maturity, the payoff $C(\omega, s = T;\ t, T)$ is equal to the maximum of conversion value $n_T S_T$ or redemption value F where n_T is the conversion ratio, S_T is the underlying stock price at maturity, and F is the face value of the convertible bond.

At each exercise time point t_k, prior to maturity, subject to certain prespecified time restrictions (if there is any), the convertible bondholders have the right to either convert the convertible bonds into shares of common stock or continue holding the bond and revisit the exercise decision at the next exercise time. The convertible bondholders have to compare the payoff for immediate exercise, in this case the conversion value with the expected payoff for continuation or the continuation value $F(\omega; t_k)$. The conversion value is known at t_k but not the continuation value. Continuation value is the value of holding the convertible bond for another period instead of exercising immediately. It is not observable, thus has to be estimated.

Assuming no arbitrage opportunity, the continuation value $F(\omega; t_k)$ can be expressed as the expectation of the remaining discounted cash flows $C(\omega, s; t_k, T)$with respect to the risk-neutral pricing measure *Q*. Specifically, at time t_k the continuation value is given as

$$F(\omega; t_k) = E_Q\left[\sum_{j=k+1}^{K} exp^{\left(-\int_{t_k}^{t_j} r(\omega,s)ds\right)} C\left(\omega, t_j; t_k, T\right)\middle| \digamma_{t_k}\right] \qquad (3)$$

where $r(\omega, s)$ is the riskless discount rate, and the expectation is taken conditional on the information set $\digamma_{t_k}$at time t_k (Longstaff and Schwartz, 2001).

A convertible bondholder opts for conversion before maturity when the conversion value $n_{t_k} S_{t_k}$ is greater than the continuation value $F(\omega; t_k)$ in order to maximise the payoff of a convertible bond. Otherwise, if the continuation value $F(\omega; t_k)$ is greater than the conversion value $n_{t_k} S_{t_k}$ at time t_k , a rational investor would continue holding the convertible bond and revisit the exercise decision at the next exercise time t_{k+1} .

3.5 Parameter Estimation

3.5.1 Stock Dynamic

The payoff structure of a convertible bond is dependent on the performance of the underlying stock price. Conventionally, under the perfect market assumptions, the Black-Scholes model assumes that the underlying stock price S_t follows the geometric Brownian motion

$$dS_t = \mu S_t dt + \sigma S_t dB_t \qquad (t > 0) \tag{4}$$

where S_t is the stock price at time t, dS_t is the change in S_t over the period $[t, t + dt]$, μ is the drift rate, σ is the volatility of the instantaneous return on S_t, and B_t is the Brownian motion with an initial condition $B_0 = 0$. Both μ and σ are constant and are independent of time and the current stock price.

The volatility is measured by standard deviation, estimated on historical basis, using the time series data of the underlying stock.

$$\hat{\sigma} = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}\left(R_t - \overline{R}\right)^2} \tag{5}$$

Historical standard deviation is model free (Poon and Granger, 2005), thus easy to calculate and requires no prior assumption about the stock market efficiency (Rotaru, 2006), but the major concern is the choice of how much past data to include and the frequency of the data (Green and Figlewski, 1999; Poon and Granger, 2005). Since our study examines the pricing on daily basis, it is consistent to employ daily data in each of the parameters. As for the daily data, only trading days will be considered because volatility is found to be larger when the exchange is open (Fama, 1965) and volatility is claimed to be affected by trading (French and Roll, 1986). Therefore, the volatility for each convertible bond is calculated using daily individual stock returns of 252 trading days prior to the first real-time trade data reported to TRACE-FINRA and is assumed to be constant.

A number of stylised facts on volatility have emerged over the years such as thick tails, volatility clustering, volatility smiles and skews, long memory and persistence, leverage effects, and volatility co-movements. Thus, it is unrealistic to assume constant volatility, specifically in our study since our observation period includes the global financial crisis (2007 to 2009) that causes great fluctuations in the financial markets. Therefore, the constant elasticity of variance (CEV) model is applied to control for the effect of volatile equity market. The CEV model is often considered to be the simplest way to extend the Black Scholes model to include the observed inverse dependence of volatility and the stock price a foundation for the observed implied volatility skew that is also associated to the leverage effect (Christie, 1982; Cox, 1975, 1996).

The CEV model assumes that stock price, S_t takes the following form.

$$dS_t = \mu S_t dt + \delta S_t^{\frac{\beta}{2}} dB_t \qquad (t > 0,\ \beta < 2) \tag{6}$$

where S_t is the stock price at time t, dS_t is the change in S_t over the period $[t, t + dt]$, μ is the expected growth rate of S_t, σ is the volatility of the instantaneous return on S_t, and B_t is the Brownian motion with an initial condition $B_0 = 0$. Both μ and σ are constant and are independent of time and the current stock price. Conventionally, the CEV model retains the constant volatility assumption of the Black Scholes model, but it introduces an additional parameter to denote the elasticity, β of the instantaneous volatility of the stock return. The level of elasticity will determine the dynamics of the underlying stock price. In Cox's (1975, 1996) study, the elasticity is bounded to $0 \leq \beta < 2$. When $\beta = 2$, the CEV model is identical to the Black-Scholes model, thus the variance rate is independent of the stock price. For this reason, the Black-Scholes model is claimed to be affiliated to the CEV model. When the elasticity decreases, the process becomes less volatile, and the reverse when the elasticity increases. This adjustment causes the absolute level of variance to decline (rise) as the stock price rises (declines), thus integrating an inverse relationship between stock prices and volatility; a phenomenon referred as the leverage effect[26] (Black, 1975).

The value of β can be estimated using the historical data of the underlying stock given the regression specifications (Beckers, 1980; Emanuel and MacBeth, 1982; Macbeth and Merville, 1980). Though the regression specification is found to be incomplete (Beckers, 1980) and gives credible but imprecise estimates of the β (Macbeth and Merville, 1980), estimated values that are significantly different from $\beta = 2$ would render some empirical support for the CEV model. The β for each convertible bond's issuer is estimated from the daily stock returns of 252 trading days prior to the first real-time trade price reported to TRACE-FINRA, which is similar to the estimation of volatility discussed earlier. The β is estimated via the following equation

$$ln\left|ln\frac{S_{t+1}}{S_t}\right| = a + blnS_t + u_t \tag{7}$$

[26] A rise (fall) in the stock price reduces (increases) the debt-to-equity ratio of the firm and is reflected by a fall (rise) in the variance of stock returns.

where $a = ln\delta$ and $b = \frac{\beta-2}{2}$. When β varies from 2 to 0, the coefficient of lnS_t will decrease from 0 to -1 (Beckers, 1980).

(INSERT TABLE 12 ABOUT HERE)

Table 12 summarises the results of regression (7).The mean coefficients of lnS_t for the overall sample (Panel A) and the subsamples (Panels B and C) are within the range 0 and -1. For the whole sample (96 convertible bonds) the mean coefficient is statistically significant at 10% level with a negative mean coefficient of -0.372. As for subsample 1, the mean coefficient, -0.507 is statistically significant at 5% level, in which 20 of the 34 coefficients are significantly negative. Conversely for subsample 2, only 22 out of 62 coefficients are found to be significantly negative, resulting in an insignificant negative mean coefficient of -0.298. Though the results are not empirically consistent, the CEV model may be a better suited model to represent the underlying stock dynamics of the convertible bonds. Since the mean coefficients of lnS_t lie between 0 and -1, the elasticity of the CEV model is assumed to be β = 0 and β = 1, similar to Cox (1975, 1996).

We also consider GARCH(1,1) of Bollerslev (1986) as robustness analysis to model the volatility of the underlying stock price of convertible bonds. GARCH (1,1) model is evidenced to account for the effect of non-constant volatility, specifically volatility clustering. The discrete-time process of the GARCH model also fits the simulation model of our study and the parameters estimation is straightforward (Ammann, et al., 2008). The conditional variance of GARCH (1,1) is given as

$$\sigma_t^2 = \alpha_0 + \alpha_1 \in_{t-1}^2 + \beta_1\sigma_{t-1}^2 \quad (8)$$

where $\alpha_0 > 0, \alpha_1 \geq 0, \beta_1 \geq 0$ and $\in_t$ are the return residuals, in which $\in_t = \sigma_t z_t$ with $z_t \sim$NID(0,1).

The underlying stock price is also adjusted for dividend payments. The stock price is expected to decrease by the same amount of dividend per share on the ex-dividend date. As for the future dividend, the dividend yield prior to the first real-time trade data disseminated by TRACE-FINRA is assumed to be constant and applies until maturity (Ammann, et al., 2008). The dividend yield expresses the dividend per share as a percentage of the share price. Issuers tend to encourage the conversion of in-the-money non-callable convertible bonds by paying higher dividends on the stocks than coupons of the convertible bonds[27] (Dunn and Eades, 1989). But for our sample, only 34 convertibles bonds (approximately 35.4%) pay dividend and only 9 of them with higher dividend yields than the coupon rates. Grundy and Vermijmeren (June 23, 2012) add that since 2000 it is common for the US convertible bonds to have dividend protection, in which the conversion price/ratio is adjusted for dividend payments. Therefore, dividend is not expected to affect the efficiency of our pricing model.

3.5.2 Interest Rate Risk

At the preliminary level, the valuation process is modelled under the risk-neutral assumption. Accordingly, the discounting factor equals to the risk-free interest rate. Daily risk-free interest rate is collected from the Federal Reserve, which is estimated from the US Treasury constant maturity nominal interest rate[28]. The risk-free interest rate is not available for all maturities, such as the US Treasury bonds with 4-, 6-, 8- and 9- year of maturity. Therefore, these interest rates are derived using the cubic spline formula, which is consistent with the methodology employed by the US Treasury department in deriving the Treasury's yield curve[29]. For each convertible bond, the risk-free interest rate is calculated by averaging the daily interest rate for 252 trading days prior to the first real-time trade data reported to TRACE-FINRA and is assumed to be constant throughout the maturity of the convertible bonds.

In fact, assuming constant interest rate does not reflect the real market specification. However, stochastic interest rates are found to be insignificant in the pricing of convertible bonds (Ammann, et al., 2008; Brennan and Schwartz, 1980; Carayannopoulos, 1996). Hence, it is more practical to assume constant interest rate to avoid further complicating the solution of the valuation model. To confirm the argument, we examine the impact of stochastic interest rates on the pricing of convertible bonds at the preliminary level. The model-

[27] Brennan and Schwartz (1977) claim that it is not optimal to convert a non-callable convertible bond except immediately prior to a dividend date or to an adverse change in the conversion terms, or at maturity.
[28] The yields on Treasury nominal securities at 'constant maturity' are interpolated by the US Treasury from the daily yield curve for non-inflation-indexed Treasury securities. This curve, which relates the yield on a security to its time to maturity, is based on the closing market bid yields on actively traded Treasury securities in the over-the-counter market. The market yields are calculated from composites of quotations obtained from Federal Reserve Bank of New York. The constant maturity yields values are read from yield curve at fixed maturities, currently 1, 3, and 6 months and 1, 2, 3, 5, 7, 10, 20, and 30 years (http://www.federalreserve.gov/releases/h15/update/).
[29] Refer http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/yieldmethod.aspx for the description of Treasury yield curve methodology.

generated values under the assumption of constant interest rates will be compared against the model-generated values using the square-root process of Cox, Ingersoll and Ross (1985) stochastic interest rate model as follows

$$dr_t = \kappa(\mu - r_t)dt + \sigma\sqrt{r_t}dB_{r,t} \qquad (9)$$

where $B_{r,t}$ is the Brownian motion. The drift factor $\kappa(\mu - r_t)$ is the mean reverting component, towards the long run value μ with speed of adjustment κ. Three parameters κ, μ and σ are constant and are independent of time and the current interest rate. The instantaneous variance $\sigma^2 r_t$ is proportional to r_t. If there is no significant difference in the model-generated values between the constant and stochastic interest rate model, then interest rates are assumed to be constant throughout the empirical study. Otherwise, the pricing model would incorporate stochastic interest rate in the valuation process.

3.5.3 Credit risk

Comparable to Ammann, et. al. (2008), this study employs the Tsiveriotis and Fernandes, TF model (1998) to account for credit risk. The TF model requires the lowest number of parameters as compared to other credit risk models. Furthermore, the TF model is commonly used in practice because of limited market credit information, such as modelling the hazard rate and the recovery rate, in the pricing of convertible bonds. Therefore, practitioners tend to build their investment and hedging strategies using the TF model. (Gushchin and Curien, 2008). To review, the TF model splits the value of convertible bonds into a stock component and a straight bond component because both components belong to different credit risk categories. The stock component is claimed to be risk free because a company is always ready to deliver its own stock but the straight bond component is risky because coupon and principal repayments depend on the issuer's ability of distributing the required cash amounts.

Therefore, the risk-free component will be discounted at risk-free rate and the risky component will be discounted at risk-adjusted rate. A credit spread[30] will be added to the risk-free rate to obtain the risk-adjusted risk. The appropriate credit spread is estimated using the rating of each convertible bond. Only 33 convertible bonds are found to be rated. In view

[30] We try to consider credit default swap (CDS) as another proxy of the credit spread, but the CDS rates are not available for 57.29% of the whole sample, thus reduces the sample to 41 convertible bonds. The pricing model is put to test, but the results are found to be inconsistent across time and by the types of real-time trade price. Therefore, we decide not to include this second proxy for credit spread.

of that, we take the credit rating of the issuer when the convertible bond is not rated, which is consistent with existing studies (Ammann, et al., 2008; Rotaru, 2006). Rating information for the convertible bonds is also disseminated by TRACE-FINRA whereas rating information for the issuer is obtained from Moody's. The data on credit spreads is obtained from Thomson Reuters EIKON.

3.6 Measurement of Mispricing

Daily model-generated prices will be compared against daily market prices to determine whether it is fairly priced, overpriced or underpriced. Then, the results will be pooled together to determine the average mispricing in percentage terms for the sample using the following equation.

$$Mean\ deviation, MD = average\left(\frac{Market\ price - Model\ price}{Market\ price}\right) \tag{10}$$

A positive mean deviation, *MD* signifies an overpricing, in which on average the market overprices the convertible bonds. Conversely, a negative *MD* signifies an underpricing, whereby on average the market underprices the convertible bonds in comparison to the model generated prices.

