Convertible Bonds from the Investment and Financing Perspectives

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ABSTRACT

This thesis examines the hybrid features, particularly the equity options, of convertible bonds from both the investment and financing perspectives. First, this thesis presents a survey of the theoretical and empirical aspects of convertible bond pricing to identify those areas of research that may improve the valuation process. The pricing of these securities is compromised by the presence of complex option features and difficulty in clearly measuring those risk factors needed as inputs to standard option models. As a result, various empirical studies identify pricing errors that vary with the sample period, valuation method and assumptions made. Accordingly, this thesis provides valuable insights into the degree of mispricing, using a unique sample of pure US convertible bonds that controls for the complex optionality present in these securities. When applied to real-time trade prices, an underpricing of 6.31% is reported for daily data from October 26, 2004 to June 30, 2011. The stochastic nature of volatility is shown to have a significant impact on the pricing of convertible bonds, while liquidity is also an important explanatory variable. The deep underpricing during the Global Financial Crisis highlights the importance of market conditions and the temporal rather than systematic nature of the pricing errors. Alternately, from the financing perspective, this thesis investigates the motivation for the issuance of convertible bonds by multinational corporations (MNCs). One benefit of internationalisation is the ability to diversify the source and type of debt, although doing so incurs agency costs. Consequently, to mitigate these costs, existing studies find that MNCs typically have lower debt ratios than domestic corporations. One key limitation of these studies is their failure to recognise the heterogeneity of debt, specifically the equity options that may be present in the bonds issued by MNCs. Results show the way debt heterogeneity can be used to

mitigate the agency costs that arise from international financing. Debt heterogeneity is in fact linked to internationalisation and a desire of the MNC to mitigate agency costs. The results hold after controlling for market conditions including the recent Global Financial Crisis and the subsequent period of quantitative easing.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

This chapter discusses the background of this thesis, which consists of three essays. In particular, it discusses the motivations and contributions of each of the three essays. The chapter concludes by outlining the structure of the overall thesis.

1.1 Introduction

Convertible bonds are an important segment of the corporate bond market with global outstanding convertible bonds approaching US$235 billion as at 2011 (refer Table 2.1). Though the nominal value is significant, these securities remain a relatively small segment of the total corporate bonds, about 3.3% in 2011. Also, in terms of research, this subject is not getting extensive attention as compared to bonds and equities. Therefore, this thesis, consisting of three essays, helps to fill this gap by presenting a comprehensive study of convertible bonds. This thesis is structured to provide additional insight, specifically on the equity options of these securities, from both the investment and financing perspectives.

A convertible bond is a hybrid derivative instrument, which shares some characteristics of bond and equity. The fixed-income (straight bond) component enables a convertible bond investor to receive fixed coupon payments periodically and the principal repayment upon maturity. On the other hand, the investor is given the option to forgo the fixed-income component by converting the convertible bond into shares of stock of the issuing firm at a predetermined conversion ratio. Therefore, a convertible bond is equivalent to a bond with an embedded call option on the firm's stock. A convertible bond can also be issued with callable (at the option of issuer) and puttable (at the option of investor) features. These provisions act as a sweetener to increase the attractiveness of convertible bonds either as an investment or financing choice.

Along with the conversion privilege, three basic terms of convertible bond are defined: first, conversion ratio is the number of common shares received, if converted, for each convertible bond. Usually, conversion ratio is prespecified at issuance and is fixed, but it changes in case of an alteration of the nominal value of the underlying stock, extraordinary dividend payments and other financial operations that may directly affect the stock price (Ammann, Kind, and Wilde, 2008); second, conversion price is the price per share, at which stock will be exchanged for a convertible bond. It is usually adjusted for any stock splits or stock dividends to protect the convertible bond investors from dilution; third, conversion value (also termed as parity or equity value) is the value of a convertible bond in terms of the common stock into which the security can be converted.

Conceptually, the hybrid feature of convertible bonds benefits both the investors and issuers. For the investor, investing in a convertible bond is more secured than stock because the equity option offers an upside potential through capital earnings should the stock price increase, whereas the fixed-income component offers a downside protection should the stock price decrease. But, the trade-off is lower yield to maturity than the non-convertible equivalent. For the issuer, a convertible bond offers cheaper financing and allows the issuer to sell common stock at a premium, in which the predetermined conversion price is higher than the stock price at the issuance of the convertible bond (Mayers, 1998). Access to the convertible bond market is also more flexible for issuers that have difficulty entering the traditional bond market due to restrictive credit rating requirements.

The first two essays focus on the pricing of convertible bonds. Pricing models are important tools in setting up investment strategies, including arbitrage, hedging and asset allocation (Ho and Pfeffer, 1996). For example, convertible arbitrage hedge funds, being the major investors, actively search for mispricing in convertible bonds and exploit it usually by buying underpriced convertible bonds and take a short position in equity (Ammann, Kind, and Seiz, 2010). On the other hand, pricing models are also important for the issuers in making financing decisions such as determining the issuance, call or put prices, as well as deciding the time to call back the convertible bonds, if they are issued with callable provisions.

The first essay of this thesis surveys the key theoretical and empirical studies on the pricing of convertible bonds to provide a comprehensive understanding of the valuation process. To date, there has not been an extensive study undertaken on this subject. Therefore, the first essay is designed to fill this gap and to identify areas for potential study that can further improve the efficiency of convertible bond pricing models. Motivated by the gap identified in the first essay, Essay Two undertakes an empirical study to clarify the degree of mispricing using a unique sample, consisting of pure convertible bonds, to control for estimation biases generated by complex option features present in these securities. The US market is chosen for two main reasons: first, the US market is the largest convertible bond market and second, the availability of real-time trade prices disseminated by TRACE-FINRA, the largest non-governmental regulator for all securities firms doing business with the US public. To the best of knowledge, this study is the first to use real-time trade data to examine the pricing of convertible bonds.

The theoretical framework for the pricing of convertible bonds is extended from the contingent claim valuation of Black and Scholes (1973) and Merton (1973, 1974). Ingersoll (1977a) views the value of a convertible bond as a contingent claim on the firm-value (structural approach) that is further extended by McConnell and Schwartz (1986), who view the value of the security as a contingent claim on the underlying issuer's stock (reduced-form approach). In general, the reduced-form approach is better accepted than the structural approach because of the ease of parameter estimation, thus subsequent studies are mostly extension from the McConnell and Schwartz's (1986) study.

Studies on convertible bonds are incomplete without the understanding of the motivation for the issuance of these securities, as one of the debt financing options. Given the increasing importance of the globalised market, the final essay of this thesis presents additional insight about the motivation for the issuance of convertible debt[1] by US-based multinational corporations (MNCs). Conflicting empirical evidence have been reported. MNCs are found to use lower levels of leverage, though theoretically international diversification enables MNCs to sustain higher leverage than domestic corporations (DCs). This study also seeks evidence from the US market, for two reasons: first, US is the largest market for convertible debt; second, to be comparable with existing studies (Burgman, 1996; Chen, Cheng, He, and Jawon, 1997; Doukas and Pantzalis, 2003; Fatemi, 1988; Lee and Kwok, 1988) as most of the conflicting evidence is generated from the US-based MNCs

Agency costs have been one of the most cited theories to explain the inverse relationship between leverage and internationalisation. In an attempt to justify the conflicting findings, this essay highlights the importance of recognising the equity option that is present in the debt component of MNCs. The risk-shifting hypothesis claims that the hybrid feature of convertible debt makes it an attractive substitute for

[1] In the first and second essays of this thesis, the term convertible bond is used, whereas in the third essay, the term convertible debt is used, in order to be consistent with previous studies.

straight debt to reduce agency costs of debt (Green, 1984). Therefore, MNCs can mitigate agency costs of debt caused by internationalisation by issuing convertible debt.

The remainder of this chapter is as follows: a brief overview of each of the three essays is presented in order in the following sections, while Section 1.5 presents the structure of the overall thesis.

1.2 Essay One: Convertible Bond Pricing Models

This essay presents a survey of the key theoretical and empirical studies on the pricing of convertible bonds to facilitate understanding of the valuation process as well as to identify areas for potential future study that can further improve the efficiency of the convertible bond pricing mechanism. To date, there has not been an extensive study undertaken on this subject. Convertible bond pricing models are typically extended from the contingent claim framework of Black and Scholes (1973) and Merton (1973, 1974), which is introduced to price convertible bonds by Ingersoll (1977a).

For the purpose of this survey, the focus is limited to conventional convertible bonds, including standard convertible bonds, reset convertible bonds and international convertible bonds, in which the payoffs are linked to the performance of the issuer's stock. Pricing convertible bonds is complicated by the hybrid features of these securities. The fixed-income component is subject to both interest rate and credit risk, whereas the conversion option is exposed to equity risk because the option to convert is dependent on the performance of the underlying stock price. The payoff structures are further complicated when convertible bonds are issued with complex option features, added as sweeteners to either investors or issuers, such as the call and put options. Nonetheless, the complexity has stimulated interest among researchers in the effort to price convertible bonds efficiently.

Existing empirical studies have documented mixed results generated from an assortment of arguments, model specifications and solution to the pricing models. Therefore, reviewing the key theoretical and empirical studies helps to identify the limitations within this subject and highlights areas of potential future research, which has also motivated the empirical study on the pricing of convertible bonds, presented in Essay Two of this thesis.

1.3 Essay Two: Pricing Convertible Bonds

This essay examines the pricing efficiency of US convertible bonds using a unique sample, identified from TRACE-FINRA that disseminates over-the-counter corporate bond real-time trade prices, including convertible bonds, which is meant to increase transparency and corporate bond market quality. This unique sample consists of 96 pure convertible bonds that controls for complex optionality present in these securities, such as the call and put options. Convertible bonds with sinking fund, mandatory, exchangeable, reset and reverse clauses are also excluded.

The valuation of convertible bonds has not been adequately addressed due to the presence of complicated payoff structures and the difficulty in clearly defining the links between valuation and the underlying risk factors such as credit risk, interest rate risk, and equity risk. Moreover, existing studies document inconsistent conclusions, subject to considerable variation in the model inputs and specifications, assumptions made and solutions to the pricing models. But, importantly former empirical evidence is generated from convertible bonds with complex option features such as the callable and puttable provisions. Therefore, the objective of this study is to clarify the degree of mispricing using a unique sample to control for estimation biases caused by the complex optionality.

This study applies the least squares Monte Carlo (LSM) simulation approach that accounts for stochastic volatility and credit risk. To keep the pricing model simple, stochastic volatility is controlled using the constant elasticity of variance (CEV) model of Cox (1975, 1996)[2], whereas credit risk is controlled using Tsiveriotis and Fernandes (1998) model. This study contributes to the existing literature in three ways. First, to the best of knowledge, this is the first study to examine the pricing efficiency of convertible bonds' real-time trade prices. Second, this study highlights the importance of identifying the option features present in these securities since it affects the efficiency of a pricing model. Also, this study highlights the importance of market conditions and the temporal rather than systematic nature of the pricing errors during the recent Global Financial Crisis.

[2] The revised version of Cox (1975) is published in the special issue of Journal of Portfolio Management in 1996.

1.4 Essay Three: Debt Heterogeneity, Internationalisation and Agency Costs

This essay examines the motivation for the issuance of convertible debt by MNCs to mitigate agency costs of debt. One benefit of internationalisation is the ability to diversify the source and type of debt, although doing so incurs agency costs. In brief, the benefit from geographical diversification is offset by the increasing agency costs as the firms expand abroad. Therefore, with the intention of mitigating the agency costs, MNCs are found to use lower levels of leverage than DCs.

Nonetheless, the inconsistent finding is generated by assuming debt as homogenous. A recent study by Rauh and Sufi (2010) documents the importance of recognising debt heterogeneity in the study of capital structure because different types of debt instruments have difference cash flow claims, control provisions and sensitivity to information. Motivated by their argument and the increasing importance of globalised markets, also supported by the theory of agency costs of debt (Jensen, 1986) and the risk-shifting hypothesis (Green, 1984), this study provides additional insight to the inverse relationship between internationalisation and leverage. Using data from 2002 to 2011, this study shows that US MNCs mitigate agency costs of debt by issuing convertible debt.

This essay provides three important contributions. First, it shows the importance of recognising the heterogeneity of debt, specifically the presence of equity options in the debt issued by MNCs to mitigate agency costs that arise from international diversification. Second, it provides evidence that debt heterogeneity is indeed linked to internationalisation. Third, this study contributes to the convertible debt literature related to the motivation for the issuance of this security to mitigate agency costs of debt from the international perspective.

1.5 Structure of the Thesis

This thesis is structured as follows. Chapter 2 presents the first essay of this thesis that surveys the pricing of convertible bonds in terms of key theoretical and empirical aspects and highlights the key areas of research that may further improve the valuation process of these securities. The technical specifications of the key pricing models are presented in Appendix A, in the last section of this thesis. This is followed by Essay Two, an empirical study that examines the pricing of real-time trade prices of pure US convertible bonds, presented in Chapter 3. Appendix B relates to Chapter 3. It includes the additional information related to TRACE-FINRA that disseminates real-time trade prices and the results of tests of pricing efficiency by subsamples. Chapter 4 presents the third essay of this thesis, also an empirical study that investigates the motivation for the issuance of convertible debt by MNCs to mitigate agency costs of debt. Chapter 5 concludes by summarising the major findings and implications of each of the three essays, together with suggestions for potential future study.

CHAPTER TWO

ESSAY ONE

CONVERTIBLE BONDS PRICING MODELS

This chapter presents a survey that highlights the key theoretical and empirical pricing features of convertible bonds and identifies those areas of research that may further improve the valuation process and application of these securities. Section 2.1 provides an overview of the structures and features of different types of convertible bonds, which helps to identify the scope of the survey. Section 2.2 presents the theoretical review of structural and reduced-form approaches of the contingent claim valuation of convertible bonds. The technical specifications of the pricing models are presented in Appendix A in the last section of this thesis. Section 2.3 reviews the numerical solutions and the theoretical illustrations of the convertible bond pricing models. Section 2.4 presents the empirical reviews of the way various pricing models are utilised to determine the value of convertible bonds. Section 2.5 concludes and provides suggestions for future empirical research. The references are listed in the Bibliography section of this thesis.

2.1 Introduction

A convertible bond is a hybrid security with debt and equity-like features. Like a straight bond, a convertible bond investor is entitled to receive regular fixed coupon payments and the principal repayment upon maturity. However, the investor also has the option to forgo the fixed-income component and convert the bond into the stock of the issuing firm, at a predetermined rate at some time in the future. Therefore, in simple terms a convertible bond is equivalent to a bond with an embedded call option on the firm's stock. The objective of this survey is to highlight the key theoretical and empirical pricing features of convertible bonds and to identify those areas of research that may further improve the valuation process and application of these securities.

The size of the convertible bond market compared to the larger corporate bond market is recorded in Table 2.1. This table provides the outstanding market value of bonds issued in the four major world markets: the Asia-Pacific region, Europe, Japan, and the US. The US is the most important convertible bond market, and comprises some 63.64% (2011) of estimated convertible bonds outstanding. Worldwide convertible bonds outstanding increased from US$190.19 billion in 2000 to US$356.66 billion in 2007, only to decrease by 41.49% in 2008 due to the adverse conditions associated with the Global Financial Crisis. The market has since recovered with worldwide outstanding of US$233.64 billion in 2011. The attractiveness of convertible bonds to issuers relies on the fact that when issued, yields of these securities are lower than those of equivalent straight corporate bonds. Consequently, with very low nominal bond yields worldwide, issuer supply of convertible bonds has declined in favour of conventional corporate bonds, which are now at record levels (US$7,054.50 billion worldwide).

Table 2.1
Convertible Bond Market Size: 2000 to 2011

This table reports the size of the convertible bond market relative to the corporate bond market for the major markets: US, Europe, Japan and Asia-Pacific, for the period from 2000 to 2011. The columns headed *CB* refer to convertible bonds, while *Bond* refers to the larger corporate bond market. The percentage of CB/Bond is recorded in the third column (*%*). The amounts shown are outstanding convertible bonds and corporate bonds, respectively in US$ billion. The convertible bond data is sourced from the Datastream. The corporate bond market is sourced from the Bank for International Settlements, BIS (2012).

	US			EUROPE			JAPAN			ASIA-PACIFIC			TOTAL		
Year	**CB**	**Bond**	**%**	**CB**	**Bond**	**%**	**CB**	**Bond**	**%**	**CB**	**Bond**	**%**	**CB**	**Bond**	**%**
2000	101.127	2,295.06	4.406	33.916	380.42	8.915	46.203	655.82	7.045	8.942	320.99	2.786	190.188	3,772.50	5.041
2001	163.406	2,379.82	6.866	48.558	436.68	11.120	33.112	613.81	5.394	10.450	358.19	2.917	255.526	3,909.89	6.535
2002	157.329	2,369.97	6.638	61.455	545.81	11.259	32.552	682.98	4.766	13.298	378.13	3.517	264.634	4,104.16	6.448
2003	228.611	2,435.95	9.385	76.142	715.97	10.635	35.426	769.79	4.602	12.323	379.85	3.244	352.501	4,460.14	7.903
2004	224.950	2,552.61	8.813	84.332	800.01	10.541	34.676	787.43	4.404	13.165	399.34	3.297	357.123	4,723.52	7.561
2005	208.227	2,696.13	7.723	72.539	735.76	9.859	30.451	704.76	4.321	9.472	414.67	2.284	320.688	4,751.79	6.749
2006	239.125	2,840.51	8.418	62.852	878.99	7.150	27.081	671.86	4.031	9.663	477.04	2.026	338.720	5,078.81	6.669
2007	261.248	3,040.96	8.591	55.508	1,077.64	5.151	25.203	728.22	3.461	14.700	531.92	2.764	356.659	5,620.67	6.345
2008	142.407	3,139.17	4.536	32.889	1,276.34	2.577	21.952	766.62	2.864	11.429	594.92	1.921	208.677	5,986.84	3.486
2009	182.897	3,025.84	6.045	51.278	1,476.39	3.473	18.595	782.68	2.376	18.218	874.24	2.084	270.988	6,445.62	4.204
2010	188.550	3,143.76	5.998	48.603	1,399.63	3.473	27.443	900.38	3.048	23.482	1,158.91	2.026	288.079	6,933.64	4.155
2011	148.699	3,488.40	4.263	40.161	1,351.50	2.972	21.012	927.00	2.267	23.772	1,287.60	1.846	233.644	7,054.50	3.312

Although the nominal value of these securities is significant, they remain a relatively small segment of the total corporate bonds issued worldwide (about 3.3% in 2011), with the largest share of this market based in the US (about 4.3% in 2011)[3]. Convertible arbitrage hedge funds are reported to be the major investors in the convertible bond market, purchasing more than 70% of convertible bonds in the primary market (Choi, Getmansky, and Tookes, 2009; Mitchell, Pedersen, and Pulvino, 2007)[4]. Consistent with these papers, Brown, Grundy, Lewis and Verwijmeren (2012) report hedge funds bought 60% of privately placed convertible bonds in 2000, with this amount increasing to 80% by the first quarter of 2008.

The attractiveness of convertible bonds to investors and issuers alike has been augmented over time with additional option features. To simplify the analysis, this survey focuses on conventional convertible bonds where payoffs are linked to the performance of the issuer's stock. These bonds include standard convertible bonds, reset convertible bonds and international convertible bonds.

There are a number of non-conventional convertible bonds including exchangeable bonds, reverse convertible bonds, and mandatory convertible bonds that are excluded from this survey[5]. A short discussion of each of these securities follows, although, brief descriptions are also provided in Table 2.2. In the case of an exchangeable bond, the

[3] Note that Henderson Jegadeesh and Weisbach (2006) record a higher percentage of convertible bonds issued in Europe and Asia than in the US during their sample 1990-2001. However since then the number of convertible bonds issued in Europe and Asia relative to straight bonds has declined, while those issued in the USA have increased.
[4] Choi et al (2009) report continuous growth in the total assets of convertible bond arbitrage hedge funds. Refer figure 3 of their study.
[5] Existing studies that examine the pricing of these non-conventional convertible bonds include Realdon (2003) for exchangeable bonds, Szymanowska, ter Horst and Veld (2009) for reverse convertible bonds, Lindauer and Seiz (2008) for (multi-) barrier reverse convertibles, Ammann and Seiz (2006) for mandatory convertible bonds and De Spiegeleer and Schoutens (2011) and Sundaresan and Wang (2010, 2011) for contingent convertibles.

payoff is linked to the performance of another firm's stock instead of the stock of the issuer. Reverse convertible bonds are issued with an embedded put option that entitles the issuer to redeem the security at par, deliver a prespecified number of the issuer's stock to the investor, or the equivalent value of stock of another firm possessed by the issuer. The valuation of these bonds is also different to a conventional convertible bond, since it is based on the value of a straight bond minus the value of a put option (Szymanowska et al., 2009). A mandatory convertible bond does not offer downside protection to the bondholder, thus the payoff structure is also different from the conventional convertible bond.

Another type of convertible bond that has attracted significant interest is the contingent convertible bond or CoCo bond. A CoCo is automatically converted to equity when the market value of the issuer's stock reaches a prespecified level, or the firm is subject to a prespecified credit event (such as a rating change) that could signal financial distress. The differences in the value of a conventional convertible bond and a CoCo are illustrated and explained in Figure 2.1. The lower section of the figure depicts the CoCo value, which offers the investor neither limited downside protection, nor unlimited upside gain. Note that Zahres (2011) provides a discussion on how this instrument could help preserve bank capital during a period of crisis.

Table 2.2
Innovative Features of Convertible Bonds

This table provides descriptions of various types of convertible bonds. These bonds contain features that are meant to enhance their attractiveness to issuers or investors. The list consists of convertible bonds that are well-known to market participants.

Type of convertible bond	**Description**
Contingent convertible bond (CoCo bond)	A CoCo is a long-term subordinated bond that is automatically converted into equity when the issuing bank reaches a prespecified level of financial distress, or the firm is subject to a prespecified credit event (such as a rating change) that could signal financial distress. The automatic conversion feature has the ability to improve the issuer's capital resources under adverse circumstances and to absorb losses (Zahres, 2011), thus has the potential to avoid bank bailouts (Albul, Jaffee, and Tchistyi, 2010). This feature appears to be attractive to the regulator because the concept fits a more stable banking system (De Spiegeleer and Schoutens, 2011). If the conversion trigger is not initiated, a CoCo can be redeemed at maturity (Zahres, 2011). For more references on contingent convertible bonds, refer to Flannery (2002, 2010), McDonald (2011) and Sundaresan and Wang (2010, 2011).
Death spiral convertible bond or floating-priced convertible bond	A death spiral convertible bond is issued with reset clauses instead of a fixed predetermined conversion ratio. The conversion ratio is adjusted if the underlying stock price does not exceed the prespecified trigger price. When the conversion price is adjusted lower, it increases the conversion ratio. This feature provides insurance against any future drop in stock prices and guarantees a fixed total value to the holder (Hillion and Vermaelen, 2004). Therefore, this type of security is usually issued when the outlook of the issuer is less favourable. The floating-price feature also benefits the issuer since they can prompt conversion at a lower conversion price, thus reducing the cost of financial distress.
Eurobond convertible	A Eurobond convertible is issued outside the domestic market and allows non-resident issuers the opportunity to gain an equity stake in the domestic firm (Yigitbasioglu, 2002). The currency of denomination of the bond can be the issuer's domestic currency (no currency risk), or a foreign currency (leading to currency risk) that converts into equity (Yigitbasioglu, 2002). Firms resort to issuing international convertible bonds when domestic issues are expensive and/or restricted by regulatory constraints (Bailey, Chung, and Kang, 1996; Kang, Kim, Park, and Stulz, 1995).
Exchangeable bond	An exchangeable bond has the same features as a conventional convertible bond but the payoff depends on the underlying stock of a different firm. The bondholder is granted an option to exchange the bond for shares of another firm (Danielova, Smart, and Boquist, 2010). Another type of exchangeable bond is termed a mandatory exchangeable bond, since it is obligatory to exchange the bond for shares of common stock at maturity. Issuing either mandatory or non-mandatory exchangeable bonds enables the issuer to divest the holdings in one firm (Danielova et al., 2010).

Table 2.2 *Continued*

Type of convertible bond	Description
Foreign currency convertible bond (FCCB)	A FCCB is a hybrid instrument issued in a currency other than the issuer’s domestic currency with an option to convert into the issuer’s common stock traded in the domestic currency (Landskroner and Raviv, 2008). The money raised by the issuing firm is in foreign currency. Equally, both the principal and periodic coupons are payable in foreign currency. Firms issue international convertible bonds when domestic issues are expensive and restricted by regulatory constraints (Bailey et al., 1996; Kang et al., 1995). But issuer is exposed to exchange rate risk.
Mandatory convertible bond	A mandatory convertible bond has to be redeemed into equity. It does not offer downside protection as there is no fixed terminal value. As such, investors are compensated with a higher yield for taking on this additional risk. The mandatory feature is first structured with preferred stock, whereby an investor receives periodic dividend payments until the bond is converted into common stock. Typically this occurs within three to four years regardless of the underlying stock price on the conversion date (Huckins, 1999).
Reverse convertible bond	A reverse convertible bond is issued with an embedded put option, which is held by the issuer, instead of a call option held by the investor. The issuer has the right to convert the convertible bond into shares of another firm possessed by the issuer. Indirectly, the issuer has the option to dispose of the shares of another firm. In fact, this feature exposes investors to a higher level of risk, and so as additional compensation, the investor is usually offered a higher coupon rate (Szymanowska et al., 2009; Yagi and Sawaki, 2010).

Conceptually, the hybrid feature of a conventional convertible bond benefits both the issuer and the investor. From the issuer’s perspective, the convertible bond is a cheaper source of fixed-income financing, because of the lower coupon rate, than a straight bond. The lower yield offers compensation to the issuer for granting the conversion option to the investor. Also, access to the convertible bond market provides added flexibility to an issuer that may face difficulty entering the conventional bond market due to the cost of the credit rating requirements. Huang and Ramirez (2010)[6], show that convertible bonds tend to be issued by either unrated, or noninvestment grade firms. However, unrated firms may also be able to issue privately placed securities.

The motivation for a firm to issue a convertible bond can be explained by two hypotheses: the first termed the 'risk-shifting' hypothesis (Green, 1984), and the second the 'backdoor-equity' hypothesis (Stein, 1992). These two hypotheses will be discussed in turn. Green's (1984) risk-shifting hypothesis argues that firms issue convertible bonds as a substitute for straight bonds to alleviate potential bondholder-stockholder conflict. This conflict may arise once straight bonds are issued, since the presence of restrictive covenants imposed by the firms' creditors may encourage the firm to only undertake low-risk investments, whereas stockholders have the opposite incentive. Alternately, undertaking high-risk investments may increase the default probability of the firm and thereby penalise bond holders through falling bond prices and higher credit spreads. These conflicts can be resolved through the use of convertible bonds since the equity component can reduce the expropriation of wealth, whereas the debt component is likely to possess less restrictive covenants than a straight bond.

The alternate 'backdoor equity' hypothesis provided by Stein (1992) argues that firms issue convertible bonds simply as substitute for equity. In this case firms characterised as having significant informational asymmetries (between managers and investors) while also facing high expected costs of financial distress, are more likely to issue convertible bonds. For example, high growth firms fall into this category. Firm managers may be reluctant to issue additional equity since it may dilute existing

[6] Huang and Ramirez (2010) analysis is based on 501 convertible bonds and 1,324 straight bonds issued from 1996 to 2004.

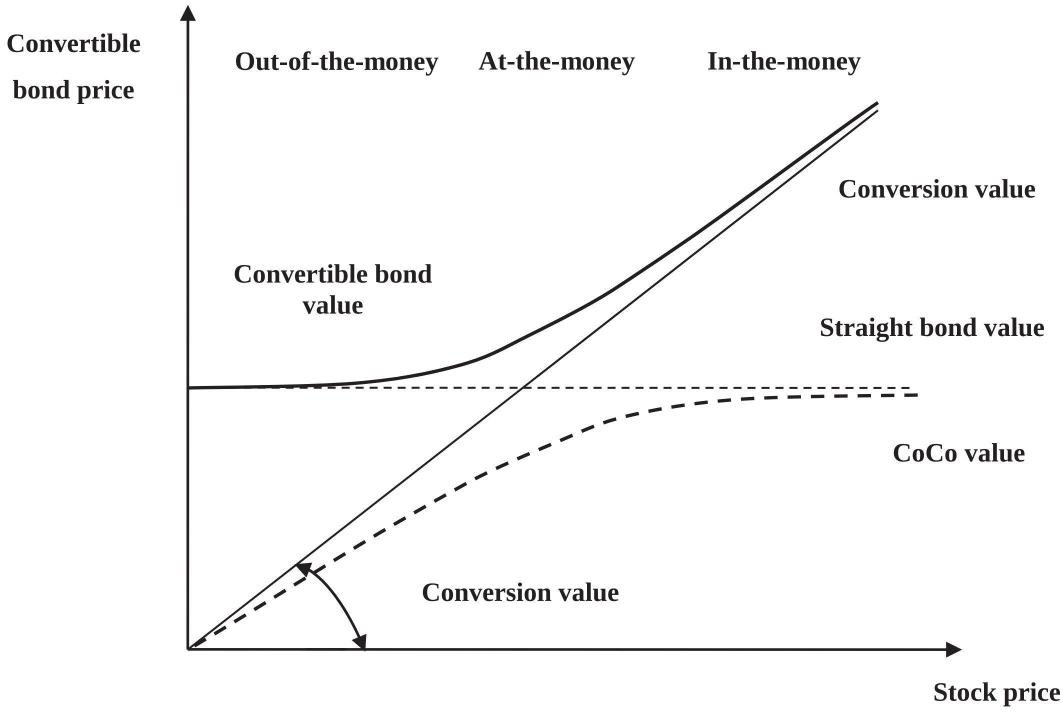
shareholders claims while information asymmetries mean that the current stock price does not adequately reflect the firm's growth opportunities. Recently, Mayers (1998) argues that convertible bonds are also a preferred security choice when an issuer faces a sequential financing problem.

From an investor's perspective a convertible bond provides a more attractive risk-return profile than equity or a conventional bond. The hybrid feature offers potentially unlimited upside gain to investors when the issuer's stock performs well. In this case the investor will convert into common stock at the prespecified conversion price, which at this time would be lower than the prevailing stock price. When the stock performs poorly, the convertible bond offers a downside protection with the cash flow from the fixed-income component. However, the investor is also exposed to the potential risk of the issuer's inability to meet the interest and principal payments, in particular when the firm is approaching default. In brief, the unique risk-return profile of a convertible bond provides an attractive avenue for investment since it is less risky than common stock but possesses the option to convert when circumstances are favourable.

While the hybrid feature of convertible bonds may make them favourable for investment and financing, the key theoretical question is how market participants decide on the price of these securities? The theoretical value of a convertible bond is described as the maximum of the straight bond value or the conversion value, plus the value of the conversion option. The conversion value is the value of the convertible bond in terms of common stock. Figure 2.1 also illustrates the value of a convertible bond when the straight bond component is assumed to be riskless – an assumption for risk-neutral option valuation. Note that the straight bond value stays relatively constant over time and is not affected by changes in the underlying stock price. In contrast, both conversion and option value move in tandem with changes in the stock price. The conversion value is therefore higher when the stock price increases and vice versa, while the option value is higher when the stock price is above the exercise price. In this case the option is said to be in-the-money (ITM).

Figure 2.1
Comparison of the Price of a Conventional Convertible Bond and a Contingent Convertible (CoCo)

This figure compares the price of a conventional convertible bond to the price of a CoCo in relation to the performance of the underlying stock. In a risk-neutral setting the value of the straight bond is assumed to be riskless. Therefore, the value stays relatively constant over time and is not affected by the changes in the underlying stock price. The conversion value moves in tandem with the stock price because the conversion value equals the stock price multiplied by the prespecified conversion ratio. The conversion privilege of a convertible bond enables an investor to participate in the growth of the firm’s equity value with protection against downside risk from the fixed-income cash flow. A CoCo offers neither limited downside protection, nor an unlimited upside gain and is automatically converted to equity when the issuer reaches a prespecified level of financial distress. The investor has to absorb the loss from converting into cheap shares (De Spiegeleer and Schoutens, 2011). If the conversion trigger is not met a CoCo can be redeemed at maturity similar to a normal bond (Zahres, 2011).