In addition, we calculate the mean absolute deviation (*MAD*) as another indicator of model fit in order to examine the degree of mispricing. The *MAD* takes into account the deviations from market prices from both sides (Zabolotnyuk, et al., 2010). Thus, a lower *MAD* indicates a lower degree of mispricing and vice versa. *MAD* is calculated as

$$Mean\ absolute\ deviation, MAD = average\left[\left|\left(\frac{Market\ price - Model\ price}{Market\ price}\right)\right|\right] \tag{11}$$

3.7 Analysis of Mispricing

The second objective is to examine the effect of liquidity on the mispricing of convertible bonds, which is an important aspect of research on the microstructure of financial markets (Brenner, Eldor, and Hauser, 2001). To achieve this objective, we perform a regression analysis. In our regression model, mispricing is measured by mean absolute deviation (*MAD*) and mean deviation (*MD*). *MAD* measures the degree of mispricing, whereas *MD* provide the direction of the mispricing. Illiquidity may cause significant pricing discrepancies (Ammann, et al., 2003) and difficulty to sell an investment or financial security quickly to meet unexpected cash flow needs. We expect illiquid convertible bonds are more likely to be underpriced with higher degree of mispricing. Three proxies are identified to measure the illiquidity of convertible bonds that includes the total issuance size (*LNTotal*), oversubscription (*Dover*), and trade frequency (*LNTrade* and *LNMil*). *LNTotal* is the issuance size measured by natural log of total issuance including oversubscription, if there is any. Larger issuance size is usually more liquid than smaller issuance size, and investors are more likely to ask for lower rate of returns for more liquid issues (Fenn, 2000; Livingston and Zhou, 2002). *DOver* is a dummy equals to one if the convertible bond is oversubscribed at issuance, thus is assumed to be more liquid, and zero otherwise. *LNTrade* measures how frequently a convertible bond trades in a day, on average. We also identify the trade frequency for trading greater than or equal to US$1 million[31], denoted by *LNMil*. Both are in natural log. Convertible bond with higher trade frequency is inferred as more liquid and the opposite for lower trade frequency.

To control for individual risk, we include moneyness (*Dequity*), time to maturity (*LNTmat*), credit spread (*Crsprd*), rating code (*Rcode*), and volatility (*Vol*) as the explanatory variables. We expect higher mispricing for riskier convertible bonds because of limited market credit information when pricing a convertible bond, particularly in modelling the hazard rate and the fractional loss that are not easily observable. *Dequity* is a dummy equals to one for an equity-like convertible bond and zero for a debt-like convertible bond. Debt-like convertible is credit sensitive, thus is of higher risk than equity-like convertible. *LNTmat* is the natural log of time to maturity in years. The longer the time to maturity, the riskier the security (Livingston and Zhou, 2002). Credit spread is estimated using the rating of each convertible bond or the credit rating of the issuer when the convertible bond is not rated. Convertible bond with higher credit spread is perceived as higher risk, thus is more likely to be underpriced. Same finding is expected for volatility. Following Fenn (Fenn, 2000), the rating code is a numerical value assigned to a particular rating; in our case is the Moody's

[31]For a particular trade in an investment-grade corporate bond, FINRA/TRACE disseminates the actual quantity of each transaction up to and including US$5 million par (face) value. For any trade greater than US$5 million, the par value will be displayed as "$5MM+." For a trade in a non-investment grade corporate bond the actual quantity of the trade will be shown up to and including US$1 million par value. For any trade greater than US$1 million, the par value will be displayed as "$1MM+. Convertible bond is included in the non-investment grade corporate bond (http://www.finra.org/investors/marketdata/p124134).

rating. For example, Aaa rating is assigned a value of 1 and Aa1 is assigned a value of 2, and so forth[32]. Higher numerical value indicates higher risk.

We control for market condition (*Dcrisis*) by adding a dummy equals to one if the trade is executed during the extreme crisis period covering from September 15, 2008 to March 15, 2009, and zero otherwise. A higher degree of underpricing is expected during the crisis period. During the crisis, the SEC imposed a temporary ban on short selling for the financial firms. Therefore, a dummy, *Dfin* is added to the regression that equals to one if the issuer is a financial firm and zero otherwise. In addition, a dummy for financial firms is necessary because these firms operate in a highly regulated industry as compared to other industries, thus is more likely to be overpriced. On the contrary, financial firms are viewed as more risky, thus are more likely to be underpriced. Coupon rate, dividend yield and conditional conversion terms are also included as control variables. *Dcond* is a dummy equals to one if a convertible bond is issued with conditional conversion and zero otherwise.

4. Empirical Results and Discussion

4.1 Tests of Pricing Efficiency

This section discusses the individual impact of stochastic interest rate, stochastic volatility and credit risk on the pricing of convertible bonds. The base model is the *Risk Neutral* model, in which the convertibles are assumed to be riskless and both the interest rate and volatility are assumed to be constant throughout the life of convertible bonds. The *CIR* model only uplifts the assumption of constant interest rate, whereas the *TF* model only accounts for credit risk, in which the others are assumed to be constant. Then, the *CEV* and *GARCH* models account only for stochastic volatility.

(INSERT TABLE 13 ABOUT HERE)

Table 13 reports the mean deviation (*MD*) for each model together with the mean differences between models, with the *Risk Neutral* as the base comparison model. On average the market prices, measured by *MPAll* are 18.971% lower than the model prices under the risk neutral assumption. The underpricing slightly reduces to 18.802% when stochastic

[32] The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21.

interest rate is incorporated but there is no significant difference in the underpricing between the models. The underpricing significantly decreases to 17.304% at 1% level when credit risk is incorporated in the pricing model (Panel B). When volatility is allowed to be stochastic, the average underpricing significantly reduces to 8.307% for $CEV_{\beta=1}$, 8.332% for $CEV_{\beta=0}$ and 9.924% for *GARCH (1,1)*, at 1% level (refer Panels D to F). Consistent results are found when the model prices are compared against the retail trade prices (*MPBuyer* and *MPSeller*), and wholesale trade price (*MPDealer*). These findings are also consistent by subsamples reported in Tables A1 and A2 of the Appendix.

Since incorporating stochastic interest rates does not significantly decrease the mispricing of convertible bonds, it is more practical to assume constant interest rates to reduce the complexity of pricing model (Ammann, et al., 2008; Brennan and Schwartz, 1980). Ammann, Kind and Seiz (2010) also find no well-defined influence of interest rates on the convertible bond fund performance. On the other hand, credit risk has always been an important consideration in the pricing of fixed-income securities, including convertible bonds (Gushchin and Curien, 2008), but from our results, the relative impact of credit risk is smaller than volatility. Convertible bond is a contingent claim on the issuer's stock, thus the value is dependent on the performance of the underlying stock. Moreover, convertible bonds tend to be issued by either unrated or non-investment grade firms (Huang and Ramírez, 2010) that are likely to have greater stock volatility. The finding could be potentially explained by the estimation of credit risk. First, the credit spread is estimated from the rating of each convertible bond at issuance and is assumed to be constant, but both the rating and credit spread change over time that potentially affect our sample of lower rated convertible bonds (Ammann, et al., 2008). Second, our pricing model does not account for possibility of default and recovery rate. But we continue with the Tsiveriotis and Fernandes (1998)'s model so that is comparable to the practitioners with limited market credit information (Gushchin and Curien, 2008).

(INSERT TABLE 14 ABOUT HERE)

The CEV model appears to perform better than the GARCH model evidenced by the lower pricing error, significant at 1% level. Results are reported in Table 14. No significant differences are found between the CEV models with different measure of elasticity. Next, we price the convertible bonds with credit risk and stochastic volatility by integrating the $CEV_{\beta=1}$ and *TF* models. An average underpricing of 6.31%, is identified that significantly improved the mispricing by 12.661%, at 1% level (refer Panel G of Table 14). Consistently, we observe underpricing in each pricing model considered in our study, similar to existing studies (Ammann, et al., 2003; Carayannopoulos, 1996; Gushchin and Curien, 2008; Ho and Pfeffer, 1996; King, 1986; McConnell and Schwartz, 1986; Rotaru, 2006).

The equity-like convertible bonds are underpriced by 0.56%, whereas the debt-like convertibles are underpriced by 10.7%, estimated from the $CEV_{\beta=1}TF$ model. The degree of mispricing tends to be lower for equity-like convertibles than debt-like convertibles (Zabolotnyuk, et al., 2010). The pricing of these securities is less challenging because the equity nature leads to higher probability of conversion. Moreover, equity-like convertible bonds are more likely to be overpriced as they more attractive for investors who more willing to pay for the equity-like feature. On the contrary, debt-like convertibles are less attractive to investors and are exposed to higher credit risk. Thus, these convertibles are more sensitive to model inputs such as credit spreads (Ammann, et al., 2008; Mitchell and Pulvino, 2012). Importantly, mispricing in convertible bonds lead to arbitrage opportunities. When a convertible bond is found to be underpriced, an arbitrageur buys the convertible bond and sells short the underlying common stock at the current delta, generating a risk-free profit.

(INSERT TABLE 15 ABOUT HERE)

The degree of mispricing is substantially high during the collapse of Lehman Brothers (*Subperiod 3*). Results are reported in Table 15. The $CEV_{\beta=1}$ model reports an underpricing of 44.989%. Even the $CEV_{\beta=1}TF$ model that account for both stochastic volatility and credit risk reports an underpricing of 42.208%. During the crisis period, the convertible bonds trade at deep discount with an average moneyness of 0.543. The convertible bonds are more debt-like, thus are sensitive to model inputs especially the credit information. The deep discount of the trade prices relative to the model-generated prices is also caused by the massive selling of convertible bonds, in particular by the convertible hedge funds during the crisis because the temporary ban on short selling restricts arbitrage opportunities. Mitchell and Pulvino (2012) report a substantial underpricing of 13.7%[33] for equity-like convertible bonds. As for our sample, on average the equity-like convertibles are underpriced by 11.122%. Mitchell and Pulvino (2012) add that the substantial discount takes approximately over a year to recover to the historical levels, which is consistent to our study as we observe decrease in mispricing

[33] Mitchell and Pulvino (2012) only focus on equity-sensitive (moneyness ratio greater than 0.65) convertible bonds to reduce estimation errors because these convertibles are less sensitive to model inputs, specifically credit spreads. The reported 13.7% is the average median discount from theoretical value on December 4, 2008.

mainly from 2010 onwards. Excluding the crisis period, on average we document an underpricing of 3.14%. Similarly, the underpricing observed from the equity-like convertibles is smaller than debt-like convertibles, to be specific 0.27% and 5.56%, respectively.

(INSERT TABLE 16 ABOUT HERE)

Given the greater impact of volatility, we further examine the importance of time varying effect of volatility on convertible bonds pricing. In Table 16, we rank the initial volatility used in the *Risk Neutral* and $CEV_{\beta=1}$ models by quintiles and compare the predictive power, measured by mean absolute deviation (*MAD*) in percentage. The initial volatility of each convertible is calculated using daily individual stock returns of 252 trading days prior to the first real-time trade data reported to TRACE-FINRA and is assumed to be constant in the *Risk Neutral* model. The mean differences between the *Risk Neutral* and $CEV_{\beta=1}$ models decrease monotonically from 7.34% to 12.26% from the third to the fifth quintiles, significant at 1% level. But there is no significant difference between the models for lower level of volatility, sorted in the first and second quintiles. These findings further confirm the importance of incorporating time-varying effect of volatility, particularly in the pricing of convertible bonds with substantial fluctuation in underlying stock returns.

(INSERT FIGURE 2 ABOUT HERE)

Figure 2 plots the relation between the rolling-sample volatility and the trade prices of 24 convertible bonds that provide complete observations by the identified subperiods. We observe substantially high volatility of the underlying stock returns. During the extreme crisis, the volatilities fall within the third and fifth quintiles, even for issuers with lower initial volatilities (within the first quintile) at issuance such as Alliant Techsystems Incorporated, Amgen Incorporated, Leucadia National Corporation, Lifepoints Hospitals Incorporated, Medtronics Incorporated, and Molson Coors Brewing Company.

4.2 Analysis of Mispricing

In this section, we discuss the empirical results that explain the mispricing of convertible bonds. First of all, Table 17 provides the correlation analysis of the explanatory variables identified in section 3.7. Most of the variables are significantly correlated at 1% level, but with lower correlation coefficient values, generally less than 0.3. Two exceptions are noted.

There is a direct relation between credit spread and volatility as indicated by a positive correlation coefficient value of 0.683. Credit spread is also positively correlated to rating code with a value of 0.591, which means the higher the credit spread, the higher the rating code, as well as the volatility. To control for multicollinearity, we exclude credit spread from the regression analysis because the inclusion leads to inconsistent results. We retain volatility in the regression analysis for two reasons. First, the correlation value between volatility and rating code is only at 0.206. Second, volatility is found to have greater impact on the pricing of convertible bonds as discussed earlier.

(INSERT TABLE 17 ABOUT HERE)

In the regression analysis, the dependent variable is the mean deviation that measures the mispricing between the real-time trade prices and the theoretical values estimated by the $CEV_{\beta=1}TF$ model. *MD* gives the direction of the mispricing. We consider four models, represented by *MPA*, *MPB*, *MPS* and *MPD*. *MPA* is the daily mispricing observed from October 26, 2004 to June 30, 2011. *MPB* is the daily deviation between the buyer reported real-time trade prices and theoretical values. *MPS* is for the seller, whereas *MPD* is for the inter-dealer. Refer Table 18 for the regression results.

(INSERT TABLE 18 ABOUT HERE)

We observe positive coefficient with *LNTotal* and *Dover*, in which convertible bonds with larger issue size and/or with oversubscription at offering are more likely to be overpriced by the market. These findings are consistent with our prediction that liquid convertibles are likely to be overpriced in contrast to illiquid convertibles that are likely to be underpriced similar to Ammann, et. al. (2003), Loncarski, et. al. (2009) and Mitchell and Pulvino (2007) Ammann et. al. (2003). But, the direction of trade frequency is different from our expectation, in which convertible bonds that trade more frequently in a day are found to be underpriced. In an unreported result, we find the same negative coefficient for number of trade greater than or equal to US$1 million. Consistent results are observed for all types of trade prices with two exceptions. Note that the predictive power of oversubscription (*Dover*) decreases when explaining the mispricing of inter-dealer reported trade prices and disappears when explaining the mispricing of buyer reported trade prices. Nonetheless, we still find evidence that liquidity has significant impact on the mispricing of convertible bonds (at the 1% level) but the direction of the mispricing is less certain.

Consistently, we find that riskier convertible bonds are more likely to be underpriced as indicated by the negative coefficients with time to maturity, rating code, and volatility (at the 1% level. Convertible bonds with longer time to maturity, higher rating code, and higher volatility are perceived to be riskier by the market, thus are expected to be underpriced. The negative relation between time to maturity and mispricing is similar to Ammann et al. (2003), Landskroner and Raviv (2008), and Rotaru (2006). The pricing of longer maturity convertible bonds are claimed to be less accurate because the arbitrage strategies are more complex and expensive (Ammann, et al., 2003). Rotaru (2006) adds that the relation between mispricing and time to maturity is more a function of volatility in interest rate markets, brought about by monetary or fiscal uncertainty. Underpricing is found to be positively related to time to maturity and coupon rate in poor market conditions because investors demand higher coupon rates to compensate for the riskier interest rate conditions, especially for longer maturity convertible bonds. The opposite relation is identified when market conditions are favourable.

The explanatory power of volatility decreases (to the 10% level) when explaining the mispricing of seller reported trade prices and disappears when explaining the mispricing of buyer reported trade prices, though retaining the negative coefficient. Interestingly, volatility is positively related to mispricing of inter-dealer reported trade prices that explains higher volatility in the underlying stock returns leads to overpricing of convertible bonds (at the 1% level). Inter-dealer trade is characterised by large transaction sizes that is executed on behalf of the institutional investors including investment and commercial banks, corporations, insurance companies and hedge funds. These institutional investors in particular the convertible arbitrage hedge funds in general look for convertible bonds with higher underlying stock returns volatility, which translate into higher value of the equity-option (Loncarski, et al., 2009).

The positive sign of *Dequity* claims that equity-like convertibles tend to be overpriced as expected and is also consistent for all types of trade prices. These findings support our justification that equity-like or less risky convertible bonds are more attractive to investors because of the higher value of equity option, thus are willing to pay more for the equity-like feature. On the other hand, debt-like features are less attractive to investors because they are exposed to greater risk; hence tend to be underpriced to compensate for the additional risk. Coupon rate is found to be statistically insignificant in explaining the mispricing of the full sample (*MPA*) and the buyer reported trade prices. But there is a positive relation exists between the coupon rate and the seller reported trade prices at a lower level of significance (at the 10% level). Conversely, the inter-dealer reported trade prices are more likely to be underpriced at a higher level of coupon rate (at the 1% level). Higher coupon convertible bonds are riskier because of the higher periodic coupon payment obligations. Dividend is found to have negative impact on the mispricing of the full sample and the retail prices (at the 1% level), signifying that convertible bonds with underlying stocks that pay higher dividend are expected to be underpriced by the market. However, the effect is not significant on the mispricing of inter-dealer reported trade prices. In brief, both the coupon rate (Ammann, et al., 2008; Lau and Kwok, 2004; Rotaru, 2006; Zabolotnyuk, et al., 2010) and dividend yield (Ammann, et al., 2008; McConnell and Schwartz, 1986) do have significant effect on the efficiency of convertible bond pricing.

In addition when we control for the attached conversion terms, we find that convertible bonds issued with conditional conversion tends to be overpriced by the market (at the 1% level). Possible explanation is the riskiness of these securities. Note that convertible bonds with conditional conversion are less risky, as indicated by the negative correlation between *Dcond* and *Vol*, as well as between *Dcond* and *Crsprd* (refer Table 17). Less risky convertible bonds are predicted to be overpriced. Convertible bonds that are issued by financial firms are also found to be overpriced. On the other hand, trades that are executed during the extreme crisis period are underpriced by the market, consistent with the highly uncertain market condition. This finding supports our subperiod analysis that reports a higher degree of underpricing during the collapse of Lehman Brothers.

5. Conclusion

Convertible bonds are a significant and developing segment of the corporate bond market. Nonetheless, the valuation of convertible bonds has not been addressed extensively due to the complicated payoff structures, the links between valuation and underlying risk factors such as credit risk, interest rate risk, and equity risk. Furthermore, former empirical literature convertible bond pricing has reported mixed results from an underpricing of 12.9% (Carayannopoulos, 1996) to an overpricing of approximately 5% (Barone-Adesi, et al., 2003). We clarify this by a unique sample, consisting of pure convertible bonds to control for complex optionality in these securities that potential affecting the efficiency of the pricing model. Therefore, convertible bonds with callable and puttable features, sinking fund, mandatory, exchangeable, reset and reverse clauses are also excluded.

We examine the pricing efficiency of the convertible bond real-time trade prices disseminated by TRACE-FINRA via a simple pricing model. The least squared Monte Carlo simulation (LSM) approach (Longstaff and Schwartz, 2001) is employed to solve the pricing model that accounts for stochastic volatility and credit risk. On average, we report an underpricing of 6.31% from daily observations, estimated from a sample of 96 pure convertible bonds, covering from October 26, 2004 to June 30, 2011. Equity-like convertible bonds are found to be less underpriced by the market because the securities are less risky, thus are more attractive to investors. Equity-like convertibles offer higher value of conversion option as compared to debt-like convertibles that are perceived to be more risky. Debt-like convertibles are sensitive to model inputs and specifications such as the credit spread, default probability and recovery rate. In addition, volatility is found to have greater impact on the pricing of convertible bonds especially in capturing substantial time-varying fluctuation of the underlying stock returns.

The pricing efficiency is also explained by the illiquid convertible bond market in comparison to the equity and straight bond markets. Illiquid convertibles tend to be underpriced by the market, as measured by the convertible bond issuance size and oversubscription of the convertibles at issuance. Riskier convertible bonds are found to be underpriced by the market too, which is explained by longer time to maturity, higher rating code, higher volatility and debt-like features. Controlling for the market condition, we find that during the most intense stage of the crisis period, convertible bonds are deeply underpriced by the market, which is consistent with the highly uncertain market condition.

Appendix

Table A1

Mean Comparison of Average Mispricing by Pricing Models for Subsample 1

The table reports the mean difference of average mispricing for the 34 convertible bonds issued without conditional conversion provision with the *Risk Neutral* as the base model. The *CIR* model is the Cox, Ingersoll and Ross (1985) stochastic interest rate model (Panel A). The *TF* model is the Tsiveriotis and Fernandes (1998) credit risk model, in which the credit spread is measured by the credit rating of the convertible bond or the issuing firm when the bond rating is not available (Panel B). The *CEV* model and *GARCH (1,1)* models capture non-constant volatility (Panels C to E). The *CEV* model is the constant elasticity of variance model by (Cox, 1975, 1996) with beta = 1 and beta = 0. The $CEV_{\beta=1}TF$ model captures both the stochastic volatility and credit risk in the pricing of convertible bonds (Panel F). *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the risk neutral and stochastic interest rate models

	Obs	Risk Neutral	Obs	CIR	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	10,116	-24.794	10,116	-23.800	-0.994	0.728	-2.422	0.434	-1.365
MPBuyer	6,654	-26.721	6,654	-26.374	-0.347	0.980	-2.269	1.574	-0.355
MPSeller	6,215	-26.459	6,215	-25.678	-0.781	1.027	-2.794	1.232	-0.761
MPDealer	4,761	-26.898	4,761	-26.847	-0.051	0.998	-2.008	1.905	-0.051

Panel B: Mean comparison between the risk neutral and credit risk models

	Obs	Risk Neutral	Obs	TF	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	10,116	-24.794	10,116	-22.243	-2.551***	0.590	-3.708	-1.394	-4.322
MPBuyer	6,654	-26.721	6,654	-24.269	-2.452***	0.763	-3.947	-0.957	-3.215
MPSeller	6,215	-26.459	6,215	-23.717	-2.742***	0.786	-4.282	-1.202	-3.491
MPDealer	4,761	-26.898	4,761	-24.295	-2.603****	0.915	-4.396	-0.810	-2.845

Panel C: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	CEV beta=1	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	10,116	-24.794	10,116	-11.873	-12.921***	0.616	-14.129	-11.713	-20.967
MPBuyer	6,654	-26.721	6,654	-12.401	-14.320***	0.799	-15.886	-12.755	-17.927
MPSeller	6,215	-26.459	6,215	-12.545	-13.914***	0.829	-15.539	-12.289	-16.782
MPDealer	4,761	-26.898	4,761	-12.705	-14.193***	0.964	-16.083	-12.302	-14.717

Panel D: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	CEV beta=0	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	10,116	-24.794	10,116	-12.287	-12.507***	0.675	-13.830	-11.184	-18.529
MPBuyer	6,654	-26.721	6,654	-12.658	-14.064***	0.867	-15.763	-12.364	-16.225
MPSeller	6,215	-26.459	6,215	-13.419	-13.040***	0.917	-14.837	-11.243	-14.223
MPDealer	4,761	-26.898	4,761	-14.067	-12.831***	1.104	-14.996	-10.666	-11.619

Panel E: Mean comparison between the risk neutral and non-constant volatility models

	Obs	**Risk Neutral**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	10,116	-24.794	10,116	-11.638	-13.155***	0.612	-14.354	-11.953	-21.508
MPBuyer	6,654	-26.721	6,654	-12.296	-14.426***	0.795	-15.985	-12.867	-18.138
MPSeller	6,215	-26.459	6,215	-12.668	-13.792***	0.827	-15.413	-12.171	-16.676
MPDealer	4,761	-26.898	4,761	-12.219	-14.680***	0.958	-16.557	-12.802	-15.326

Panel F: Mean comparison between the risk neutral and stochastic volatility and credit risk model

	Obs	**Risk Neutral**	**Obs**	$CEV_{\beta=1}\,TF$	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	10,116	-18.971	10,116	-8.551	-10.420***	0.599	-17.416	-15.069	-27.127
MPBuyer	6,654	-19.215	6,654	-9.214	-10.001***	0.779	-19.034	-15.981	-22.478
MPSeller	6,215	-18.468	6,215	-9.289	-9.179***	0.808	-18.753	-15.587	-21.263
MPDealer	4,761	-17.389	4,761	-9.174	-8.214***	0.924	-19.536	-15.912	-19.175

Table A2
Mean Comparison of Average Mispricing by Pricing Models for Subsample 2

The table reports the mean difference of average mispricing for the 62 convertible bonds issued with conditional conversion provision with the *Risk Neutral* model as the base model. The *CIR* model is the Cox, Ingersoll and Ross (1985) stochastic interest rate model (Panel A). The *TF* model is the Tsiveriotis and Fernandes (1998) credit risk model, in which the credit spread is measured by the credit rating of the convertible bond or the issuing firm when the bond rating is not available (Panel B). The *CEV* model and *GARCH (1,1)* models capture non-constant volatility (Panels C to E). The *CEV* model is the constant elasticity of variance model by (Cox, 1975, 1996) with beta = 1 and beta = 0. The $CEV_{\beta=1}TF$ model captures both the stochastic volatility and credit risk in the pricing of convertible bonds (Panel F). *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the risk neutral and stochastic interest rate models

	Obs	Risk Neutral	Obs	CIR	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-17.195	0.097	0.282	-0.456	0.651	0.344
MPBuyer	20,102	-16.668	20,102	-16.794	0.126	0.324	-0.510	0.761	0.388
MPSeller	18,505	-15.767	18,505	-16.039	0.271	0.329	-0.373	0.916	0.826
MPDealer	14,873	-14.391	14,873	-14.869	0.477	0.356	-0.221	1.176	1.340

Panel B: Mean comparison between the risk neutral and credit risk models

	Obs	Risk Neutral	Obs	TF	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-15.716	-1.382***	0.275	-1.922	-0.843	-5.022
MPBuyer	20,102	-16.668	20,102	-15.203	-1.466***	0.309	-2.072	-0.859	-4.736
MPSeller	18,505	-15.767	18,505	-14.427	-1.341***	0.314	-1.957	-0.725	-4.266
MPDealer	14,873	-14.391	14,873	-13.268	-1.123***	0.335	-1.780	-0.467	-3.354

Panel C: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	CEV beta=1	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-7.160	-9.938***	0.278	-10.483	-9.392	-35.717
MPBuyer	20,102	-16.668	20,102	-6.456	-10.212***	0.311	-10.822	-9.602	-32.809
MPSeller	18,505	-15.767	18,505	-6.058	-9.709***	0.314	-10.326	-9.093	-30.879
MPDealer	14,873	-14.391	14,873	-5.522	-8.869***	0.337	-9.531	-8.208	-26.281

Panel D: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	CEV beta=0	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-7.059	-10.039***	0.278	-10.584	-9.493	-36.062
MPBuyer	20,102	-16.668	20,102	-6.034	-10.634***	0.311	-10.940	-9.719	-33.165
MPSeller	18,505	-15.767	18,505	-9.818	-5.949***	0.315	-10.435	-9.202	-31.206
MPDealer	14,873	-14.391	14,873	-5.438	-8.954***	0.338	-9.616	-8.292	-26.519

Panel E: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	GARCH (1,1)	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-9.373	-7.725***	0.280	-8.275	-7.176	-27.545
MPBuyer	20,102	-16.668	20,102	-8.990	-7.678***	0.315	-8.295	-7.061	-24.389
MPSeller	18,505	-15.767	18,505	-8.577	-7.190***	0.318	-7.814	-6.566	-22.594
MPDealer	14,873	-14.391	14,873	-7.468	-6.923***	0.342	-7.595	-6.252	-20.221

Panel F: Mean comparison between the risk neutral and stochastic volatility and credit risk model

	Obs	Risk Neutral	Obs	$CEV_{\beta=1}TF$	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	31,608	-17.098	31,608	-5.588	-11.510***	0.275	-12.049	-10.970	-41.817
MPBuyer	20,102	-16.668	20,102	-4.911	-11.757***	0.306	-12.358	-11.156	-38.362
MPSeller	18,505	-15.767	18,505	-4.437	-11.331***	0.310	-11.937	-10.724	-36.609
MPDealer	14,873	-14.391	14,873	-4.194	-10.197***	0.332	-10.848	-9.547	-30.721

Table A3

Mean Comparison of Average Mispricing between the Stochastic Volatility Models for Subsample 1

The table reports the differences in the average mispricing between the stochastic volatility models for the 34 convertible bonds issued without conditional conversion provision. Three models are considered, i.e. the CEV models when the elasticity (beta) equals to 1 and 0 together with the GARCH (1,1) model. *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the CEV models with different measure of elasticity