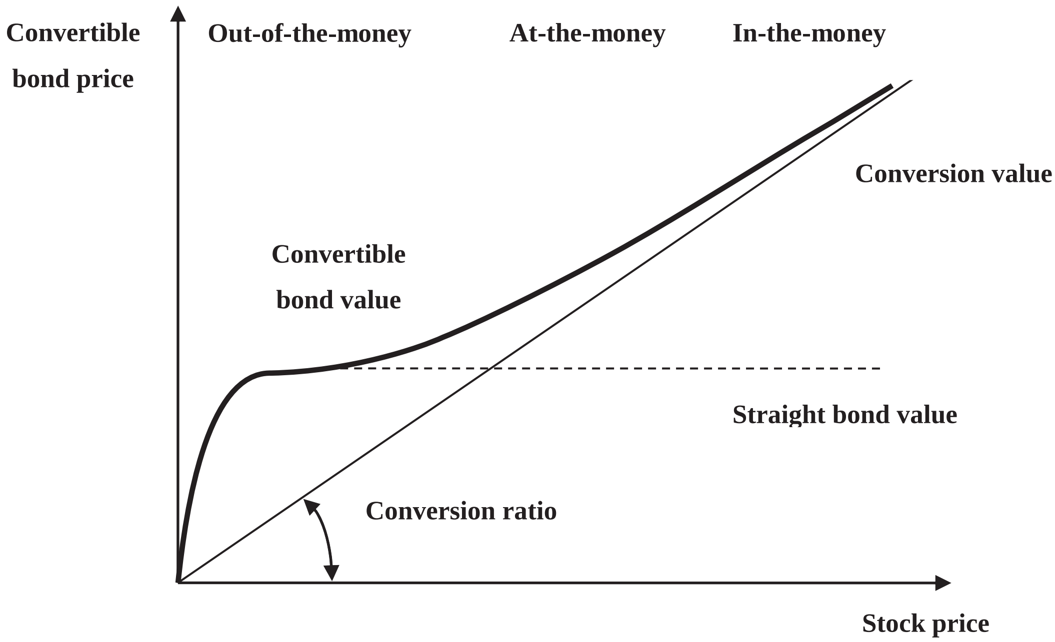
Though the valuation of a convertible bond may appear straightforward, its hybrid feature complicates valuation. This difficulty arises from the number of specific factors that affect its value: the time to maturity, coupon rate, face value, conversion ratio, and dividend yield of the underlying asset. As noted earlier, the straight bond component is subject to both credit and interest rate risk, whereas the conversion option is exposed to equity risk. When credit risk is taken into account, the straight bond value falls when the stock price drops substantially, such as when the firm is approaching default. In this case, the conversion option has zero value and so the value of the convertible bond is merely the value of the straight bond component. The theoretical value of a convertible bond with a risky straight bond component is illustrated in Figure 2.2.

The value of a convertible bond is also affected by additional boundary conditions, or features added as incentives (or sweeteners) to either investors or issuers. These include call (the right of the issuer to buy back the bond at a specified call price), put (the right of the investor to sell back the bond at a specified put price), and other complicated features such as a 'Parisian' feature. Theoretically, it is optimal for the issuer to only call the bond when the predetermined call price is equivalent to the conversion value (Ingersoll, 1977b). However, in many cases, the call is time dependent (termed a 'hard call' provision) or conditional on the performance of the underlying stock price (termed a 'soft call' provision). A number of papers, including Asquith (1995) and Ingersoll (1977b)[7] provide additional details. A hard call provision prevents the issuer from calling the bond back before a certain time period, whereas a soft call provision allows the security to be called if the underlying stock price exceeds either the predetermined trigger price or the excursion time requirement.

[7] Ingersoll (1977b) notes that on average, issuers call back the convertible bond when the conversion value is 43.9% above the effective call price.

Figure 2.2
The Theoretical Value of a Convertible Bond with a Risky Straight Bond Component

This figure shows the relationship between the price of a convertible bond and the underlying stock. A convertible bond allows the investor to convert into a predetermined number of shares, known as the conversion ratio. The conversion value is simply the stock price multiplied by the conversion ratio, so it increases in tandem with the stock price. As a result, the convertible bond value is higher than the maximum of the straight bond value, or the conversion value. The difference between the two is the option value given by the conversion privilege, which is also an increasing function of the stock price. When the stock price falls to a substantially low level relative to the bond conversion value, the option value is considered to be deep out-of-the-money since it is unlikely to be exercised. The straight bond value could also fall substantially when the firm is approaching default, and so the conversion option has zero value. Hence, at this point the value of a convertible bond is only the value of the straight bond component. However, when the stock price increases, the straight bond value stays relatively constant.



The excursion time requirement, or ‘Parisian’ feature, prevents the issuer from calling back the convertible bond too soon, as may occur if the market interest rate falls significantly after issuance. This provision states that the convertible bond is only callable when the underlying stock price is at a certain percentage above the trigger price for n consecutive trading days. The n consecutive trading days are the excursion time requirement. Furthermore, when a convertible bond is called, the bondholder is given a call notice period to decide on acceptance of the final payoff. This payoff is based on surrendering the bond at the call price, or converting at the prevailing stock price, whichever is higher. In summary, it is not straightforward to price a convertible bond given the challenges in the valuation process, which stem from the complicated payoff structures and the link between the valuation and the underlying risk factors.

Nonetheless, it is the complexity of the payoff structure of convertible bonds that has stimulated interest among researchers. Typically, the valuation process is derived from the contingent claim approach, which integrates both the Black and Scholes (1973) and Merton (1973) option pricing models, as well as the Merton (1974) corporate bond pricing model. Since the early work of Ingersoll (1977a) and Brennan and Schwartz (1977, 1980), an assortment of arguments, model specifications, and solutions to the pricing models have been developed to reflect real market specifications in the pricing of convertible bonds. These studies have also generated inconsistent conclusions in the appropriateness of different valuation processes due to considerable variation in the model inputs and assumptions adopted that may not necessarily reflect actual market behaviour.

Importantly for the context of this study, to date there has not been a thorough review undertaken of the pricing of these securities. This study fills this gap by providing a summary and perspective on the many theoretical and empirical studies on the pricing and valuation of convertible bonds. Reviewing these papers also helps to identify the limitations within this subject area and highlights key areas for future research that can be used to improve the efficiency of the convertible bond pricing mechanism.

This chapter is structured as follows: Section 2.2 presents the fundamental idea of the contingent claim approach that is extended to price convertible bonds. Section 2.3 reviews the numerical solutions and the theoretical illustrations that portray the impact of multiple underlying risk factors, convertible bond specific factors, and boundary conditions on the value of convertible bonds. Section 2.4 then reviews the way various pricing models are utilised to determine the value of convertible bonds. Section 2.5 concludes and provides suggestions for future empirical research.

2.2 Theoretical Review

2.2.1 The Fundamentals of Contingent Claim Pricing Models

A contingent claim asset is a class of security where the expected value is dependent on the performance of another security (termed the underlying asset). The pricing framework for options that is used today is based on the seminal work of Black and Scholes (1973) and Merton (1973). An option is considered a contingent claim asset because the expected value is dependent on the performance of the underlying asset, such as common stock. Merton (1974) applies the option pricing framework to value corporate liabilities, which may be regarded as a contingent claim on firm value. This approach uses a standard partial differential equation (PDE) that can be applied to value any financial security depending on the boundary specifications. The technical specifications of Merton's (1974) contingent claim valuation of corporate debt is presented in Appendix A.1.

Initially, the PDE is solved for discount bonds with some possibility of default. Default occurs when the total firm value falls below the total redemption value of debt at maturity. In this context, the degree of solvency is a function of the capital structure of the firm and may be measured as the ratio between the market value of assets and the book value of debt. Under the structural approach of Merton (1974), the firm's capital structure consists of only a single, homogenous class of debt, and equity. Upon default, bondholders receive the entire firm's assets, whereas the shareholders receive nothing. Merton (1974) also illustrates the pricing of risky coupon-bearing bonds by adding continuous coupon payments to the PDE. Nevertheless, the bond is assumed to be perpetual and pays a continuous coupon because a closed-form solution is not available for a bond with a discrete path and finite horizon (Black and Scholes, 1973; Merton, 1973, 1974). Additionally, this pricing model accommodates callable bonds that allow the issuer to buy back the bond once the price passes a threshold value (termed the call price). This typically occurs if the credit rating of the firm improves, or yields fall considerably after the bond is issued. Under these circumstances firm managers should act in the best interest of shareholders by calling the bonds immediately after the prevailing price exceeds the prespecified call price. This decision will maximize the value of equity and minimise the value of the bonds.

Though these three papers are constrained by a number of restrictive assumptions, they mark the breakthrough for pricing contingent claim assets. The contingent claim approach can be further extended by relaxing these assumptions and incorporating real market specifications, such as credit risk and interest rate risk. In addition, the pricing model allows for the pricing of a convertible bond[8] given the similarity of the contingent claim features embedded in the conversion option. However, the valuation of

[8] Pricing models for convertible bonds first appeared in the 1960s. For example Baumol, Malkiel and Quandt (1966), Jennings (1974), Walter and Que (1973) and Weil, Segall and Green (1968) investigated the pricing of convertible bonds. In general, these early studies view the value of a convertible bond as the maximum of the straight bond value, or the conversion value, plus a premium.

a convertible bond is more complicated than a standard option, or debt, because of the hybrid feature discussed earlier.

2.2.2 Convertible Bond Pricing Model

The convertible bond valuation process is based on two main approaches: the first is termed the structural approach (or firm-value approach), and the second is termed the reduced-form approach (stock-value approach). The basic difference between these two approaches is the type of input variables used. The structural approach uses company-specific information whereas the reduced-form approach uses market information (Kao, 2000).

2.2.2.1 Structural Approach

Inspired by the earlier contingent claim models Ingersoll (1977a) derives a PDE (refer Appendix A.2 for the technical specifications) under the structural approach that views a convertible bond as a contingent claim on firm value. This bond is assumed to be the only senior debt in the firm's capital structure, plus common stock. This simple capital structure assumption is important to determine the default condition. A default would occur when the firm value falls below the total redemption value of the convertible bonds. Therefore, upon default the convertible bondholders are expected to receive the value of the entire firm's assets.

The capital structure assumption leads to three possible payoffs at maturity: Convertible bondholders receive either the conversion value if it exceeds the face value of the convertible bond, the face value if it exceeds the conversion value, or finally a proportionate share of the firm value if the firm value falls below the par value of outstanding bonds. Meanwhile, to control for arbitrage opportunities, the offer price of a convertible bond must at least equal the conversion value. Ingersoll (1977a) adds that if perfect market assumptions hold, with no dividends and constant conversion terms, it is never optimal for investors to opt for early conversion. Investors will only convert involuntarily at maturity, or at call, if the conversion value exceeds the call price, or the face value. Since the firm would never allow the conversion value to exceed the call price, the firm would call back the convertible bond as soon as the condition guarantees conversion.

This approach suggests a closed-form solution may be appropriate when determining the price of a convertible bond. However, it is difficult to generalise the solution given the perfect market assumptions, continuous time factor, and the ability to only allow slight modification to the capital structure. Ingersoll (1977a) also acknowledges the restrictions of the closed-form solution, in which path-dependent features, such as call and finite horizon could not be integrated. Accordingly, Brennan and Schwartz (1977) develop a numerical method to solve the pricing of convertible bonds with discrete coupons and dividends, early conversion, and call provisions. Further description of this pricing model is presented in Appendix A.3.

The introduction of numerical solutions in subsequent studies encourages the extension of these models to incorporate various imperfect market specifications. In a later paper, Brennan and Schwartz (1980) suggest a two-factor model that allows firm value and interest rates to be stochastic. The model also includes senior debt in the capital structure. Thus, in the event of default, convertible bondholders receive the net firm value after the senior debt holders are paid off. These debt holders would either recover the full amount or a fraction of the par value, while the final payoff would be zero if the senior claims exhausted the firm value. Appendix A.4 illustrates the boundary conditions and PDE of Brennan and Schwartz's (1980) two-factor model.

Overall, the literature on the structural approach to convertible bond pricing is limited due to a number of drawbacks. First, the default condition is dependent on the assumption of capital structure because there is a direct relationship between the firm value and debt value. Second, it is impractical to assume that convertible bonds are the only form of firm debt. This is especially important since firm debt typically has different degrees of seniority. Thus, in the event of bankruptcy, the convertible bondholders would only be paid after the senior debt holders. Consequently, a pricing model that only assumes a simple capital structure cannot correctly price a standard convertible bond. However, when the pricing model takes senior debt into account, the solution to the valuation process poses significant computational challenges. This is particularly true in practice, since most firms have multiple liability claims. Third, the structural approach also requires knowledge of company-specific data such as firm value, debt structures and contractual terms. Furthermore, it may not be easy to obtain data on firm value if the firm's stock is not traded.

2.2.2.2 Reduced-Form Approach

To overcome drawbacks in the structural approach, McConnell and Schwartz (1986) estimate a reduced-form model for the pricing of convertible bonds. This approach views a convertible bond as a contingent claim on the stock price, with the stock price dynamics assumed to follow geometric Brownian motion. Note that under the reduced-form approach the possible payoff at maturity has been simplified. The value of a convertible bond equals the maximum of the conversion value, or the par value. By comparison, under the structural approach, the payoff structures at maturity are dependent on the assumptions made of the firm's capital structure. The technical specifications are listed in Appendix A.5.

In the reduced-form approach the matter of credit risk remains an important consideration. This model bypasses the need for firm parameters and estimates credit risk exogenously. This means that both the default risk and the recovery rate during default must be estimated based on publicly available information, such as historical time series observations of the default experience and recovery rates. If a risk-free interest rate is used in the estimation, the possibility of bankruptcy is excluded and the model will overestimate the value of a convertible bond. Consequently, the higher the possibility of bankruptcy, the greater the overestimation of the convertible bond value and vice versa. On the other hand, a higher discount rate tends to reduce the value of the convertible bond. McConnell and Schwartz (1986) attempt to overcome these concerns by applying a risk-adjusted interest rate that is grossed up by a constant credit spread to capture the default risk of the issuer. However, this approach is subject to criticism since credit spreads are neither constant over time, nor constant along the yield curve.

In general, the reduced-form approach is well accepted compared with the structural approach because of the ease of parameter estimation. Therefore, subsequent studies are mostly extensions of the McConnell and Schwartz (1986) reduced-form approach to convertible bond pricing. These are reviewed later in subsection 2.3.

2.2.3 The Mechanics of Convertible Bond Arbitrage

The complexity of convertible bond pricing provides market participants with the opportunity to arbitrage perceived differences between the theoretical value and the market price of a convertible bond. Convertible arbitrage hedge funds are active convertible bond traders with the 'buy-and-hedge' strategy helping to explain hedge funds returns (Agarwal, Fung, Loon, and Naik, 2011) and mutual fund returns (Ammann et al., 2010)[9] Funds that employ dynamic trading strategies related to convertible arbitrage are reported by these authors as having significantly higher performance than simple buy and hold investment strategies.

The 'buy-and-hedge' strategy involves matching a long position in the convertible bond with a short position in the issuer's common stock at a current ratio, termed the delta. The delta measures the sensitivity of the price of a convertible bond relative to the changes in the price of the underlying stock. The delta is maintained between near zero for an out-of-the-money (OTM) debt-like convertible bond and approximately one for an ITM equity-like convertible bond. If the arbitrageur has accurate data on both the common stock and the convertible bond, the delta can be estimated using correlation-

[9] Ammann et al (2010) examine the performance of US mutual funds. They find that the higher the difference in the percentage of assets invested in convertible bonds compared to the percentage invested in stocks, the higher the performance. In addition, the higher performance is contributed by the trading strategies related to convertible arbitrage, especially those performed by hedge funds.

based techniques, such as least squares regression. Nonetheless, delta hedging as a strategy is unstable (since the correlation is unstable) and so the delta hedge must be constantly rebalanced.

In order to immunise the convertible bond from equity risk, an arbitrageur will short sell an amount of the underlying stock determined by the conversion ratio of the convertible bond, multiplied by the delta. The hedge also has to be dynamically rebalanced[10] as the stock price changes, to lock in any profits. When the stock price increases, the delta also increases. As a result, the arbitrageur has to add to the short position. Alternately, when the stock price decreases the arbitrageur has to purchase stock to cover part of the short position since the delta has also declined (Choi et al., 2009). The overall effect of these actions on markets is claimed to improve market liquidity (Chordia, Roll, and Subrahmanyam, 2002). Choi et al. (2009) also show using changes in the monthly short interest at the issuance date as the proxy for convertible arbitrage activity that arbitrage activity increases stock liquidity following convertible bond issuance.

In addition to hedging equity risk, an arbitrageur may also hedge convertible bonds against other risk factors such as changes in interest rates and credit risk. This requires the selling of either actual risk-free securities (or equivalent futures contracts) to hedge the interest rate risk, selling short non-convertible bonds or buying credit default swaps to hedge changes in credit ratings or the credit spread, and selling stock options to hedge the volatility risk (Mitchell et al., 2007). In practice, it is easier to directly hedge equity risk than credit risk or the straight debt component of a convertible bond because obtaining the market price for the debt component may be difficult compared with the

[10] The frequency of rehedging depends on the transaction cost and the arbitrageur's attitude to risk (Hutchinson and Gallagher, 2004). As a general rule, rehedging will take place every 3-5% move in the underlying stock price (Blatter, 2002).

equity market (Asness, Berger, and Palazzolo, 2009). Therefore, arbitrageurs tend to prefer convertible bonds that are equity sensitive, or ITM convertible bonds since these bonds are more highly correlated with stock prices. Loncarski, ter Horst and Veld (2009)[11] also find that convertible arbitrage activity is more significant for equity-like convertible bonds because these securities are more underpriced than debt-like convertibles at issuance. However, in past years, convertible bonds have become more debt-like, which is likely to explain the lower convertible arbitrage returns.

Theoretically, a perfect arbitrage offers riskless profits, but practically, arbitrageurs can experience significant losses due to difficulty in execution. Agarwal et al. (2011) highlights the importance of non-price variables such as the supply of convertible bonds (Ammann et al., 2010) and extreme market shocks, or liquidity events, in affecting the performance of convertible arbitrageurs. For example, in 1998 the hedge fund Long-Term Capital Management (LTCM) experienced large losses when the Russian government defaulted on their government bonds. As a result LTCM was forced to liquidate large convertible arbitrage bond positions (see Jorion (1999) for further discussion). Choi, Getmansky, Henderson and Tookes (2010) also point out the difficulties faced by convertible bond arbitrageurs in 2008 following the collapse of Lehman Brothers when the ban on short selling of stock was introduced in September and October of that year. During these periods, instead of being the natural liquidity providers to the market, convertible bond arbitrageurs become liquidity demanders.

[11] Loncarski et al. (2009) find that on average the equity-like convertible bonds are 25% underpriced whereas the debt-like convertible bonds are 5% underpriced at issuance, based on the Tsiveriotis and Fernandes (1998) convertible bond pricing model.

2.3 Choice of Numerical Solutions for the Pricing of Convertible Bonds

When additional stochastic variables are taken into account when pricing convertible bonds, an appropriate solution would ideally increase the efficiency of the pricing model and reduce computational time. However, the closed-form solution is developed under a set of perfect market assumptions, continuous time factors and with only minor modifications to the capital structure (Ingersoll, 1977a; Lewis, 1991). Thus, accommodating time varying factors such as interest rate risk, credit risk and equity risk, path dependent features such as call and put provisions, finite horizon, discrete coupons and dividend payments is not possible using this model.

Accordingly, numerical solutions are suggested by Ingersoll (1977a) and Brennan and Schwartz (1977, 1980) that include finite difference, finite element, lattice-based and simulation methods have been developed. Table 2.3 reviews the numerical solutions that have been proposed to accommodate market imperfections in the pricing model and provides theoretical justification for their approach.

Table 2.3 shows that under the reduced-form approach a number of studies focus on the credit risk of convertible bonds, which is treated as an exogenous feature of the pricing model. The discussion on credit risk begins with the concept of a constant credit spread (McConnell and Schwartz, 1986), the decomposition of a convertible bond into a fixed-income and stock component (Tsiveriotis and Fernandes, 1998), and then integration of the probability of default, hazard rate, fractional loss as well as recovery upon bankruptcy (Ayache, Forsyth, and Vetzal, 2003; Takahashi, Kobayashi, and Nakagawa, 2001). Restrictive assumptions such as the requirement of constant interest rate and volatility can also be addressed when a numerical solution is proposed. Numerical solutions also cater for conversion, call and put features of the convertible bonds prior to maturity, thereby improving the pricing efficiency of convertible bond pricing models. Table 2.3 is subdivided into four panels based on the type of numerical solutions. The Table summarises the focus of each study and the key modelling implications. For example, the finite difference method and the finite element method attempt to approximate solutions for the PDE of the pricing model.

A finite difference approximation is obtained by replacing the partial derivatives with finite differences after building a grid of mesh points (Brennan and Schwartz, 1978; Moreno and Navas, 2003). Three types of finite difference schemes are available. Both the explicit (forward) and implicit (backward) finite difference are considered one-sided finite difference approximations. These approaches are considered less stable compared to the central finite difference approximation (also known as the Crank-Nicolson method) in approximating the PDE[12]. This method combines both the explicit and implicit differences into a single approximation. Nonetheless, Yigitbasioglu (2002) finds that while the Crank-Nicolson method does improve the stability of the pricing model, it is computationally inefficient when extra risk factors are included in the pricing model.

[12] Explicit and implicit finite difference methods are introduced Schwartz (1977) and Brennan and Schwartz (1977; 1978), whereas Crank-Nicolson finite difference method was first used for option pricing by Courtadon (1982).

Table 2.3
Numerical Solutions to the Pricing of Convertible Bonds and Key Findings

This table summarises the numerical solutions that have been used to price convertible bonds. There are four panels in this table, which are grouped by the types of numerical solution: (A) finite difference method; (B) finite element method; (C) lattice-based method; and (D) simulation method. The focus of these studies is not on generating empirical evidence from market data. Instead they extend, or test, the pricing models by including various assumptions about the imperfect nature of markets.

Authors (year)	**Focus of the study**	**Findings**
Panel A: Finite difference method		
Tsiveriotis and Fernandes (1998)	<u>Credit risk</u> • Allows a convertible bond to be decomposed into a fixed-income component and a stock component. • The fixed-income component is discounted at a risk-adjusted rate. • The stock component is discounted at the risk-free rate.	• The value of a convertible bond is a decreasing function of the credit spread.
Yigitbasioglu (2002)	<u>Stochastic interest rate, credit risk, equity risk and currency risk</u> • Develops a quasi-five factor model to price cross-currency convertible bonds that is contingent on the performance of foreign equity. • The Interest rate is modelled using Cox, Ingersoll and Ross (1985). • Credit risk is modelled using Tsiveriotis and Fernandes (1998). • Applies the concept of a local volatility surface. • The exchange rate is assumed to follow a geometric Brownian process similar to the stock price.	• The fixed-income component of a convertible bond has the highest value when either the call or conversion is least likely to happen because the investors will continue receiving the periodic payments. • Extra risk factors lead to computational inefficiency due to increased PDE dimensionality.
Takahashi, Kobayashi and Nakagawa (2001)	<u>Credit risk</u> • Incorporates default risk embedded in the stock component and partial recovery during default. • Applies Duffie and Singleton's (1999) model with an implicit jump process and discrete movements. The stock price is assumed to jump to zero at default, thus the fractional loss is assumed to be fixed at one.	• The hazard rate is a decreasing function of the stock price.

Table 2.3 *Continued*

Authors (year)	Focus of the study	Findings
Ayache, Forsyth and Vetzal (2003)	Credit risk • Proposes a Poisson distribution process, in which the stock price drops by a specified percentage upon default, i.e. fractional loss is from 0% to 100%.	• Total default occurs when the fractional loss is 100%. The equity component equals zero. But convertible bondholders can recover a fraction of the security face value. • In the case of partial default (fractional loss = 0%), the stock price is unchanged. Convertible bondholders can recover a fraction of the security face value or opt for conversion.
Lau and Kwok (2004)	Call provisions • Examines the impact of hard call and soft call provisions on the value of convertible bonds. • Employs Takahashi et al. (2001) model.	• Investors are better protected with stringent call requirements, thus they are more likely to pay a higher value for convertible bonds. • The theoretical critical call price is an increasing function of volatility, interest rate and the prespecified call price, but a decreasing function of the coupon, hazard and recovery rates.
Panel B: Finite element method		
Barone-Adesi, Bermudez and Hatgioannides (2003)	• Stochastic interest rate and volatility • The interest rate term structure is assumed to follow Hull and White's (1990) model that incorporates a mean-reverting feature of the spot interest rate process.	• The convertible bond value is positively related to the underlying stock price but negatively related to the spot rate.

Table 2.3 *Continued*

Authors (year)	Focus of the study	Findings
Gong and Meng (2007)	Call provisions • Examines the impact of a Parisian feature (barrier time or excursion time requirement) on the value of a convertible bond.	• The Parisian feature restricts the execution of a call. This increases the value of a convertible bond because investors are more likely to implement the optimal conversion strategy. • Call provisions have a significant impact on a convertible bond -when the underlying stock price is around the barrier price- because neither the issuer, nor the investor, can undertake the call and conversion strategy with certainty.
Panel C: Lattice-based method		
Hung and Wang (2002)	Stochastic interest rate and credit risk • Applies a binomial tree model. • Applies the Ho and Lee (1986) interest rate model and Jarrow and Turnbull (1995) credit risk model whereby stock price jumps to zero at default. • At each node, 3 probabilities have to be estimated, i.e. • probability of the stock price movements • probability of the interest rate movements • probability of default • The correlation between the stock price and risk-free rate is assumed to be zero. • When the stock price jumps to zero, the convertible bondholders receive only the recovery rate upon default.	• The suggested model is found to better price the convertible bonds because it accounts for: • stochastic interest rates • default risk

Table 2.3 *Continued*

Authors (year)	Focus of the study	Findings
Chambers and Lu (2007)	Stochastic interest rate and credit risk • Applies a binomial tree model • Extends Hung and Wang's (2002) pricing model to include non-zero correlation between stock price and risk-free rate. • Applies Ho and Lee (1986) interest rate model and Jarrow and Turnbull (1995) credit risk model.	• Correlation between stock price and interest rate is important in the pricing of convertible bonds.
Das and Sundaram (2007)	Stochastic volatility, stochastic interest rate and credit risk • Applies a binomial tree model. • Stochastic volatility is captured by the CEV model, whereas the stochastic interest rate model is represented by the Heath, Jarrow and Morton (1990) model. • There exists a correlation between the equity model and the term structure model. • Default probability is given as a function of equity prices. The interest rate and recovery rate is assumed to be constant.	• The value of a convertible bonds declines as default risk increases. • The difference between the value of a plain vanilla convertible bond and callable convertible bond decreases to zero as the default risk increase. The impact of default risk on the value of a convertible bond is greater when volatility increases.
Panel D: Simulation method		
Lvov, Yigitbasioglu and El Bachir (2004)	Stochastic interest rate and credit risk Compares the accuracy of least squares Monte Carlo simulation (LSM) model against the finite difference method of Ayache et al. (2003) The short rate follows Cox et al. (1985) square root process. The default intensity is assumed to be constant.	Hypothetical results show that the proposed numerical solutions perform fairly well with an average error of 0.24%. There is a potential for further extension to include other risk factors and path-dependent features using simulation methods.

Table 2.3 *Continued*

Authors (year)	Focus of the study	Findings
Wilde and Kind (2005)	Credit risk and stochastic interest rate • Applies a least squares Monte Carlo simulation (LSM) model. • Allows for the possibility of default, governed by a company-specific default probability and an issue-specific recovery rate. • Probabilities of default and recovery rate are assumed to be constant. • Compares the pricing efficiency of LSM model to closed-form solution and binomial tree model for the European and American convertible bonds. • Applies Cox et al (1985) model and allow for correlation between stock price and interest rate.	• The simulation model is claimed to be more promising for practical applications instead of the closed-form solution and the lattice-based methods. • A stochastic interest rate has an impact particularly on at-the-money (ATM) convertible bonds. • The correlation between the stock price and interest rate does affect the valuation process.
Kimura and Shinohara (2006)	Conversion with reset clause. • Derives a solution to price non-callable risky reset convertible bonds. • A reset clause entitles the issuer to decrease the prespecified conversion price (increasing conversion ratio) when the underlying stock price does not exceed the trigger price. • The stock price drops to zero in the event of default.	• The relationship between the value of conversion option and reset time is indicated by a hump-shaped curve. • The stock price has an inverse relationship to time to maturity and conversion ratio but is insensitive to the reset time especially when it is near to maturity. • The best reset time for the issuer is at maturity because the conversion probability is a decreasing function of reset.
Yang, Choi, Li and Yu (2010)	Conversion with reset clause • Extends Kimura and Shinohara's (2006) model to incorporate a dilution effect when there is a downward revision in the conversion price.	• Suggests that future studies may include a stochastic interest rate in their model.

The use of the finite element method is an alternative way of deriving a solution to the PDE. From the viewpoint of computational practicality, Barone-Adesi, et al. (2003) and Gong and Meng (2007) recommend the finite element (FE) method over the finite difference (FD) method for the following reasons: first, the FE method is suitable for modular programming; second, a solution for the entire domain is computed with FE instead of isolated nodes as with the FD codes; third, the FE method can easily deal with irregular domains; fourth, the FE method provides more flexibility in terms of incorporating final conditions and boundary conditions; and fifth, the FE method allows for unstructured meshing, thus generating better precision. Nonetheless, Barone-Adesi et al. (2003) state that the difference between the FE and FD methods is only relevant at the theoretical level and adds little in terms of improvements in pricing.

There are a number of popular alternate approaches that involve the use of less complicated lattice-based and simulation methods, thereby allowing for the discretisation of time and space. These approaches are different from the finite difference and finite element methods because they do not attempt to solve the PDE of the pricing model. The lattice-based method describes the evolution of asset prices based on backward induction starting from the payoff at the final node of the stock price tree. Then, the value is rolled back through the tree to time, $t = 0$.

Cox, Ross and Rubinstein (1979) introduced the first binomial tree model to value stock options. This model allows the underlying asset price to move either up or down at each time path or interval. In order to construct a tree model, there is a need to specify the length of the time step and the transition probability, both of which are typically assumed to be constant throughout the tree (Cox et al., 1979). A univariate binomial tree is contingent only on the performance of the underlying common stock. This approach can easily be extended to a bivariate binomial tree to account for two stochastic variables, or to a multivariate setting, to account for more than two stochastic variables (Chambers and Lu, 2007; Hung and Wang, 2002). In practice, a trinomial tree model is preferred to the binomial tree model because a trinomial tree allows for three different states, explicitly, up, down and a middle (sideways) move at each path. In addition, the trinomial tree model has been proven to converge faster than the binomial tree model.

The other method for pricing a convertible bond is to use simulation methods. Simulation is recommended because the solution to a convertible bond is a multidimensional problem involving equity, interest rate and credit risks. Moreover, convertible bonds are issued with complicated path-dependent features such as hard calls, soft calls, call trigger conditions, resettable conversion ratios, and sequential conversion, to name just a few. Therefore, simulation should better capture the dynamics of the underlying state variables and the complex features of real world convertible bonds. In addition, simulation is also computationally efficient because it converges faster than the aforementioned numerical methods (Longstaff and Schwartz, 2001).

In the valuation process, the simulation model is used to generate a random path of the underlying stock price. The next step is to determine the optimal exercise strategies of the investor and the issuer at any possible exercise date. The conversion option is exercised prior to maturity if the immediate payoff from exercising is higher than the continuation value from holding the convertible bond for another period. For example, the continuation value can be estimated using a backward-induction procedure by means of simple regression, known as the least-squares Monte Carlo simulation model that Longstaff and Schwartz (2001) introduced to price American options.

The simulation method is also favourable to the other three numerical solutions considered. While the finite difference, finite element and lattice-based methods are efficient to solve pricing models with one or two sources of uncertainty (Broadie and Glasserman, 1997; Longstaff and Schwartz, 2001), the computational time increases exponentially with the number of state variables (Fu, Laprise, Madan, Su, and Wu, 2001). Since the value of a convertible bond is a function of multiple sources of uncertainty, the simulation model is usually recommended to overcome complicated computations, difficulties in incorporating path dependencies and low flexibility in modelling the underlying state variables (Lvov et al., 2004; Wilde and Kind, 2005). Another advantage of the simulation method is that it can solve derivative securities with multiple stochastic factors, American feature, and path-dependent payoff structures (Longstaff and Schwartz, 2001; Lvov et al., 2004; Wilde and Kind, 2005). Moreover, it allows for significant gains in computational speed and efficiency (Longstaff and Schwartz, 2001) since the convergence rate is independent of the number of state variables (Fu et al., 2001).

2.4 Empirical Review

There has been extensive research undertaken testing the various pricing models. Table 2.4 summarises the data and methodology used by these various empirical studies, together with key findings. The degree of mispricing is also reported. Underpricing occurs when a convertible bond sells at a discount over the model-generated value, whereas overpricing occurs when a convertible bond sells at a premium over the model-generated value. The results show a wide range of mispricing from an average underpricing of 1.94% (Landskroner and Raviv, 2008) to 12.9% (Carayannopoulos, 1996) and an average overpricing ranging from 0.36% (Ammann et al., 2008) to approximately 5% (Barone-Adesi et al., 2003). The next two sections summarise the tests of structural and reduced form models in this context.

2.4.1 Tests of Structural Models

Empirical studies on the structural approach of Brennan and Schwartz (1977, 1980) to convertible bond pricing are limited, since firm value is neither observable nor tradable. This clearly complicates parameter estimation. For example, King (1986) and Carayannopoulos (1996) use the standard deviation of the historical stock returns as the proxy for volatility instead of the changes in the firm value. Both of these studies also include riskless senior debt in the firm's capital structure. This assumption is expected to bias the results of firms with higher credit risk, indicated by relatively low firm value. King's (1986) model also excludes firms with preferred stock or/and multiple issues of convertible bonds outstanding. The restrictions imposed on the firm capital structure are meant to avoid further complications arising from the boundary conditions that would otherwise affect the efficiency of computation.

The inclusion of a stochastic interest rate further complicates the model. Nonetheless, the model is expected to better reflect real market specifications. Interestingly, Carayannopoulos (1996) finds that the pricing differences between the two-factor model and the one-factor model are less than 1% and the root mean square error for the two-factor model is 10.66 versus 11.18 for the one-factor model. The improvement in the pricing error, after incorporating a stochastic interest rate, is therefore very marginal.

Consequently, it would be computationally more efficient to employ the one-factor model. Moreover, additional anecdotal evidence on the appropriateness of using these models is evident from the pricing errors. While the sample size and periods differ the average pricing error of the Carayannopoulos (1996) two-factor model of 12.9% is significantly higher than King's (1986) one-factor model of 3.75%.The test for estimation bias by King (1986) and Carayannopoulos (1996) also show that underpricing is more likely to be observed for OTM, high variance rate, and shorter maturity convertible bonds (and vice versa). The moneyness of the option is found to be correlated with both the variance rate and the time to maturity. A riskier convertible bond is therefore more likely to be underpriced because an investor would demand a higher yield premium for a bond issued by a firm with a lower value.

Table 2.4
Empirical Studies

This table summarises the data and methodology used by various empirical studies for the pricing of convertible bonds, together with key results. Panel A and B list the studies of domestic convertible bonds undertaken using the structural and the reduced-form approaches. Panel C presents the results of studies of international convertible bonds undertaken using the reduced-form approach. This table provides information on the types of numerical solutions used: (1) finite difference method; (2) finite element method; (3) lattice-based method (binomial tree and trinomial tree); and (4) simulation method, market, sample size and sample period. The estimation of each parameter is also outlined. The key result is the pricing error (right hand column). Underpricing occurs when a convertible bond sells at a discount to the model-generated value, whereas overpricing occurs when a convertible bond sells at a premium to the model-generated value.

Author (year)	Solution	Market	Sample size and period	Parameter estimation			Pricing error
				Volatility	Interest rate	Credit risk	
Panel A: Structural approach (Firm-value approach): Domestic convertible bond.							
King (1986)	Finite-difference method	US	103 callable convertible bonds. 2 valuation dates, i.e. on the 31/3/1977 and 31/12/1977.	Deterministic. Estimated from historical stock return.	Deterministic	Depends on the capital structure's assumption	Underpricing of 3.75%
Carayannopoulos (1996)	Finite-difference method	US	30 callable convertible bonds. 12 valuation dates, i.e. from 4th quarter of 1989 to 3rd quarter of 1990 (monthly basis).	Deterministic. Estimated from historical stock return.	Cox, Ingersoll and Ross (1985) model	Depends on the capital structure's assumption	Underpricing of 12.9%
Panel B: Reduced-form approach (Stock-value approach): Domestic convertible bond.							
McConnell and Schwartz (1986)	Finite-difference method	US	1 zero-coupon, callable and puttable convertible bond or LYON (Liquid Yield Option Note). 20 valuation dates, i.e. from 12/4/1985 to 10/5/1985.	Deterministic. Standard deviation of stock returns from 100 trading days.	Deterministic	Deterministic-a credit spread is added to the risk-free interest rate.	Underpricing
Ho and Pfeffer (1996)	Binomial tree	US	7 callable convertible bonds. 1 valuation date, i.e. on the 8/3/1995.	Deterministic	Ho and Lee (1986) model	Option-adjusted spread	Underpricing

Table 2.4 *Continued*

Author (year)	Solution	Market	Sample size and period	Parameter estimation			Pricing error
				Volatility	Interest rate	Credit risk	
Barone-Adesi, Bermudez and Hatgioannides (2003)	Finite-element method	UK	1 callable convertible bond. Daily valuation from 21/8/2000 to 15/6/2001.	Implied volatility	Hull and White (1990) model	Risk-free interest rate	Overpricing of approximately 5%
Ammann, Kind and Wilde (2003)	Binomial tree	France	21 callable and puttable convertible bonds. Daily valuation from 19/2/1999 to 5/9/2000.	Deterministic. Standard deviation of stock return from 520 trading days.	Deterministic	Tsiveriotis and Fernandes (1998) model.	Underpricing of 3.24%
Carayannopoulos and Kalimipalli (2003)	Trinomial tree	US	25 issuers of callable convertible bonds. Monthly valuations from Jan 2001 to September 2002.	Deterministic. Standard deviation of 52 weekly stock returns.	Deterministic	Duffie and Singleton (1999) model, parallel to Takahashi et al. (2001).	Overpricing of 0.58%.
Gushchin and Curien (2008)	Trinomial tree	Various markets	1,500 convertible bonds from 8 exchanges.	Deterministic. Standard deviation of stock return from 20 trading days	Deterministic	Tsiveriotis and Fernandes (1998) model with probability of default and recovery rate.	Underpricing of 3.7%
Rotaru (2006)	Trinomial tree	US	233 new callable convertible bonds.	Deterministic. Standard deviation of stock return from 150 trading days	Deterministic	Deterministic credit spread is added to the risk-free interest rate.	Underpricing of 4.84%

Table 2.4 *Continued*

Author (year)	Solution	Market	Sample size and period	Parameter estimation			Pricing error
				Volatility	Interest rate	Credit risk	
Ammann, Kind and Wilde (2008)	Simulation method	US	32 callable convertible bonds. Daily observations from 10/5/1996 to 12/2/2002	Stochastic volatility. GARCH model.	Deterministic	Tsiveriotis and Fernandes (1998) model.	Overpricing of 0.36%
Panel C: Reduced-form approach (Stock-value approach): International convertible bond.							
Bailey, Chung and Kang (1996)	Closed-form solution	Korea	4 Euro-convertible bonds. Observation period from Jan 1989 to Dec 1992.	Deterministic. Standard deviation of 72 months of stock returns.	Deterministic	Riskless assumption	Overpricing
Landskroner and Raviv (2008)	Binomial tree	Israel	26 inflation-indexed convertible bonds (IICBs). Monthly observations from May 2003 to April 2006.	Deterministic. Standard deviation of 52 weekly stock returns.	Deterministic	Tsiveriotis and Fernandes (1998) model	Underpricing of 1.94%

2.4.2 Tests of Reduced Form Models

The first study of the reduced-form approach for the pricing of convertible bonds is undertaken by McConnell and Schwartz (1986). Since then, most studies have been extensions of this approach. Their solution to the complexity of the pricing model involves simplification of the boundary conditions at maturity as well as the parameter estimation. As a result, a number of extensions of their model have been developed to incorporate real market imperfections in the pricing model with the intention of further improving the efficiency of the valuation process.

One of the main features investigated is the effect of credit risk. As a preliminary attempt, McConnell and Schwartz (1986) use a risk-adjusted interest rate that is grossed up by a constant credit spread to capture the default risk of the issuer while maintaining other parameters constant. Ho and Pfeffer (1996) also apply the same approach. Both studies report an average underpricing. The same result is also reported in Ammann, et al. (2003), Gushchin and Curien (2008), and Rotaru (2006) with an average underpricing of 3.24%, 3.7% and 4.84%, respectively, when these studies apply the Tsiveriotis and Fernandes (1998) credit risk model. Tsiveriotis and Fernandes (1998) suggest that 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.

Gushchin and Curien (2008) include the probability of default and the recovery rate in their pricing model, thereby overcoming the key drawbacks of the Tsiveriotis and Fernandes (1998) model, originally pointed out by Ayache et al (2003) Initially, a pricing error of 15.8% is identified when their pricing model precludes credit risk. The pricing error is higher for lower-rated convertible bonds compared with investment-rated convertible bonds. When the pricing model includes a constant implied credit spread, the pricing error declines to 6.85%. In the third trial, the pricing model applies a moving-average implied credit spread to account for stochastic credit spreads, which further reduces the pricing error to 3.7%.

It is important to recognise that these pricing errors should lead to arbitrage opportunities involving the short selling of the expensive asset and the simultaneous purchase of the cheap asset (Mitchell and Pulvino, 2012). Therefore, 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. The ability to profit from perceived mispricing is very much a function of market conditions and the regulatory environment. For example, should market volatility increase, then the likely correlation or covariance structure between assets will become unstable, leading to difficulty in correctly delta hedging the arbitrage portfolio.

The results from Gushchin and Curien's (2008) study also indicate the importance of incorporating credit risk in the pricing of convertible bonds. In fact, a lower-rated convertible bond is less attractive to an investor because of higher credit risk. Hence, it is more likely to be underpriced. Conversely, the pricing of a higher-rated convertible bond is more likely to be consistent with the market because it is easier to estimate the credit condition of the convertible bond. In addition, credit risk only has marginal impact on the pricing when it is close to the redemption date of the security. Nonetheless, the empirical evidence is not so clear-cut: Ammann et al. (2008) report an average overpricing of 0.36% when applying the Tsiveriotis and Fernandes (1998) model, while Carayannopoulos and Kalimipalli (2003) report an average overpricing of 0.58% when applying the Takahashi et al. (2001) extension of Duffie and Singleton's (1999) credit risk model.

2.4.3 The Limitations of Existing Models

A recent paper by Zabolotnyuk, Jones, and Veld (2010) compares the efficiency of three pricing models by Brennan and Schwartz (1980), Tsiveriotis and Fernandes (1998), and Ayache et al. (2003) respectively. These models each treat credit risk differently. The Ayache et al. (2003) model generates the lowest mean absolute deviation of 1.86% in comparison to the 1.94% for the Tsiveriotis and Fernandes (1998) model, and 3.73% for the Brennan and Schwartz (1980) model. Noticeably, the Ayache et al. (2003) model that includes default risk embedded in the equity component of a convertible bond and the partial recovery during default, better prices convertible bonds when compared with the Tsiveriotis and Fernandes (1998) model. On the other hand, the efficiency of the Brennan and Schwartz (1980) model is restricted by the assumption of the capital structure.

The convertible bond pricing models developed using the reduced-form approach do not require credit risk information based on the firm's parameters as in the structural approach. Instead, credit information such as the credit spread, the possibility of default, and the recovery rate are determined exogenously from market data. Typically, practitioners have limited market credit information when pricing convertible bonds, particularly in modelling the hazard rate and the fractional loss, which are not observable. Instead, recovery rates can be obtained from the major credit rating agencies' publication of their historical recovery rates. As a result, practitioners are more likely to use the Tsiveriotis and Fernandes (1998) model in setting up investment and hedging strategies because this model only requires the estimation of credit spreads. Furthermore, the credit spread is often assumed to be constant with respect to the future dates (Gushchin and Curien, 2008), although in practice they are both time varying and vary with the maturity of the bond.

The question of the effect of stochastic interest rates on the pricing of convertible bonds is also debated under the reduced-form approach, with contrary arguments reported. In order to simplify the solution, Ammann et al. (2008) implement their study in two stages, with the first stage examining the impact of stochastic interest rates. They find no significant difference in the model-generated values between the constant interest rate model and stochastic interest rate model. Therefore, the interest rate is assumed to be constant throughout their empirical study for the purpose of reducing the complexity of the pricing model. But this finding is not fully supported by other studies including Ho and Pfeffer (1996) and Barone-Adesi et al.(2003).

This raises the important question of how stochastic interest rate behaviour should be modelled. Chan, Karolyi, Longstaff and Sanders (1992) provide evidence that one of the most important features of the term structure is the dependence of its volatility on the level of interest rates. They argue that the most commonly used term structure models that assume constant volatility, such as Merton (1973); Vasicek (1977) and Cox et al. (1985) are misspecified and do not capture the time varying volatility of interest rates. To date, none of the existing studies have considered Chan et al. (1992) findings in the pricing of convertible bonds. Therefore, one avenue for future study would be to further investigate the appropriate use of stochastic interest rates or constant interest rates in the pricing of convertible bonds. Note that clearly the monetary policy environment at the time of any empirical investigation must be considered. For example, studies using US data from the 1980s need to accommodate the significant changes to the level of interest rates that occurred during a period of high inflation.

Conventional practice assumes the underlying asset of a convertible bond follows a lognormal distribution with constant volatility. Volatility is measured as the standard deviation of stock returns, although implied volatility can also be estimated using the standard Black-Scholes (1973) option framework. As noted in Table 2.4 this assumption is commonly used in the valuation of convertible bonds. The historical standard deviation is also preferred because it is model free (Poon and Granger, 2005), easy to calculate and requires no prior assumption about stock market efficiency (Rotaru, 2006).

Nevertheless, it is impractical to assume constant volatility when the payoff structure of a convertible bond is dependent on the volatility of the stock price (Black and Scholes, 1973). Also, the life of a convertible bond is typically long, and during this period stock return variance may change substantially. Practitioners also recognise the drawback of assuming constant volatility and attempt to adjust the variance rate used in any modelling (MacBeth and Merville, 1980). In the context of convertible bonds, the empirical evidence on stochastic volatility is still limited with few studies acknowledging the importance of time varying volatility in their empirical work. For example, Barone-Adesi et al. (2003) consider implied volatility, while Ammann et al.

(2008) use GARCH volatility in their modelling and report an average overpricing of approximately 5% and 0.36%, respectively.

Further analysis reveals that OTM convertible bonds tend to be underpriced, whereas ITM convertible bonds are more likely to be overpriced (Ammann et al., 2003; Carayannopoulos and Kalimipalli, 2003; Zabolotnyuk et al., 2010), which is similar to the structural approach. Reasonably, an OTM convertible bond is less attractive for an investor, thus reducing its price. But, interestingly there are studies that find otherwise, in which OTM convertible bonds are frequently overpriced (Ammann et al., 2008; Landskroner and Raviv, 2008). The pricing of an OTM convertible bond is very similar to a straight bond equivalent. The larger pricing error is mainly attributed to the difficulty in determining the appropriate information for credit risk. On the other hand, the pricing of an ITM convertible bond is claimed to be less challenging because the security has a higher probability of conversion, making it similar to equity.

Another important feature is that pricing errors increase with bond maturity. For example, convertible bonds with longer maturities are found to be underpriced by Ammann et al. (2003) and Landskroner and Raviv (2008). Ammann et al. (2003) note that longer maturity convertible bonds are priced less accurately because the arbitrage strategies are more complex and expensive. Nonetheless, Rotaru (2006) comments that the relationship between pricing error 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 relationship is identified when market conditions are favourable.

The value of a convertible bond is also sensitive to the underlying assumption of the dividend yield or payment (Ammann et al., 2008; McConnell and Schwartz, 1986), coupon payment (Ammann et al., 2008; Lau and Kwok, 2004; Rotaru, 2006), and conversion ratio (Lau and Kwok, 2004; Rotaru, 2006). In addition, boundary conditions, particularly the call provisions, do affect the value of convertible bonds (Ammann et al., 2003). The call feature is valuable to the issuers but not the investors. Therefore, the value is higher for a non-callable convertible bond as compared to a callable convertible bond (McConnell and Schwartz, 1986). Theoretically, issuers are assumed to act optimally, that is to call the securities when it guarantees conversion. But in practice the securities are not called immediately even though the conversion price equals the call price because of prespecified call provisions, such as the call protection period, call notice period and call trigger. These restrictions lead to non-optimal calls that cause further estimation biases (Carayannopoulos and Kalimipalli, 2003).

2.4.4 International Convertible Bonds

The previous empirical studies examined the pricing of convertible bonds with embedded call options on the issuers' stocks issued in domestic financial markets. In addition to raising fund domestically, firms can raise funds from the foreign markets, or in the international bond markets. A good example is the Euro-convertible bond. This security is issued outside the country of operation of the firm, enabling foreign investors to take equity stakes in the domestic firm. The denomination currency can be the issuer's domestic currency, or another foreign currency. Firms resort to issuing international convertible bonds when domestic issues are expensive and restricted by regulatory constraints (Bailey et al., 1996). Nonetheless, when the security is issued in a foreign currency, the issuer and the investors may be exposed to foreign exchange risk. Panel C of Table 2.4 presents the empirical studies on international convertible bonds. The value of an international convertible bond is equivalent to the value of a straight bond plus the embedded call option value. Hence, the underlying pricing principle is similar to standard domestic convertible bonds, but requires an additional parameter that is the foreign exchange risk. For example, in Bailey et al. (1996) the underlying stock price is determined when foreign investors value the underlying stock after converting the foreign prices into US dollar. The foreign exchange risk can be managed using standard foreign exchange derivatives or forward contracts.

Landskroner and Raviv (2008) derive a solution for foreign currency convertible bonds (FCCB) and inflation indexed convertible bonds (IICB), whereby the fixed-income component is linked to a foreign exchange rate and a general price index, respectively. There is a need to estimate an additional parameter for the price index at each IICB's issuance date and each valuation date that is assumed to be correlated to the underlying stock price. On the other hand, the estimation for the other parameters such as the credit risk, interest rate risk and volatility is similar to the pricing of standard domestic convertible bonds.

In brief, reported inconsistencies are generally attributable to the limitations and differences of the model specifications. Some pricing models are developed under a restrictive set of simplified assumptions (Bailey et al., 1996; King, 1986), whereas others are extended to include real market specifications, such as credit risk. The estimation of credit-related measures, such as the credit spread, hazard rate, fractional loss and recovery rate upon default becomes an important consideration in these pricing models, especially when the credit risk is treated as an exogenous function.

In addition, there may be concerns with the length of the study, or statistical limitations due to few observations, which may generate estimation biases. For example, Ho and Pfeffer (1996) use one day (8/3/1995), King (1986) use two days (31/3/1977 and 31/12/1977), Carayannopoulos (1996) use 12 days (a year of monthly data), Carayannopoulos and Kalimipalli (2003) use 19 days (monthly data), Rotaru (2006) use the first five days after the issuance date, McConnell and Schwartz (1986) use 30 days (a month of daily data), Landskroner and Raviv (2008) use 36 days (monthly data) as the number of data points and Bailey et al. (1996) use 48 days (monthly data). Furthermore, the efficiency of the pricing model is only tested on a relatively small sample size. For example, McConnell and Schwartz (1986) and Barone-Adesi et al. (2003) both use one convertible bond, Ho and Pfeffer (1996) use seven convertible bonds, and Bailey et al. (1996) use four Euro-convertible bonds in their study. Similarly, this could lead to estimation biases and limit the ability to generalise the results and models used.

2.5 Conclusion

Over the past three decades, researchers have developed a number of convertible bond pricing models that closely reflect real market behaviour. Like other asset-pricing models in finance, such as the well-known Capital Asset Pricing Model, and the Black-

Scholes option pricing model, the model-generated price is very sensitive to the inputs and assumptions adopted. Typically, convertible bond models are extensions of the contingent claim framework of Ingersoll (1977a) and the option pricing models of Black and Scholes (1973) and Merton (1973, 1974). Nevertheless, the valuation process is not as straightforward as the pricing of straight bonds and options given the complex hybrid features typically present in convertible bonds.

Simply stated, the value of a convertible bond is a function of the issuance-specific factors, the underlying risk factors (credit, interest rate, and equity risks), and the boundary conditions such as call, put, and conversion provisions. Either a closed-form solution or a numerical solution can be employed to solve the value of a convertible bond. The choice will depend on the ability to address the underlying assumptions governing each pricing model. A closed-form solution is restrictive, cannot accommodate market imperfections and so has difficulty in generalising a solution, whereas numerical solutions are able to accommodate the multiple boundary conditions, the path-dependent payoff structures and the multiple factors of the pricing models (Nyborg, 1996; Wilde and Kind, 2005). These solutions include finite difference and finite element methods, and lattice-based and simulation models.

After reviewing the existing empirical literature, it is clear there remains scope for further examination of the appropriateness of methods used for convertible bond valuation. This review highlights a number of limitations to these studies with differences in the specifications of the pricing models generating inconsistent findings. For example, there is the critical question of using stochastic instead of constant interest rates in the pricing model. Chan et al. (1992) find that one of the most important features of the term structure is its dependence on interest rate volatility, thus term structure models that assume constant volatility are clearly misspecified.

Moreover, future empirical research may benefit from larger samples, which provide the additional benefit of improving statistical inference. In addition, analysis of markets outside the much studied US market may offer insights from alternate institutional settings and financial environments. There are also no comparative studies of convertible bonds issued in developed and developing, or emerging capital markets. Such an analysis will also be of interest to issuers and investors in determining the appropriateness of different financing and investment decisions such as asset allocation, diversification and arbitrage strategies[13].

Interestingly, while existing studies have tried to explain pricing errors and improve upon the valuation models, from the viewpoint of either issuance-specific or model-related risk factors, external factors such as the effect of market liquidity on the pricing of convertible bonds have not been considered. The issue of liquidity has also become increasingly important to market participants, particularly following the Global Financial Crisis of 2007 to 2009, as is clearly evidenced by the significant decline in the total market value reported in Table 2.1

[13] There have been a number of studies that consider corporate bond markets as part of a broader perspective on the role of emerging financial markets (Claessens and Yurtoglu, 2012; Kearney, 2012). More specifically, a number of recent studies focus on the trade-offs between bonds and domestic and international stock markets (Bianconi, Yoshino, and De Sousa, 2013; Neaime, 2012; Pei, 2005), explanations for bond pricing and spreads (Ammer and Cai, 2011; Comelli, 2012; Gabrisch and Orlowski, 2010; Mizen and Tsoukas, 2012), the role of corporate governance and conflicts in family owned-firms (González, Guzmán, Pombo, and Trujillo, 2012), role of bonds as a funding alternative and bank financing (Bourgain, Pieretti, and Zanaj, 2012; Flavin and O'Connor, 2010; Gimet and Lagoarde-Segot, 2012; Maquieira, Preve, and Sarria-Allende, 2012). Nonetheless, none of these works specifically consider the role convertible bonds.

CHAPTER THREE

ESSAY TWO

PRICING CONVERTIBLE BONDS

This chapter examines the real-time trade prices of US pure convertible bonds that control for the complex optionality present in these securities. A brief overview of the study is presented in Section 3.1 and a review of the literature is undertaken in Section 3.2. Section 3.3 describes the data and methodology used in this study, which includes the valuation framework and analysis of mispricing. Section 3.4 discusses the empirical findings while Section 3.5 concludes. The chapter's appendices and references are presented in Appendix B and the Bibliography sections, respectively.

3.1 Introduction

A convertible bond is a type of path-dependent derivative that is equivalent to a bond with an embedded call option on the firm's stock. Pricing these securities is made complex by the presence of additional option features, and the difficulty in clearly identifying the underlying risk factors needed by standard option pricing models. This has led to many studies identifying pricing errors, although these errors appear to vary with the bond sample, the time period and the method of valuation. In this study, results show that these pricing errors remain even after the convertible feature is isolated from other types of bond optionality. Later, this study demonstrates that the stochastic nature of volatility and the differences in the level of bond liquidity cause the pricing errors identified by this and other studies.

In nominal terms convertible bonds are an important segment of the corporate bond market with global outstanding of US$234 billion in 2011[14]. One key advantage of this security for investors is that the fixed-income component acts as a cushion to the effect of a declining stock price, which should make the security attractive for retail investors. However, hedge funds are the key market participants and purchase as much as 70% of convertible issues in the primary market (Choi et al., 2009; Mitchell et al., 2007) and approximately 80% of those that are privately-placed (Brown et al., 2012).

Correctly pricing these securities is therefore a critical task for investors when establishing their investment strategies, including arbitrage, hedging and asset allocation, as well as for issuers when deciding the price of new issues (Ho and Pfeffer, 1996). However, the empirical literature provides inconsistent evidence on the

[14] See Table 2.1

appropriate pricing of these securities. For example, Carayannopoulos (1996) reports convertible bonds being underpriced by 12.9%, while Barone-Adesi et al. (2003) show they may be overpriced by approximately 5%. The inconsistency is potentially attributable to the limitations and differences in the model specifications. Market participants, especially hedge funds, actively seek and arbitrage mispriced convertibles, for example, by buying underpriced convertibles that are selling at a discount to their theoretical value and then taking a short position in the underlying equity (Ammann et al., 2010). Importantly, other authors[15] show that, when present, underpricing persists for a long period of time after issuance (suggesting that it cannot easily be arbitraged away), although it does eventually decrease (Loncarski et al., 2009). These varying findings highlight the need for a study to consistently investigate convertible bond pricing and appropriately control for the macroeconomic environment, estimation period and model inputs to clearly establish the degree and persistence of mispricing, if any.

Importantly, the existing empirical evidence on convertible bond pricing has been based largely on samples of convertibles with additional call (the right for the issuer to buy back the bond) and put (the right for the investor to sell back the bond) features[16]. This study avoids possible price distortions by using a unique dataset that consists of pure convertible bonds and so controls for other types of optionality. Of particular concern is the presence of call features, which are valuable to the issuer but not to the investor, since it allows for the redistribution of wealth to convertible bondholders from

[15] For example are Ammann et al.(2003), Loncarski et al. (2009) and Rotaru (2006).

[16] 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 (1996), 1 callable convertible in 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 et al. (2008).

stockholders (Brown et al., 2012) prior to maturity[17]. Theoretically, issuers are assumed to call back the convertible bonds when it guarantees conversion but practically issuers do not act optimally. This leads to biases in the valuation process (Carayannopoulos and Kalimipalli, 2003). Also, convertible arbitrage is complicated by the presence of call features. For example, Choi et al. (2009) find that the lack of put and call options on a particular stock is associated with greater convertible bond arbitrage activity. Similarly, Brown et al. (2012) document a significantly lower involvement of hedge funds in callable convertible bonds.

One key innovation of this study is that it is able to control for these features, and so highlight the importance of identifying the specific option features present in a convertible bond, which otherwise will affect the efficiency of any particular pricing model. This study examines the pricing of real-time trade prices of pure convertible bonds identified from TRACE-FINRA, which exclude callable and puttable features. Convertible bonds with sinking fund, mandatory, exchangeable, reset and reverse clauses are also excluded. To the best of knowledge, this is the first study to examine the pricing efficiency of these convertible bonds using real-time trade prices. The dissemination of real-time trade data is meant to increase the transparency level to market participants and also enables regulators to monitor the quality of market pricing and execution.

This study applies the least squares 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 approach is recommended to overcome the complicated

[17] Subject to call provisions such as the call protection period, call notice period, and the call trigger. King and Mauer (2012) provide further discussion on the determinants of call policy of convertible bonds.

computations, difficulties in incorporating path dependencies and low flexibility in the pricing of a convertible bond (Lvov et al., 2004; Wilde and Kind, 2005). This numerical approach can solve for derivative securities with multiple stochastic factors, American feature, and path-dependent payoff structures (Longstaff and Schwartz, 2001; Lvov et al., 2004; Wilde and Kind, 2005), with significant gains in computational speed and efficiency (Longstaff and Schwartz, 2001) because the convergence rate is independent of the number of state variables (Fu et al., 2001). Thus, it is popular among 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. First, the payoff structures of convertible bonds are contingent on the performance of the underlying stock. Second, convertible bonds tend to be issued by either unrated, or non-investment grade firms (Huang and Ramírez, 2010), which will likely add to stock volatility. Therefore, the stochastic nature of volatility is controlled 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 is also associated with the leverage effect (Cox, 1975, 1996). As for credit risk, this study follows the approach of Tsiveriotis and Fernandes (1998) to keep the pricing model simple. Consequently, 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.

An average underpricing of 6.31% is documented from daily observations, estimated from a sample of 96 pure convertible bonds, covering the period from October 26, 2004 to June 30, 2011. Underpricing is reported throughout the observation period, which is a finding consistent with Ammann et al. (2003), Carayannopoulos (1996), Gushchin and Curien (2008), King (1986) and Rotaru (2006). Equity-like convertible bonds are less underpriced (0.56%) by the market than debt-like convertibles (10.70%). Excluding the most volatile period of the Global Financial Crisis around the collapse of Lehman Brothers (September 15, 2008 to March 15, 2009), this study documents an average underpricing of 3.14%. Similar to the average results for the full sample, the underpricing observed from equity-like convertibles is smaller than debt-like convertibles (0.03% and 5.56%, respectively). Equity-like convertible bonds are less risky and more attractive to investors because of the higher value of the conversion option. On the other hand, debt-like convertibles have 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 Global Financial Crisis, convertible bonds on average traded at a deep discount with a moneyess ratio of 0.54. Therefore, a significant average underpricing of 42.97%, is observed, with the debt-like convertibles underpriced by 48.27% and the equity-like convertibles underpriced by 11.12%. During this period of extreme volatility and higher probability of default risk, the US Securities and Exchange Commission (SEC) imposed a temporary ban on short selling[18] that added to the massive selling

[18] SEC banned the short selling of 799 financial companies for three weeks that is from September 19, 2008 to October 2, 2008 in 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).

pressure from arbitrageurs. The ban restricted convertible arbitrage opportunities causing arbitrageurs to become liquidity demanders instead of natural liquidity providers to the market (Choi et al., 2010). Furthermore, Hedge Fund Research Inc. reported that its convertible arbitrage index realised losses of 34% in 2008, mainly due to the extreme market volatility and illiquidity during the period from September to November 2008 (Mitchell et al., 2007).

In addition, stochastic volatility is found to have a significant effect on the efficiency of convertible bond pricing. The impact is relatively greater for convertible bonds with higher underlying stock returns 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 the time-varying effects of volatility, particularly in the pricing of convertible bonds susceptible to substantial fluctuations in the underlying stock returns. Note that the effect of stochastic interest rates is not included in the subsequent pricing model. This is due to the findings from preliminary tests, which showed an insignificant mean difference in the mispricing between the constant interest rate model and the stochastic interest rate model. Therefore, interest rate is allowed to remain constant, which is consistent with Ammann et al. (2008) and Brennan and Schwartz (1980).

Given the fact that the convertible bond market is relatively illiquid when compared with the equity and straight bond markets, some mispricing may be attributable to differences in the level of liquidity over time and for specific securities (Ammann et al., 2003; Loncarski et al., 2009). In general, illiquidity may cause significant pricing discrepancies and there may be difficulty in selling a convertible investment quickly to meet unexpected cash flow needs. This issue has become increasingly important for regulators, rating agencies, security exchanges, and institutional investors (Chordia, Sarkar, and Subrahmanyam, 2005; Longstaff, 1995).

To identify these potential effects, this study utilises regression analysis and find that illiquidity has a significant effect on the mispricing of convertible bonds. Illiquid convertibles tend to be underpriced by the market, as measured by the convertible bonds issuance size and oversubscription of the convertibles at issuance. Also, riskier convertible bonds (those with a 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 et al. (2010), this study finds 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; a finding consistent with the highly uncertain market conditions. This result also supports the earlier finding of deep underpricing around the time of the collapse of Lehman Brothers.

This chapter is structured as follows: next, a review of the literature is undertaken. Then, in Section 3.3 the data and methods used in this study are established; Section 3.4 provides the empirical results and discussion, while the final Section 3.5, presents the concluding remarks.

3.2 Review of the Literature

The theoretical framework for the pricing of contingent claim assets is established with the well-known publication of Black and Scholes (1973) and Merton (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 (1977a) views the value of a convertible bond as a contingent claim on the firm-value but this approach is subject to two key drawbacks. First, 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). Second, the solution to the partial differential equation (PDE) of the contingent-claim becomes complicated when the model considers more complex capital structure (Takahashi et al., 2001; Zabolotnyuk et al., 2010). Consequently, the reduced-form approach is introduced by McConnell and Schwartz (1986) to price convertible bonds that views 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. A closed-form solution is restricted to perfect market assumptions and continuous time factor so it is unlikely to generalise the solution (Ingersoll, 1977a; 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 et al., 2003; Brennan and Schwartz, 1977; Takahashi et al., 2001; Tsiveriotis and Fernandes, 1998; Yigitbasioglu, 2002), (2) finite element method (Barone-Adesi et al., 2003), (3) tree model (Chambers and Lu, 2007; Hung and Wang, 2002; Yagi and

Sawaki, 2010) and (4) simulation model (Lvov et al., 2004; Wilde and Kind, 2005) are suggested. A recent paper by Batten, Khaw and Young (2013) provide a survey on the pros and cons of these numerical solutions as well as a comprehensive empirical review of the existing studies on the pricing of convertible bonds.

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 computationally efficient to assume a flat term structure. Ammann 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. Tsiveriotis and Fernandes (1998) claim that a convertible bond can be decomposed into the fixed-income component that is exposed to credit risk and the stock component that 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).

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 returns 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. Studies that have considered stochastic volatility includes 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 interestingly, Ammann et al. (2008) and Landskroner and Raviv (2008) find evidence of underpricing in ITM convertible bonds. The relationship between the mispricing and term to maturity is also found to be mixed. 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/payments (Ammann et al., 2008; McConnell and Schwartz, 1986), coupon payments (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, et al. (2008).

In brief, the reported mixed results could be 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, in addition to the characteristics of the examined convertible bonds. These limitations may generate estimation biases and limit the ability to generalise the results and models used. Therefore, there remains scope for further examination on the pricing of convertible bonds.

3.3 Data and Methodology

3.3.1 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 2.1). Throughout the observed period, US holds more than half of the convertible bond market share. 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[19] (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 also enables the regulators to monitor the market, pricing and execution quality.

TRACE was implemented in three phases (refer Table B.1 in Appendix B). 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[20] 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,

[19]National Association of Securities Dealers, NASD (2004) estimates that 99% of the US corporate bond trading is transacted over-the-counter.
[20]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).

including convertible bonds. Nonetheless, any transactions pursuant to Rule 144A[21] are not disseminated.