	Obs	**CEV beta=1**	**Obs**	**CEV beta=0**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	10,116	-11.873	10,116	-12.287	0.414	0.687	-0.932	1.760	0.603
MPBuyer	6,654	-12.401	6,654	-12.658	0.257	0.885	-1.479	1.992	0.290
MPSeller	6,215	-12.545	6,215	-13.419	0.874	0.935	-0.959	2.707	0.935
MPDealer	4,761	-12.705	4,761	-14.067	1.362	1.112	-0.830	3.554	1.218

Panel B: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=1**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	10,116	-11.873	10,116	-11.638	-0.234	0.625	-1.459	0.990	-0.375
MPBuyer	6,654	-12.401	6,654	-12.296	-0.105	0.815	-1.704	1.493	-0.129
MPSeller	6,215	-12.545	6,215	-12.668	0.122	0.847	-1.538	1.783	0.144
MPDealer	4,761	-12.705	4,761	-12.219	-0.487	0.974	-2.396	1.422	-0.500

Panel C: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=0**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	10,116	-12.287	10,116	-11.638	-0.648	0.683	-1.986	0.690	-0.950
MPBuyer	6,654	-12.658	6,654	-12.296	-0.362	0.882	-2.091	1.367	-0.411
MPSeller	6,215	-13.419	6,215	-12.668	-0.752	0.933	-2.581	1.077	-0.806
MPDealer	4,761	-14.067	4,761	-12.219	-1.849*	1.111	-4.029	0.332	-1.662

Table A4

Mean Comparison of Average Mispricing between the Stochastic Volatility Models for Subsample 2

The table reports the differences in the average mispricing between the stochastic volatility models for the 62 convertible bonds issued with conditional conversion provision. Three models are considered, i.e. the CEV models when the elasticity (beta) equals to 1 and 0 together with the GARCH (1,1) model. *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the CEV models with different measure of elasticity

	Obs	**CEV beta=1**	**Obs**	**CEV beta=0**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	31,608	-7.160	31,608	-7.059	-0.101	0.276	-0.642	0.441	-0.365
MPBuyer	20,102	-6.456	20,102	-6.034	-0.422	0.304	-0.713	0.478	-0.372
MPSeller	18,505	-6.058	18,505	-9.818	3.760	0.309	-0.714	0.496	-0.353
MPDealer	14,873	-5.522	14,873	-5.438	-0.085	0.336	-0.744	0.575	-0.252

Panel B: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=1**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	31,608	-7.160	31,608	-9.373	2.213***	0.278	1.667	2.758	7.946
MPBuyer	20,102	-6.456	20,102	-8.990	2.534***	0.307	1.932	3.136	8.247
MPSeller	18,505	-6.058	18,505	-8.577	2.519***	0.313	1.907	3.132	8.059
MPDealer	14,873	-5.522	14,873	-7.468	1.946***	0.341	1.277	2.615	5.702

Panel C: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=0**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	31,608	-7.059	31,608	-9.373	2.313***	0.279	1.767	2.859	8.304
MPBuyer	20,102	-6.034	20,102	-8.990	2.956***	0.308	2.049	3.255	8.624
MPSeller	18,505	-9.818	18,505	-8.577	-1.241***	0.313	2.015	3.241	8.403
MPDealer	14,873	-5.438	14,873	-7.468	2.030***	0.341	1.361	2.700	5.947

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Table 1
Market Capitalisation and Market Size of Convertible Bonds by Major Markets during the years 2000 to 2011

The table reports the market value and the market share of convertible bonds by major markets, specifically US, Europe, Japan and Asia-Pacific from year 2000 to 2011. The annual data are recorded as at the last trading day of each year in billions of US dollar. The last column sums up the market value of the four major markets to provide a best estimate of the overall size of convertible bond market. Meanwhile, the market share is given in the percentage of total market capitalisation of the convertible bonds. US has the largest market share throughout the observed period, followed by Europe, Japan and Asia-Pacific. The convertible bond data is sourced from Datastream.

Year	US		Europe		Japan		Asia-Pacific		Total
	US$'billion	%	US$'billion	%	US$'billion	%	US$'billion	%	US$'billion
2000	101.13	53.17	33.92	17.83	46.20	24.29	8.94	4.70	190.19
2001	163.41	63.95	48.56	19.00	33.11	12.96	10.45	4.09	255.53
2002	157.33	59.45	61.45	23.22	32.55	12.30	13.3	5.03	264.63
2003	228.61	64.85	76.14	21.60	35.43	10.05	12.32	3.50	352.5
2004	224.95	62.99	84.33	23.61	34.68	9.71	13.17	3.69	357.12
2005	208.23	64.93	72.54	22.62	30.45	9.50	9.47	2.95	320.69
2006	239.13	70.60	62.85	18.56	27.08	7.99	9.66	2.85	338.72
2007	261.25	73.25	55.51	15.56	25.20	7.07	14.7	4.12	356.66
2008	142.41	68.24	32.89	15.76	21.95	10.52	11.43	5.48	208.68
2009	182.9	67.49	51.28	18.92	18.59	6.86	18.22	6.72	270.99
2010	188.55	65.45	48.60	16.87	27.44	9.53	23.48	8.15	288.08
2011	148.70	63.64	40.16	17.19	21.01	8.99	23.77	10.17	233.64

Table 2
Trade Reporting and Compliance Engine (TRACE) Timeline

The table outlines the phases of implementation of TRACE in disseminating over-the-counter (OTC) corporate bond real-time trade data and trade volume information to the public. The implementation was executed in three phases, which was officially launched on July 1, 2002 and was fully phased in by January 2006.

Note: The information is adopted from FINRA-TRACE Fact Book 2010, available at FINRA's website www.FINRA.org

July 1, 2002	TRACE launched with Phase I dissemination and 75-minute transaction reporting requirement
March 3, 2003	Phase IIa dissemination: dissemination of additional AAA, AA, A rated bonds
April 14, 2003	Phase IIb dissemination: dissemination of 120BB rated bonds
October 1, 2003	45-minute transaction reporting requirement effective
October 1, 2004	Phase IIIa dissemination: dissemination of all bonds not qualified for delayed dissemination; 30-minute transaction reporting requirement effective
February 7, 2005	Phase IIIb dissemination: dissemination of all public transactions subject to delayed dissemination
July 1, 2005	15-minute transaction reporting requirement effective
January 9, 2006	Immediate dissemination of all public TRACE-reportable transactions
November 3, 2008	TRACE-eligible securities with equity CUSIPs are reportable to TRACE
March 1, 2010	Agency debentures and primary market transactions are reportable to TRACE

Table 3
Summary Statistics of the Sample

The table reports the summary statistics of the observed characteristics for the sample of 96 convertible bonds identified from the Trade Reporting and Compliance Engine (TRACE) of Financial Industry Regulatory Authority (FINRA). *Maturity* is the convertible bond's time to maturity at issuance in years. *Coupon* is the convertible bond coupon rate per annum in percentage. *Conversion price* is the prespecified price per share in US dollars of a common stock when conversion takes place. *Conversion premium* measure the percentage by which the conversion price exceeds the underlying stock price at offering. *Initial issuance* is the convertible bond's issuance size (face value) in millions of US dollars, not including *Overallotment* or oversubscription of the convertible bond. *Total issuance* equals to the sum of *Initial issuance* and *Overallotment*, in millions of US dollars. *Degree of overallotment* measures the percentage of oversubscription. *Rating* information is collected from Moody's. The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21.

	Mean	**Standard deviation**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Maturity (years)	5.927	2.069	3	5	5	7	20
Coupon (%)	3.750	2.088	0.375	2.5	3.4375	4.625	15
Conversion price (US$)	32.105	25.827	1.235	12.374	26.682	46.207	134.481
Conversion premium (%)	31.059	32.397	-9.804	18.602	24.057	30.074	197.442
Initial issuance (US$' mil)	408.261	394.700	1.5	187.488	300	467.5	2500
Overallotment (US$' mil)	16.410	23.000	0	0	0	30	75
Degree of overallotment (%)	5.501	6.877	0	0	0	15	15
Total issuance (US$' mil)	424.670	393.009	1.5	187.488	316.25	487.5	2500
Rating	12.573	3.279	5	10	13	15	20

Table 4
Summary Statistics and Mean Comparison of the Subsamples Identified by the Conversion Terms

The table reports the summary statistics of the observed characteristics for two subsamples, identified by the attached conversion terms. Panel A is for the subsample of 34 convertible bonds without provision on conversion (subsample 1) whereas Panel B is for the subsample of 62 convertible bonds with conditional conversion term (subsample 2). Panel C reports the mean differences of the subsamples. *Maturity* is the convertible bond's time to maturity at issuance in years. *Coupon* is the convertible bond coupon rate per annum in percentage. *Conversion price* is the prespecified price per share in US dollars of a common stock when conversion takes place. *Conversion premium* measure the percentage by which the conversion price exceeds the underlying stock price at offering. *Initial issuance* is the convertible bond's issuance size (face value) in millions of US dollars, not including *Overallotment* or oversubscription of the convertible bond. *Total issuance* equals to the sum of *Initial issuance* and *Overallotment*, in millions of US dollars. *Degree of overallotment* measures the percentage of oversubscription. *Rating* information is collected from Moody's. The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21. A superscript ** or *** indicates significance at the 95% and 99% confidence levels, respectively.

	Mean	**Standard deviation**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Panel A: Subsample 1 - Convertible bonds without conditional conversion							
Maturity (years)	5.706	1.767	3	5	5	7	10
Coupon (%)	4.860	2.572	1.250	3.250	4.125	6.500	15
Conversion price (US$)	23.636	25.686	1.235	5.490	16.413	32.819	134.481
Conversion premium (%)	33.661	37.168	-7.344	20	25.619	30	197.442
Initial issuance (US$' mil)	353.464	251.554	1.5	199.976	291.250	450	1150
Overallotment (US$' mil)	17.134	22.718	0	0	0	41.250	75
Degree of overallotment (%)	5.782	6.935	0	0	0	15	15
Total issuance (US$' mil)	370.598	252.138	1.5	199.976	308.125	460	1150
Rating	12.794	3.24	7	10	13	15	19
Panel B: Subsample 2 - Convertible bonds with conditional conversion							
Maturity (years)	6.048	2.221	3	5	5	7	20
Coupon (%)	3.141	1.465	0.375	2	3	4	6.5
Conversion price (US$)	36.749	24.899	8.288	14.025	31.794	51.788	118.319
Conversion premium (%)	29.633	29.638	-9.804	17.505	23.568	31	172.954
Initial issuance (US$' mil)	438.311	453.648	2.2	160	300	475	2500
Overallotment (US$' mil)	16.012	23.328	0	0	0	30	75
Degree of overallotment (%)	5.347	6.898	0	0	0	15	15
Total issuance (US$' mil)	454.323	451.254	2.2	172.5	320.625	500	2500
Rating	12.452	3.322	5	10	13	15	20

Panel C: Mean comparison

	Subsample 1	**Subsample 2**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
Maturity (years)	5.706	6.048	-0.343	0.442	-1.221	0.536	-0.774
Coupon (%)	4.860	3.141	1.719***	0.411	0.903	2.536	4.180
Conversion price (US$)	23.636	36.749	-13.113***	5.373	-23.782	-2.445	-2.441
Conversion premium (%)	33.661	29.633	4.029	7.403	-10.799	18.856	0.544
Initial issuance (US$'mil)	353.464	438.311	-84.847	84.224	-252.075	82.381	-1.007
Overallotment (US$'mil)	17.134	16.012	1.122	4.933	-8.673	10.917	0.227
Degree of overallotment (%)	5.782	5.347	0.436	1.475	-2.493	3.364	0.295
Total issuance (US$'mil)	370.598	454.323	-83.725	83.871	-250.252	82.802	-0.998
Rating	12.794	12.452	0.343	0.703	-1.053	1.738	0.488

Table 5

Summary Statistics and Mean Comparison of the Subsamples Identified by the Type of Placement

The table reports the summary statistics of the observed characteristics for two subsamples, identified by the type of placement when the convertible bonds are first issued. Equally, there are 48 convertible bonds in each subsample. Subsample A includes of convertible bonds that are first issued via private placement pursuant to Rule 144A (refer Panel A). Subsample B consists of convertible bonds that are issued via public placement (refer Panel B). Panel C reports the mean comparison for both subsamples. *Maturity* is the convertible bond's time to maturity at issuance in years. *Coupon* is the convertible bond coupon rate per annum in percentage. *Conversion price* is the prespecified price per share in US dollars of a common stock when conversion takes place. *Conversion premium* measure the percentage by which the conversion price exceeds the underlying stock price at offering. *Initial issuance* is the convertible bond's issuance size (face value) in millions of US dollars, not including *Overallotment* or oversubscription of the convertible bond. *Total issuance* equals to the sum of *Initial issuance* and *Overallotment*, in millions of US dollars. *Degree of overallotment* measures the percentage of oversubscription. *Rating* information is collected from Moody's. The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Mean	**Standard deviation**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Panel A: Subsample A – First issued via Rule 144A							
Maturity (years)	6.292	2.543	3	5	6	7	20
Coupon (%)	3.167	1.652	0.375	1.813	3.125	4	7
Conversion price (US$)	37.551	24.719	3.025	18.562	33.997	48.86	118.319
Conversion premium (%)	33.790	41.637	-9.804	15.451	22.526	31.75	197.442
Initial issuance (US$' mil)	512.130	525.524	1.5	174.988	300	575	2500
Overallotment (US$' mil)	1.172	6.292	0	0	0	0	41
Degree of overallotment (%)	0.625	3.029	0	0	0	0	15
Total issuance (US$' mil)	513.302	524.915	1.5	174.988	300	575	2500
Rating	12.208	3.332	5	10	13	14	20
Panel B: Subsample B – Public placement							
Maturity (years)	5.563	1.382	3	5	5	7	10
Coupon (%)	4.333	2.321	1.25	3	3.938	5.25	15
Conversion price (US$)	26.660	26.013	1.24	10.955	15.896	34.609	134.481
Conversion premium (%)	28.328	19.203	9.02	20	24.986	30	140
Initial issuance (US$' mil)	304.392	129.148	100	187.5	300	389.75	550
Overallotment (US$' mil)	31.647	23.568	0	9	30	50	75
Degree of overallotment (%)	10.377	6.154	0	5.417	14.643	15	15
Total issuance (US$' mil)	336.039	143.587	100	202.5	324.938	426.25	600
Rating	12.938	3.218	7	10	13	16	19

Panel C: Mean comparison

	Subsample A	**Subsample B**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
Maturity (years)	6.292	5.563	0.729*	0.418	-0.100	1.559	1.745
Coupon (%)	3.167	4.333	-1.166***	0.411	-1.983	-0.350	-2.838
Conversion price (US$)	37.551	26.66	10.891**	5.179	0.607	21.175	2.103
Conversion premium (%)	33.790	28.328	5.462	6.618	-7.678	18.603	0.825
Initial issuance (US$'mil)	512.130	304.392	207.738***	78.110	52.650	362.827	2.660
Overallotment (US$'mil)	1.172	31.647	-30.475***	3.521	-37.466	-23.485	-8.656
Degree of overallotment (%)	0.625	10.377	-9.752***	0.990	-11.727	-7.777	-9.850
Total issuance (US$'mil)	513.302	336.039	177.263**	78.548	21.304	333.222	2.257
Rating	12.208	12.938	-0.729	0.669	-2.057	0.599	-1.091

Table 6
Summary Statistics of the Market Data for the Sample

The table reports the summary statistics of the real-time trade price and the moneyness for the convertible bonds. The sample consists of 96 convertible bonds. *Obs* is the total number of daily observations. *MP* is the market price of the convertibles bond that is calculated as the intraday average price from the disseminated real-time trade data. The market price is reported at par US$100, though the actual face value of each convertible bond is US$1,000. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. Buyer and seller represent customer trade whereas dealer represents the inter-dealer trade, which is always a sell. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 date disseminated by TRACE-FINRA through June 30, 2011. *Moneyness* is the ratio of the stock price over the conversion price. A convertible bond with moneyness less than 0.84 is defined as debt-like (credit-sensitive), whereas a convertible bond with moneyness greater than 0.84 is defined as equity-like (equity-sensitive).

	Obs	**Mean**	**Standard deviation**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
MPAll	41,774	110.972	34.360	15.000	91.736	104.828	123.73	317.488
MPBuyer	26,756	112.035	35.644	15.000	92.753	104.500	125.019	318.037
MPSeller	24,720	111.824	35.249	18.000	93.000	104.400	125.000	316.939
MPDealer	19,634	110.031	33.545	22.500	93.040	102.979	122.000	304.935
Moneyness	41,774	0.840	0.512	0.004	0.497	0.769	1.050	4.721

Table 7
Mean Comparison between the Types of Real-time Trade Price

The table reports the test of mean differences by the types of real-time trade price (in percentage) available for the sample of 96 convertible bonds. *Obs* is the total number of daily observations. *MP* is the market price of the convertibles bond that is calculated as the intraday average price from the disseminated real-time trade data. The market price is reported at par US$100, though the actual face value of each convertible bond is US$1,000. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. Buyer and seller represent customer trade whereas dealer represents the inter-dealer trade, which is always a sell. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	MPBuyer	***MPSeller***	***MPDealer***
MPAll	-1.062***	-0.851***	0.941***
std error	0.275	0.280	0.294
t-value	-3.859	-3.039	3.198
MPBuyer		0.211	2.003***
std error		0.313	0.325
t-value		0.674	6.158
MPSeller			1.793***
std error			0.330
t-value			5.440
MPDealer			
std error			
t-value			

Table 8
Summary Statistics and Mean Comparison of the Market Data for the Subsamples Identified by the Conversion Terms

The table reports the summary statistics of the real-time trade price and the moneyness for convertible bonds. The sample is divided into two subsamples by the attached conversion terms. Panel A is for the subsample of 34 convertible bonds without provision on conversion (subsample 1) whereas Panel B is for the subsample of 62 convertible bonds with conditional conversion term (subsample 2). *Obs* is the total number of daily observations. *MP* is the market price of the convertibles bond that is calculated as the intraday average price from the disseminated real-time trade data. The market price is reported at par US$100, though the actual face value of each convertible bond is US$1,000. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. Buyer and seller represent customer trade whereas dealer represents the inter-dealer trade, which is always a sell. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. *Moneyness* is the ratio of the stock price over the conversion price. A convertible bond with moneyness less than 0.84 is defined as debt-like (credit-sensitive), whereas a convertible bond with moneyness greater than 0.84 is defined as equity-like (equity-sensitive). Panel C reports the mean differences of the subsamples. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Obs	Mean	Standard deviation	Min	First quartile	Median	Third quartile	Max
Panel A: Subsample 1 – Convertible bonds without conditional conversion								
MPAll	10,116	123.910	43.594	15.000	99.141	113.160	141.658	296.000
MPBuyer	6,654	127.922	44.417	15.000	101.502	116.263	148.111	296.000
MPSeller	6,215	127.188	44.463	18.000	102.014	115.187	146.25	288.475
MPDealer	4,761	126.497	44.617	22.500	101.000	115.000	146.551	291.033
Moneyness	10,116	0.974	0.529	0.020	0.618	0.896	1.234	2.819
Panel B:Subsample 2 – Convertible bonds with conditional conversion								
MPAll	31,608	106.811	29.630	15.400	89.968	102.125	120.500	317.488
MPBuyer	20,102	106.776	30.445	21.576	90.250	101.136	120.539	318.037
MPSeller	18,505	106.664	29.832	19.000	90.375	101.062	120.500	316.939
MPDealer	14,873	105.155	27.661	26.500	91.000	100.500	117.275	304.935
Moneyness	31,608	0.797	0.499	0.004	0.468	0.730	0.995	4.721

Panel C: Mean comparison

	Obs	Subsample 1	Obs	Subsample 2	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	10,116	123.910	31,608	106.811	17.099***	0.463	16.191	18.008	36.9019
MPBuyer	6,654	127.922	20,102	106.776	21.146***	0.585	19.999	22.293	36.128
MPSeller	6,215	127.188	18,505	106.664	20.525***	0.605	19.339	21.711	33.918
MPDealer	4,761	126.497	14,873	105.155	21.342***	0.710	19.951	22.733	30.078
Moneyness	10,116	0.974	31,608	0.797	0.177***	0.006	0.165	0.189	29.760

Table 9

Market Data for the Sample and Subsamples by Subperiods

The table reports the real-time trade price (in percentage), moneyness, and conversion premium by subperiods. *Subperiod1* is the period prior to the subprime-mortgage-related turmoil (prior to mid-August 2007). *Subperiod 2* covers the subprime-mortgage-related turmoil (from mid-August 2007 to mid-September 2008), whereas *Subperiod 3* covers from the collapse of Lehman Brothers (September 15, 2008) to mid-March 2009 (the most intense stage of the crisis). *Subperiods 4, 5* and *6* are the recovery stages, which spans from mid-March 2009 to December 2009, January to December 2010 and the first six months of 2011, respectively. Panel A shows the basic statistics of *MPAll,* and *Moneyness* for the whole sample. Panel B is for the subsample of 34 convertible bonds without provision on conversion (subsample 1) whereas Panel C is for the subsample of 62 convertible bonds with conditional conversion term (subsample 2). *Obs* is the total number of daily observations. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. *Moneyness* is the ratio of the stock price over the conversion price. A convertible bond with moneyness less than 0.84 is defined as debt-like (credit-sensitive), whereas a convertible bond with moneyness greater than 0.84 is defined as equity-like (equity-sensitive).

Observation	Obs	MPAll							Moneyness						
period		Mean	Standard Deviation	Min	First Quartile	Median	Third quartile	Max	Mean	Standard Deviation	Min	First quartile	Median	Third quartile	Max
Panel A: Overall sample															
Subperiod 1	2,875	112.119	16.465	79.048	101.622	108.497	119.244	215.058	0.909	0.359	0.238	0.720	0.894	1.033	2.748
Subperiod 2	6,458	108.483	31.777	37.611	87.295	104.952	123.161	254.178	0.920	0.691	0.150	0.543	0.752	1.049	4.72
Subperiod 3	3,328	77.560	26.995	15.000	58.675	78.384	94.738	232.19	0.543	0.363	0.020	0.303	0.509	0.724	3.387
Subperiod 4	9,159	101.393	30.633	22.625	84.000	97.058	115.313	260.313	0.717	0.423	0.041	0.410	0.664	0.915	2.535
Subperiod 5	12,896	117.255	31.112	27.594	97.153	107.531	129.583	296.000	0.863	0.467	0.004	0.503	0.794	1.142	2.727
Subperiod 6	7,058	130.162	39.742	67.983	103.185	117.411	140.343	317.488	0.997	0.528	0.023	0.674	0.926	1.223	3.068
Panel B: Subsample 1 – Convertible bonds without conditional conversion															
Subperiod 1	915	118.224	21.203	83.880	101.625	113.501	131.805	215.058	0.846	0.347	0.238	0.573	0.880	1.096	2.049
Subperiod 2	1,094	113.401	49.224	51.830	83.500	91.607	139.905	254.178	0.861	0.579	0.174	0.509	0.626	1.255	2.436
Subperiod 3	420	66.472	34.843	15.000	35.197	63.168	88.280	197.800	0.471	0.391	0.020	0.128	0.382	0.733	1.908
Subperiod 4	2,131	112.853	42.157	24.971	90.000	106.816	123.653	230.313	0.875	0.491	0.058	0.617	0.824	1.015	2.535
Subperiod 5	3,431	130.431	36.882	83.100	103.534	119.311	144.655	296.000	1.034	0.493	0.126	0.697	0.973	1.279	2.727
Subperiod 6	2,175	143.216	45.707	87.749	110.000	121.392	168.053	291.033	1.182	0.567	0.292	0.792	1.048	1.453	2.819
Panel C: Subsample 2 – Convertible bonds with conditional conversion															
Subperiod 1	1,960	109.260	12.731	79.048	101.599	107.924	115.673	180.650	0.939	0.361	0.412	0.755	0.898	1.004	2.748
Subperiod 2	5,365	107.474	26.723	37.611	88.444	106.607	122.772	246.994	0.932	0.711	0.149	0.555	0.812	1.045	4.721
Subperiod 3	2,908	79.154	25.280	15.400	61.088	79.958	94.998	232.190	0.554	0.357	0.030	0.319	0.532	0.723	3.388
Subperiod 4	7,028	97.915	25.140	22.625	83.159	93.728	111.253	200.138	0.669	0.387	0.041	0.383	0.618	0.882	2.245
Subperiod 5	9,465	112.426	27.155	27.594	95.79675	102.839	125.575	247.63	0.801	0.441	0.004	0.450	0.738	1.067	2.471
Subperiod 6	4,883	124.200	35.122	67.983	101.113	116.169	132.523	317.488	0.914	0.488	0.023	0.589	0.857	1.161	3.068

Table 10

Mean Comparison for the Market Data for the Sample by Subperiods

The table reports the mean differences of the real-time trade price and moneyness by subperiods for the sample of 96 convertible bonds. *Subperiod1* is the period prior to the subprime-mortgage-related turmoil (prior to mid-August 2007). *Subperiod2* covers the subprime-mortgage-related turmoil (from mid-August 2007 to mid-September 2008), whereas *Subperiod3* covers from the collapse of Lehman Brothers (September 15, 2008) to mid-March 2009 (the most intense stage of the crisis). *Subperiods 4, 5* and *6* are the recovery stages, which spans from mid-March 2009 to December 2009, January to December 2010 and the first six months of 2011, respectively. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. *Moneyness* is the ratio of the stock price over the conversion price. Ratios between 0.9 and 1.1 denote at-the-money convertible bond. A convertible bond with moneyness less than 0.84 is defined as debt-like (credit-sensitive), whereas a convertible bond with moneyness greater than 0.84 is defined as equity-like (equity-sensitive). A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Subperiod 2		**Subperiod 3**		**Subperiod 4**		**Subperiod 5**		**Subperiod 6**	
	MPAll	*Moneyness*	*MPAll*	*Moneyness*	*MPAll*	*Moneyness*	*MPAll*	*Moneyness*	*MPAll*	*Moneyness*
Subperiod 1										
mean diff	-3.635***	0.108	-34.559***	-0.366***	-10.725***	-0.192***	5.136***	-0.047***	18.043***	0.088***
std error	0.502	0.011	0.557	0.009	0.444	0.008	0.413	0.008	0.568	0.009
t-value	-7.240	0.990	-62.030	-39.928	-24.151	-23.915	12.441	-5.917	31.779	9.524
Subperiod 2										
mean diff			-30.924***	-0.377***	-7.090***	-0.203***	8.771***	-0.057***	21.679***	0.077***
std error			0.611	0.011	0.510	0.010	0.483	0.010	0.620	0.011
t-value			-50.637	-35.400	-13.911	-20.955	18.171	-6.009	34.942	7.194
Subperiod 3										
mean diff					23.834***	0.174***	39.695***	0.319***	52.602***	0.454***
std error					0.564	0.008	0.540	0.007	0.666	0.009
t-value					42.252	22.734	73.552	42.743	79.016	51.219
Subperiod 4										
mean diff							15.861***	0.146***	28.769***	0.280***
std error							0.422	0.006	0.574	0.008
t-value							37.586	24.129	50.079	36.426
Subperiod 5										
mean diff									12.907***	0.134***
std error									0.551	0.008
t-value									23.439	17.865

Table 11
Payoff Structure of Convertible Bonds

The table summarises the payoff structure of convertible bonds at maturity and prior to maturity subject to the boundary conditions. The first column lists the optimal strategies to be undertaken when the boundary conditions are met. Time restriction indicates the set of time in which conversion can be exercised, as stated in the issuance contract. Four outcomes are identified. $C(\omega, s;\ t, T)$ is the payoff from convertible bond in state X_t at time t, F is the final redemption value, $n_T S_T$ is the conversion value at maturity date, $n_{t_k} S_{t_k}$is the conversion value at any time prior to maturity, and $F(\omega; t_k)$ is the continuation value that is the value of a convertible bond which is not exercised immediately. Ω_{conv} is the time restriction to exercise the embedded conversion option.