3.3.2 Sample Selection

This study examines the pricing of real-time trade data of the US convertible bonds that are disseminated by TRACE-FINRA. Initially, 511 convertible bonds that are offered before June 30, 2011 are identified. 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 3.1). The mean maturity of the sample of this study is 5.93 years (refer Table 3.1), 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.

301 convertible bonds are found to be attached with callable feature. These convertible bonds have to be excluded from the sample selection to control for the impact of non-optimal call on pricing efficiency, thus reducing the sample to 211 convertible bonds. Also, the valuation process becomes more 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 in the future study. The sample also excludes convertible bonds that are attached with puttable, sinking fund or mandatory features. In addition, the selection criteria requires the convertible bonds to be public bonds issued by the US local firms, to have prospectus in

[21] Rule 144A, adopted by the Security and Exchange Commission of US 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/).

EDGAR[22] and with active underlying common stock of the issuer. Therefore, exchangeable convertible bonds and convertible bonds with delisted underlying stock or have filed for Chapter 11 are also excluded to ensure the sample consists only of pure convertible bonds. These criteria further reduce the sample size to 177 convertible bonds.

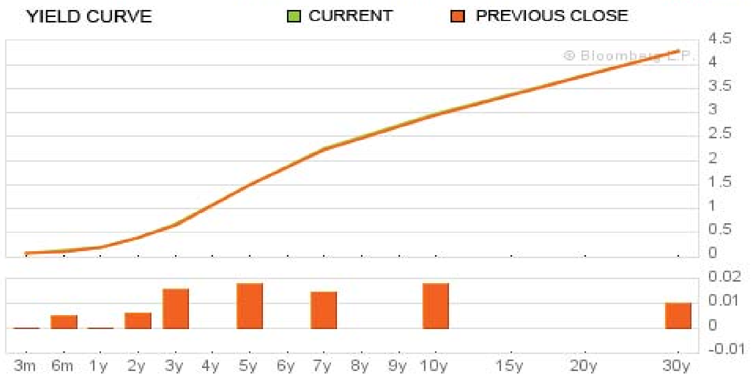
Figure 3.1
Market Data of US Government Bonds as at July 27, 2011

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



[22] 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. 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.

Furthermore, it is required that the convertible bond sample has credit ratings to account for credit risk. Only 33 convertible bonds are found to be rated. In view of that, the credit rating of the issuer is considered 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, a unique sample consisting of 96 issues of pure convertible bonds is obtained. A pure convertible bond is defined as a bond embedded with only the conversion provision.

The observation period is from the first trade date disseminated by TRACE-FINRA for the selected sample. This is from October 26, 2004 through June 30, 2011. This study examines the pricing efficiency on daily observation, thus the intraday average price from the disseminated real-time data have to be calculated. 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.

There are four types of real-time intraday average price for comparison, with the total number of daily observations in parentheses for the whole sample. To be specific, 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, *MPBuyer* and *MPSeller* representing the retail trade prices and *MPDealer* representing the wholesale trade prices are available. 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 SEC that are publicly accessible via EDGAR. The corresponding synchronous stock prices are collected from Datastream.

3.3.3 Sample Description

Table 3.1 reports the summary statistics for the overall sample of 96 convertible bonds. The mean maturity at issuance is 5.93 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 0.38% to a high rate of 15%. On average, the convertible bond can be converted at a conversion price of US$32.11 per share and a conversion premium at offering of 31.06%. 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$16.4 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.

Table 3.1
Summary Statistics of the Sample

This table reports the summary statistics of the observed characteristics for the sample of 96 convertible bonds identified from TRACE-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. *SD* denotes the standard deviation.

	Mean	**SD**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Maturity (years)	5.927	2.069	3.000	5.000	5.000	7.000	20.000
Coupon (%)	3.750	2.088	0.375	2.500	3.438	4.625	15.000
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	1.500	187.488	300.000	467.500	2500.000
Overallotment (US$' mil)	16.410	23.000	0.000	0.000	0.000	30.000	75.000
Degree of overallotment (%)	5.501	6.877	0.000	0.000	0.000	15.000	15.000
Total issuance (US$' mil)	424.670	393.009	1.500	187.488	316.250	487.500	2500.000
Rating	12.573	3.279	5.000	10.000	13.000	15.000	20.000

This is of no surprise as the convertible bond market is more accessible 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, the sample is divided 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 by 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.

Panels A and B of Table 3.2 describes the summary statistics for subsamples 1 and 2, respectively. Panel C reports the test of mean differences for the observed characteristics. Statistical evidence shows that there are significant differences at the 1% level, between the coupon rate and conversion price of 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 3.14% and a range from 0.38% to 6.50%. 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 a lower interest rate environment.

Table 3.2

Summary Statistics and Mean Comparison of Subsamples by Conversion Terms

This 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. *SD* denotes the standard deviation, while *SE* denotes the standard error. A superscript *,** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Mean	**SD**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Panel A: Subsample 1 - Convertible bonds without conditional conversion							
Maturity (years)	5.706	1.767	3.000	5.000	5.000	7.000	10.000
Coupon (%)	4.860	2.572	1.250	3.250	4.125	6.500	15.000
Conversion price (US$)	23.636	25.686	1.235	5.490	16.413	32.819	134.481
Conversion premium (%)	33.661	37.168	-7.344	20.000	25.619	30.000	197.442
Initial issuance (US$' mil)	353.464	251.554	1.500	199.976	291.250	450.000	1150.000
Overallotment (US$' mil)	17.134	22.718	0.000	0.000	0.000	41.250	75.000
Degree of overallotment (%)	5.782	6.935	0.000	0.000	0.000	15.000	15.000
Total issuance (US$' mil)	370.598	252.138	1.500	199.976	308.125	460.000	1150.000
Rating	12.794	3.240	7.000	10.000	13.000	15.000	19.000
Panel B: Subsample 2 - Convertible bonds with conditional conversion							
Maturity (years)	6.048	2.221	3.000	5.000	5.000	7.000	20.000
Coupon (%)	3.141	1.465	0.375	2.000	3.000	4.000	6.500
Conversion price (US$)	36.749	24.899	8.288	14.025	31.794	51.788	118.319
Conversion premium (%)	29.633	29.638	-9.804	17.505	23.568	31.000	172.954
Initial issuance (US$' mil)	438.311	453.648	2.200	160.000	300.000	475.000	2500.000
Overallotment (US$' mil)	16.012	23.328	0.000	0.000	0.000	30.000	75.000
Degree of overallotment (%)	5.347	6.898	0.000	0.000	0.000	15.000	15.000
Total issuance (US$' mil)	454.323	451.254	2.200	172.500	320.625	500.000	2500.000
Rating	12.452	3.322	5.000	10.000	13.000	15.000	20.000

Table 3.2 *Continued*

Panel C: Mean comparison

	Sub sample 1	Sub sample 2	Mean difference	SE	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

The mean conversion price for subsample 2 is significantly lower than subsample 1 at the 1% level by US$13.11 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, is a discussion of 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. There are 48 convertible bonds in each subsample. Subsample A includes convertible bonds that are first issued via private placement pursuant to Rule 144A and are subsequently registered with the SEC to be public issues, whereas subsample B consists of convertible bonds that are issued via public placement.

Huang and Ramírez (2010) find that approximately 88% of convertible bonds 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) find a longer period, ranging from three to seven months for high-yield bonds. Huang and Ramírez (2010) further claim that the difference is because of the date of registration with SEC is used instead of the time of completion of the exchange offer used to complete the registration. Existing studies (Fenn, 2000; Huang and Ramírez, 2010; Livingston and Zhou, 2002) have reported a large increase in the size of the 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. On the 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[23] have advantages over public lenders in dealing with firms with

[23]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, (Brown et al., 2012).

high credit risk and information asymmetry, supporting the lender specialisation hypothesis.

Panels A and B of Table 3.3 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 this 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 option 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 0.73 years, significant at the 10% level, similar to Huang and Ramírez (2010). Conversely, the mean coupon rate for subsample A is significantly lower than subsample B, at the 1% level, with a mean difference of 1.17%. Rule 144A is meant 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 the 5% level by US$10.89 per share. Nonetheless, there is no statistical difference in mean found for the conversion premium at offering.

Table 3.3
Summary Statistics and Mean Comparison of Subsamples by Type of Placement

This 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. *SD* denotes the standard deviation, while *SE* denotes the standard error. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Mean	**SD**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
Panel A: Subsample A – First issued via Rule 144A							
Maturity (years)	6.292	2.543	3.000	5.000	6.000	7.000	20.000
Coupon (%)	3.167	1.652	0.375	1.813	3.125	4.000	7.000
Conversion price (US$)	37.551	24.719	3.025	18.562	33.997	48.860	118.319
Conversion premium (%)	33.790	41.637	-9.804	15.451	22.526	31.750	197.442
Initial issuance (US$' mil)	512.130	525.524	1.500	174.988	300.000	575.000	2500.000
Overallotment (US$' mil)	1.172	6.292	0.000	0.000	0.000	0.000	41.000
Degree of overallotment (%)	0.625	3.029	0.000	0.000	0.000	0.000	15.000
Total issuance (US$' mil)	513.302	524.915	1.500	174.988	300.000	575.000	2500.000
Rating	12.208	3.332	5.000	10.000	13.000	14.000	20.000
Panel B: Subsample B – Public placement							
Maturity (years)	5.563	1.382	3.000	5.000	5.000	7.000	10.000
Coupon (%)	4.333	2.321	1.250	3.000	3.938	5.250	15.000
Conversion price (US$)	26.660	26.013	1.240	10.955	15.896	34.609	134.481
Conversion premium (%)	28.328	19.203	9.020	20.000	24.986	30.000	140.000
Initial issuance (US$' mil)	304.392	129.148	100.000	187.500	300.000	389.750	550.000
Overallotment (US$' mil)	31.647	23.568	0.000	9.000	30.000	50.000	75.000
Degree of overallotment (%)	10.377	6.154	0.000	5.417	14.643	15.000	15.000
Total issuance (US$' mil)	336.039	143.587	100.000	202.500	324.938	426.250	600.000
Rating	12.938	3.218	7.000	10.000	13.000	16.000	19.000

Table 3.3 *Continued*

Panel C: Mean comparison

	Sub sample A	Sub sample B	Mean difference	SE	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$)	37.551	26.660	10.891**	5.179	0.607	21.175	2.103
Conversion premium (%)	33.790	28.328	5.462	6.618	-7.678	18.603	0.825
Initial issuance (US$'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

In addition, the total issuance for subsample A is significantly higher than subsample B with a mean difference of US$177.26 million, at the 5% level. The amount of overallotment for subsample A is significantly lower than subsample B at the 1% level. The mean difference between the subsamples is US$30.48 million. In general, debt issued via Rule 144A has a smaller base of potential buyers (only the QIBs), less stringent disclosure requirements and weaker legal protection. Because of these factors, the 144A debt are claimed to be less liquid and more risky, thus producing a yield premium over public issues (Fenn, 2000; Livingston and Zhou, 2002). As a result, issuers in the 144A market are more likely to issue a larger bond size because investors are more likely to ask for a lower rate of return for larger issues that are usually more liquid than smaller issues (Fenn, 2000; Livingston and Zhou, 2002). Furthermore, there is evidence of a negative relationship between gross underwriter spread and size of issuance, explained by economies of scale (Livingston and Zhou, 2002). For subsequent tests, only subsamples by the terms of conversion are considered because rationally, once these convertible bonds are registered to become public issues, the type of placement is assumed not to have any significant effect on the pricing efficiency of the convertible bonds.

Table 3.4 reports the characteristics of the real-time trade prices disseminated by TRACE-FINRA and the moneyness of 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.

Table 3.4
Summary Statistics of the Market Data for the Sample

This table reports the summary statistics of the real-time trade prices 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 that is 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). *SD* denotes the standard deviation.

	Obs	**Mean**	**SD**	**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

From October 26, 2004 through June 30, 2011, the average daily real-time trade price (*MPAll*) is US$110.97. Retail trades denoted by *MPBuyer* and *MPSeller* are recorded at US$112.04 and US$111.82, respectively, whereas the wholesale trade denoted by *MPDealer* is recorded at US$110.03. To be consistent with the literature on convertible bond pricing, the moneyness is reported instead of the conversion premium. The mean moneyness is 0.84, and with reference to Mitchell and Pulvino (2012), convertible bonds with mean moneyness less than 0.84 are defined as debt-like (credit-sensitive), whereas convertible bonds with mean moneyness greater than 0.84 are defined as equity-like (equity-sensitive). The sample is also defined by the median of moneyness (0.77) and the results for the subsequent tests are consistent whether the sample is sorted by the mean or median of moneyness.

Table 3.5 reports statistically insignificant mean difference between the retail trade prices. However, the retail trade prices are found to be significantly higher than the wholesale trade prices, at the 1% level probably due to lower trade frequency. This study also reports the market data by terms of conversion. From Panel C of Table 3.6, convertible bonds that are issued without conditional conversion are priced significantly higher than the convertible bonds that are issued with conditional conversion at the 1% level. These 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 0.97 and 0.80, respectively.

Table 3.5
Mean Comparison between the Types of Real-time Trade Price

This 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. *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			

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[24] as compared to those in subsample 2 that limit the bondholders from taking immediate advantage of the favourable market condition.

[24] 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).

Table 3.6
Summary Statistics and Mean Comparison of the Market Data for the Subsamples Identified by the Conversion Terms

This table reports the summary statistics of the real-time trade prices 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. *SD* denotes the standard deviation, while *SE* denotes the standard error. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Obs	**Mean**	**SD**	**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

	Sub sample 1	**Sub sample 2**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	123.910	106.811	17.099***	0.463	16.191	18.008	36.9019
MPBuyer	127.922	106.776	21.146***	0.585	19.999	22.293	36.128
MPSeller	127.188	106.664	20.525***	0.605	19.339	21.711	33.918
MPDealer	126.497	105.155	21.342***	0.710	19.951	22.733	30.078
Moneyness	0.974	0.797	0.177***	0.006	0.165	0.189	29.760

In addition, this study examines 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, the observation period includes the extreme period of financial instability. The subperiods are defined with reference to the 79th annual report of the Bank for International Settlements (BIS)[25], but with slight changes to fit the selected sample periods.

Six subperiods are defined for the 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 on 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. The three subperiods: first, from mid-March 2009 to December 2009; second, from January 2010 to December 2010 and third, from January 2011 to June 2011.

Panel A of Table 3.7 summarises the statistics of the sample, with Panels B and C being the subsamples by conversion terms. Table 3.7 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 the 1% level (refer Table 3.8).

[25] 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).

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 SEC imposed a temporary ban on short selling within a week of Lehman's collapse. The ban restricted convertible arbitrage opportunities that cause 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 2008 (Mitchell and Pulvino, 2012).

Prior to the subprime-mortgage-related turmoil (*Subperiod 1*), on average the convertible bonds are equity-like, traded at US$112.12 that decreases to US$108.48 in *Subperiod 2*. The moneyness decrease to 0.54 during the collapse of Lehman Brothers (*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$101.39 in the last three quarters of 2009, then to US$117.26 in 2010, and to US$130.16 in the first half of 2011. On average, the moneyness improves to 0.72, 0.86 and approximately 1.00, respectively. The increase signifies a gradual change from debt-like to equity-like convertible bonds. Similar trends are observed in the subsamples.

Table 3.7
Market Data for the Sample and Subsamples by Subperiods

This table reports the real-time trade prices (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 January to June 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). *SD* denotes the standard deviation.

Observation period	Obs	MPAll							Moneyness						
		Mean	SD	Min	First quartile	Median	Third quartile	Max	Mean	SD	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	4.720
Subperiod 3	3,328	77.560	26.995	15.000	58.675	78.384	94.738	232.190	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

Table 3.7 *Continued*

Panel C: Subsample 2 – Convertible bonds with conditional conversion

Observation period	Obs	MPAll							Moneyness						
		Mean	**SD**	**Min**	**First quartile**	**Median**	**Third Quartile**	**Max**	**Mean**	**SD**	**Min**	**First quartile**	**Median**	**Third quartile**	**Max**
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	95.797	102.839	125.575	247.630	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 3.8
Mean Comparison for the Market Data for the Sample by Subperiods

This table reports the mean differences of the real-time trade prices 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 January to June 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. 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

Subsequently, this study examines 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, the major driver of a change in the moneyness is the performance of the stock price that affects the value of a convertible bond. Table 3.8 shows that there is significant decrease in the mean trade prices (*MPAll*) between *Subperiods 1* and *2*. But the mean moneyness between these two subperiods is statistically insignificant. Moving from *Subperiods 2* to *3*, *MPAll* significantly decreases by US$0.075[26] when moneyness decreases by one basis point. Once the market starts to pick up in *Subperiod 4*, significantly *MPAll* increases by US$0.074 for every one basis point increase in the moneyness. This figure 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.

3.3.4 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's (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.

[26] The change in *MPAll* is calculated on the actual face value, US$1,000 of each convertible bond to provide a clear relationship between the trade price and moneyness.

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 distinguishable events at time T, and P is the probability measure corresponding to F. Let $C(\omega, s;\ t, T), \omega \in \Omega, s \in (t, T)$ denotes the payoff of a convertible bond, conditional on the convertible bond being exercised after time 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 $\tau*$ together with the payoff illustrated in Table 3.9. 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

$$C_{tot}(\omega, \tau^*;\ t_k, T) = C(\omega, \tau^*, t_k, T) + c(\tau^*) \qquad (3.1)$$

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.

$$V_0 = \frac{1}{n}\sum_{i=1}^{n} exp^{\left(-\int_{t_0}^{t_i^*} r(\omega_i,s)ds\right)} C_{tot}(\omega_i, \tau_i^*; t_0, T) \qquad (3.2)$$

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.

The valuation process considers discrete time, with daily frequency and time t belonging to a set of a 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 3.9 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.

Table 3.9
Payoff Structure of Convertible Bonds

This 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	

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

$$F(\omega; t_k) = E_Q\left[\sum_{j=k+1}^{K} exp^{\left(-\int_{t_k}^{t_j} r(\omega,s)ds\right)} C\left(\omega, t_j; t_k, T\right) \middle| \digamma_{t_k}\right] \tag{3.3}$$

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}.

3.3.5 Parameter Estimation

3.3.5.1 Stock Dynamics

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

$$dS_t = \mu S_t dt + \sigma S_t dB_t \qquad (t > 0) \tag{3.4}$$

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 a historical basis, using the time series data of the underlying stock.

$$\hat{\sigma} = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}\left(R_t - \overline{R}\right)^2} \tag{3.5}$$

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 this study examines the pricing on daily basis, it is consistent to employ daily data in each of the parameters. Consistent with previous studies, the volatility for each convertible bond is calculated using daily individual stock returns for 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 this study since the observation period includes the Global Financial Crisis (2007 to 2009) that caused excessive fluctuations in the financial markets. Therefore, the constant elasticity of variance (CEV) model is applied to control for the effect of a 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 is a foundation for the observed implied volatility skew that is also associated with the leverage effect (Christie, 1982; Cox, 1975, 1996).

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

$$dS_t = \mu S_t dt + \delta S_t^{\frac{\beta}{2}} dB_t \qquad (t > 0,\ \beta < 2) \tag{3.6}$$

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 (Black, 1975) as 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.

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.

$$ln\left|ln\frac{S_{t+1}}{S_t}\right| = a + blnS_t + u_t \tag{3.7}$$

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).

Table 3.10 summarises the results of Equation (3.7). 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 the 10% level with a negative mean coefficient of -0.37. As for subsample 1, the mean coefficient, -0.51 is statistically significant at the 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 -0.30. Though the results are not empirically consistent, the CEV model may be better suited 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).

Table 3.10
Estimated Parameters for the CEV Model

This table summarises the descriptive statistics of the estimated parameters, *a* and *b* from Equation (3.7). Panel A shows the summary statistics for the overall sample of 96 convertible bonds. Panel B is for the subsample of 34 convertible bonds without provision on conversion whereas Panel C is for the subsample of 62 convertible bonds with conditional conversion term. *SD* denotes the standard deviation. A superscript * , ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

	Mean	SD	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

This study also considers 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 this study and the parameters estimation is straightforward (Ammann et al., 2008).

The conditional variance of GARCH (1,1) is given as

$$\sigma_t^2 = \alpha_0 + \alpha_1 \in_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{3.8}$$

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 $z_t \sim \mathrm{NID}(0,1)$.

The underlying stock price is also adjusted for dividend payments. The stock price is expected to decrease by the same amount as the 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, which is also similar to Ammann et al. (2008). The dividend yield expresses the dividend per share as a percentage of the share price. 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. Therefore, 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 (Dunn and Eades, 1989). But for the sample of this study, only 34 convertibles bonds (approximately 35%) pay dividend and only nine of them with higher dividend yields than the coupon rates. Grundy and Vermijmeren (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, dividends are not expected to have substantial impact on the efficiency of the pricing model.

3.3.5.2 Interest Rate Risk

At the preliminary level, the valuation process is modelled under the risk-neutral assumption. Accordingly, the discounting factor equals the risk-free interest rate. Daily risk-free interest rates are collected from the Federal Reserve, which is estimated from the US Treasury constant maturity nominal interest rate[27]. 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[28]. 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 a constant interest rate does not reflect the real market specification, but 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, this study examines the impact of stochastic interest rates on the pricing of convertible bonds at the preliminary level. The model-generated values under the assumption of constant interest rates will

[27] 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/).

[28] Refer http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/yieldmethod.aspx for the description of Treasury yield curve methodology.

be compared against the model-generated values using the square-root process of Cox et al. (1985) stochastic interest rate model as follows

$$dr_t = \kappa(\mu - r_t)dt + \sigma\sqrt{r_t}dB_{r,t} \tag{3.9}$$

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.

3.3.5.3 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 the risk-free rate and the risky component will be discounted at the risk-adjusted rate. A credit spread will be added to the risk-free rate to obtain the risk-adjusted rate. The appropriate credit spread is estimated using the rating of each convertible bond. Only 33 convertible bonds are found to be rated. In view of this, the credit rating of the issuer is considered 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. This study also tries to consider credit default swap (CDS) as another proxy of the credit spread, but the CDS rates are not available for approximately 58% of the sample, thus reduces the sample to 41 convertible bonds. The pricing model is tested, but the results are found to be inconsistent across time and by the types of real-time trade price. Therefore, the second proxy for credit spread is not included in this study.

3.3.6 Measurement of Mispricing

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

$$Mean\ deviation,\ MD = average\left(\frac{Market\ price - Model\ price}{Market\ price}\right) \tag{3.10}$$

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, mean absolute deviation (*MAD*) is calculated 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

$$Mean\ absolute\ deviation,\ MAD = average\left[\left|\left(\frac{Market\ price - Model\ price}{Market\ price}\right)\right|\right] \tag{3.11}$$

3.3.7 Identification of Explanatory Variables

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, a regression analysis is performed. In the regression model, mispricing is measured by mean deviation (*MD*) that provides 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. Illiquid convertible bonds are expected to be more likely to be underpriced. 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 the 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 a lower rate of return 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. This study also identifies the trade frequency for trading greater than or equal to US$1 million[29], denoted by *LNMil*. Both are in natural log form. A convertible bond with higher trade frequency is inferred as being more liquid and the opposite applies for lower trade frequency.

To control for individual risk, the analysis includes moneyness (*Dequity*), time to maturity (*LNTmat*), credit spread (*Crsprd*), rating code (*Rcode*), and volatility (*Vol*) as the explanatory variables. Greater mispricing is expected for riskier convertible bonds because of limited market credit information when pricing a convertible bond, particularly in modelling the hazard rate and 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 more credit sensitive, thus is of higher risk than equity-like convertible. *LNTmat* is the natural log of time to

[29]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).

maturity in years, where 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 (2000) the rating code is a numerical value assigned to a particular rating and in this study is the Moody's rating. For example, Aaa rating is assigned a value of 1 and Aa1 is assigned a value of 2, and so forth[30]. Higher numerical value indicates higher risk.

This study controls 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. 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. There are two possible outcomes for this variable. 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 other hand, 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.

[30] 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.

3.4 Empirical Results and Discussion

3.4.1 Tests of Pricing Efficiency

This section discusses the individual impact of stochastic interest rates, 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 accounts for the assumption of constant interest rates, whereas the *TF* model only accounts for credit risk. The other variables are assumed to be constant. The *CEV* and *GARCH* models only account for stochastic volatility.

Table 3.11 reports the mean deviation (*MD*) for each model together with the mean differences between models, with the *Risk Neutral* model being the base comparison model. On average the market prices, measured by *MPAll* are 18.97% lower than the model prices under the risk neutral assumption. The underpricing slightly reduces to 18.80% when stochastic interest rates are incorporated but there is no significant difference in the underpricing between the models. The underpricing significantly decreases to 17.30% at the 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 8.31% for $CEV_{\beta=1}$, 8.33% for $CEV_{\beta=0}$ and 9.92% for *GARCH (1,1)*, at the 1% level (refer Panels C to E). Consistent results are found when the model prices are compared against the retail trade prices (*MPBuyer* and *MPSeller*), and wholesale trade prices (*MPDealer*), as well as by subsamples as reported in Tables B.2 and B.3 of Appendix B.

Table 3.11
Mean Comparison and Average Mispricing by the Pricing Models

This table reports the mean differences 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* 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. *SE* denotes the standard error. 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**	**CIR**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	-18.802	-0.169	0.183	-0.714	0.377	-0.605
MPBuyer	26,756	-19.215	-19.192	-0.023	0.348	-0.704	0.658	-0.067
MPSeller	24,720	-18.468	-18.474	0.006	0.360	-0.699	0.710	0.016
MPDealer	19,634	-17.389	-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**	**TF**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	-17.304	-1.667***	0.254	-2.164	-1.169	-6.565
MPBuyer	26,756	-19.215	-17.473	-1.742***	0.303	-2.337	-1.149	-5.752
MPSeller	24,720	-18.468	-16.773	-1.695***	0.310	-2.302	-1.087	-5.468
MPDealer	19,634	-17.389	-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**	**CEV beta=1**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	41,774	-18.971	-8.307	-10.664***	0.259	-11.172	-10.156	-41.144
MPBuyer	26,756	-19.215	-7.944	-11.271***	0.309	-11.877	-10.665	-36.446
MPSeller	24,720	-18.468	-7.697	-10.771***	0.317	-11.392	-10.151	-34.015
MPDealer	19,634	-17.389	-7.244	-10.145***	0.348	-10.827	-9.463	-29.142

Table 3.11 *Continued*

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

	Obs	Risk Neutral	CEV beta=0	Mean difference	SE	95% Confidence interval		t-value
MPAll	41,774	-18.971	-8.332	-10.639***	0.268	-11.164	-10.114	-39.724
MPBuyer	26,756	-19.215	-7.921	-11.294***	0.321	-11.923	-10.666	-35.221
MPSeller	24,720	-18.468	-7.836	-10.632***	0.332	-11.283	-9.981	-32.025
MPDealer	19,634	-17.389	-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	GARCH (1,1)	Mean difference	SE	95% Confidence interval		t-value
MPAll	41,774	-18.971	-9.924	-9.047***	0.260	-9.556	-8.537	-34.827
MPBuyer	26,756	-19.215	-9.812	-9.403***	0.310	-10.011	-8.795	-30.316
MPSeller	24,720	-18.468	-9.606	-8.862***	0.318	-9.486	-8.239	-27.875
MPDealer	19,634	-17.389	-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	$CEV_{\beta=1}TF$	Mean difference	SE	95% Confidence interval		t-value
MPAll	41,774	-18.971	-6.310	-12.661***	0.255	-13.161	-12.162	-49.698
MPBuyer	26,756	-19.215	-5.981	-13.234***	0.303	-13.828	-12.641	-43.694
MPSeller	24,720	-18.468	-5.657	-12.811***	0.310	-13.419	-12.204	-41.339
MPDealer	19,634	-17.389	-5.402	-11.987***	0.339	-12.651	-11.323	-35.382

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 et al. (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 the results, the relative impact of credit risk is smaller than volatility. A 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, the pricing model does not account for the possibility of default and recovery rate. But the Tsiveriotis and Fernandes (1998)'s credit risk model is selected so as to be comparable to the practitioners with limited market credit information (Gushchin and Curien, 2008).

The CEV model appears to perform better than the GARCH model evidenced by the lower pricing error, significant at the 1% level. Results are reported in Table 3.12. No significant differences are found between the CEV models with different measure of elasticity (beta). Consistent results are reported for the subsamples, specifically subsample 2 that consists of convertible bonds issued with conditional conversion option (refer Table B.4 and B.5 of Appendix B). Next, the convertible bonds are priced 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 12.66%, at the 1% level (refer Panel F of Table 3.11). Consistently, underpricing is observed in each pricing model considered in the 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).

Table 3.12
Mean Comparison of Average Mispricing between the Stochastic Volatility Models

This 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. *SE* denotes the standard error. 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 (β)

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

Panel B: Mean comparison between the $CEV_{\beta=1}$ and GARCH(1,1) models

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

Panel C: Mean comparison between the $CEV_{\beta=0}$ and GARCH(1,1) models

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

The equity-like convertible bonds are underpriced by 0.56%, whereas the debt-like convertibles are underpriced by 10.70%, 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 a higher probability of conversion. Moreover, equity-like convertible bonds are more likely to be overpriced as they are more attractive to investors who are 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 of convertible bonds leads 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, potentially generating a risk-free profit.

The degree of mispricing is substantially high during the collapse of Lehman Brothers (*Subperiod 3*). Results are reported in Table 3.13. The $CEV_{\beta=1}TF$ model that accounts for both stochastic volatility and credit risk reports an underpricing of 42.97%. During the crisis period, the convertible bonds trade at deep discount with an average moneyness of 0.54. 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 substantial 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 13.70% for equity-like convertible bonds (moneyness ratio greater than 0.65). As for the sample of this study, on average the equity-like convertibles are underpriced by 11.12%.

Table 3.13
Mispricing of Convertible Bonds by the Identified Subperiods

This 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 January to June 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	-42.969	67.301
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

Mitchell and Pulvino (2012) add that the substantial discount takes over a year to recover to the historical levels, which is consistent to this study as it observes decrease in mispricing mainly from 2010 onwards. Excluding the crisis period, on average this study documents an underpricing of 3.14%. Similarly, the underpricing observed from the equity-like convertibles is smaller than debt-like convertibles, to be specific 0.03% and 5.56%, respectively.

Given the greater impact of volatility, this study further examines the importance of the time varying effect of volatility on convertible bonds pricing. In Table 3.14 the initial volatility used in the *Risk Neutral* and $CEV_{\beta=1}$ models is ranked by quintiles to compare the predictive power, measured by mean absolute deviation (*MAD*) in percentage terms. The initial volatility of each convertible is calculated using daily individual stock returns for 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 improve monotonically from 7.34% to 12.26% from the third to the fifth quintiles, significant at the 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 the time-varying effect of volatility, particularly in the pricing of convertible bonds with substantial fluctuation in underlying stock returns.

Table 3.14
Mean Comparison between the *Risk Neutral* and $CEV_{\beta=1}$ models by Level of Volatility (by quintiles)

This 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 of market prices (*MPAll*) from both sides. *SE* denotes the standard error. A superscript *, ** or *** indicates significance at the 90%, 95% and 99% confidence levels, respectively.

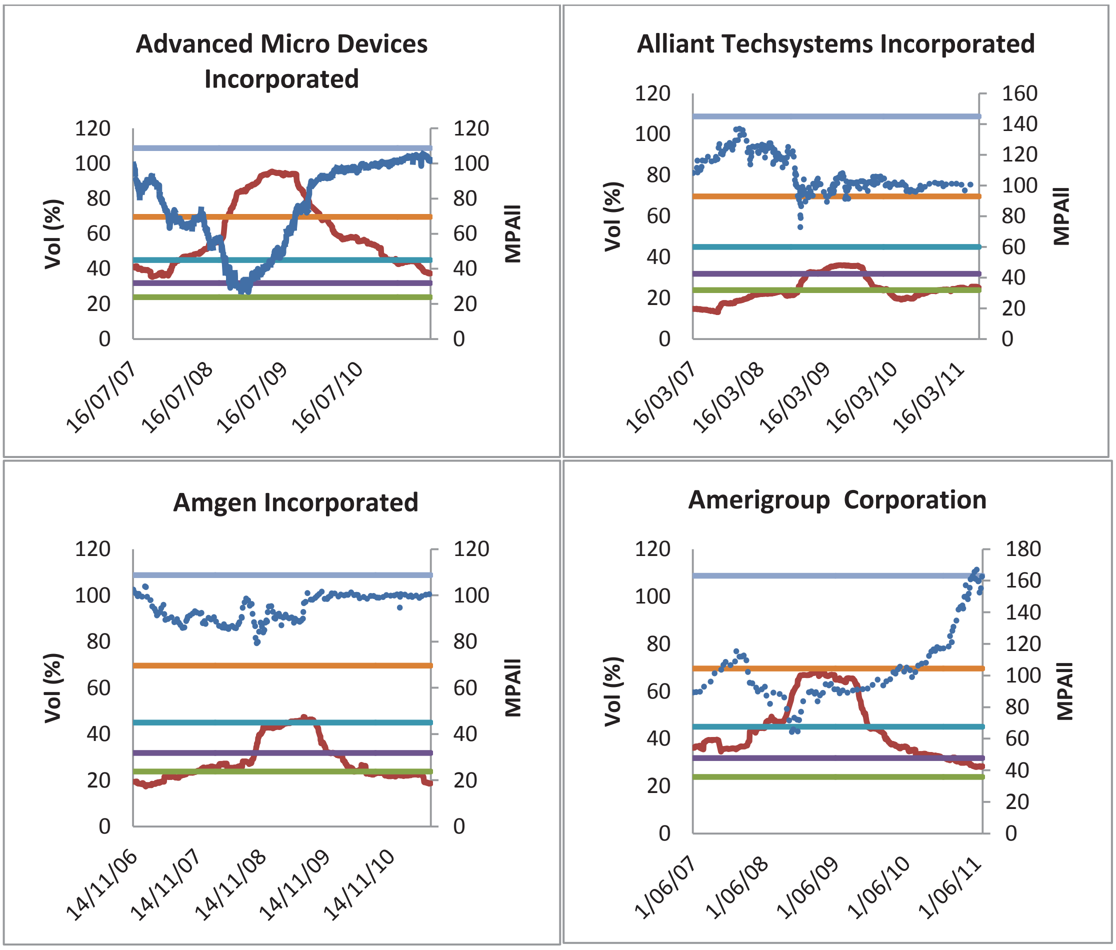
Quintile	Initial volatility		MAD Risk neutral		MAD CEV beta=1		Mean difference		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	t-value
1	23.803	0.885	14.035	4.482	14.280	4.388	-0.244	1.545	-0.158
2	31.797	0.679	17.080	3.401	15.665	2.751	1.415	1.625	0.870
3	45.006	1.201	26.519	3.503	19.182	3.972	7.337***	1.336	5.490
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

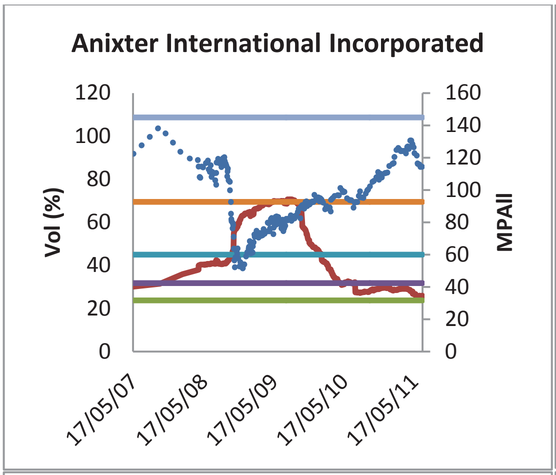
Figure 3.2 plots the relationship between the rolling-sample volatility and the trade prices of 24 convertible bonds that provide complete observations by the identified subperiods. There is substantially high volatility of the underlying stock returns. During the extreme crisis, the volatilities fall 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.

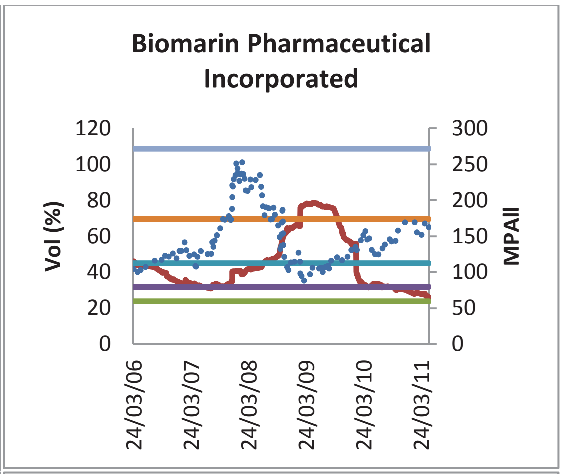
Figure 3.2

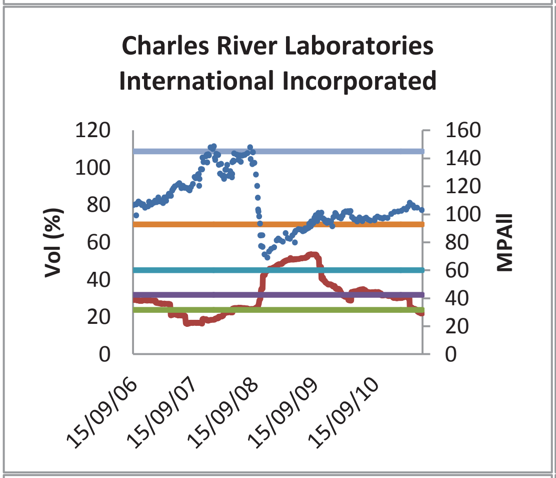
Relationship between Rolling-sample Volatility and Real-time Trade Prices of Individual Convertible Bonds

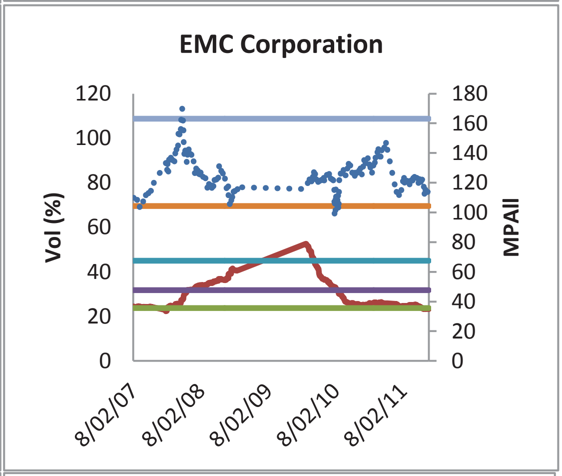
These charts plot the relationship between the rolling-sample volatility and real-time trade price on daily basis, from the first trade date to June 30, 2011. Out of the sample, 24 convertible bonds provide complete observations by all the subperiods identified in the study, which include prior to subprime-mortgage 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 prices 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 for 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 prices, respectively.

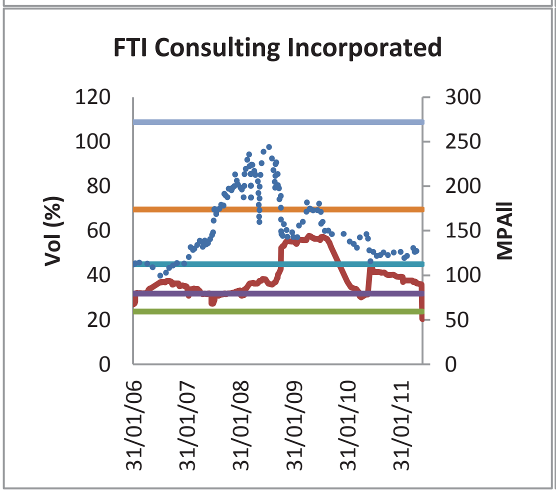


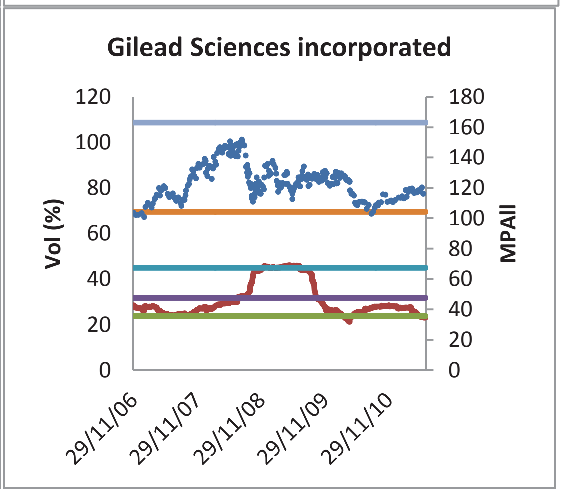

Anixter International Incorporated
Vol (%)
MPAII
120
100
80
60
40
20
0
160
140
120
100
80
60
40
20
0
17/05/07
17/05/08
17/05/09
17/05/10
17/05/11

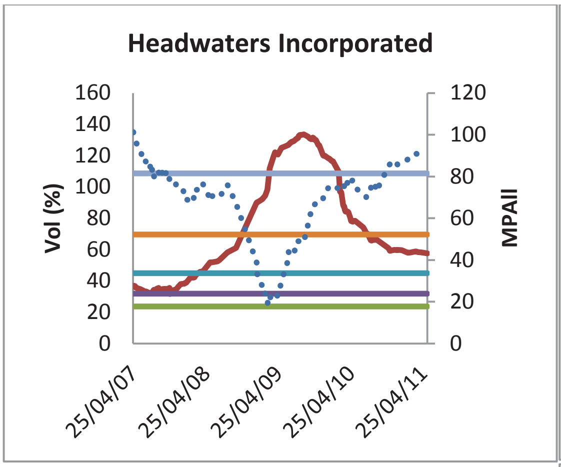

Biomarin Pharmaceutical Incorporated
Vol (%)
MPAII
120
100
80
60
40
20
0
300
250
200
150
100
50
0
24/03/06
24/03/07
24/03/08
24/03/09
24/03/10
24/03/11

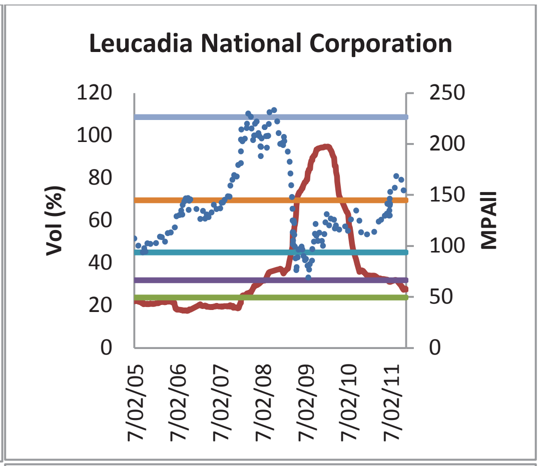

Charles River Laboratories International Incorporated
Vol (%)
MPAII
120
100
80
60
40
20
0
160
140
120
100
80
60
40
20
0
15/09/06
15/09/07
15/09/08
15/09/09
15/09/10

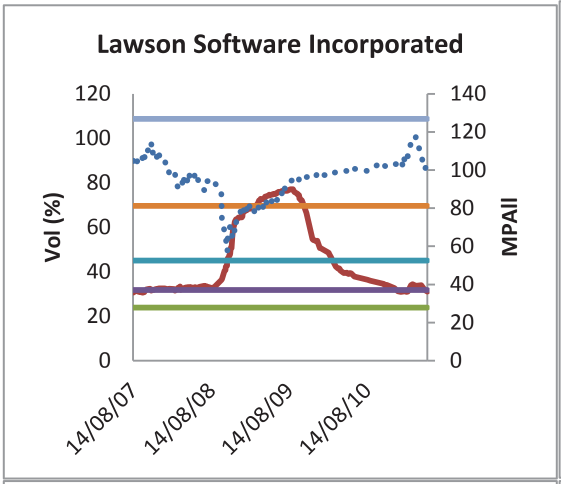

EMC Corporation
Vol (%)
MPAII
120
100
80
60
40
20
0
180
160
140
120
100
80
60
40
20
0
8/02/07
8/02/08
8/02/09
8/02/10
8/02/11

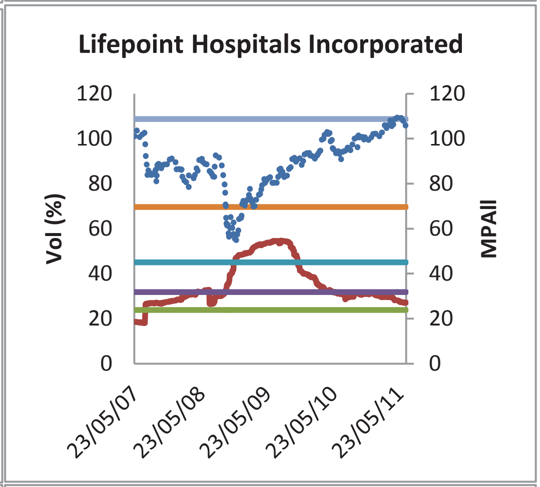

FTI Consulting Incorporated
Vol (%)
MPAII
120
100
80
60
40
20
0
300
250
200
150
100
50
0
31/01/06
31/01/07
31/01/08
31/01/09
31/01/10
31/01/11

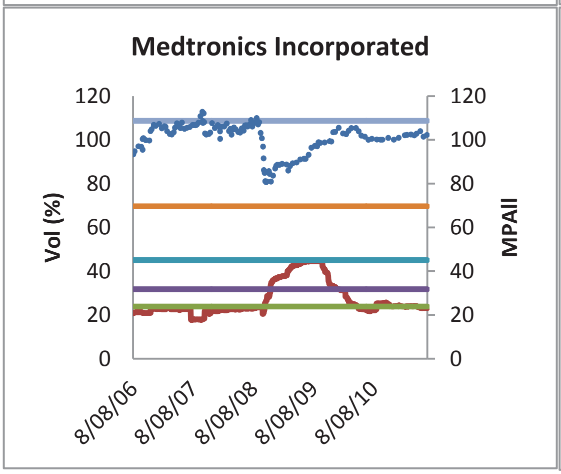

Gilead Sciences incorporated
Vol (%)
MPAII
120
100
80
60
40
20
0
180
160
140
120
100
80
60
40
20
0
29/11/06
29/11/07
29/11/08
29/11/09
29/11/10

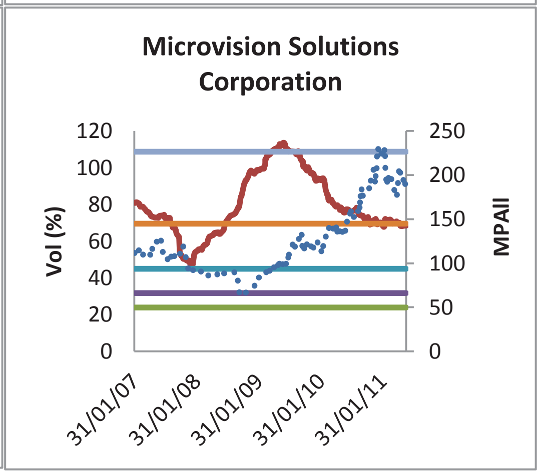

Headwaters Incorporated
160
140
120
100
80
60
40
20
0
Vol (%)
120
100
80
60
40
20
0
MPAII
25/04/07
25/04/08
25/04/09
25/04/10
25/04/11

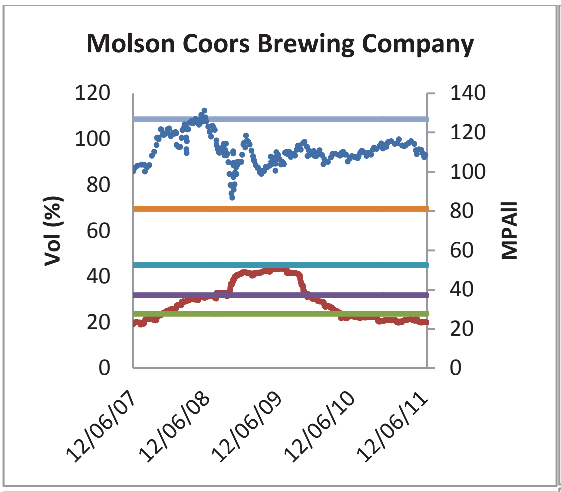

Leucadia National Corporation
120
100
80
60
40
20
0
Vol (%)
250
200
150
100
50
0
MPAII
7/02/05
7/02/06
7/02/07
7/02/08
7/02/09
7/02/10
7/02/11

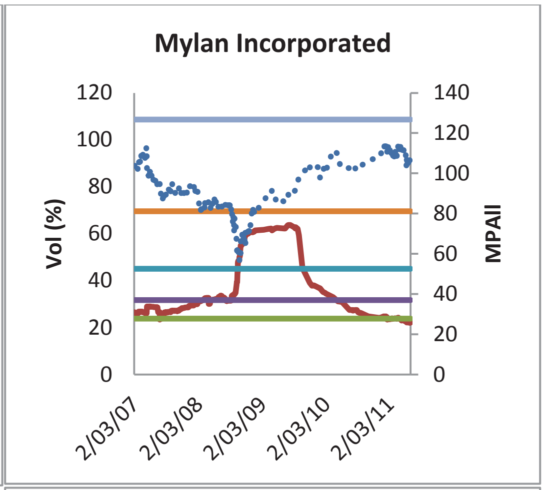

Lawson Software Incorporated
120
100
80
60
40
20
0
Vol (%)
140
120
100
80
60
40
20
0
MPAII
14/08/07
14/08/08
14/08/09
14/08/10

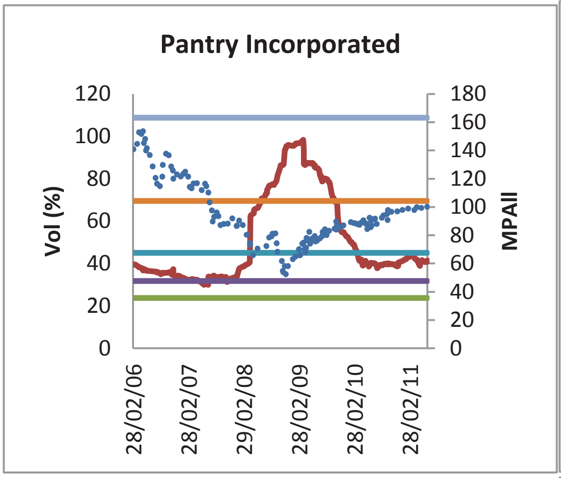

Lifepoint Hospitals Incorporated
120
100
80
60
40
20
0
Vol (%)
120
100
80
60
40
20
0
MPAII
23/05/07
23/05/08
23/05/09
23/05/10
23/05/11

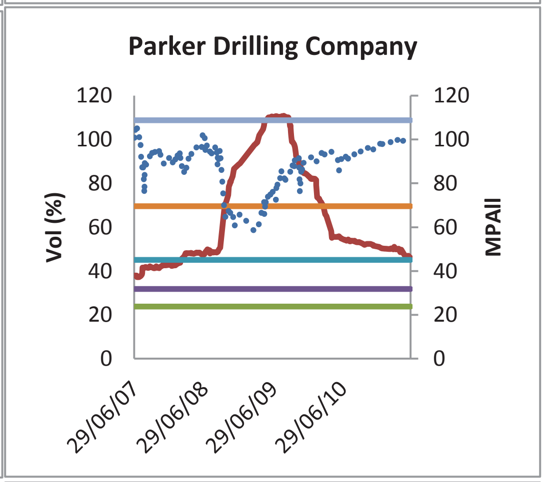

Medtronics Incorporated
120
100
80
60
40
20
0
Vol (%)
120
100
80
60
40
20
0
MPAII
8/08/06
8/08/07
8/08/08
8/08/09
8/08/10

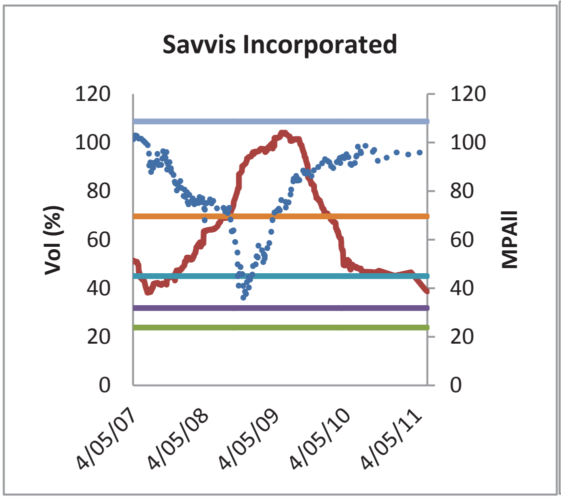

Microvision Solutions Corporation
120
100
80
60
40
20
0
Vol (%)
250
200
150
100
50
0
MPAII
31/01/07
31/01/08
31/01/09
31/01/10
31/01/11

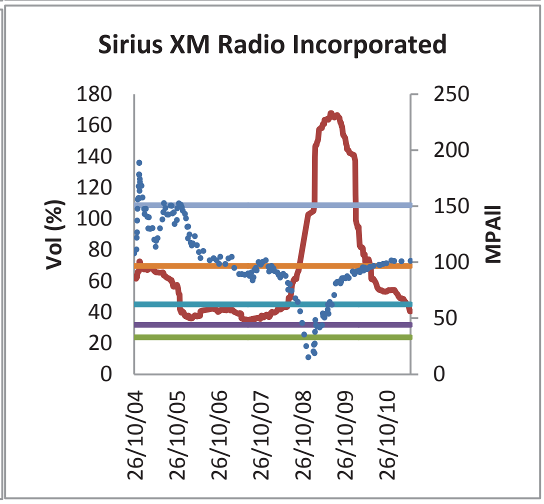

Molson Coors Brewing Company
Vol (%)
MPAII
0
20
40
60
80
100
120
140
12/06/07
12/06/08
12/06/09
12/06/10
12/06/11


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

3.4.2 Analysis of Mispricing

This section discusses the empirical results that explain the mispricing of convertible bonds. First, Table 3.15 provides the correlation analysis of the explanatory variables identified in Section 3.3.7. Most of the variables are significantly correlated at the 1% level, but with lower correlation coefficient values, generally less than 0.3. Two exceptions are noted. There is a direct relationship between credit spread and volatility as indicated by a positive correlation coefficient value of 0.68. Credit spread is also positively correlated to rating code with a value of 0.59, which means the higher the credit spread, the higher the rating code, as well as the volatility. To control for multicollinearity, credit spread is excluded from the regression analysis because the inclusion leads to inconsistent results. Volatility is retained in the regression analysis for two reasons. First, the correlation value between volatility and the rating code is only at 0.21. Second, volatility is found to have greater impact on the pricing of convertible bonds as discussed earlier.

In the regression analysis, the dependent variable is the mean deviation (*MD*) 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. This study considers 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 3.16 for the regression results.

Table 3.15

Correlation Matrix of Explanatory Variables to Explain the Mispricing of Convertible Bonds

This 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 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. *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 3.16
Estimates from Analysis of Mispricing

This 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	**Expected Sign**	**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

A positive coefficient is observed between *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 the 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 (2012). But, the direction of trade frequency is different from the expectation, in which convertible bonds that trade more frequently in a day are found to be underpriced. In an unreported result, the same negative coefficient is found for the number of trade greater than or equal to US$1 million (*LNMil*). 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, this analysis does find evidence that liquidity has a significant impact on the mispricing of convertible bonds (at the 1% level) but the direction of the mispricing is less certain.

Consistently, 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 relationship 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 relationship 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 during 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 relationship 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 (*MPD*). This explains that higher volatility in the underlying stock returns leads to overpricing of convertible bonds (at the 1% level). An 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* indicates that equity-like convertibles tend to be overpriced as expected and is consistent for all types of trade prices. These findings support the view that equity-like or less risky convertible bonds are more attractive to investors because of the higher value of the equity option, thus they 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.

The coupon rate is found to be statistically insignificant in explaining the mispricing of the full sample (*MPA*) and the buyer reported trade prices. But a positive relationship 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 a significant effect on the efficiency of convertible bond pricing.

In addition when this study controls for the attached conversion terms, it is found that convertible bonds issued with conditional conversion tends to be overpriced by the market (at the 1% level). A 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 3.15). Less risky convertible bonds are more likely 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 conditions. This finding supports the subperiod analysis (refer Tables 3.7 and 3.8) that reports a higher degree of underpricing around the time of the Lehman's collapse.

3.5 Conclusion

Convertible bonds are a significant and developing segment of the corporate bond market. Nonetheless, the valuation of convertible bonds has not been adequately addressed due to the presence of complicated payoff structures and the difficulty in clearly defining the links between valuation and the underlying risk factors such as credit risk, interest rate risk, and equity risk. Furthermore, the existing empirical literature on convertible bond pricing reports mixed results on their degree of mispricing (e.g. Carayannopoulos (1996) reports an underpricing of 12.9%, whereas Barone-Adesi et al., (2003) report an overpricing of approximately 5%).

This study is able to clarify the degree of mispricing using a unique sample, consisting of pure convertible bonds. It controls for complex optionality in these securities that potentially affects the efficiency of a pricing model. Therefore, the sample of convertible bonds is one which excludes callable and puttable features, sinking funds, mandatory, exchangeable, reset and reverse clauses.

In addition, this study examines the pricing efficiency of convertible bonds using real-time trade prices disseminated by TRACE-FINRA. The least squares Monte Carlo simulation (LSM) approach of Longstaff and Schwartz (2001) is employed to identify the pricing model that accounts for stochastic volatility and credit risk. On average, underpricing of 6.31% is reported using daily observations, estimated from a sample of 96 pure convertible bonds, covering the period 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 and are more attractive to investors. Equity-like convertibles offer higher value of the conversion option compared with debt-like convertibles that are perceived to be more risky. Debt-like convertibles are more sensitive to model inputs and specifications such as the credit spread, default probability and recovery rate. In addition, volatility is found to have a greater impact on the pricing of convertible bonds due to the substantial time-varying fluctuations of the underlying stock returns.

Pricing efficiency is also explained by the level of liquidity in the convertible bond market, compared to the equity and straight bond markets. This study finds that illiquid convertible bonds tend to be underpriced by the market, where liquidity is measured by the convertible bond issuance size and oversubscription of the convertibles at issuance. Riskier convertible bonds (those with longer time to maturity, higher rating codes, higher volatility and debt-like features) are also found to be underpriced by the market. This study also shows the time-varying effects of mispricing may be due to changes in the macroeconomic environment. For example, during the most volatile stage of the Global Financial Crisis period around the time of the Lehman's collapse, convertible bonds are deeply underpriced by the market.

CHAPTER FOUR

ESSAY THREE

DEBT HETEROGENEITY, INTERNATIONALISATION AND AGENCY COSTS

This chapter shows the importance of recognising debt heterogeneity in influencing the multinational corporations' (MNCs) debt financing decision to mitigate agency costs of debt, as a result of geographical diversification. Section 4.1 provides an overview of the study. Review of literature is undertaken in Section 4.2, with the data and methodology used in this study described in Section 4.3. Section 4.4 presents the empirical results and discussion, while the final Section 4.5, presents concluding remarks. The chapter's references are presented in the Bibliography section of this thesis.

4.1 Introduction

The results of this study show that multinational corporations (hereafter MNCs) are able to mitigate agency costs of debt that arises from international diversification by issuing convertible debt[31]. Convertible debt is defined as a hybrid security that shares some characteristics of debt and equity. The equity options allow the debt holders to forgo the fixed-income component by converting the securities into shares of stock of the issuing firm at a predetermined conversion ratio. Green's (1984) risk-shifting hypothesis states that convertible debt is designed to mitigate the debt holder-shareholder agency costs. Though firms can issue equity to mitigate the agency costs of debt, doing so may exacerbate other equity-related costs of external financing. Therefore, convertible debt is claimed to be a better substitute for straight debt because the equity options (conversion feature) can restore value maximising incentives, and thus mitigating the distortionary incentives created by risky debt (Green, 1984).

Motivated by the hybrid feature of convertible debt, this study aims to examine how the equity options of convertible debt can explain why MNCs are less leveraged than domestic corporations (hereafter DCs). Theoretically, MNCs tend to sustain higher leverage as compared to DCs because of larger firm size, lower bankruptcy risk and greater access to international capital markets given the diversification benefits (Hughes, Logue, and Sweeney, 1975; Rugman, 1976). However, empirical evidence, specifically from US-based MNCs, shows otherwise. MNCs are found to have lower debt ratios than DCs (Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Fatemi, 1988; Lee and Kwok, 1988). It is argued that when MNCs expand to less stable

[31] In the first and second essays of this thesis, the term convertible bond is used, whereas in the third essay, the term convertible debt is used, in order to be consistent with former studies.

markets (e.g. non US markets), the negative impact of agency costs of debt on leverage is greater than the increase of business risk (Mittoo and Zhang, 2008).

Agency costs have been one of the most cited theories in explaining the contradictory finding. The benefits from international diversification are offset by systematic differences in agency costs of debt between MNCs and DCs, thus leading to a lower level of debt financing (Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Lee and Kwok, 1988; Mittoo and Zhang, 2008). Importantly, the empirical evidence is generated by assuming debt as homogenous. But different types of debt instruments have difference cash flow claims, control provisions and sensitivity to information (Rauh and Sufi, 2010). Therefore, it is important to recognise debt heterogeneity in the studies of capital structure. Additional insight can be provided when debt components are examined separately (Rauh and Sufi, 2010). Also, recent studies on capital structure have placed more emphasis on the various attributes of debt instead of the conventional debt-equity choice (Johnson, 2003). For example, Doukas and Pantzalis (2003) and Singh and Nejadmalayeri (2004) examine the effect of debt maturity (short-term and long-term debt) on MNCs' leverage in mitigating the agency costs of debt. To the best of knowledge, limited attention has been devoted to examine how the equity options of convertible debt[32] can be used to mitigate agency costs of debt that arises from internationalisation.

Given the differences between MNCs and DCs as well as the increasing importance of globalised markets, this paper fills a gap in the literature by recognising the importance

[32] Doukas and Pantzalis (2003) find a significantly higher ratio of convertible debt used by MNCs than DCs at the descriptive level, but no further tests are undertaken to confirm or justify the preliminary finding. Instead their study examines the use of short-term and long-term debt between MNCs and DCs. They show that degree of internationalisation exacerbates agency costs of debt, leading to lower use of long-term debt but greater use of short-term debt.

of debt heterogeneity in the studies of capital structure. This study provides three important contributions. First, this study accounts for the heterogeneous characteristic of debt by distinguishing convertible debt from non-convertible debt. It shows the way security design, specifically the presence of equity options in the debt issued by MNCs, can be used to mitigate agency costs of debt. Second, it provides evidence that debt heterogeneity is linked to internationalisation and mitigation of agency costs of debt. Third, this study contributes to the convertible debt literature related to use of this security to mitigate agency costs of debt from the international perspective.

Two samples of MNCs are identified. A firm is defined as MNC when the degree of internationalisation is greater than or equals to 10% (MNC10) and 25% (MNC25). MNC10 (MNC25) consists of 740 MNCs (574 MNCs) with 3,504 firm-year observations (2,475 firm-year observations), covering the period from 2002 to 2011. Results from this study support the negative relationship between agency costs of debt and long-term debt for both samples of MNCs, in line with previous studies (Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Lee and Kwok, 1988). The agency problem is also inversely related to non-convertible debt. But, degree of internationalisation is found to have insignificant impact on long-term debt and non-convertible debt. A further test finds that the insignificant degree of internationalisation is not due to the perceived non-linearity relationship, consistent with Singh and Nejadmalayeri (2004)[33].

Interestingly, degree of internationalisation, proxied by foreign sales ratio and agency costs of debt, proxied by market-to-book ratio are found to be positively related to convertible debt. The evidence is more significant for MNCs with degree of

[33] Singh and Nejadmalayeri (2004) find that international diversification only affects short-term leverage non-linearity instead of the total leverage and long-term leverage.

internationalisation greater than or equal to 25% (MNC25), implying that MNCs mitigate agency costs of debt, caused by internationalisation, by issuing convertible debt. As the degree of internationalisation increases, benefits from internationalisation are offset by the increase in the agency problem because geographical diversification incurs more resources in the monitoring activities (Lee and Kwok, 1988). Furthermore, issuers of convertible debt are more likely to be growth firms (Lewis, Rogalski, and Seward, 1999), thus the impact of international diversification on agency costs of debt would be greater for these firms. Hence under these circumstances, MNCs are more likely to issue convertible debt instead of straight debt equivalents, supporting the risk-shifting hypothesis (Green, 1984) because convertible debt has less restrictive debt covenants than straight debt. Additionally, the conversion feature can restore value maximising incentives, thus alleviating the distortionary incentives of risky debt (Green, 1984).

Results remain consistent after controlling for market conditions such as the recent Global Financial Crisis and the subsequent quantitative easing policy that may potentially affect MNCs' choice of debt. Quantitative easing contributes to the decrease of the issuance of convertible debt because during such periods, with very low interest rates, conventional corporate debt is favoured over convertible debt (Batten et al., 2013). The equity options of convertible debt that act as a sweetener, allow the issuers to issue these securities at a lower interest rate as an alternative to straight debt (Billingsley and Smith, 1996). This feature becomes less attractive during a low interest rate environment because firms can issue straight debt (or other equivalent non-convertible debt) at a lower interest rate. However, as the degree of internationalisation increases, the relative impact of agency costs of debt is greater than the impact of quantitative easing, thus convertible debt is preferred to mitigate the agency problem.

Key finding holds, even after comparing with DCs. Results show that the motivation to issue convertible debt by DCs is not driven by the agency problem in comparison to MNCs. Also, evidence shows that the decision to issue convertible debt to mitigate the agency problem is not because of the MNCs being NASDAQ-listed firms, which tend to be high-tech firms with high growth opportunities, or non-NASDAQ-listed firms, but is due to internationalisation. Therefore, the contribution of this study is to link debt heterogeneity to internationalisation.

This chapter is structured as follows: next, a review of the literature is undertaken. Then in Section 4.3 the data and methods used in this study are established; Section 4.4 provides the empirical results and discussion, while the final Section 4.5, presents the concluding remarks.