Optimal outcome	Payoff $\boldsymbol{C(\omega, s;\ t, T)}$	Boundary condition	Time restriction
Redemption (at maturity)	F	$F > n_T S_T$	$For\ t = T \in \Omega_{conv}$
Conversion (at maturity)	$n_T S_T$	$n_T S_T < F$	$For\ t = T \in \Omega_{conv}$
Voluntary conversion	$n_{t_k} S_{t_k}$	$n_{t_k} S_{t_k} >\ F(\omega; t_k)$	$For\ t \in \Omega_{conv}$
Continuation	0	Otherwise	

Table 12
Estimated Parameters for the CEV Model

The table summarises the descriptive statistics of the estimated parameters, *a* and *b* from equation (7). Panel A shows the summary statistics for the overall sample of 96 convertible bonds. Panel B is the subsample of 34 convertible bonds without provision on conversion whereas Panel C is the subsample of 62 convertible bonds with conditional conversion term. A superscript * , ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively. Equation (7) is as follows.

$$ln\left|ln\frac{S_{t+1}}{S_t}\right| = a + blnS_t + u_t$$

	Mean	**Standard deviation**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Panel A: Overall sample							
a	-3.275***	3.480	-14.472	-5.101	-2.393	-1.376	7.064
t-value	-3.114	3.069	-11.530	-5.105	-2.410	-0.910	3.460
b	-0.372*	1.007	-3.438	-0.954	-0.522	0.173	2.577
t-value	-1.692	2.771	-7.690	-3.545	-1.350	0.225	5.360
R^2	0.008	0.306	-2.920	1.696	1.854	1.928	0.198
Panel B: Subsample 1 – Convertible bonds without conditional conversion							
a	-2.735***	2.900	-11.392	-3.783	-2.162	-0.952	2.014
t-value	-3.562	3.528	-11.530	-6.030	-2.315	-1.210	2.120
b	-0.507**	0.920	-1.909	-1.080	-0.700	-0.165	2.118
t-value	-2.441	2.569	-7.030	-3.780	-2.430	-0.780	1.960
R^2	0.046	0.045	0.000	0.013	0.031	0.056	0.153
Panel C: Subsample 2 – Convertible bonds with conditional conversion							
A	-3.571***	3.750	-14.472	-5.693	-3.650	-1.800	7.064
t-value	-2.869	2.786	-10.060	-4.990	-2.410	-0.870	3.460
B	-0.298	1.052	-3.438	-0.842	-0.360	0.258	2.577
t-value	-1.281	2.811	-7.690	-3.220	-0.600	0.410	5.360
R^2	0.035	0.379	0.000	0.001	0.009	0.052	0.198

Table 13
Mean Comparison and Average Mispricing by the Pricing Models

The table reports the mean difference of average mispricing with the *Risk Neutral* as the base model. The *CIR* model is the Cox, Ingersoll and Ross (1985) stochastic interest rate model (Panel A). The *TF* model is the Tsiveriotis and Fernandes (1998) credit risk model, in which the credit spread is measured by the credit rating of the convertible bond or the issuing firm when the bond rating is not available (Panel B). The *CEV* model and *GARCH (1,1)* models capture non-constant volatility (Panels C to E). The *CEV* model is the constant elasticity of variance model by (Cox, 1975, 1996) with beta = 1 and beta = 0. The $CEV_{\beta=1}TF$ model captures both the stochastic volatility and credit risk in the pricing of convertible bonds (Panel F). *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the risk neutral and stochastic interest rate models

	Obs	**Risk Neutral**	**Obs**	**CIR**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	41,774	-18.802	-0.169	0.183	-0.714	0.377	-0.605
MPBuyer	26,756	-19.215	26,756	-19.192	-0.023	0.348	-0.704	0.658	-0.067
MPSeller	24,720	-18.468	24,720	-18.474	0.006	0.360	-0.699	0.710	0.016
MPDealer	19,634	-17.389	19,634	-17.740	0.351	0.365	-0.365	1.067	0.960

Panel B: Mean comparison between the risk neutral and credit risk models

	Obs	**Risk Neutral**	**Obs**	**TF**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	41,774	-17.304	-1.667***	0.254	-2.164	-1.169	-6.565
MPBuyer	26,756	-19.215	26,756	-17.473	-1.742***	0.303	-2.337	-1.149	-5.752
MPSeller	24,720	-18.468	24,720	-16.773	-1.695***	0.310	-2.302	-1.087	-5.468
MPDealer	19,634	-17.389	19,634	-15.911	-1.478***	0.340	-2.144	-0.812	-4.348

Panel C: Mean comparison between the risk neutral and non-constant volatility models

	Obs	**Risk Neutral**	**Obs**	**CEV beta=1**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	41,774	-8.307	-10.664***	0.259	-11.172	-10.156	-41.144
MPBuyer	26,756	-19.215	26,756	-7.944	-11.271***	0.309	-11.877	-10.665	-36.446
MPSeller	24,720	-18.468	24,720	-7.697	-10.771***	0.317	-11.392	-10.151	-34.015
MPDealer	19,634	-17.389	19,634	-7.244	-10.145***	0.348	-10.827	-9.463	-29.142

Panel D: Mean comparison between the risk neutral and non-constant volatility models

	Obs	**Risk Neutral**	**Obs**	**CEV beta=0**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	41,774	-8.332	-10.639***	0.268	-11.164	-10.114	-39.724
MPBuyer	26,756	-19.215	26,756	-7.921	-11.294***	0.321	-11.923	-10.666	-35.221
MPSeller	24,720	-18.468	24,720	-7.836	-10.632***	0.332	-11.283	-9.981	-32.025
MPDealer	19,634	-17.389	19,634	-7.506	-9.883***	0.372	-10.611	-9.155	-26.596

Panel E: Mean comparison between the risk neutral and non-constant volatility models

	Obs	Risk Neutral	Obs	GARCH (1,1)	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	41,774	-18.971	41,774	-9.924	-9.047***	0.260	-9.556	-8.537	-34.827
MPBuyer	26,756	-19.215	26,756	-9.812	-9.403***	0.310	-10.011	-8.795	-30.316
MPSeller	24,720	-18.468	24,720	-9.606	-8.862***	0.318	-9.486	-8.239	-27.875
MPDealer	19,634	-17.389	19,634	-8.620	-8.769***	0.350	-9.455	-8.083	-25.053

Panel F: Mean comparison between the risk neutral and stochastic volatility and credit risk model

	Obs	Risk Neutral	Obs	$CEV_{\beta=1}$TF	Mean difference	Standard error	95% Confidence interval		t-value
MPAll	41,774	-18.971	41,774	-6.310	-12.661***	0.255	-13.161	-12.162	-49.698
MPBuyer	26,756	-19.215	26,756	-5.981	-13.234***	0.303	-13.828	-12.641	-43.694
MPSeller	24,720	-18.468	24,720	-5.657	-12.811***	0.310	-13.419	-12.204	-41.339
MPDealer	19,634	-17.389	19,634	-5.402	-11.987***	0.339	-12.651	-11.323	-35.382

Table 14

Mean Comparison of Average Mispricing between the Stochastic Volatility Models

The table reports the differences in the average mispricing between the stochastic volatility models. Three models are considered, i.e. the CEV models when the elasticity (beta) equals to 1 and 0 together with the GARCH (1,1) model. *Obs* is the total number of daily observations. From November 2008, TRACE-FINRA disseminates the real-time trade price by three reporting parties, i.e. the buyer *(MPBuyer)*, seller *(MPSeller)* and dealer *(MPDealer)*. *MPAll* reports the average for the overall period, i.e. from October 26, 2004 through June 30, 2011. A negative *MD* signifies an underpricing. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Panel A: Mean comparison between the CEV models with different measure of elasticity

	Obs	**CEV beta=1**	**Obs**	**CEV beta=0**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-8.307	41,774	-8.332	0.025	0.268	-0.501	0.550	0.091
MPBuyer	26,756	-7.944	26,756	-7.921	-0.024	0.319	-0.648	0.601	-0.075
MPSeller	24,720	-7.697	24,720	-7.836	0.139	0.331	-0.510	0.789	0.420
MPDealer	19,634	-7.244	19,634	-7.506	0.262	0.372	-0.467	0.991	0.704

Panel B: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=1**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-8.307	41,774	-9.924	1.617***	0.260	1.107	2.127	6.219
MPBuyer	26,756	-7.944	26,756	-9.812	1.868***	0.308	1.264	-0.858	6.063
MPSeller	24,720	-7.697	24,720	-9.606	1.909***	0.317	1.287	2.531	6.016
MPDealer	19,634	-7.244	19,634	-8.620	1.376***	0.351	0.689	2.063	3.926

Panel C: Mean comparison between the CEV and GARCH(1,1) models

	Obs	**CEV beta=0**	**Obs**	**GARCH (1,1)**	**Mean difference**	**Standard error**	**95% Confidence interval**		**t-value**
MPAll	41,774	-8.332	41,774	-9.924	1.593***	0.269	1.066	2.119	5.928
MPBuyer	26,756	-7.921	26,756	-9.812	1.892***	0.320	1.265	2.518	5.920
MPSeller	24,720	-7.836	24,720	-9.606	1.770***	0.333	1.118	2.422	5.320
MPDealer	19,634	-7.506	19,634	-8.620	1.114***	0.374	0.382	1.847	2.981

Table 15

Mispricing of Convertible Bonds by the Identified Subperiods

The table reports the mean deviation (MD) and standard deviation (SD) in percentage (%) of the *MPAll*, i.e. the real-time trade price available from October 26, 2004 through June 30, 2011 by the identified subperiods. The *CIR* model is the Cox, Ingersoll and Ross (1985) stochastic interest rate model. The *TF* model is the Tsiveriotis and Fernandes (1998) credit risk model, in which the credit spread is measured by the credit rating of the convertible bond or the issuing firm when the bond rating is not available. The $CEV_{\beta=1}$ model captures non-constant volatility when the elasticity equals to 1. The $CEV_{\beta=1}TF$ model captures both the stochastic volatility and credit risk in the pricing of convertible bonds. *Obs* is the total number of daily observations. *Subperiod 1* is the period prior to the subprime-mortgage-related turmoil (prior to mid-August 2007). *Subperiod 2* covers the subprime-mortgage-related turmoil (from mid-August 2007 to mid-September 2008), whereas *Subperiod 3* covers from the collapse of Lehman Brothers (September 15, 2008) to mid-March 2009 (the most intense stage of the crisis). Subperiods 4, *5* and *6* are the recovery stages, which span from mid-March 2009 to December 2009, January to December 2010 and the first six months of 2011, respectively.

Observation periods	**Obs**	**Risk Neutral**		**CIR**		**TF**		**$CEV_{\beta=1}$**		**$CEV_{\beta=1}TF$**	
		MD	**SD**	**MD**	**SD**	**MD**	**SD**	**MD**	**SD**	**MD**	**SD**
Subperiod 1	2,875	-6.523	21.352	-6.675	21.444	-5.109	21.514	3.244	21.11	5.033	21.800
Subperiod 2	6,458	-19.840	45.238	-18.802	45.788	-18.217	44.896	-10.978	46.860	-9.306	46.500
Subperiod 3	3,328	-53.158	38.906	-52.047	69.702	-50.400	65.245	-44.989	70.550	-42.208	67.082
Subperiod 4	9,159	-26.295	38.094	-26.717	55.775	-24.230	34.185	-14.074	37.118	-11.608	35.951
Subperiod 5	12,896	-13.149	21.668	-13.145	24.309	-11.727	22.345	-1.845	20.185	0.061	19.413
Subperiod 6	7,058	-8.342	19.911	-8.180	22.804	-7.127	19.830	2.255	18.294	3.818	17.785

Table 16

Mean Comparison between the *Risk Neutral* and $CEV_{\beta=1}$ models by Level of Volatility (by quintiles)

The table reports the mean difference between the *Risk Neutral* and $CEV_{\beta=1}$ models at different level of volatility sorted by quintiles. *Initial volatility* is the estimated parameter used to determine the stock dynamics in both the *Risk Neutral* and $CEV_{\beta=1}$ models, measured by the standard deviation of the underlying stock returns. The level of the initial volatility is ranked by quintiles. *MAD* is the mean absolute deviation, also an indicator of model fit, which takes into account the deviations from market prices (*MPAll*) from both sides. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Quintile	Initial volatility		MAD Risk neutral		MAD CEV beta=1		Mean difference		
	Mean	Standard error	Mean	Standard error	Mean	Standard error	Mean	Standard error	t-value
1	23.803	0.885	14.035	4.482	14.280	4.388	-0.244	1.545	-0.158
2	31.797	0.679	17.080	3.401	15.665	2.751	1.415	1.625	0.870
3	45.006	1.201	26.519	3.503	19.182	3.972	7.337***	1.336	5.490
4	69.566	2.169	30.868	5.076	19.228	4.863	11.640***	2.552	4.562
5	108.691	4.539	26.497	5.612	14.234	5.550	12.263***	2.595	4.725

Table 17
Correlation Matrix

The table reports the correlation matrix for the identified explanatory variables to explain the mispricing of convertible bonds. *LNTotal* is the issuance size measured by natural log of total issuance including oversubscription, if there is any. *LNTrade* measures how frequently a convertible bond trades in a day, on average. *DOver* is a dummy equals to one if the convertible bond is oversubscribed at issuanceand zero otherwise. *Dequity* is a dummy equals to one for an equity-like convertible bond and zero for a debt-like convertible bond. *LNTmat* is the natural log of time to maturity in years. *Rcode,* the rating code is a numerical value assigned to Moody's rating. The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21. *Crsprd* is the credit spread, estimated using the rating of each convertible bond or the credit rating of the issuer when the convertible bond is not rated. *Vol* measures the volatility of underlying stock returns. *Div* is the dividend yield, whereas *Coupon* is the coupon rate of the convertible bond. *Dcond* is the dummy equals to one if the convertible bond is issued with conditional conversion and zero otherwise. *Dfin* equals to one if the issuer is a financial firm and zero otherwise. *Dcrisis* is a dummy equals to one if the trade is executed during the extreme crisis period covering from September 15, 2008 to March 15, 2009, and zero otherwise. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	LNTotal	**LNTrade**	**Dover**	**Dequity**	**LNTmat**	**Rcode**	**Crsprd**	**Vol**	**Div**	**Coupon**	**Dcond**	**Dfin**	**Dcrisis**
LNTotal	1.000												
LNTrade	0.099***	1.000											
Dover	-0.008	-0.147***	1.000										
Dequity	0.189***	-0.062***	0.089***	1.000									
LNTmat	-0.002	0.013***	0.034***	0.057***	1.000								
Rcode	-0.329***	-0.322***	0.150***	-0.229***	0.042***	1.000							
Crsprd	-0.168***	-0.235***	0.296***	0.113***	0.061***	0.591***	1.000						
Vol	-0.121***	-0.143***	0.424***	0.229***	-0.114***	0.206***	0.683***	1.000					
Div	0.035***	-0.046***	0.233***	0.169***	-0.092***	-0.133***	0.097***	0.176***	1.000				
Coupon	-0.227***	-0.043***	0.304***	0.128***	-0.166***	0.098***	0.177***	0.281***	0.155***	1.000			
Dcond	0.218***	0.086***	-0.197***	-0.139***	-0.051***	-0.070***	-0.298***	-0.285***	-0.112***	-0.116***	1.000		
Dfin	-0.030***	-0.063***	0.000	-0.055***	-0.100***	-0.020***	0.074***	0.230***	0.162***	0.028***	-0.066***	1.000	
Dcrisis	-0.003	0.030***	-0.051***	-0.172***	0.121***	-0.012***	-0.124**	-0.139***	-0.043***	-0.045***	0.080***	-0.052***	1.000

Table 18

Regression Results

The table reports the results of the regression analysis. The mispricing is measured by mean deviation that provides the direction of the mispricing. *LNTotal* is the issuance size measured by natural log of total issuance including oversubscription, if there is any. *LNTrade* measures how frequently a convertible bond trades in a day, on average. *DOver* is a dummy equals to one if the convertible bond is oversubscribed at issuance and zero otherwise. *Dequity* is a dummy equals to one for an equity-like convertible bond and zero for a debt-like convertible bond. *LNTmat* is the natural log of time to maturity in years. *Rcode,* the rating code is a numerical value assigned to Moody's rating. The numerical values for credit ratings are: Aaa = 1, Aa1 = 2, Aa2 = 3, Aa3 = 4, A1 = 5, A2 = 6, A3 = 7, Baa1 = 8, Baa2 = 9, Baa3 = 10, Ba1 = 11, Ba2 = 12, Ba3 = 13, B1 = 14, B2 = 15, B3 = 16, Caa1 = 17, Caa2 = 18, Caa3 = 19, Ca = 20, C = 21. *Vol* is the volatility of the underlying stock return and *Div* is the dividend yield of the underlying stock. *Coupon* is the coupon rate of the convertible bond. *Dcond* is a dummy equals to one if the convertible bond is issued with conditional conversion and zero otherwise. *Dfin* equals to one if the issuer is a financial firm and zero otherwise. *Dcrisis* is a dummy equals to one if the trade is executed during the extreme crisis period covering from September 15, 2008 to March 15, 2009, and zero otherwise. *MPA* is the mispricing observed from October 26, 2004 through June 30, 2011. *MPB*, *MPS* and *MPD* are the mispricing by reporting parties, namely the buyer, seller and dealer, respectively. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

Variables	Mean Deviation			
	MPA	**MPB**	**MPS**	**MPD**
Constant	-0.106***	-0.193***	-0.188***	-0.072***
	(-7.70)	(-12.87)	(-11.65)	(-3.97)
LNTotal	0.049***	0.058***	0.055***	0.041***
	(35.33)	(36.44)	(32.48)	(21.92)
LNTrade	-0.037***	-0.024***	-0.036***	-0.028***
	(-21.02)	(-9.18)	(-12.55)	(-9.16)
Dover	0.017***	-0.004	-0.015***	0.012*
	(4.43)	(-0.83)	(-2.84)	(1.89)
Dequity	0.037***	0.076***	0.071***	0.038***
	(9.72)	(17.40)	(13.27)	(6.30)
LNTmat	-0.034***	-0.019***	-0.015***	-0.022***
	(-9.82)	(-4.89)	(-3.23)	(-4.00)
Rcode	-0.010***	-0.016***	-0.014***	-0.021***
	(-17.64)	(-24.19)	(-19.03)	(-24.20)
Vol	-0.051***	-0.010	-0.017*	0.056***
	(-7.79)	(-1.42)	(-1.93)	(4.85)
Div	-0.837***	-1.348***	-1.093***	0.030
	(-6.78)	(-9.90)	(-6.84)	(0.14)
Coupon	-0.064	-0.009	0.100*	-0.389***
	(-1.26)	(-0.18)	(1.74)	(-5.62)
Dcond	0.015***	0.040***	0.041***	0.066***
	(3.59)	(8.53)	(7.44)	(9.25)
Dfin	0.088***	0.086***	0.094***	0.022**
	(13.16)	(11.92)	(11.45)	(2.04)
Dcrisis	-0.382***	-0.401***	-0.383***	-0.354***
	(-61.79)	(-57.24)	(-47.16)	(-38.44)
Adj R-squared	0.159	0.237	0.233	0.229
RMSE	0.332	0.298	0.303	0.290

Figure 1
Market Data of US Government Bonds as at July 27, 2011.

The figure shows the coupon rate and maturity date for different maturities of US government bonds. The figure is sourced from Bloomberg on July 27, 2011. Note that the issuance of long term bonds stopped temporarily. Short term Treasury bills are not affected as indicated by the maturity date. For the 5-year and 7-year bonds, the issuance temporarily stopped on June 30, 2011 indicated by the maturity date.

Government Bonds
U.S. UK Germany Japan Hong Kong Australia Brazil

U.S. Treasuries

	COUPON	MATURITY	PRICE/YIELD	PRICE/YIELD CHANGE	TIME
3-Month	0.000	10/27/2011	0.07 / 0.07	0.000 / 0.000	00:16
6-Month	0.000	01/26/2012	0.11 / 0.11	0.005 / 0.005	00:16
12-Month	0.000	06/28/2012	0.19 / 0.19	0.000 / 0.000	00:16
2-Year	0.375	06/30/2013	99-30¾ / 0.41	-0-00+ / 0.006	00:16
3-Year	0.625	07/15/2014	99-28+ / 0.66	-0-01½ / 0.016	00:15
5-Year	1.500	06/30/2016	100-00½ / 1.50	-0-02+ / 0.017	00:15
7-Year	2.375	06/30/2018	100-28 / 2.24	-0-03 / 0.015	00:15
10-Year	3.125	05/15/2021	101-09¾ / 2.97	-0-04¾ / 0.017	00:16
30-Year	4.375	05/15/2041	101-11+ / 4.29	-0-06 / 0.011	00:15

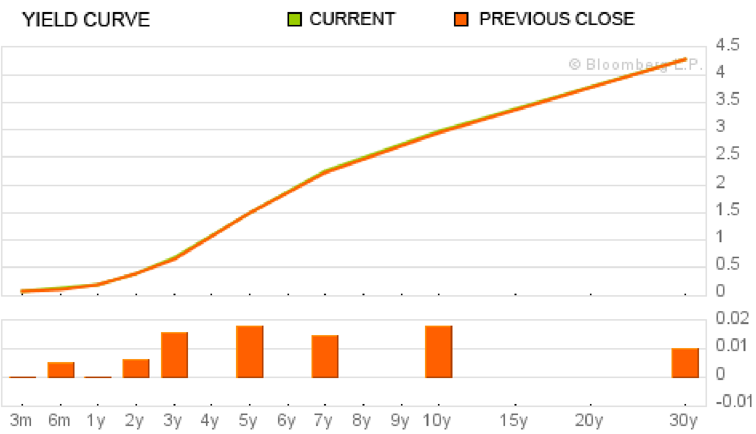
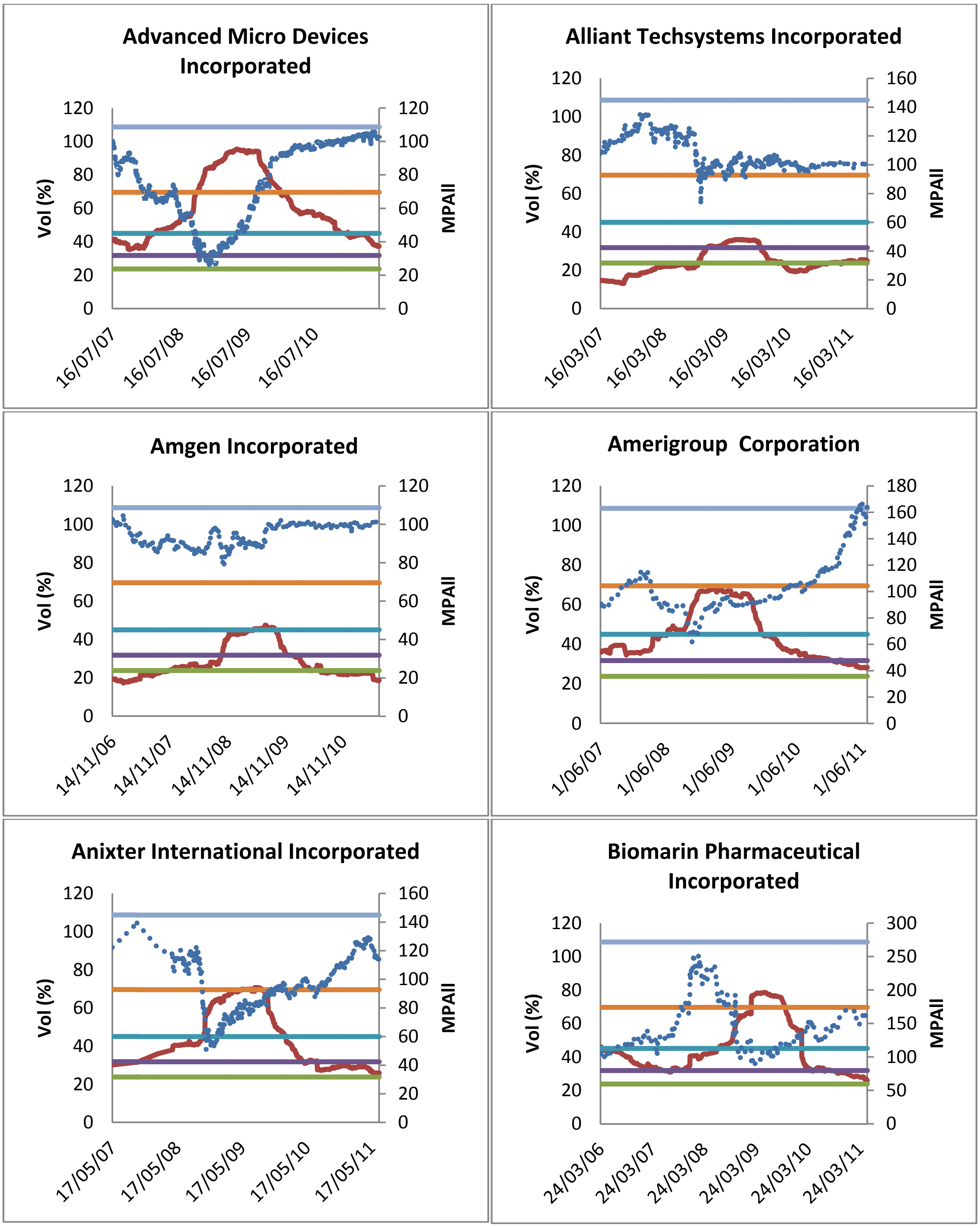
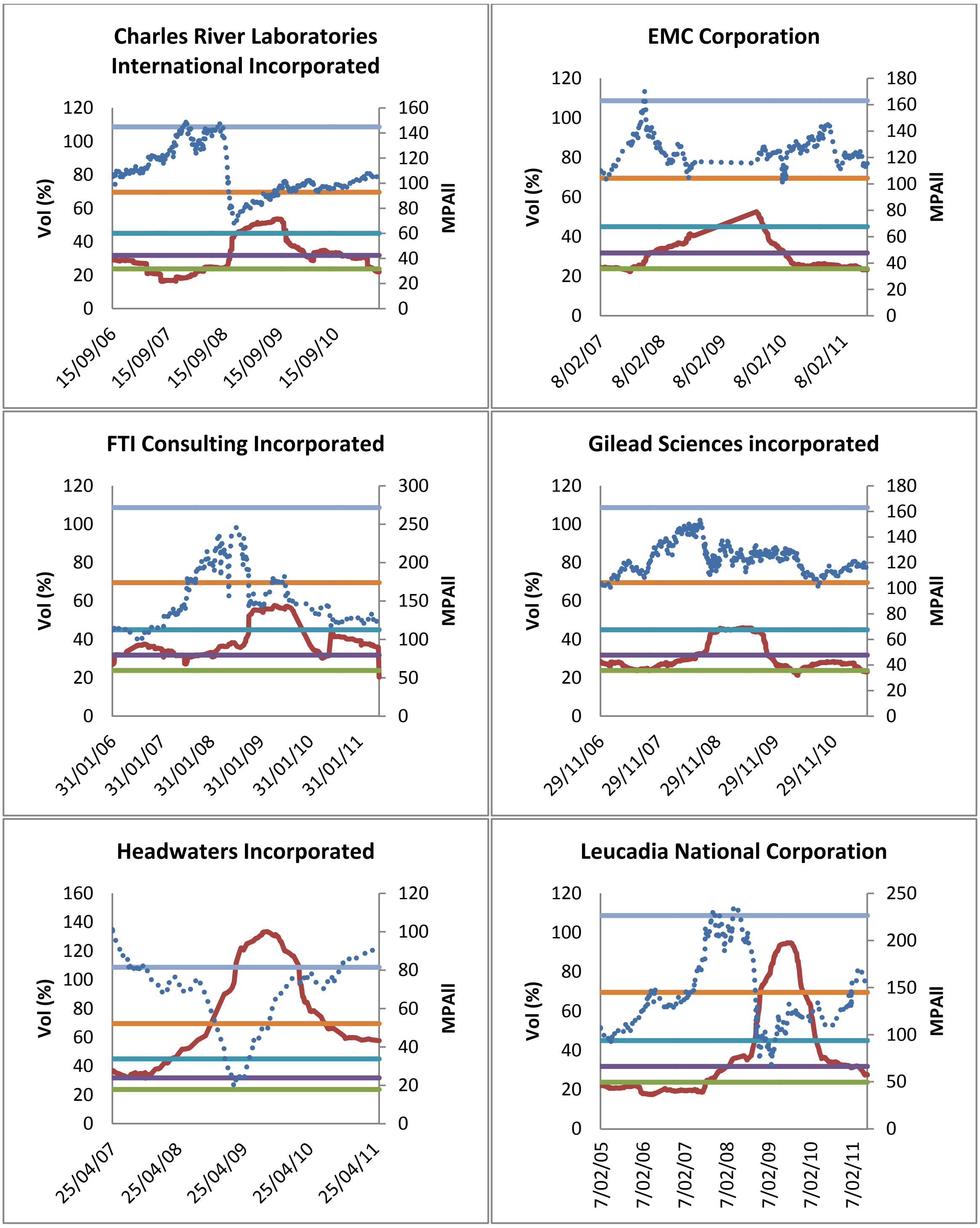