4.2 Review of the Literature

4.2.1 Theories of Capital Structure

The theorem of Modigliani-Miller (1958) forms the basis for modern thinking on capital structure. In an imperfect market, corporate financing decision would affect a firm's value. But, how does a firm decide on its capital structure? Finance literature has focused on the trade-off theory, agency costs of debt, and pecking order theory to explain the financing decision. The trade-off theory states that a firm's optimal leverage is determined by the trade-off between the gains (tax shelter effect) and losses (bankruptcy costs) from debt financing. As the debt increases, the marginal tax shelter decreases while the marginal bankruptcy costs increase because of the increasing probability of bankruptcy. An optimal debt ratio is achieved when the gains equal the losses from debt financing. Debt financing can also mitigate the conflicts of interest between managers and shareholders, termed as the agency costs of free cash flow problem by reducing the excess funds available for spending at the discretion of managers. This is because firms are committed to contractual payments of interest and principal at maturity (Jensen, 1986). Therefore, firms with higher free cash flow are expected to have higher leverage.

However, there are agency costs of debt due to the conflicts of interest among the financial claimants, specifically the holders of equity and debt (Jensen and Meckling, 1976). Firms are likely to have higher agency costs of debt with the existence of the asset substitution problem (Jensen and Meckling, 1976) and/or underinvestment problem (Myers, 1977). Substitution occurs when shareholders have the incentive to invest in high-risk projects yielding higher returns that transfers the wealth from the bondholders to the shareholders (Jensen and Meckling, 1976). In addition, Myer's (1977) underinvestment problem suggest that shareholders are likely to reject positive net present value investment opportunities when the benefits of accepting these projects accrue mostly to the bondholders, but not to the shareholders wealth. Therefore, the existence of agency costs of debt can lead to suboptimal investment decisions.

The pecking order theory states that firms prefer internal to external financing and debt to equity if the firms resort to external sources (Myers, 1984). The core of the pecking order is the assumption of asymmetric information. For example, profitability is claimed to be more negatively correlated with the least informative-sensitive types of debt (Rauh and Sufi, 2010). Firm managers or insiders are assumed to be well-informed about the characteristics of a firm's returns stream and investment opportunities in comparison to the less informed investors (Myers and Majluf, 1984). For that reason, the underinvestment problem is likely to happen. For example, managers would give up projects with positive net present value if the firm's equity is underpriced. Since internal funds avoid informational problems, retained earnings are the most preferred mode of financing. But when firms resort to external financing, debt is preferred to equity because debt is considered to be a less informative sensitive mode of financing, whereas hybrid securities fall between debt and equity such as convertible debt.

4.2.2 Capital Structure from the Multinational Perspective

Theoretically, MNCs should be able to sustain higher leverage than DCs because international diversification of earnings can reduce overall bankruptcy risk in turn leading to a lower cost of debt financing (Hughes et al., 1975; Rugman, 1976). Nonetheless, empirical results have provided conflicting evidence. US-based MNCs are found to utilise lower levels of debt in their capital structure than DCs after controlling for firm size and industry effects (Burgman, 1996; Chen et al., 1997; Fatemi, 1988; Lee and Kwok, 1988). However, when Mansi and Reeb (2002) allows for non-linearity, their finding shows a positive non-monotonic relationship between the degree of internationalisation and leverage. But, it has to be noted that their study includes only non-provisional debt in the definition of debt. Debt with convertible, detachable warrants and other embedded options are excluded from their study.

Several justifications have been put forward to explain the less levered MNCs than DCs. The international factors claims that MNCs are exposed to exchange rate risk and political risk (Burgman, 1996; Lee and Kwok, 1988). If the relative impact from these debt-decreasing factors, such as additional exchange rate risk and political risk, are greater than debt-increasing factors, such as reduction in business risk due to international diversification, then the net effect is lower debt ratio for MNCs (Burgman, 1996). Also, the benefits from international diversification are offset by systematic differences in agency costs of debt between MNCs and DCs (Burgman, 1996). The agency costs of debt have been one of the most cited theories in explaining the lower debt ratio of MNCs. (Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Lee and Kwok, 1988). Doukas and Pantzalis (2003) find greater impact on the firms' leverage as the agency costs of debt increases with the increasing degree of internationalisation. Instead, MNCs are more likely to use short-term debt to deal with the higher agency costs (Doukas and Pantzalis, 2003; Fatemi, 1988).

The geographical diversification will incur more resources in the monitoring activities such as the auditing activities and preparation of multiple financial statements for each country (Lee and Kwok, 1988). Differences in languages, varying legal systems and greater information gaps across countries could also result in higher agency costs of debt (Burgman, 1996). In addition, MNCs are likely to have greater growth opportunities because geographical diversification enables the MNCs to have better access to international markets (Lee and Kwok, 1988; Mittoo and Zhang, 2008). Greater investment opportunities complicate the monitoring activities, thus result in higher agency costs of debt (Kim and Lyn, 1986). Therefore, MNCs are likely to have lower debt ratio consistent with Myer's (1977) argument.

However, evidence from the non-US markets show mixed results. Singh and Nejadmalayeri (2004) find a positive relationship between the degree of internationalisation and leverage for the French MNCs as compared to the DCs. The same relationship is observed by Mittoo and Zhang (2008) for the Canadian MNCs but the finding is mainly from their US operations because of lower agency costs of debt. When a Canadian MNC invests in a more stable market like the US, there will be an increase in leverage due to the decrease in business risk. As for the expansion to non-US markets, there is little impact on the leverage.

On the other hand, the Japanese MNCs are found to be less levered than the DCs, and multinationality is a significant aspect of leverage for the Japanese MNCs (Akhtar and Oliver, 2009). Note that Akhtar and Oliver's (2009) study exclude lease commitments from the long-term debt's definition due to a considerable variation in the reporting practices in Japan. As for Australian firms, an insignificant difference in the level of leverage is reported between the MNCs and DCs (Akhtar, 2005). More to the point, a positive relationship is reported between the degree of internationalisation and leverage when product diversification is integrated into the analysis. This finding suggests the importance of recognising heterogeneity of the capital structure in addition to the financial profiles of MNCs (Chkir and Cosset, 2001).

4.2.3 Motivation for the Issuance of Convertible Debt

The risk-shifting (Green, 1984) and backdoor equity financing (Stein, 1992) hypotheses provide a basis to explain the motivation for the issuance of convertible debt as an alternative to equity and debt. Green's (1984) risk-shifting hypothesis states that firms substitute convertible debt for straight debt to mitigate the conflict of interest between financial claimants. Green (1984) develops this argument from the Jensen and Meckling's (1976) asset substitution problem. When straight debt is issued, the restrictive covenants create an incentive for the debt holders to force the firm into low-risk activities. Though issuance of equity can alleviate the agency costs related to risky straight debt financing, it may incur other equity-related costs. Shareholders have the incentive to overinvest in high-risk investment projects and even undertake negative NPV projects that further transfer the wealth from debt holders to shareholders through falling debt prices and higher credit spreads. These conflicts can be resolved by utilising the hybrid features of convertible debt. The equity component can reduce the expropriation of wealth, whereas the debt component is likely to possess less restrictive debt covenants than straight debt. Green (1984) adds that the conversion feature can restore value maximising incentives, thus alleviating the distortionary incentives created by risky debt. Therefore, convertible debt is expected to substitute for straight debt.

Alternatively, the backdoor equity financing hypothesis argues that firms issue convertible debt as a substitute for equity (Stein, 1992). Firms that face significant informational asymmetries (between managers and investors) and higher costs of financial distress are more likely to issue convertible debt, which also explain the reason growth firms find it attractive to issue convertibles. Moreover, firm managers may be reluctant to issue equity if the prevailing stock price does not adequately reflect the firm's growth opportunities since it may dilute existing shareholders' claims. Even if the firm is fairly valued, convertible debt is preferred due to the information asymmetry problem that causes the investors to reduce the value of the firm's share upon announcement at issuance (Jen, Choi, and Lee, 1997). For these firms, equity is a less attractive mode of financing as its value is sensitive to the subsequent disclosure of the firm's private information. Firms can choose to issue the less informative sensitive straight debt as another financing solution to mitigate the adverse selection costs of an immediate sale of equity. Nonetheless, straight debt may incur other value-decreasing costs such as costs of financial distress that could potentially outweigh the adverse selection costs. Hence under these circumstances, firms are more likely to issue convertible debt.

Subsequently, Mayers (1998) extend the backdoor equity hypothesis by arguing that convertible debt is also a preferred security choice when issuers face sequential financing problems involving investment option with future maturity date. In brief, the sequential financing hypothesis is based on the uncertainty about the value of future investment. Convertible debt is expected to alleviate the free cash flow (overinvestment) problem of Jensen (1986) by returning the funds to debt holders (through redemption) when the investment option is not valuable. But when the investment option is valuable, convertible debt economises issue costs because conversion leaves funds in the firm and reduces leverage (Mayers, 1998).

By linking together the theories and empirical evidence from capital structure and internationalisation together with the motivation for the issuance of convertible debt, this study suggests the following proposition.

Proposition: MNCs can mitigate the agency cost of debt as a result of internationalisation by issuing convertible debt.

4.3 Data and Methodology

4.3.1 Sample Selection

Initially, 9,568 US firms with active company data are identified from the Compustat database for the fiscal year from 2002 to 2011. The filtering process begins by excluding the regulated firms (SIC coded 4000-4999) and financial firms (SIC coded 6000-6999), to be consistent with previous studies (Burgman, 1996; Chkir and Cosset, 2001; Lee and Kwok, 1988; Mittoo and Zhang, 2008), in which 4,129 firms are excluded. This filtration is necessary because there may exist a systematic relationship between the regulations and the firms' financial leverage (Lee and Kwok, 1988) and the debt-like liabilities of financial firms are not strictly comparable to the debt issued by non-financial firms (Rajan and Zingales, 1995). The sample is limited to the US incorporated firms that are publicly traded on major exchanges such as the New York Stock Exchange (NYSE) and NASDAQ. These limitations further reduce the sample to 2,428 firms.

Statement of Financial Accounting Standard (SFAS) No. 14 requires an issuer to report its revenues, operating profit (loss), and identifiable assets if a segment's revenues, operating profit or identifiable assets are 10% or more of related consolidated amounts. Equally, a firm is defined as MNC when the degree of internationalisation is greater than or equals to 10%, which is also consistent with the existing studies (Akhtar, 2005; Burgman, 1996; Lee and Kwok, 1988; Mittoo and Zhang, 2008). Different proxies have been used to measure the degree of internationalisation, which include the foreign sales ratio (Doukas and Pantzalis, 2003; Fatemi, 1988; Kim and Lyn, 1986; Michel and Shaked, 1986; Mittoo and Zhang, 2008; Singh and Nejadmalayeri, 2004), foreign tax ratio (Burgman, 1996; Chkir and Cosset, 2001; Lee and Kwok, 1988), foreign assets ratio (Akhtar, 2005; Doukas and Pantzalis, 2003; Kwok and Reeb, 2000; Mittoo and Zhang, 2008), foreign pre-tax income ratio (Chen et al., 1997) and the number of geographical segments where the firm have foreign operations (Akhtar, 2005; Kim and Lyn, 1986; Michel and Shaked, 1986).

Though foreign sales ratio is commonly used for determining the degree of internationalisation, it is subject to a major drawback. The reported sales figures include both sales by foreign subsidiaries and exports by the parent company, thus does not differentiate between the international investment and international trade (Burgman, 1996; Lee and Kwok, 1988). Therefore, the foreign tax ratio is suggested, but this ratio is affected by the performance of the investment and the tax benefit related to foreign activities (Chen et al., 1997). On the other hand, the foreign assets ratio represents the investment of foreign activities that alleviates the disadvantage of foreign sales ratio (Kwok and Reeb, 2000), whereas the foreign pre-tax income ratio considers both revenues and expenses of operations but avoids the effect of foreign tax benefit (Chen et al., 1997). However, there are potential biases with the foreign asset ratio and reported earnings, due to possible differences in reporting and accounting practices (Fatemi, 1988).

This study applies the commonly used foreign sales ratio as the proxy for the degree of internationalisation, measured as the ratio of foreign sales to total sales. But as mentioned earlier, there is potential bias from the reported foreign sales because the reported figures include both sales by foreign subsidiaries and exports by parent company. Therefore, the firms are also filtered by foreign tax ratio so that exports by parent companies can be excluded since exports are considered as locally taxed revenues. Two samples of MNCs are constructed to provide more robust empirical evidence. The first sample, MNC10 is constructed when both the foreign sales ratio and the foreign tax ratio are greater than or equal to 10%. The second sample, MNC25 is more restrictive, as it defines a firm as MNC when both the foreign sales ratio and the foreign tax ratio are greater than or equal to 25%, consistent with Burgman (1996) and Lee and Kwok (1988).

MNC10 consists of 740 MNCs with 3,504 firm-year observations, whereas MNC25 consists of 574 MNCs with 2,465 firm-year observations. The final samples are obtained after excluding all equity firms, firms with negative growth opportunities, and firms with total assets below $10 million to control for potential bias in size differences between MNCs and DCs (Chen et al., 1997; Lee and Kwok, 1988). Any firm-year observation with missing financial information for the identified variables is also excluded. For robustness purpose, a sample of DCs is defined, consisting of 741 firms with 3,518 firm-year observations. A DC is defined as a firm that reports no foreign sales and foreign tax. Firms that have observations in both the MNC and DC samples are also excluded.

4.3.2 Variables Selection

Two key determinants are identified, specifically the agency costs of debt and degree of internationalisation, to examine whether MNCs reduce their agency costs of debt by issuing convertible debt. To begin with, this study examines the effect of these determinants on MNCs' long-term debt, so as to be comparable with previous studies. The long-term debt ratio is the proxy for leverage scaled by total capital, which is the sum of long-term debt and market value of shareholders' equity (Akhtar, 2005; Akhtar and Oliver, 2009; Burgman, 1996; Chkir and Cosset, 2001; Lee and Kwok, 1988; Singh and Nejadmalayeri, 2004). Then, the long-term debt is categorised into convertible debt and non-convertible debt to examine the proposed proposition. Both are also scaled by total capital.

The market-to book ratio (*GO*) is the commonly used proxy for agency costs in the MNCs literature, which measures the future growth opportunities of firms (Akhtar, 2005; Akhtar and Oliver, 2009; Chen et al., 1997; Lewis et al., 1999; Rauh and Sufi, 2010). This study considers the natural log of the market-to-book ratio to smooth the distribution of the market-to-book value ratio[34]. MNCs are more likely to have greater growth opportunities than DCs because MNCs have better access to international markets (Akhtar, 2005; Burgman, 1996; Chen et al., 1997; Lee and Kwok, 1988). Nonetheless, higher growth opportunities actually leads to higher agency costs (Myers,

[34] The range of market-to-book ratio of the observations is between 1.001 and 587.816 for MNC10 and 1.001 and 493.829 for MNC25.

1977) that explains why MNCs have lower debt ratios than DCs (Akhtar, 2005; Akhtar and Oliver, 2009; Burgman, 1996; Chen et al., 1997; Fatemi, 1988; Lee and Kwok, 1988). On the other hand, the risk-shifting hypothesis shows that high growth firms are more likely to issue convertible debt to mitigate the conflict of interest between financial claimants (Green, 1984). Also, this hypothesis is supported empirically (Lewis et al., 1999; Mayers, 1998). Accordingly, MNCs with higher agency costs are expected to have lower long-term and non-convertible debt financing but higher convertible debt financing.

The second key determinant is the degree of internationalisation (*DOI*) measured by the foreign sales ratio, which is added to the regression to examine the impact of foreign involvement on leverage. Doukas and Pantzalis (2003) document that the higher the foreign involvement the greater the agency costs of debt, leading to a lower use of long-term debt financing but higher use of short-term debt financing. Equally, MNCs with a higher a degree of internationalisation are expected to be more likely to have lower long-term debt and non-convertible debt but higher convertible debt, because of the higher agency costs of debt. For the control variables, four commonly used firm-specific variables are identified from the capital structure literature to be included in the regression model. These control variables, including size, tangibility, risk and profitability, are meant to account for trade-off and pecking order theories.

SIZE is measured by the natural log of total assets, which is included to control for any effects related to firm size. Firm size is claimed to be positively related to leverage levels (Akhtar, 2005; Chkir and Cosset, 2001; Lewis et al., 1999; Mittoo and Zhang, 2008; Rajan and Zingales, 1995). Firm size may also measure the magnitude of financial distress and bankruptcy costs (Akhtar, 2005; Lewis et al., 1999). Larger size firms are expected to have lower financial distress costs, thus allowing the firm to tolerate a higher level of leverage. Moreover, firm size is considered as the measure of degree of information asymmetry (Lewis et al., 1999). Large firms are more likely to issue straight debt because these firms face less information asymmetry as large firms tends to be more mature and established. Conversely, convertible debt issuers tend to be smaller and riskier than straight debt issuers that are potentially vulnerable to adverse selection problems (Lewis et al., 1999). Accordingly, a larger size MNC is predicted to be more likely to have higher long-term debt and non-convertible debt and less convertible debt in the debt structure.

Tangibility (*TG*) represents the collateral available for debt financing. According to the trade-off theory, firms with a higher level of tangible assets are expected to have higher leverage due to lower default costs and less debt-related agency problems (Akhtar and Oliver, 2009; Mittoo and Zhang, 2008; Rauh and Sufi, 2010). Tangibility is measured by the ratio of net plant and equipment to total assets (Jen et al., 1997). Firms with higher tangible assets are claimed to have more collateral for debt issuance and a higher liquidation value in the event of bankruptcy (Deesomsak, Paudyal, and Pescetto, 2004). Therefore, there is higher incentive for the issuance of straight debt equivalents. Mayers (1998) shows that convertible debt issuers tend to have lower than the industry median ratio of tangible to total assets. Also Jen et al. (1997) add that the value of growth firms come largely through investment opportunities rather than tangible assets, thus these firms are more likely to issue convertible debt. MNCs with higher tangible assets are predicted to be positively related to long-term debt and non-convertible debt but negatively related to convertible debt.

The Altman Z-score, reported by Compustat, is chosen as the proxy for firm's financial strength (*RISK*) (Chkir and Cosset, 2001) that measures the probability of a firm's bankruptcy (Altman, 1968). A lower value Z-score denotes higher risk and higher probability of bankruptcy, and vice versa. The trade-off theory claims that as risk increases, firms' debt capacity decreases because of the increasing probability of financial distress and bankruptcy costs. On the other hand, convertible debt issuers are found to have higher risk than straight debt issuers (Lewis et al., 1999). Chang et al.(2004) and Jen et al. (1997) add that risk is positively related to the use of convertible debt. Issuers with higher expected financial distress costs are more likely to issue convertible debt to reduce the interest coupon and financial risk (Jen et al., 1997). Therefore, risker MNCs are predicted to issue convertible debt rather than non-convertible debt.

Profitability (*PROFIT*), represented by return on assets is included to account for the pecking order hypothesis of Myers (1984). Profitable firms are expected to utilise less debt (Akhtar and Oliver, 2009; Mittoo and Zhang, 2008; Rauh and Sufi, 2010) because of informational asymmetry between managers and investors (Deesomsak et al., 2004). Accordingly, firms would follow a financing hierarchy, in which retained earnings are the most preferred choice for financing, followed by debt and equity, with convertible debt in between. An inverse relationship is expected between profitability and leverage. But, when convertible debt is compared with non-convertible debt, profitable MNCs are expected to utilise higher levels of non-convertible as compared to convertible debt.

In addition, three dummy variables are introduced to the regression model. *DNasdaq* is a dummy equal to one if the issuer is a NASDAQ-listed firm and zero otherwise.

NASDAQ provides a platform for small firms and venture-capital firms, mostly the high-tech and high growth firms to raise funds. Therefore, this dummy variable is necessary to control for NASDAQ-listed firms that are also more likely to be small firms with higher growth opportunities (Loughran, 1997; Schwert, 2002). *Dboth* is added to control for firms that have both convertible and non-convertible bonds in their debt structure. It is a dummy equal to one if the issuer's debt structure consists of both types of debt and zero otherwise. *DCBsub* is a dummy equal to one if the debt is a subordinated convertible debt and zero otherwise, which is used to control for lower priority convertible debt. The data for the identified variables are sourced from Compustat, which covers from the fiscal year 2002 to 2011.

4.3.3 Methodology

As a preliminary step, a pooled cross-sectional with robust standard error regression model is employed to examine whether MNCs can mitigate the agency problems by the use of convertible debt. Equation 4.1 is as follows:

$$\frac{Debt\ type_{i,t}}{Total\ capital_{i,t}} = \beta_0 + \beta_1 DOI_{i,t} + \beta_2 GO_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 TG_{i,t} + \beta_5 RISK_{i,t} + \beta_6 PROFIT_{i,t} + \beta_7 DNasdaq_i + \beta_8 Dboth_{i,t} + \beta_9 DCBsub_{i,t} + \varepsilon_{i,t} \quad (4.1)$$

Debt type includes the long-term debt and is divided into convertible and non-convertible debt. This study also controls for year and industry effects (Burgman, 1996; Chen et al., 1997; Fatemi, 1988; Lee and Kwok, 1988; Mittoo and Zhang, 2008; Rauh and Sufi, 2010). The MNCs are classified by the four-digit SIC code with reference to the Fama–French 12-industry classification. Three industry groups are dropped. These consist of the financial firms (SIC codes 6000 – 6999) and two industry groups for the regulated firms because the SIC code falls within 4000 to 4999, including telephone and television transmission (SIC codes between 4800 – 4899) and utilities (SIC Codes between 4900 – 4949). This leaves nine industry groups being defined as in Table 4.1.

Note that there could be potential bias in the pooled cross-sectional regression due to correlation of the error terms across years. Since the dataset have dimensions of both cross-sectional and time-series, panel data regression provides more robust analysis (Akhtar, 2005). In order to decide between fixed and random effects, the Hausman test is performed. If the error terms are correlated with the explanatory variables, then fixed effects are favoured over random effects.

Fixed effects panel regression:

$$\frac{Debt\ type_{i,t}}{Total\ capital_{i,t}} = \beta_0 + \beta_1 DOI_{i,t} + \beta_2 GO_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 TG_{i,t} + \beta_5 RISK_{i,t} + \beta_6 PROFIT_{i,t} + \beta \quad Dboth_{i,t} + \beta_8 DCBsub_{i,t} + \gamma_i + \varepsilon_{i,t} \tag{4.2}$$

Random effects panel regression:

$$\frac{Debt\ type_{i,t}}{Total\ capital_{i,t}} = \beta_0 + \beta_1 DOI_{i,t} + \beta_2 GO_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 TG_{i,t} + \beta_5 RISK_{i,t} + \beta_6 PROFIT_{i,t} + \beta_7 Dboth_{i,t} + \beta_8 DCBsub_{i,t} + \gamma_{i,t} + \varepsilon_{i,t} \tag{4.3}$$

4.4 Empirical Results and Discussion

4.4.1 Sample Description

This section provides discussion of the sample characteristics. Table 4.1 classifies the MNCs by industry group when both the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), 25% (MNC25), 50% (MNC50) and 75% (MNC75). The largest industry group is the business equipment that includes computers, software and electronic equipment. As the degree of internationalisation increases from 10% to 75%, the size of MNCs in the business equipment industry increases from 30.81% to 47.37%. Conversely, the size of manufacturing industry, the second largest industry group decreases from 22.57% to 10.53% as the degree of internationalisation increases.

Table 4.1
Sample Distribution by Degree of Internationalisation

This table describes the sample distribution in percentage (%) when the degree of internationalisation measured by foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), 25% (MNC25), 50% (MNC50) and 75% (MNC75). The MNCs are sorted according to the Fama-French 12-industry classification. Regulated firms (SIC codes between 4000 – 4999) and financial firms (SIC codes 6000 – 6999) are both excluded. Two industry groups fall within the regulated firms, including Telephone and Television transmission (SIC codes between 4800 – 4899) and Utilities (SIC Codes between 4900 – 4949). *No* is the number of firms in each sample.

Industry Classification	**MNC10 (No = 740)**	**MNC25 (No = 574)**	**MNC50 (No = 301)**	**MNC75 (No = 76)**
Consumer Nondurables	7.162	5.923	4.651	3.947
Consumer Durables	5.270	5.575	6.645	7.895
Manufacturing	22.568	22.997	21.595	10.526
Oil and Mining	3.919	3.833	3.654	2.632
Chemical and Allied products	7.027	7.491	8.638	10.526
Business equipment	30.811	33.624	38.206	47.368
Wholesale and Retail	2.892	4.878	3.654	6.579
Healthcare, Medical equipment and Drugs	8.649	8.537	7.309	3.947
Others	7.703	7.143	5.648	6.579

Table 4.2 reports the descriptive statistics for the samples with different degree of internationalisation. Though MNC10 and MNC25 are the main samples of the study, MNC50 and MNC75 are included to provide further information about the characteristics of the identified variables as the level of internationalisation increases. On average, MNCs in MNC10 utilise about 17.4% of long-term debt, in which 2.5% is convertible debt and 14.9% is non-convertible debt, scaled by total capital. When leverage is scaled by long-term debt, MNCs utilise 13.7% of convertible debt for financing. Both long-term and non-convertible debt decrease, as the degree of internationalisation increases. A similar trend is also observed when both debt types are scaled by long-term debt. The agency problem increases with degree of internationalisation. This preliminary finding supports existing studies that MNCs tend to use lower debt in their capital structure as the agency costs of debt increases with the degree of internationalisation (Akhtar, 2005).

Interestingly, the ratio of convertible debt increases from 2.5% for MNC10 to 3.8% for MNC75, scaled by total capital. When the debt level is scaled by long-term debt, the convertible debt ratio increases from 13.7% for MNC10 to 22.4% for MNC75, whereas non-convertible debt ratio decreases from 86.2% for MNC10 to 77.6% for MNC75. This implies the potential use of convertible debt by MNCs to mitigate agency problems when the degree of internationalisation increases. About 30.3% of the firm-year observations for MNC10 are from NASDAQ-listed firms and the size increases to 48.9% for MNC75.

Table 4.2
Descriptive Statistics by Degree of Internationalisation

This table reports the mean and standard deviation of the observed characteristics for the samples when the foreign sales ratio and foreign tax ratio are greater than or equals to 10% (MNC10), 25% (MNC25), 50% (MNC50) and 75% (MNC75). Equity, long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt *(Non-CNV*) are scaled by total capital. Total capital is defined as the sum of total long-term debt and market value of shareholders' equity. *CNV/LTDebt* and *Non-CNV/LTDebt* are the ratios of convertible debt and non-convertible debt over long-term debt, respectively. *DOI* is the degree of internationalisation measured by foreign sales ratio. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *DNasdaq* is a dummy equals to one if the issuer is a NASDAQ-listed firm and zero otherwise. *Dboth* is a dummy equals to one if the firm uses both convertible and non-convertible debt in financing and zero otherwise. *DCBsub* is a dummy equals to one if the convertible debt is a subordinated debt and zero otherwise. *N* is the number of firm-year observations.

Variables	**MNC10 (N = 3504)**		**MNC25 (N = 2465)**		**MNC50 (N = 970)**		**MNC75 (N = 184)**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Equity	0.826	0.137	0.829	0.135	0.826	0.144	0.854	0.121
LTDebt	0.174	0.137	0.171	0.135	0.174	0.144	0.146	0.121
CNV	0.025	0.065	0.026	0.066	0.031	0.078	0.038	0.072
Non-CNV	0.149	0.136	0.145	0.132	0.143	0.140	0.108	0.119
CNV/LTDebt	0.137	0.306	0.140	0.132	0.161	0.333	0.224	0.376
Non-CNV/LTDebt	0.862	0.306	0.860	0.309	0.839	0.333	0.776	0.376
DOI	0.461	0.198	0.531	0.167	0.671	0.115	0.836	0.070
GO	0.992	0.676	0.999	0.664	1.001	0.715	1.035	0.836
SIZE	7.666	1.660	7.727	1.690	7.592	1.697	7.246	1.628
TG	0.220	0.168	0.216	0.164	0.235	0.168	0.232	0.178
RISK	3.450	2.372	3.340	2.175	3.136	2.283	3.474	2.473
PROFIT	0.051	0.085	0.047	0.080	0.040	0.089	0.037	0.108
DNasdaq	0.303	0.459	0.293	0.455	0.320	0.467	0.489	0.501
Dboth	0.173	0.378	0.178	0.382	0.181	0.386	0.223	0.417
DCBsub	0.104	0.306	0.105	0.307	0.130	0.336	0.130	0.338

Table 4.3 provides the correlation analysis for the explanatory variables identified in Section 4.3.2. Most of the variables are significantly correlated at the 1% level, generally below 0.3. Three exceptions are identified. *SIZE* is negatively correlated with *DNasdaq* with a negative coefficient value of -0.40 (-0.44) for MNC10 (MNC25), indicating that NASDAQ-listed MNCs tend to be smaller size firm (Loughran, 1997; Schwert, 2002). It also implies the importance to control for the size effect. On the other hand, *RISK* and *PROFIT* is positively correlated at 0.44 (0.51) for MNC10 (MNC25). MNCs that issue both convertible and non-convertible debt are more likely to issue lower priority convertible debt, denoted by a positive correlation between *Dboth* and *DCBsub.* The coefficient is approximately 0.5 for both samples. Nonetheless, these variables are retained because they do not affect the results in the subsequent analyses.

Table 4.3
Correlation Matrix of Observed Variables for Samples MNC10 and MNC25

This table reports the correlation matrix of the observed variables when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*Panel A*) and 25% (*Panel B*). *DOI* is measured by the ratio of foreign sales to total sales. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *DNasdaq* is a dummy equals to one if the issuer is a NASDAQ-listed firm and zero otherwise. *Dboth* is a dummy equals to one if the firm uses both convertible and non-convertible debt in the financing and zero otherwise. *DCBsub* is a dummy equals to one if the convertible debt is a subordinated debt and zero otherwise. *N* is the number of firm-year observations. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Panel A: MNC10 (N = 3504)

	DOI	**GO**	**SIZE**	**TG**	**RISK**	**PROFIT**	**DNasdaq**	**Dboth**	**DCBsub**
DOI	1.000								
GO	0.068***	1.000							
SIZE	0.038**	0.100***	1.000						
TG	-0.021	-0.048***	0.176***	1.000					
RISK	0.022	0.190***	0.054***	0.004	1.000				
PROFIT	0.007	0.202***	0.265***	0.063***	0.438***	1.000			
DNasdaq	0.123***	-0.038**	-0.395***	-0.246***	-0.053***	-0.186***	1.000		
Dboth	0.020	-0.028	0.124***	-0.049***	-0.108***	-0.089***	0.005	1.000	
DCBsub	0.056***	-0.033*	-0.047***	-0.088***	-0.114***	-0.129***	0.181***	0.498***	1.000

Panel B: MNC25 (N = 2654)

	DOI	**GO**	**SIZE**	**TG**	**RISK**	**PROFIT**	**DNasdaq**	**Dboth**	**DCBsub**
DOI	1.000								
GO	0.048**	1.000							
SIZE	-0.018	0.106***	1.000						
TG	0.042**	-0.041**	0.154***	1.000					
RISK	0.046**	0.174***	0.102***	0.020	1.000				
PROFIT	0.030	0.198***	0.334***	0.107***	0.509***	1.000			
DNasdaq	0.141***	-0.038*	-0.444***	-0.246***	-0.104***	-0.231***	1.000		
Dboth	-0.002	-0.022	0.109***	-0.069***	-0.118***	-0.096***	-0.001	1.000	
DCBsub	0.044**	-0.040**	-0.057***	-0.096***	-0.141***	-0.151***	0.174***	0.497***	1.000

4.4.2 Pooled Cross-sectional Regression

The analysis begins with a pooled cross-sectional regression to be comparable with previous studies (Akhtar, 2005; Chen et al., 1997; Mittoo and Zhang, 2008). Heteroskedasticity is controlled using the robust standard error. Table 4.4 reports the results by long-term debt, convertible debt and non-convertible debt for MNC10 (Panel A) and MNC25 (Panel B). Panel A shows that the degree of internationalisation and agency costs of debt are found to be inversely related to long-term debt, significant at the 1% level. This implies that MNCs tend to use a lower level of leverage at a higher level of internationalisation and agency costs of debt, which is in line with Akhtar and Oliver (2009), Burgman (1996), Chen et al (1997), Doukas and Pantzalis (2003) and Lee and Kwok (1988). MNCs are claimed to have greater growth opportunities, thus greater agency problems.

Consistent with the trade-off theory, larger size MNCs with higher levels of tangible assets tend to use debt financing because these firms are expected to have lower financial distress costs (Akhtar, 2005). Moreover, large firms are more mature and established, thus they face less information asymmetry (Lewis et al., 1999). As for business risk, MNCs with higher probabilities of bankruptcy tend to have less debt, which is also consistent with the trade-off theory. On the other hand, profitable MNCs tend to utilise less debt in their capital structure because of informational asymmetry between managers and investors (Deesomsak et al., 2004). The inverse relationship between profitability and leverage supports the pecking order hypothesis.

Table 4.4
Pooled Cross-sectional Regression

This table reports the regression estimates with robust standard error by types of debt when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*Panel A*) and 25% (*Panel B* The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *DOI* is measured by the ratio of foreign sales to total sales. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *DNasdaq* is a dummy equals to one if the issuer is a NASDAQ-listed firm and zero otherwise. *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Panel A: MNC10 (N=3504)

Variables	**Expected Sign**		**LTDebt**		**CNV**		**Non-CNV**	
	(a)	**(b)**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
DOI	-	+	-0.069***	-0.068***	0.016***	0.018***	-0.085***	-0.086***
			(-6.44)	(-6.20)	(3.28)	(3.39)	(-8.08)	(-8.12)
GO	-	+	-0.019***	-0.159***	0.006***	0.002***	-0.025***	-0.022***
			(-4.33)	(-3.67)	(2.81)	(2.84)	(-5.89)	(-5.40)
SIZE	+	-	0.003**	0.004***	-0.002***	-0.002***	0.005***	0.006***
			(2.15)	(2.84)	(-3.03)	(-3.53)	(3.77)	(4.84)
TG	+	-	0.089***	0.116***	-0.022***	-0.032***	0.110***	0.148***
			(6.53)	(6.99)	(-4.85)	(-5.86)	(7.83)	(8.82)
RISK	-	+	-0.022***	-0.022***	-0.004***	-0.004***	-0.019***	-0.018***
			(-6.48)	(-6.33)	(-5.79)	(-5.66)	(-5.92)	(-5.82)
PROFIT	+	-	-0.153**	-0.164**	-0.088***	-0.089***	-0.065	-0.075
			(-2.41)	(-2.51)	(-2.60)	(-2.61)	(-1.41)	(-1.59)
DNasdaq	-	+	-0.037***	-0.025***	0.015***	0.012***	-0.051***	-0.038***
			(-6.77)	(-4.46)	(6.84)	(6.02)	(-9.30)	(-6.60)
Dboth	+/-	+/-	0.026***	0.033***	0.048***	0.048***	-0.022***	-0.015**
			(3.95)	(4.97)	(11.54)	(11.56)	(-3.52)	(-2.45)
DCBsub	+/-	+/-	0.019**	0.026***	0.074***	0.072***	-0.055***	-0.046***
			(2.24)	(3.02)	(11.44)	(11.16)	(-6.86)	(-5.84)
Constant			0.272***	0.245***	0.028***	0.033***	0.244***	0.057***
			(17.07)	(13.87)	(5.29)	(5.27)	(16.59)	(4.27)
Fixed-year effect			No	Yes	No	Yes	No	Yes
Industry effect			No	Yes	No	Yes	No	Yes
R-squared			0.280	0.318	0.430	0.448	0.260	0.311

Table 4.4 *Continued*

Panel B: MNC25 (N=2465)

Variables	Expected Sign		LTDebt		CNV		Non-CNV	
	(a)	**(b)**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
DOI	-	+	-0.045***	-0.051***	0.022***	0.022***	-0.068***	-0.072***
			(-3.09)	(-3.46)	(2.96)	(2.78)	(-4.74)	(-5.18)
GO	-	+	-0.018***	-0.013**	0.009***	0.010***	-0.027***	-0.023***
			(-3.30)	(-2.46)	(3.08)	(3.17)	(-5.24)	(-4.57)
SIZE	+	-	0.003**	0.004**	-0.001*	-0.001*	0.004***	0.006***
			(2.01)	(2.48)	(-1.65)	(-1.77)	(2.77)	(3.41)
TG	+	-	0.082***	0.104***	-0.016***	-0.025***	0.098***	0.130***
			(5.29)	(5.68)	(-2.92)	(-3.88)	(6.08)	(6.98)
RISK	-	+	-0.026***	-0.026***	-0.004***	-0.004***	-0.022***	-0.022***
			(-7.07)	(-6.90)	(-5.54)	(-5.55)	(-6.20)	(-6.11)
PROFIT	+	-	-0.124*	-0.136*	-0.109***	-0.108***	-0.015	-0.028
			(-1.78)	(-1.90)	(-3.83)	(-3.74)	(-0.25)	(-0.46)
DNasdaq	-	+	-0.040***	-0.029***	0.016***	0.014***	-0.056***	-0.043***
			(-6.54)	(-4.41)	(6.08)	(5.42)	(-8.85)	(-6.42)
Dboth	+/-	+/-	0.029***	0.037***	0.049***	0.049***	-0.020***	-0.011
			(3.74)	(4.88)	(9.43)	(9.41)	(-2.78)	(-1.63)
DCBsub	+/-	+/-	0.024**	0.031***	0.078***	0.076***	-0.054***	-0.045***
			(2.27)	(2.87)	(9.56)	(9.25)	(-5.60)	(-4.79)
Constant			0.267***	0.226***	0.014**	0.020**	0.253***	0.205***
			(13.85)	(10.43)	(2.25)	(2.51)	(13.72)	(9.90)
Fixed-year effect			No	Yes	No	Yes	No	Yes
Industry effect			No	Yes	No	Yes	No	Yes
R-squared			0.291	0.338	0.459	0.469	0.259	0.321

Note that non NASDAQ-listed MNCs are more likely to use long-term debt as their financing choice as compared to NASDAQ-listed MNCs. MNCs that have both convertible and non-convertible debt in their debt structure are more likely to issue subordinated convertible debt, indicated by the significantly positive coefficient. The results remain even after controlling for year and industry fixed effects.

Nonetheless, when the analysis is extended to account for debt heterogeneity, additional insight is attained about the debt structure of MNCs. Since the main focus of the study is on the equity option that is present in the debt issued by MNCs, long-term debt is identified by convertible and non-convertible debt, scaled by the sum of long-term debt and market value of equity. The degree of internationalisation and agency costs of debt are found to be negatively related to non-convertible debt at the 1% level, which is consistent with the conventional argument. Geographical diversification allows MNCs to have greater access to international markets, leading to greater growth opportunities that are traded off by higher agency costs of debt owing to complicated monitoring activities. But interestingly, MNCs with a higher degree of internationalisation and agency costs of debt are more likely to issue convertible debt, as denoted by the significantly positive coefficients at the 1% level. Consistent with the risk-shifting hypothesis, MNCs with greater agency problems substitute convertible debt for straight debt to mitigate the conflict of interest between financial claimants (Green, 1984). Importantly, this finding appears to support the proposition that MNCs do use convertible debt to mitigate agency costs of debt.

The effects of the control variables on convertible debt and non-convertible debt are also found to be different. For instance, convertible debt is more likely to be issued by smaller size MNCs with a lower level of tangible assets as opposed to non-convertible debt. Also, riskier MNCs tend to opt for convertible debt, suggested by the less negative coefficient. The access to the convertible debt market is also more flexible for issuers who have difficulty entering the conventional debt market due to restrictive credit rating requirements. On the other hand, profitable MNCs are less likely to issue convertible debt as denoted by the significantly negative *PROFIT* at the 1% level. According to the pecking order hypothesis, firms follow a financing hierarchy. Retained earnings are the preferred financing mode, followed by debt and equity, whereas convertible debt falls between debt and equity. However, the negative coefficient of *PROFIT* is statistically insignificant for non-convertible debt, implying that the choice for non-convertible debt may not be explained by the pecking order hypothesis.

NASDAQ-listed MNCs are more likely to issue convertible debt. Moreover, convertible debt issuers tend to have both convertible debt and non-convertible debt in their debt structure and the convertible debt are more likely to be subordinated. The coefficients of these three dummy variables are found to be significantly negative for non-convertible debt, suggesting the opposite characteristics for non-convertible issuers. These results are not affected by the year and industry fixed effects and remain consistent for MNC25 as in Panel B. To this point, the pooled cross-sectional analysis shows that MNCs have a tendency to issue convertible debt to reduce the agency costs of debt.

4.4.3 Fixed Effects Panel Data Regression

In the following test, the analysis in Section 4.4.2 is repeated using panel data regression to control for any potential bias in the pooled cross-sectional analysis due to correlation of the error terms across years. Both fixed effects (Equation 4.2) and random effects (Equation 4.3) panel data regressions are performed. But only the estimates from the fixed effects model are reported in Table 4.5 because the results from the Hausman test consistently support the fixed effects over random effects. Note that the results from the random effects model, which assumes no correlation between error terms and explanatory variables, are found to be qualitatively similar to the results from the pooled cross-sectional regression in Table 4.4. These findings are in line with Doukas and Pantzalis (2003). They find that the fixed effects model better explains their dataset in examining the effect of the agency costs of debt on leverage caused by internationalisation.

When the fixed effects panel analysis is considered, the degree of internationalisation is found to have an insignificant impact on either the degree of long-term debt of MNC10 and MNC25 or the non-convertible debt component of MNC25. Consistently, Singh and Nejadmalayeri (2004) find that international diversification, which is also measured by the ratio of foreign sales to total sales, is insignificant in explaining the degree of debt ratio and even the short- and long-term debt. One possible explanation would be the existence of a non-linearity relationship between the explanatory and explained variables (Singh and Nejadmalayeri, 2004). Therefore, the square of degree of internationalisation (*DOIsq*) is included, measured by the ratio of foreign sales to total sales in Equation (4.2). The results are presented in Table 4.6. Both *DOI* and *DOIsq* are found to be insignificant for the considered debt types, suggesting that the insignificant *DOI* is not caused by the perceived non-linearity relation, which is consistent to Singh and Nejadmalayeri (2004).

Interestingly, the coefficient of *DOI* is statistically significant at the 10% level for MNC10 and at the 5% level for MNC25 (refer Table 4.5) for the convertible debt model, indicating that MNCs have the tendency to issue convertible debt when the degree of internationalisation increases. Moreover, the degree of internationalisation has a greater impact on the convertible debt when the minimum measure of internationalisation increases from 10% to 25%. In general, convertible debt issuers tend to be smaller and riskier growth firms (Lewis et al., 1999), thus are reluctant to issue straight debt or the equivalent because the higher fixed obligation of debt tends to increase the expected cost of financial distress of these firms. Conversely, these firms would not issue equity if the current stock price does not reflect the firms' growth opportunities (Chang et al., 2004; Stein, 1992). Therefore, as these firms extend abroad, convertible debt is the preferred choice of financing.

Table 4.5
Fixed Effects Panel Data Regression

This table reports the estimates of panel regression by types of debt when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*MNC10*) and 25% (*MNC25*). The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *DOI* is measured by foreign sales ratio. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	**Expected Sign**			**MNC10**			**MNC25**	
	(a)	**(b)**	**LTDebt**	**CNV**	**Non-CNV**	**LTDebt**	**CNV**	**Non-CNV**
DOI	-	+	-0.020	0.015*	-0.035*	-0.003	0.027**	-0.030
			(-1.08)	(1.68)	(-1.95)	(-0.13)	(2.34)	(-1.37)
GO	-	+	-0.021***	0.002	-0.023***	-0.014***	0.004**	-0.018***
			(-6.69)	(1.39)	(-7.61)	(-3.97)	(2.20)	(-5.32)
SIZE	+	-	0.012***	-0.006***	0.018***	0.017***	-0.007***	0.024***
			(2.96)	(-2.86)	(4.48)	(3.68)	(-2.73)	(5.30)
TG	+	-	0.047	-0.040**	0.087***	0.060	-0.049**	0.108***
			(1.40)	(-2.49)	(2.69)	(1.49)	(-2.42)	(2.84)
RISK	-	+	-0.034***	-0.005***	-0.030***	-0.033***	-0.003***	-0.030***
			(-26.17)	(-7.60)	(-23.29)	(-20.08)	(-3.72)	(-19.07)
PROFIT	+	-	-0.062***	-0.048***	-0.014	-0.142***	-0.121***	-0.020
			(-3.01)	(-4.84)	(-0.71)	(-4.41)	(-7.49)	(-0.66)
Dboth	+/-	+/-	0.014**	0.052***	-0.037***	0.023***	0.050***	-0.027***
			(2.57)	(19.37)	(-6.95)	(3.57)	(15.37)	(-4.38)
DCBsub	+/-	+/-	0.020**	0.037***	-0.017**	0.020**	0.040***	-0.020**
			(2.34)	(9.18)	(-2.13)	(2.13)	(8.30)	(-2.15)
Constant			0.217***	0.073***	0.143***	0.152***	0.072***	0.080**
			(6.42)	(4.52)	(4.39)	(3.77)	(3.53)	(2.08)
R-squared			0.246	0.401	0.197	0.261	0.406	0.195
N				3504			2465	

Table 4.6
Non-linearity of Internationalisation on Leverage by Types of Debt

This table reports the estimates of fixed effects panel regression by types of debt when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*MNC10*) and 25% (*MNC25*). The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *DOI* is measured by foreign sales ratio and *DOIsq* is the squared of DOI to proxy for non-linearity. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	**Expected Sign**		**MNC10**			**MNC25**		
	(a)	**(b)**	**LTDebt**	**CNV**	**Non-CNV**	**LTDebt**	**CNV**	**Non-CNV**
DOI	-	+	-0.033	-0.006	-0.027	-0.041	0.017	-0.057
			(-0.55)	(-0.22)	(-0.46)	(-0.44)	(0.36)	(-0.65)
DOIsq	+	+/-	0.013	0.021	-0.008	0.034	0.010	0.024
			(0.23)	(0.79)	(-0.16)	(0.42)	(0.23)	(0.32)
GO	-	+	-0.021***	0.002	-0.023***	-0.014***	0.004**	-0.018***
			(-6.68)	(1.40)	(-7.61)	(-3.97)	(2.20)	(-5.32)
SIZE	+	-	0.012***	-0.005***	0.018***	0.018***	-0.006***	0.024***
			(2.97)	(-2.80)	(4.46)	(3.70)	(-2.70)	(5.30)
TG	+	-	0.047	-0.040**	0.086***	0.060	-0.049**	0.109***
			(1.41)	(-2.48)	(2.68)	(1.50)	(-2.41)	(2.85)
RISK	-	+	-0.034***	-0.005***	-0.029***	-0.034***	-0.003***	-0.030***
			(-26.16)	(-7.62)	(-23.28)	(-20.06)	(-3.72)	(-19.04)
PROFIT	+	-	-0.063***	-0.049***	-0.014	-0.142***	-0.121***	-0.021
			(-3.01)	(-4.87)	(-0.70)	(-4.42)	(-7.49)	(-0.68)
Dboth	+/-	+/-	0.014**	0.051***	-0.037***	0.023***	0.050***	-0.027***
			(2.56)	(19.33)	(-6.94)	(3.57)	(15.37)	(-4.38)
DCBsub	+/-	+/-	0.020**	0.037***	-0.017**	0.020**	0.040***	-0.020**
			(2.35)	(9.20)	(-2.13)	(2.13)	(8.29)	(-2.15)
Constant			0.219***	0.077***	0.142***	0.160***	0.074***	0.086**
			(6.23)	(4.56)	(4.18)	(3.58)	(3.28)	(2.01)
R-squared			0.247	0.403	0.196	0.262	0.407	0.195
N				3504			2465	

On the contrary, MNCs with higher agency cost of debt tend to utilise less long-term debt and non-convertible debt in their debt structure, indicated by the significantly negative coefficients of *GO*, at the 1% level. These results are consistent for both MNC10 and MNC25. But, the positive coefficient of *GO* becomes insignificant in the convertible debt component for MNC10 but is statistically significant at the 5% level for MNC25. This implies an increase of the agency problem in MNCs when the minimum measure of internationalisation increases from 10% to 25%. Agency costs of debt increases as international diversification increases (Akhtar, 2005). Therefore, it further motivates the MNCs to issue convertible debt, particularly those in MNC25 to mitigate the conflict of interest between financial claimants (Green, 1984). This finding further supports the proposition that MNCs use convertible debt to mitigate agency costs of debt.

For the control variables (refer Tables 4.5 and 4.6), the coefficients are mostly significant at the 1% level, which is consistent with the hypothesised signs except for the effect of tangibility on long-term debt and the effect of profitability on non-convertible debt. The positive coefficient of *TG* becomes insignificant in the long-term debt model for both MNC10 and MNC25. Also, the dummy variable *DNasdaq* that control for NASDAQ-listed MNCs is dropped from the analysis because the fixed effects model only analyses the impact of variables that vary over time but *DNasdaq* remains invariant over time. For subsequent tests, the fixed effects panel data regression is employed to provide more robust analysis (Akhtar, 2005).

4.4.4 Effects of Market Conditions on Leverage by Debt Type

This section examines the impact of the market environment on MNCs' debt choice. Two dummy variables are introduced to capture the recent Global Financial Crisis (*Crisis*) and quantitative easing policy (*QE*). *Crisis* is to control for the 2007-2009 Global Financial Crisis. A quantitative easing policy is introduced when the interest rates are close to zero, in which central bank buys financial securities to create new money in order to stimulate the economy. QE1 spans from November 25, 2008 to March 2010, whereas QE2 spans from November 2010 to June 2011. Since this study consists of annual observation, the *QE* variable can only be approximated, in which it equals to one for observations from 2009 to 2011 and zero otherwise.

Table 4.7 reports the estimates of the fixed effects panel regression for MNC10 and MNC25 when market conditions are included in the analysis. Though *Crisis* and *QE* are added to Equation (4.2), the coefficients and the significance of the observed determinants remain the same as those reported in Table 4.5. Global financial crisis does not have significant impact on the MNCs' debt choice. But, the negative coefficient of *QE* is statistically significant at the 5% level for the long-term debt model and the 1% level for the convertible debt model (refer MNC10). This implies that MNCs issue less long-term debt during the quantitative easing, which is mainly contributed by the decrease in convertible debt issuance.

Table 4.7
Effects of Market Conditions on Leverage by Types of Debt

This table reports the estimates of fixed effects panel regression by types of debt when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*MNC10*) and 25% (*MNC25*). The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *DOI* is measured by foreign sales ratio. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. *Crisis* is a dummy equals to one if the firm-year observation is either 2008 or 2009, whereas *QE* is a dummy equals to one if the firm-year observation is either 2009, 2010 or 2011. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	**Expected Sign**		**MNC10**			**MNC25**		
	(a)	**(b)**	**LTDebt**	**CNV**	**Non-CNV**	**LTDebt**	**CNV**	**Non-CNV**
DOI	-	+	-0.011	0.018*	-0.030	0.004	0.031**	-0.027
			(-0.59)	(1.97)	(-1.59)	(0.16)	(2.54)	(-1.17)
GO	-	+	-0.020***	0.002	-0.023***	-0.014***	0.004**	-0.018***
			(-6.64)	(1.47)	(-7.59)	(-3.89)	(2.31)	(-5.29)
SIZE	+	-	0.015***	-0.004**	0.020***	0.020***	-0.005**	0.025***
			(3.47)	(-2.03)	(4.59)	(3.86)	(-2.02)	(5.11)
TG	+	-	0.044	-0.041***	0.085***	0.058	-0.049**	0.108***
			(1.32)	(-2.59)	(2.64)	(1.46)	(-2.45)	(2.82)
RISK	-	+	-0.034***	-0.005***	-0.029***	-0.034***	-0.003***	-0.030***
			(-26.29)	(-7.74)	(-23.33)	(-20.13)	(-3.80)	(-19.06)
PROFIT	+	-	-0.064***	-0.049***	-0.015	-0.143***	-0.122***	-0.021
			(-3.11)	(-4.92)	(-0.77)	(-4.45)	(-7.53)	(-0.69)
Dboth	+/-	+/-	0.013**	0.051***	-0.038***	0.022***	0.050***	-0.027***
			(2.34)	(19.08)	(-7.03)	(3.43)	(15.17)	(-4.41)
DCBsub	+/-	+/-	0.020**	0.037***	-0.017**	0.021**	0.040***	-0.019**
			(2.38)	(9.25)	(-2.12)	(2.18)	(8.36)	(-2.13)
Crisis			0.002	0.002	0.000	-0.005	0.002	-0.000
			(0.77)	(1.41)	(0.10)	(-1.52)	(1.05)	(0.06)
QE			-0.007**	-0.003***	-0.004	0.002	-0.003*	-0.002
			(-2.44)	(-2.26)	(-1.41)	(0.59)	(-1.72)	(-0.68)
Constant			0.191***	0.063***	0.128***	0.131***	0.061***	0.070*
			(5.25)	(3.63)	(3.62)	(3.02)	(2.77)	(1.69)
R-squared			0.240	0.408	0.193	0.255	0.417	0.192
N				3504			2465	

During the quantitative easing, with very low nominal debt yields total issuance of convertible debt has declined in favour of conventional corporate debt. Convertible debt becomes a less preferred debt choice when the interest rate is lower than those of equivalent straight debts (Batten et al., 2013). Nonetheless, the significance of the *QE* decreases to the 10% level for MNC25. Possibly this is because of the increase of agency cost of debt as the degree of internationalisation increases, pointed out by the significantly positive *DOI* and *GO* at the 5% level when the minimum degree of internationalisation increases to 25%. In summary, convertible debt is still the preferred debt choice when the relative impact of the agency problem is greater than the impact of quantitative easing as the degree of internationalisation increases.

4.4.5 Robustness Check

4.4.5.1 Subsamples Analysis

To provide more in-depth analysis, both samples of MNC10 and MNC25 are divided by NASDAQ and non NASDAQ-listed MNCs. As documented by Table 4.2, about one-third of the sample observations are NASDAQ-listed MNCs. NASDAQ-listed firms tend to be smaller firms with higher growth opportunities (Loughran, 1997; Schwert, 2002) as compared to non-NASDAQ-listed firms. Therefore, potentially the positive relationship between agency costs of debt and convertible debt is affected by the NASDAQ-listed MNCs given the differences in the firm characteristics, instead of internationalisation. Table 4.8 presents the results of mean differences between the characteristics of NASDAQ and non-NASDAQ-listed MNCs for both samples, MNC10 and MNC25. Most of the observed characteristics are significantly difference at the 1% level, except *GO* and *Dboth*.

Table 4.8
Mean Difference between NASDAQ and Non NASDAQ-Listed MNCs

This table reports the mean of the observed characteristics together with the mean difference between the NASDAQ and non NASDAQ-listed MNCs. Two samples of MNCs are defined. A firm is defined as MNC when the degree of internationalisation measured by foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), and 25% (MNC25). Equity, long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt *(Non-CNV*) are scaled by total capital. Total capital is defined as the sum of total long-term debt and market value of shareholders' equity. *CNV/LTDebt* and *Non-CNV/LTDebt* are the ratios of convertible debt and non-convertible debt over long-term debt, respectively. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the firm uses both convertible and non-convertible debt in the financing and zero otherwise. *DCBsub* is a dummy equals to one if the convertible debt is a subordinated debt and zero otherwise. *N* is the number of firm-year observations. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	MNC10				MNC25			
	NASDAQ (N = 1060)	Non NASDAQ (N = 2444)	Mean difference	t-value	NASDAQ (N = 722)	Non NASDAQ (N = 1743)	Mean difference	t-value
Equity	0.852	0.815	0.037***	7.525	0.852	0.819	0.034***	5.672
LTDebt	0.148	0.185	-0.037***	-7.525	0.148	0.181	-0.034***	-5.672
CNV	0.048	0.015	0.033***	14.356	0.051	0.016	0.035***	12.437
Non-CNV	0.100	0.170	-0.070***	-14.554	0.097	0.166	-0.069***	-12.144
CNV/LTDebt	0.272	0.078	0.194***	18.003	0.280	0.082	0.198***	15.100
Non-CNV/LTDebt	0.728	0.922	-0.194***	-18.003	0.720	0.918	-0.198***	-15.100
DOI	0.498	0.445	0.053***	7.319	0.568	0.516	0.518***	7.086
GO	0.953	1.009	-0.056**	2.244	0.960	1.014	-0.055*	-1.874
SIZE	6.671	8.098	-1.427***	-25.447	6.560	8.210	-1.649***	-24.619
TG	0.158	0.248	-0.090***	-15.005	0.153	0.242	-0.089***	-12.605
RISK	3.258	3.533	-0.275***	-3.158	2.988	3.486	-0.498***	-5.202
PROFIT	0.027	0.062	-0.035***	-11.219	0.019	0.059	-0.041***	-11.773
Dboth	0.175	0.171	0.004	0.290	0.177	0.178	-0.001	-0.034
DCBsub	0.189	0.068	0.121***	10.914	0.188	0.071	0.117***	8.752

Surprisingly, the agency cost of debt (*GO*) of NASDAQ MNCs is significantly lower than non-NASDAQ-listed MNCs at the 5% level for MNC10 and the significance level reduces to 10% for MNC25. When the other characteristics are compared, NASDAQ-listed MNCs are more likely to use less long-term debt in their capital structure. But looking at the debt structure, NASDAQ-listed MNCs tend to issue more convertible debt and, thus less non-convertible debt as compared to non NASDAQ-listed MNCs. In addition, NASDAQ-listed MNCs are of smaller size with lower tangible assets, of higher risk indicated by the lower Z-score value and less profitable in comparison to non NASDAQ-listed MNCs. These findings are consistent for both samples.

Panel A of Table 4.9 reports the estimates for NASDAQ-listed MNCs when the degree of internationalisation is greater than or equal to 10% (MNC10) and 25% (MNC25). *DOI* is only found to be negatively related to long-term debt for MNC10, but the coefficient is marginally significant at the 10% level and is not significant for MNC25. The significantly positive coefficient of *GO* in the convertible debt model suggest that NASDAQ-listed MNCs have the tendency to use convertible debt in their debt structure to mitigate the agency problems. Note that the significant level improves from 10% for MNC10 to 1% for MNC25. Reasonably, this indicates the importance of the agency problem in influencing the decision for the issuance of convertible debt when the minimum measure of internationalisation increases from 10% to 25%. This is because NASDAQ-listed MNCs tend to be high growth firms, thus are expected to have higher agency problems as these firms expand abroad. Therefore, convertible debt is the preferred choice of debt to mitigate the conflict of interest between financial claimants, consistent with the risk-shifting hypothesis (Green, 1984).

Table 4.9
Analysis by Subsamples on Leverage by Types of Debt

This table reports the estimates of fixed effects panel regression by types of debt when the foreign sales ratio and foreign tax ratio are greater than or equal to 10% (*MNC10*) and 25% (*MNC25*). Panel A shows the estimates of NASDAQ-listed firms, whereas Panel B shows the estimates of non NASDAQ-listed firms. The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *DOI* is measured by foreign sales ratio. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Panel A: NASDAQ-listed MNCs

Variables	Expected Sign		MNC10			MNC25		
	(a)	(b)	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV
DOI	-	+	-0.060*	-0.010	-0.050	-0.013	0.001	-0.015
			(-1.70)	(-0.42)	(-1.63)	(-0.30)	(0.05)	(-0.39)
GO	-	+	-0.007	0.007*	-0.014***	0.006	0.015***	-0.008
			(-1.11)	(1.82)	(-2.74)	(0.93)	(3.03)	(-1.43)
SIZE	+	-	0.031***	0.005	0.026***	0.021***	0.008	0.026***
			(3.75)	(0.91)	(3.63)	(4.58)	(1.14)	(3.00)
TG	+	-	0.037	-0.108*	0.145**	0.154***	-0.149**	0.174**
			(0.44)	(-1.88)	(2.01)	(3.01)	(-2.05)	(2.01)
RISK	-	+	-0.024***	-0.006***	-0.018***	-0.016***	-0.006***	-0.018***
			(-12.27)	(-4.61)	(-10.57)	(-9.18)	(-3.02)	(-8.03)
PROFIT	+	-	-0.090**	-0.119***	0.029	-0.091**	-0.147***	0.040
			(-2.38)	(-4.57)	(0.89)	(-2.31)	(-4.67)	(1.07)
Dboth	+/-	+/-	0.006	0.029***	-0.023**	0.005	0.020**	-0.020*
			(0.56)	(3.87)	(-2.44)	(0.38)	(2.18)	(-1.75)
DCBsub	+/-	+/-	0.021	0.059***	-0.038***	0.037***	0.072***	-0.031**
			(1.38)	(5.70)	(-2.93)	(2.63)	(5.66)	(-2.02)
Constant			0.049	0.036	0.013	0.058*	0.008	-0.018
			(0.81)	(0.88)	(0.24)	(1.66)	(0.16)	(-0.29)
R-squared			0.156	0.379	0.107	0.237	0.411	0.127
N				1060			722	

Table 4.9 *Continued*

Panel B:Non NASDAQ-listed MNCs

Variables	Expected Sign		MNC10			MNC25		
	(a)	(b)	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV
DOI	-	+	0.001	0.028***	-0.026	-0.003	0.035***	-0.038
			(0.07)	(3.68)	(-1.21)	(-0.12)	(3.49)	(-1.46)
GO	-	+	-0.021***	-0.001	-0.020***	-0.019***	-0.001	-0.018***
			(-6.02)	(-0.79)	(-5.74)	(-4.58)	(-0.75)	(-4.31)
SIZE	+	-	-0.001	-0.008***	0.007	0.007	-0.010***	0.017***
			(-0.15)	(-4.87)	(1.54)	(1.37)	(-4.95)	(3.28)
TG	+	-	0.039	-0.017	0.055	0.053	-0.023	0.075*
			(1.10)	(-1.35)	(1.57)	(1.26)	(-1.42)	(1.81)
RISK	-	+	-0.045***	-0.003***	-0.041***	-0.042***	-0.002***	-0.039***
			(-25.62)	(-5.45)	(-23.68)	(-18.78)	(-2.70)	(-17.85)
PROFIT	+	-	-0.037	-0.011	-0.026	-0.185***	-0.077***	-0.108**
			(-1.53)	(-1.35)	(-1.06)	(-3.76)	(-4.08)	(-2.21)
Dboth	+/-	+/-	0.016**	0.062***	-0.046***	0.029***	0.063***	-0.034***
			(2.50)	(28.06)	(-7.25)	(4.01)	(22.61)	(-4.65)
DCBsub	+/-	+/-	0.015	0.025***	-0.010	0.008	0.024***	-0.016
			(1.52)	(7.13)	(-0.96)	(0.74)	(5.69)	(-1.44)
Constant			0.358***	0.071***	0.287***	0.280***	0.086***	0.194***
			(8.79)	(5.00)	(7.04)	(5.81)	(4.67)	(4.05)
R-squared			0.427	0.483	0.388	0.414	0.451	0.334
N				2444			1743	

For the control variables, the coefficients are mostly significant and consistent with the hypothesised signs with some minor exceptions. Firm size is not a significant determinant in the convertible debt model, possibly because NASDAQ-listed MNCs that issue convertible debt are more likely to be smaller firm size. But the degree of firm size is a significant determinant if the MNCs are considering non-convertible debt as their financing choice because larger size firms are expected to have lower financial distress (Doukas and Pantzalis, 2003; Lewis et al., 1999), thus allowing NASDAQ-listed MNCs to tolerate a higher level of fixed obligation of debt. Similar to the results reported in Tables 4.4 to 4.6, the negative coefficient of *PROFIT* is insignificant for non-convertible debt. NASDAQ-listed MNCs that issue convertible debt are more likely to have both convertible and non-convertible debt in the debt structure and the convertible debt are more likely to be subordinated, as opposed to non-convertible debt issuers. These findings are consistent for both samples.

Interestingly, Panel B shows that *DOI* is positively significant at the 1% level for non-NASDAQ-listed MNCs but *GO* is insignificant. These results only apply for the convertible debt model. On the contrary, for the non-convertible debt model and long-term debt model *DOI* is insignificant but *GO* is negatively significant at the 1% level. In brief, for the non-NASDAQ-listed MNCs, the choice of issuing convertible debt is affected by the degree of internationalisation instead of the agency problem. As the degree of internationalisation increases, non-NASDAQ-listed MNCs are more likely to issue convertible debt. A possible explanation is these MNCs face additional financial distress costs, such as exchange rate risk and political risk, as they expand their business abroad. Hence, they are discouraged from issuing non-convertible debt to reduce the interest coupon and financial risk (Jen et al., 1997), supporting the trade-off theory. This is also supported by the less negative coefficient of *RISK* for the convertible debt model as compared to the non-convertible debt model. Therefore, non NASDAQ-listed MNCs are more likely to issue convertible debt when the degree of internationalisation increases.

Nonetheless, the choice of issuing non-convertible debt is still affected by agency costs of debt and the same applies for long-term debt financing, which is consistent with previous studies (Akhtar and Oliver, 2009; Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Lee and Kwok, 1988). The estimates of the control variables are consistent with the hypothesised sign but are not consistently significant such as *TG*, *PROFIT* and *DCBsub*. Tangibility becomes insignificant in explaining the financing choice of the non-NASDAQ-listed MNCs, whereas profitability is insignificant only for MNC10. Though the empirical evidence shows that the positive relationship between agency costs of debt and convertible debt is attributed to the NASDAQ characteristics of MNCs, it is important to further compare the findings with domestic corporations (DCs), before accepting the results.

4.4.5.2 Comparison between MNCs and DCs

To provide more robust evidence to the empirical findings so far, comparison tests between the MNCs and DCs are conducted. Table 4.10 reports the mean difference of the observed variables between MNC10 and DCs as well as MNC25 and DCs. The observed variables are significantly different between the MNCs and DCs at the 1% level, except the *GO* and *RISK*. MNCs are found to use less long-term debt as compared to DCs, consistent with previous studies (Akhtar and Oliver, 2009; Burgman, 1996; Chen et al., 1997; Doukas and Pantzalis, 2003; Fatemi, 1988; Lee and Kwok, 1988).

Examining the leverage by types of debt, note that MNCs use less non-convertible debt in their debt structure. In contrast, the ratio of convertible debt used by MNCs is significantly higher for DCs, indicating that MNCs tend to issue convertible debt to mitigate agency costs of debt (Doukas and Pantzalis, 2003) because MNCs are claimed to have a higher agency problem than DCs. This is also supported by the significantly higher *GO* at the 10% level. Moreover, MNCs tend to utilise both convertible and non-convertible in their debt structure and the convertible debt are more likely to be subordinated in comparison to DCs.