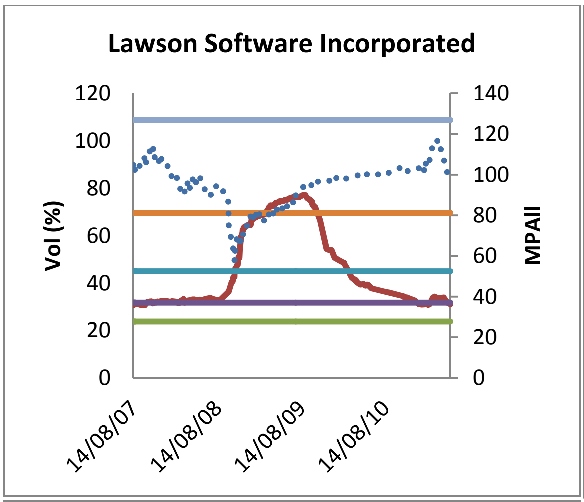
Figure 2

Relation between Rolling-sample Volatility and Real-time Trade Price of Individual Convertible Bond

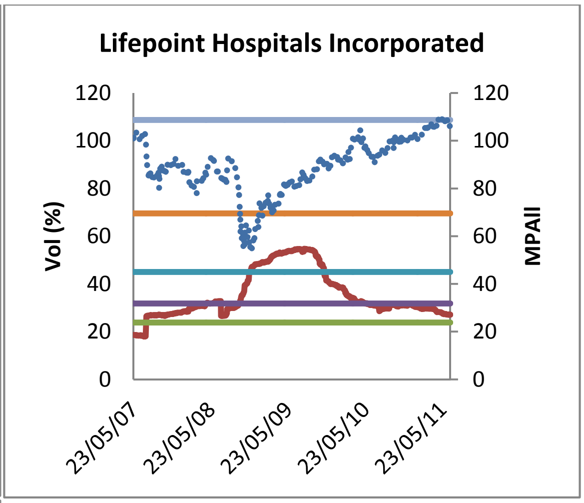
The charts plot the relation between the rolling-sample volatility and real-time trade price on daily basis, from the first trade date to June 30, 2011. Out of the sample, 24 convertible bonds provide complete observations by all the subperiods identified in the study, which include prior to subprime-mortgage related turmoil, during the subprime mortgage related turmoil, collapse of Lehman Brothers, and the recovery stages. The y-axis on the left represents the level of volatility in percentage, whereas the y-axis on the right represents the level of real-time trade price in US$, measured by *MPAll*. The five horizontal lines are the means of initial volatility determined from the whole sample, ranked by quintiles. The lowest line represents the mean volatility of the first quintile and follows on until the fifth quintile. The initial volatility is calculated from the daily stock returns of 252 trading days prior to the first trade date reported to TRACE-FINRA and is assumed to be constant. The solid line and dotted line plot the rolling-sample volatility and real-time trade price, respectively.



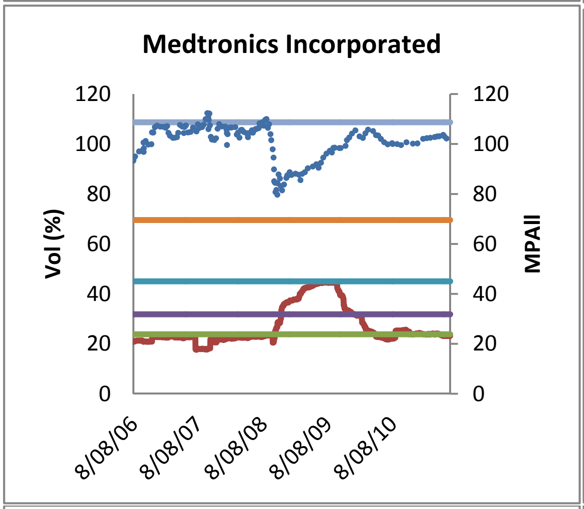

Charles River Laboratories International Incorporated
Vol (%)
MPAII
15/09/06
15/09/07
15/09/08
15/09/09
15/09/10
EMC Corporation
8/02/07
8/02/08
8/02/09
8/02/10
8/02/11
FTI Consulting Incorporated
31/01/06
31/01/07
31/01/08
31/01/09
31/01/10
31/01/11
Gilead Sciences incorporated
29/11/06
29/11/07
29/11/08
29/11/09
29/11/10
Headwaters Incorporated
25/04/07
25/04/08
25/04/09
25/04/10
25/04/11
Leucadia National Corporation
7/02/05
7/02/06
7/02/07
7/02/08
7/02/09
7/02/10
7/02/11



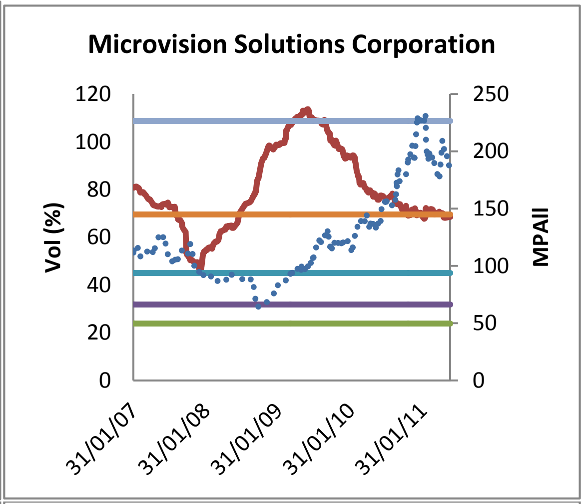
Lawson Software Incorporated
Vol (%)
MPAII
14/08/07
14/08/08
14/08/09
14/08/10



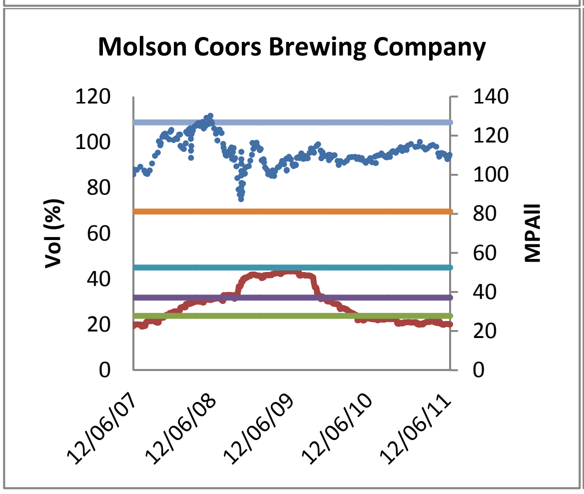
Lifepoint Hospitals Incorporated
Vol (%)
MPAII
23/05/07
23/05/08
23/05/09
23/05/10
23/05/11



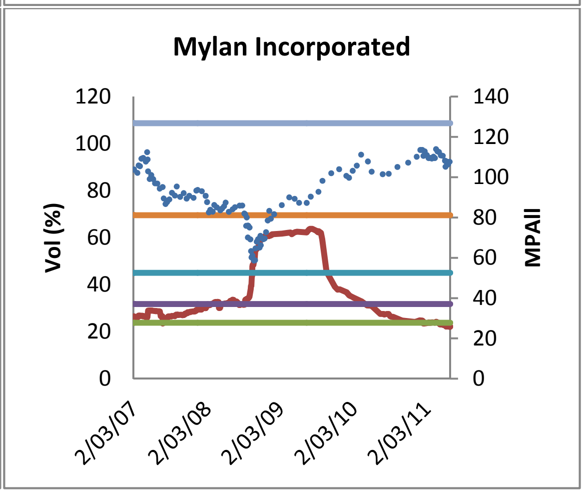
Medtronics Incorporated
Vol (%)
MPAII
8/08/06
8/08/07
8/08/08
8/08/09
8/08/10



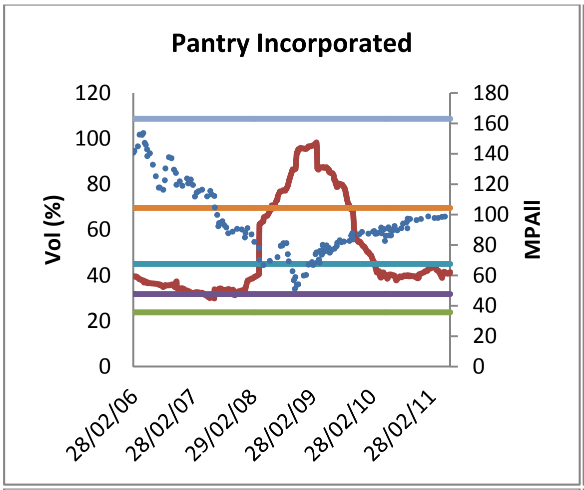
Microvision Solutions Corporation
Vol (%)
MPAII
31/01/07
31/01/08
31/01/09
31/01/10
31/01/11

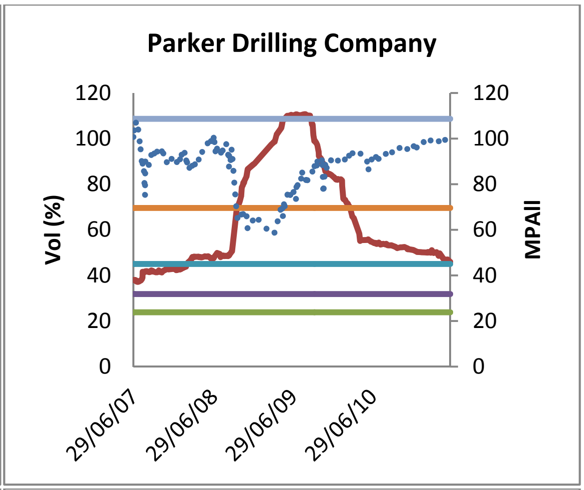


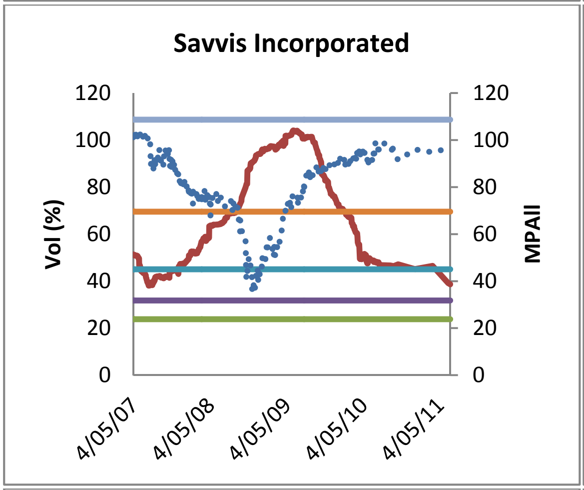
Molson Coors Brewing Company
Vol (%)
MPAII
12/06/07
12/06/08
12/06/09
12/06/10
12/06/11

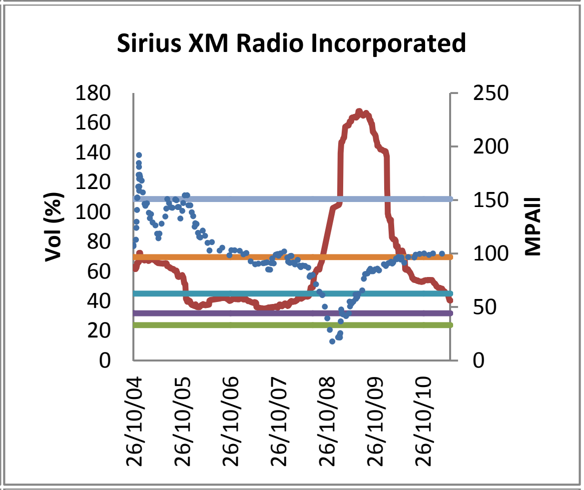


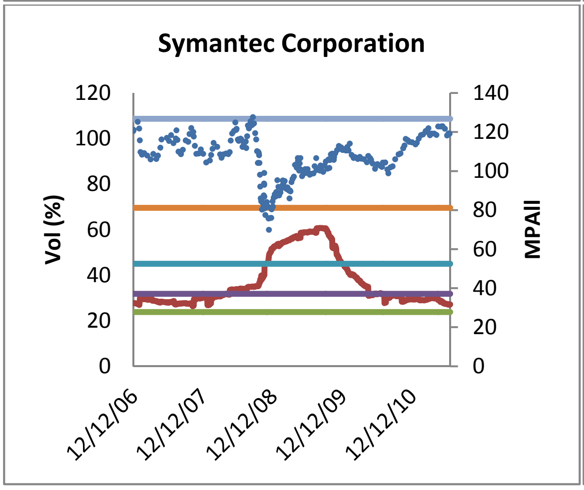
Mylan Incorporated
Vol (%)
MPAII
2/03/07
2/03/08
2/03/09
2/03/10
2/03/11

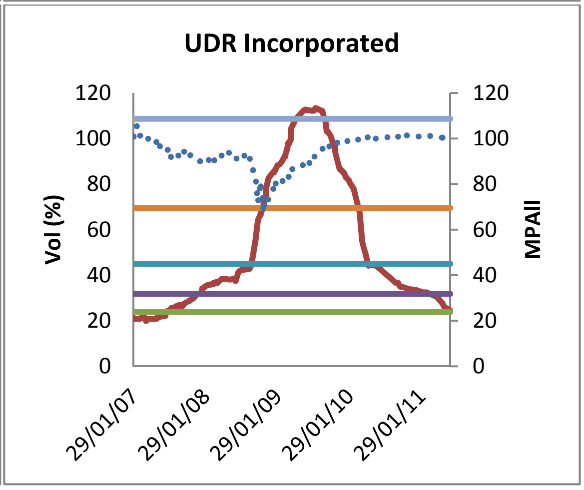

Pantry Incorporated
Vol (%)
MPAII
0
20
40
60
80
100
120
180
160
140
120
100
80
60
40
20
0
28/02/06
28/02/07
29/02/08
28/02/09
28/02/10
28/02/11


Parker Drilling Company
Vol (%)
MPAII
0
20
40
60
80
100
120
29/06/07
29/06/08
29/06/09
29/06/10


Savvis Incorporated
Vol (%)
MPAII
0
20
40
60
80
100
120
4/05/07
4/05/08
4/05/09
4/05/10
4/05/11


Sirius XM Radio Incorporated
Vol (%)
MPAII
180
160
140
120
100
80
60
40
20
0
250
200
150
100
50
0
26/10/04
26/10/05
26/10/06
26/10/07
26/10/08
26/10/09
26/10/10


Symantec Corporation
Vol (%)
MPAII
0
20
40
60
80
100
120
140
12/12/06
12/12/07
12/12/08
12/12/09
12/12/10


UDR Incorporated
Vol (%)
MPAII
0
20
40
60
80
100
120
29/01/07
29/01/08
29/01/09
29/01/10
29/01/11