Table 4.10
Mean Comparison between MNCs and DCs

This table reports the mean of the observed characteristics together with the mean difference between the MNCs and DCs. A firm is defined as MNC when the degree of internationalisation measured by foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), and 25% (MNC25). A firm is defined as DC when it reports no foreign sales and foreign tax. Equity, long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt *(Non-CNV)* are scaled by total capital. Total capital is defined as the sum of total long-term debt and market value of shareholders' equity. *CNV/LTDebt* and *Non-CNV/LTDebt* are the ratios of convertible debt and non-convertible debt over long-term debt, respectively. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *DNasdaq* is a dummy equals to one if the issuer is a NASDAQ-listed firm and zero otherwise. *Dboth* is a dummy equals to one if the firm uses both convertible and non-convertible debt in the financing and zero otherwise. *DCBsub* is a dummy equals to one if the convertible debt is a subordinated debt and zero otherwise. *N* is the number of firm-year observations. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	MNC10 (N = 3504)	DC (N = 3518)	Mean difference	t-value	MNC25 (N = 2465)	DC (N = 3518)	Mean difference	t-value
Equity	0.851	0.816	0.035***	9.469	0.855	0.816	0.039***	9.377
LTDebt	0.174	0.202	-0.028***	-7.809	0.171	0.202	-0.031***	-7.585
CNV	0.025	0.019	0.006***	4.196	0.026	0.019	0.007***	4.513
Non-CNV	0.149	0.184	-0.035***	-9.469	0.145	0.184	-0.039***	-9.377
CNV/LTDebt	0.137	0.096	0.041***	6.078	0.140	0.096	0.044***	5.939
Non-CNV/LTDebt	0.863	0.904	-0.041***	-6.078	0.860	0.904	-0.044***	-5.939
GO	0.992	0.963	0.029*	1.651	0.999	0.963	0.036*	1.825
SIZE	7.666	6.223	1.443***	34.545	7.727	6.223	1.504***	32.212
TG	0.220	0.359	-0.139***	-25.981	0.216	0.359	-0.143***	-23.593
RISK	3.450	3.205	0.245***	3.654	3.340	3.205	0.135*	1.826
PROFIT	0.051	0.008	0.043***	11.624	0.047	0.008	0.039***	9.177
DNasdaq	0.303	0.506	-0.203***	-11.741	0.293	0.506	-0.213***	-16.817
Dboth	0.173	0.117	0.056***	6.712	0.178	0.117	0.061***	6.703
DCBsub	0.104	0.065	0.039***	5.892	0.105	0.065	0.040***	5.584

MNCs are found to have larger firm size than DCs and the firm size increases as the minimum degree of internationalisation increases to 25% but MNCs have less tangible assets than DCs. Furthermore, MNCs face lower financial risk than DCs, given the higher Z-score value. Large firms are expected to have lower financial distress costs (Doukas and Pantzalis, 2003; Lewis et al., 1999) and face less information asymmetry as they tend to be more mature and established, thus less collateral is required when these firms opt for debt financing. Also, MNCs are more profitable than DCs. *DNasdaq* suggests that about half of the DCs' observations are from NASDAQ-listed firms that alert the importance for subsamples analysis between NASDAQ and non-NASDAQ-listed firms.

Next, this study performs fixed effects panel data regressions to examine the influence of MNCs and DCs on leverage by types of debt. Table 4.11 reports the estimates for three samples, specifically MNC10, MNC25 and DC. The inverse relationship between *GO* and *CNV* suggests that the motivation for the issuance of convertible debt by DCs is not driven by the agency problem, as compared to MNCs. Conversely, the coefficient of *GO* is significantly positive at the 1% level, in particular for MNC25. This implies the importance of the agency problem is due to internationalisation, as one of the key considerations in influencing the decision for the issuance of convertible debt. Again, this finding supports the proposition that MNCs issue convertible debt to mitigate the agency costs of debt problem.

Table 4.11
Analysis by MNCs and DCs on Leverage by Types of Debt

This table reports the estimates of fixed effects panel regression for the MNCs and DCs by types of debt. A firm is defined as MNC when the degree of internationalisation measured by foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), and 25% (MNC25). A firm is defined as DC when it reports no foreign sales and foreign tax.The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Variables	**Expected Sign**		**MNC10**			**MNC25**			**DC**		
	(a)	**(b)**	**LTDebt**	**CNV**	**Non-CNV**	**LTDebt**	**CNV**	**Non-CNV**	**LTDebt**	**CNV**	**Non-CNV**
GO	-	+	-0.021***	0.002	-0.023***	-0.014***	0.004***	-0.018***	-0.024***	-0.002**	-0.022***
			(-6.68)	(1.37)	(-7.58)	(-3.97)	(2.16)	(-5.30)	(-7.91)	(-2.18)	(-7.20)
SIZE	+	-	0.011***	-0.005**	0.016***	0.017***	-0.005**	0.023***	0.035***	-0.002*	0.038***
			(2.78)	(-2.51)	(4.11)	(3.76)	(-2.24)	(5.12)	(8.68)	(-1.79)	(9.34)
TG	+	-	0.052	-0.044***	0.095***	0.060	-0.056***	0.116***	0.165***	-0.019**	0.185***
			(1.57)	(-2.76)	(2.99)	(1.52)	(-2.78)	(3.07)	(6.14)	(-2.12)	(6.90)
RISK	-	+	-0.034***	-0.005***	-0.029***	-0.033***	-0.003***	-0.030***	-0.023***	-0.002***	-0.021***
			(-26.16)	(-7.61)	(-23.27)	(-20.10)	(-3.80)	(19.03)	(-21.49)	(-4.83)	(-19.95)
PROFIT	+	-	-0.062***	-0.048***	-0.014	-0.142***	-0.119***	-0.023	0.003	-0.013***	0.015
			(-2.99)	(-4.87)	(-0.67)	(-4.43)	(-7.36)	(-0.74)	(0.19)	(-2.63)	(1.09)
Dboth	+/-	+/-	0.014**	0.052***	-0.037***	0.023***	0.051***	-0.027***	0.030***	0.088***	-0.058***
			(2.57)	(19.37)	(-6.95)	(3.57)	(15.40)	(4.40)	(3.72)	(31.71)	(-7.15)
DCBsub	+/-	+/-	0.020**	0.039***	-0.017**	0.020**	0.039***	-0.019**	0.059***	0.022***	0.037***
			(2.37)	(9.13)	(-2.08)	(2.14)	(8.20)	(-2.10)	(4.77)	(5.24)	(3.00)
Constant			0.215***	0.075***	0.140***	0.151***	0.078***	0.073*	0.015	0.037***	-0.023
			(6.37)	(4.62)	(4.29)	(3.79)	(3.85)	(1.93)	(0.50)	(3.75)	(-0.78)
R-squared			0.243	0.397	0.188	0.261	0.404	0.192	0.214	0.418	0.192
N					3504			2465			3518

For the control variables, the sign and significance of the coefficients are consistent between MNCs and DCs. For example, MNCs with smaller firm size, lower tangibility ratio and less profitable are more likely to issue convertible debt and the same applies for DCs. Also, riskier MNCs, denoted by the less negative coefficient of *RISK* tend to opt for convertible debt, which is similar to DCs. These findings are consistent with the expectations discussed earlier. In addition, the insignificant *PROFIT* variable in the non-convertible debt model implies that the choice of non-convertible debt financing is not explained by the pecking order hypothesis and is consistent throughout the study. Nonetheless, one exception is found being the positive relationship between *DCBsub* and *Non-CNV*, only for the DCs.

As mentioned earlier, about half of the DCs' observations are from NASDAQ-listed firms, thus the DCs are subsampled into NASDAQ and non NASDAQ-listed to examine whether NASDAQ-listed DCs that tend to be smaller firms with higher growth opportunities (Loughran, 1997; Schwert, 2002) are positively related to the issuance of convertible debt. Results are reported in Table 4.12. An important finding can be inferred from the *GO* variable. Panels A and B show an inverse relationship between the agency problem and non-convertible debt for both MNCs and DCs. They tend to use less non-convertible debt when agency costs of debt increases and the evidence is the same for NASDAQ and non NASDAQ-listed firms.

Table 4.12
Subsamples Analysis for MNCs and DCs on Leverage by Types of Debt

This table reports the estimates of fixed effects panel regression for the MNCs and DCs by types of debt. A firm is defined as MNC when the degree of internationalisation measured by foreign sales ratio and foreign tax ratio are greater than or equal to 10% (MNC10), and 25% (MNC25). A firm is defined as DC when it reports no foreign sales and foreign tax. Panel A shows the estimates of NASDAQ-listed firms, whereas Panel B shows the estimates of non NASDAQ-listed firms. The long-term debt (*LTDebt*), convertible debt (*CNV*) and non-convertible debt (*Non-CNV*) are scaled by total capital measured as the sum of long-term debt and the equity at market value. *GO* is the growth opportunities measured by the natural log of market-to-book value, whereas *SIZE* is the firm size measured by the natural log of total assets. *TG* is the tangibility measured by the ratio of net plant and equipment to total assets. Altman Z-score is the proxy for risk (*RISK*) and return on assets is the proxy for profitability (*PROFIT*). *Dboth* is a dummy equals to one if the issuer's debt structure has both convertible and non-convertible debt and zero otherwise. *DCBsub* is a dummy equals to one if the debt is a subordinated convertible debt and zero otherwise. . Column (a) shows the expected sign for LTDebt and Non-CNV models, while column (b) shows the expected sign for CNV model. *N* is the number of firm-year observations. *N* is the number of firm-year observations. The t-values are reported in the parentheses. A superscript *, ** or *** indicates significance at the 90%, 95% or 99% confidence levels, respectively.

Panel A: NASDAQ firms

Variables	Expected Sign		MNC10			MNC25			DC		
	(a)	(b)	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV
GO	-	+	-0.007	0.007*	-0.020***	0.006	0.015***	-0.009	-0.019***	-0.002	-0.017***
			(-1.24)	(1.79)	(-4.21)	(0.91)	(3.06)	(-1.49)	(-5.49)	(-1.03)	(-4.32)
SIZE	+	-	0.028***	0.005	0.015***	0.033***	0.008	0.025***	0.041***	-0.008***	0.052***
			(3.44)	(0.83)	(4.01)	(3.41)	(1.20)	(3.00)	(11.19)	(-3.48)	(9.52)
TG	+	-	0.053	-0.106*	0.234***	0.028	-0.149**	0.176**	0.175***	0.003	0.206***
			(0.63)	(-1.85)	(5.50)	(0.27)	(-2.06)	(2.04)	(8.13)	(0.21)	(5.60)
RISK	-	+	-0.024***	-0.006***	-0.013***	-0.024***	-0.006***	-0.018***	-0.015***	-0.001***	-0.015***
			(-12.16)	(-4.59)	(-10.04)	(-9.02)	(-3.05)	(-8.05)	(-14.80)	(-3.06)	(-12.93)
PROFIT	+	-	-0.094**	-0.119***	0.023	-0.108**	-0.147***	0.039	0.012	-0.012**	0.013
			(-2.50)	(-4.62)	(0.76)	(-2.46)	(-4.70)	(1.03)	(0.87)	(-1.98)	(0.85)
Dboth	+/-	+/-	0.006	0.029***	-0.017*	0.001	0.020**	-0.020*	0.032***	0.102***	-0.065***
			(0.59)	(3.88)	(-1.94)	(0.06)	(2.18)	(-1.75)	(2.84)	(21.23)	(-5.54)
DCBsub	+/-	+/-	0.022	0.059***	-0.057***	0.042**	0.072***	-0.030**	0.044***	0.015**	0.027
			(1.48)	(5.73)	(-5.17)	(2.33)	(5.68)	(-2.00)	(2.72)	(2.06)	(1.49)
Constant			0.039	0.035	0.043	-0.013	0.008	-0.021	-0.038*	0.057***	-0.117***
			(0.64)	(0.84)	(1.59)	(-0.18)	(0.17)	(-0.35)	(-1.75)	(4.08)	(-3.39)
R-squared			0.152	0.387	0.149	0.187	0.410	0.123	0.255	0.297	0.225
N				1060			722			1779	

Table 4.12 *Continued*

Panel A: Non NASDAQ firms

Variables	Expected Sign		MNC10			MNC25			DC		
	(a)	(b)	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV	LTDebt	CNV	Non-CNV
GO	-	+	-0.021***	-0.001	-0.020***	-0.019***	-0.001	-0.018***	-0.024***	-0.003**	-0.020***
			(-6.04)	(-0.97)	(-5.69)	(-4.59)	(-1.02)	(-4.21)	(-5.28)	(-2.58)	(-4.43)
SIZE	+	-	-0.001	-0.006***	0.006	0.007	-0.008***	0.015***	0.132**	0.003*	0.010*
			(-0.14)	(-4.04)	(1.27)	(1.38)	(-4.25)	(3.03)	(2.43)	(1.94)	(1.82)
TG	+	-	0.038	-0.024*	0.062*	0.054	-0.033**	0.086**	0.126***	-0.042***	0.168***
			(1.11)	(-1.94)	(1.78)	(1.30)	(-2.06)	(2.10)	(3.53)	(-4.03)	(4.62)
RISK	-	+	-0.045***	-0.003***	-0.041***	-0.042***	-0.002	-0.039***	-0.050***	-0.002***	-0.047***
			(-25.64)	(-5.29)	(-23.74)	(-18.80)	(-2.64)	(-17.86)	(-21.46)	(-3.51)	(-20.00)
PROFIT	+	-	-0.038	-0.013	-0.024	-0.185***	-0.076***	-0.109**	0.074**	-0.000	0.074**
			(-1.54)	(-1.58)	(-0.98)	(-3.76)	(-4.01)	(-2.23)	(2.20)	(-0.02)	(2.16)
Dboth	+/-	+/-	0.016**	0.062***	-0.045***	0.029***	0.064***	-0.034***	0.021**	0.077***	-0.055***
			(2.50)	(28.01)	(-7.26)	(4.01)	(22.60)	(-4.68)	(2.09)	(25.71)	(-5.36)
DCBsub	+/-	+/-	0.015	0.025***	-0.010	0.008	0.024***	-0.016	0.077***	0.028***	0.048***
			(1.52)	(7.08)	(-0.95)	(0.75)	(5.61)	(-1.41)	(4.97)	(6.26)	(3.07)
Constant			0.358***	0.072***	0.286***	0.279***	0.094***	0.186***	0.255***	0.010	0.245***
			(8.80)	(5.10)	(7.01)	(5.84)	(5.10)	(3.90)	(5.66)	(0.78)	(5.31)
R-squared			0.427	0.490	0.384	0.414	0.460	0.337	0.263	0.487	0.223
N				2444			1743			1739	

Interestingly, only NASDAQ-listed MNCs are more likely to issue convertible debt as agency problem increases, but not the DCs (refer Panel A). The coefficient of *GO* is negative for NASDAQ (though insignificant) and non-NASDAQ-listed DCs (significant at the 1% level), suggesting that DCs are less likely to issue convertible debt when agency costs of debt increases. In comparison to MNCs, agency problem is not the key determinant that motivates the issuance of convertible debt by DCs.

Conversely, Panel B shows that the agency problem is insignificant to motivate non-NASDAQ-listed MNCs to issue of convertible debt, instead it is motivated by the degree of internationalisation (refer Panel B of Table 4.9). Non-NASDAQ-listed MNCs are likely to issue convertible debt at a higher degree of internationalisation. This supports the trade-off theory. MNCs face additional uncertainties when they expand abroad, hence are less likely to issue debt with a higher fixed obligation such as straight debt or equivalent. In summary, this study finds that the motivation to issue convertible debt to mitigate agency costs of debt is not because of the firms being NASDAQ or non-NASDAQ-listed firms but is due to internationalisation.

4.5 Conclusion

Capital structure is one of the most researched topics in the finance literature and remains a controversial issue in modern corporate finance. Conceptually, MNCs are able to sustain a higher level of leverage than DCs because MNCs are of larger firm size, have lower bankruptcy risk and greater access to international capital markets. Nonetheless, empirical evidence has shown otherwise. MNCs are found to have greater agency costs of debt as they expand abroad, thus lowering the leverage. Motivated by the differences between MNCs and DCs, as well as the increasing importance of globalised markets due to trade liberalisation, this study examines the debt financing decision of MNCs when the analysis is extended to account for debt heterogeneity.

This study identifies long-term debt by convertible and non-convertible debt. The conversion feature is the key focus of the study because the conversion feature is claimed to be able to restore value maximizing incentives, thus reducing the agency costs of debt. Results from the pooled cross-sectional and panel data regressions show that MNCs mitigate agency costs of debt by issuing convertible debt. Conversely, MNCs are found to have lower long-term debt and non-convertible debt, as the agency problem increases, as a result of internationalisation. These results remain robust after controlling for firm size and industry effects in the pooled cross-sectional regressions, as well as, firm and year fixed effects in the panel regression.

To provide more comprehensive results, a comparison test between MNCs and DCs is presented. Results support the proposition of this study. DCs are shown to be less likely to issue convertible debt when the agency problem increases. The same results are reported when the study accounts for the NASDAQ and non-NASDAQ-listed characteristic of MNCs and DCs. Moreover, convertible debt is still the preferred financing mode, when the relative impact from the agency problem is greater than the impact from market conditions such as the recent Global Financial Crisis and the subsequent quantitative easing policy as the degree of internationalisation increases.

CHAPTER FIVE

CONCLUSION

This chapter concludes the thesis by providing a summary of the major findings and implications for each of the three essays, presented in Section 5.1. Also, Section 5.2 suggests potential areas for future research.

5.1 Major Findings and Implications

5.1.1 Essay One: Convertible Bond Pricing Models

This essay surveys the key theoretical and empirical studies on the pricing of convertible bonds to facilitate understanding of the valuation process and identifies those areas of research that may further improve the valuation process and application of these securities. Over the years, researchers have undertaken a number of studies with the intention of developing pricing models that would closely reflect the real market behaviour to price convertible bonds efficiently. Convertible bond pricing model is first extended by Ingersoll (1977a) from the contingent claim approach of Black and Scholes (1973) and Merton (1973, 1974). But, the valuation process is not as straightforward as in the pricing of standard options and straight bonds because the hybrid feature of convertible bonds complicates valuation.

The payoff structures of these securities are subject to the issue-specific factors such as the time to maturity, coupon rate, face value, conversion ratio, and dividend yield of the underlying asset. In addition, the straight bond component is subject to both credit and interest rate risk, whereas the conversion option is exposed to equity risk. Pricing of convertible bonds is further complicated with the presence of complex optionality or boundary conditions that are added as sweeteners to either investors or issuers, especially the call and put provisions. Either the closed-form solution or numerical solution can be utilised to solve the value of convertible bonds, depending on the underlying assumptions governing each pricing model.

Empirically, this survey shows that there remains scope for potential examination to further improve the efficiency of convertible bond pricing models. This survey highlights the inconsistent findings, limitations in the former studies, differences in the model specifications, and less extensive empirical literature on the pricing of convertible bonds. For example, the debate of using stochastic instead of constant interest rate in the pricing model. Chan et al. (1992) find that one of the most important features of the term structure is its dependence on interest rate volatility, thus term structure models that assume constant volatility are clearly misspecified.

Future empirical research may benefit from seeking evidence from larger samples to improve the statistical inference or may seek evidence from other capital markets to provide additional insight to the much studied US market. Comparative study among developed capital markets or between developed and emerging capital markets is also expected to add to the understanding of convertible bond pricing behaviour in different capital markets. The analysis will be of interest to both the issuers and investors in determining the financing and investment decisions such as asset allocation, diversification and arbitrage strategies, internationally. In fact, external factor such as the effect of market liquidity on the pricing of convertible bonds has not been considered. The issue of liquidity has also become increasingly important to the market participants, particularly during the recent Global Financial Crisis.

5.1.2 Essay Two: Pricing Convertible Bonds

This essay examines the pricing efficiency of real-time trade prices of US convertible bonds. A unique sample of 96 pure convertible bonds is identified from TRACE-FINRA, which exclude callable and puttable features. Convertible bonds that are issued with other complicated payoff structures are also excluded so that the sample consists only of convertible bonds with an equity option (conversion option). This enables the study to clarify the degree of mispricing of convertible bonds using a unique sample to control for estimation biases caused by the complex optionality present in these securities.

The least squares Monte Carlo simulation (LSM) approach of Longstaff and Schwartz (2001) is employed to solve for a pricing model that accounts for stochastic volatility and credit risk. The LSM offers significant gain in computational speed and efficiency in handling multiple state variables and path dependencies (Longstaff and Schwartz, 2001). An average underpricing of 6.31% is reported from daily observations, covering the period from October 26, 2004 to June 30, 2011. Excluding the most volatile period of Global Financial Crisis around the collapse of Lehman Brothers (September 15, 2008 to March 15, 2009), an average underpricing of 3.14% is documented. During the most volatile period, convertible bonds trade at deep discount of 42.97%, which highlight the importance of market conditions and the temporal rather than systematic nature of the pricing errors.

Consistent with Mitchell and Pulvino (2012), equity-like convertible bonds are found to be less underpriced by the market as compared to debt-like convertible bonds. The value of the conversion option is higher for the equity-like convertible, thus is less risky and more attractive to investor and the opposite for debt-like convertibles. Also, debt-like convertibles are sensitive to model assumptions and inputs, such as the credit spread, default probability and recovery rate. Volatility is found to have greater impact on the pricing efficiency, in particular for convertible bonds with substantial time-varying fluctuation in the underlying stock returns. Nonetheless, stochastic interest rates are found to have an insignificant effect on the pricing efficiency of these securities, which is a finding consistent with Ammann et al. (2008) and Brennan and Schwartz (1980). In addition to the model-specific and issue-specific factors, the level of liquidity of convertible bonds is also a significant factor to explain the pricing efficiency of these securities.

Underpricing is reported throughout the observation period, which is consistent with Ammann et al. (2003) Carayannopoulos (1996) Gushchin and Curien (2008) King (1986) and Rotaru (2006). This finding is able to clarify the mixed results reported in existing studies and support the existing arguments that claim convertible bonds are sold at discount from theoretical values (Ammann et al., 2003; Loncarski et al., 2009; Rotaru, 2006). It is important to recognise these pricing errors because they should lead to arbitrage opportunities. Convertible arbitrage hedge funds exploit the mispricing by buying underpriced convertible bonds and selling the underlying common stock at the current delta to potentially generate risk-free profits.

Nonetheless, there could be potential for model error that is attributed to the assumptions and specifications of the employed pricing model as well as the limitations in this study, such as the estimation of volatility and credit risk. In this essay, historical volatility is used in the pricing model instead of forward looking volatility. In addition, the credit spread that is added to the risk-free interest rate to discount the fixed-income component of a convertible bond is assumed to be constant throughout the observation period.

5.1.3 Essay Three: Debt Heterogeneity, Internationalisation and Agency Costs

This essay examines whether MNCs can mitigate agency costs of debt caused by internationalisation by the use of convertible debt. One benefit of internationalisation is the ability to diversify the source and type of debt, but the benefit is offset by the increasing agency costs as the firms expand abroad. As a result, MNCs use lower levels of leverage to reduce these agency costs. One key limitation of this conclusion is the failure to recognise debt heterogeneity, specifically the equity options (conversion options) that are present in the debt components of MNCs. The equity option is claimed to be able to restore value maximizing incentives, thus reducing the agency costs of debt.

Accordingly, long-term debt is further identified as convertible and non-convertible debt. The research question is examined using two samples of MNCs, covering the period from 2002 to 2011.The first sample MNC10 is constructed when both the foreign sales ratio and foreign tax ratio are greater than or equal to 10%. The second sample MNC25 is constructed when both ratios are greater than or equal to 25%. Pooled cross-sectional regressions show that MNCs mitigate agency costs by issuing convertible debt. Consistent with the exiting evidence, MNCs are found to have lower long-term debt and non-convertible debt at a higher degree of internationalisation. MNCs are claimed to have greater growth opportunities, thus greater agency costs. These results remain robust after controlling for year and industry effects.

The positive relationship between convertible debt and the degree of internationalisation are reexamined using fixed effects panel regression. Consistent results are reported specifically for MNC25, implying that internationalisation has a greater impact on the issuance of convertible debt, specifically when the degree of internationalisation is greater than or equal to 25% because of the greater agency costs incurred. Results remain robust during adverse market conditions, including the recent Global Financial Crisis and the subsequent period of quantitative easing. To provide more comprehensive results, this study presents a comparison test between MNCs and DCs. DCs are shown to be less likely to issue convertible debt than MNCs though agency costs exist implying that debt heterogeneity is indeed linked to internationalisation. In summary, these findings highlight the importance of recognising debt heterogeneity to mitigate agency costs that arise from international financing.

5.2 Future Areas of Research

The first essay of this thesis highlights a number of limitations in the existing empirical studies and identifies areas for potential future research that can further improve the pricing efficiency of convertible bonds. However, the scope of this survey is limited to conventional convertible bonds where the payoffs are linked to the performance of the issuer's stock. These include standard convertible bonds, reset convertible bonds and international convertible bonds.

Over the years, financial innovation has created variations of non-conventional convertible bonds to augment the attractiveness of these securities to either investors or issuers. For example, exchangeable convertible bonds, death spiral convertible bonds, mandatory convertible bonds, reverse convertible bonds, and contingent convertible bonds or CoCo bonds. CoCo bonds have attracted significant interest, specifically since the recent Global Financial Crisis. Potentially, future study can undertake a survey of key theoretical and empirical studies on the pricing of these non-conventional convertible bonds that also compare and contrast the characteristics, payoff structures, and pricing models of these securities. As a result, market participants would have a comprehensive understanding of convertible bonds. Also, this would further motivate future empirical studies on these non-conventional convertible bonds.

For the second essay, there are a number of potential areas that are worth examining. First, is to extend the assumption on credit risk in this study, specifically for the pricing of debt-like convertible bonds. Equity-like convertibles are found to be less underpriced than debt-like convertibles. For example, equity-like are underpriced by 0.55%, whereas debt-like are underpriced by 10.70% for the full sample (October 26, 2004 to June 30, 2011). During the most volatility period of the Global Financial Crisis that is around the collapse of Lehman Brothers (September 15, 2008 to March 31, 2009), equity-like are underpriced by 11.12%, whereas debt-like are underpriced by 48.27%.

These findings can be explained by the estimation of credit risk. Debt-like convertible bonds are exposed to higher risk because the equity component is less likely to be exercised, especially during the most volatile period where the straight bond component of these securities could fall substantially if the issuing firm is approaching default.

Therefore, debt-like convertibles are sensitive to model inputs and specifications, in particular the credit spread, default probability and recovery rate. But in the second essay, to keep the pricing model simple, credit spread is assumed to be constant and possibility of default and recovery rate are not taken into consideration in the pricing model. Further study can therefore extend this study by incorporating these credit risk consideration into the pricing of debt-like convertible bonds.

Essay Two also finds that stochastic interest rates do not have significant impact on the pricing of convertible bonds. But the first essay of this thesis highlights an important question of how stochastic interest rate behaviour should be modelled. Accordingly, future research can extend the valuation process by incorporating the Chan et al. (1992) interest rate model that capture time varying volatility of interest rates. In addition, the level of liquidity of convertible bonds is also a significant factor to explain the pricing efficiency of these securities. This evidence is generated by regression analysis. Thus, further study could provide theoretical contribution by quantifying liquidity into the pricing model. Additionally, future study may shed some light by examining the determinants for the issuance of convertible bonds with different types of optionality.

The final essay shows that MNCs mitigate agency costs of debt as a result of internationalisation by issuing convertible debt and debt heterogeneity is in fact linked with internationalisation. Future study could further examine whether there may be a corporate governance argument for the use of convertible debt by MNCs.

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APPENDIX A

ESSAY ONE

CONVERTIBLE BOND PRICING MODELS

Appendix A.1

Merton's (1974) Contingent Claim Valuation of Corporate Bonds

This section discusses the technical specification of Merton's (1974) contingent claim pricing model of corporate liabilities, which is regarded as a contingent claim on firm value. A standard partial differential equation (PDE) is derived from Merton's (1973) three-security portfolio concept, consisting of a common stock, an option and a riskless bond that equates the portfolio to zero. This is achieved by using the proceeds of short sales and borrowings to finance the long position.

The firm value, V is a stochastic process that is assumed to follow geometric Brownian motion with constant variance.

$$dV = (\mu_V V - C)dt + \sigma_V dz \tag{1}$$

where μ_V and σ_V are the drift rate and standard deviation, respectively, whereas C is the total dollar payouts, and dz is a standard Gauss-Wiener process.

The security's value $B(V,\tau)$ satisfies the standard PDE as follows:

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 B}{\partial V^2} + (rV - C)\frac{\partial B}{\partial V} + \frac{\partial B}{\partial t} - rB + C_t = 0 \tag{2}$$

where C_y is the dollar payout per unit of time for the security, while *r* is the risk-free interest rate.

Merton (1974) adds that by distinguishing the boundary specifications, the PDE is applicable to price any financial instrument, which is contingent on the firm value. As an initial trial, the PDE is modified to solve for *discount bonds* without any dividend payouts, but with possibility of default. To determine the value of *risky discount bond* $B(V,t)$ it has to satisfy the following conditions.

(i) Firm's capital structure is assumed to consist only of a single, homogenous class of discount bond (*B*) and equity (*E*), in which both take on non-negative values.

$$B(0,t) = E(0,t) = 0 \tag{3a}$$

(ii) The regularity condition states that,

$$\frac{B(V,t)}{V/\lambda} \leq 1 \tag{3b}$$

where λ is the number of bonds outstanding.

(iii) Initial condition at t = 0,

$$B(V,0) = min\left(\frac{V}{\lambda}, P\right) \qquad (3c)$$

where P is the redemption value (face value) at maturity.

(iv) At maturity, t = T, the possible payoff would be

$$B(V,T) = \begin{bmatrix} P \;\; if \; \frac{V(T)}{\lambda} > P \\ \frac{V}{\lambda} \;\; if \; \frac{V(T)}{\lambda} < P \end{bmatrix} \qquad (3d)$$

Subject to the conditions in (3), the value of *risky discount bond* satisfies the following PDE.

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 B}{\partial V^2} + rV\frac{\partial B}{\partial V} - \frac{\partial B}{\partial \tau} - rB_t = 0 \qquad (4)$$

Note that $C_y = 0$ because no coupons are paid on the bonds and $C = 0$ because the firm neither issues any new senior claims nor pays any cash dividends or repurchases shares prior to the maturity of the risky discount bond. $\tau \equiv T - t$ is the length of time until maturity so that $\frac{\partial B}{\partial t} = -\frac{\partial B}{\partial \tau}$ whereas t is the calendar time.

Equation (2) and the boundary conditions in (3) are still valid to determine the value of *coupon bonds*, specified by Equation (5), where $\bar{C}$ is the continuous coupon payments.

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 B}{\partial V^2} + (rV - \bar{C})\frac{\partial B}{\partial V} - \frac{\partial B}{\partial \tau} - rB + \bar{C} = 0 \qquad (5)$$

Equation (5) can be employed to price *callable coupon bond* with minor modification to the boundary condition (3b). The firm value at any time before maturity must be greater than $\bar{V}(\tau)$ so that it would be advantageous for the firm to call back the bonds. Hence, the new boundary condition would be

$$B(\bar{V}(t), t) = \kappa(t) \qquad (6)$$

where $\kappa(t)$ is the call price. Therefore, Equation (5), subject to boundary conditions 3(a), 3(c) and (6) can be solved to determine the value of the *callable coupon bond*. $\bar{V}(t)$ will be the value that maximises the value of equity, *E* while minimises the value of bond.

Appendix A.2

Ingersoll's (1977a) Structural Approach of Convertible Bonds Pricing Model

Comparable to Black and Scholes (1973) and Merton (1973, 1974), Ingersoll (1977a) derives a PDE under a set of restrictive assumptions to price convertible bonds. The pricing model allows for continuous coupon and dividend payments. Firstly, the concept of conversion ratio has to be defined. Conversion ratio, q equals to the face value of convertible bond divided by the conversion price. It can also be expressed by the dilution factor γ that is the fraction of common equity that is converted from each convertible bond.

$$\gamma = \frac{q}{Q+N} \tag{7}$$

where N denotes the outstanding common stock, whereas Q denotes the aggregate number of shares the convertible bonds can be exchanged into common stock.

Several boundary conditions are defined in (8) to price *non-callable discount convertible bond,* $CB(0,t)$.

(i) Firm value consists only of a single, homogenous class of convertible bond and equity that take on non-negative values.

$$CB(0,t) = E(0,t) = 0 \tag{8a}$$

(ii) To control for arbitrage opportunities, an initial condition is determined. It states that the offer price of a convertible bond must at least equal to the conversion value. Initial condition at $t = 0$,

$$CB(V,0) = max\left[\gamma V, min\left(\frac{V}{\omega}, P\right)\right] \tag{8b}$$

where γV is the conversion value and ω is the number of convertible bonds outstanding.

(iii) At any time prior to maturity,

$$CB(V,T) \leq \frac{V}{\lambda} \tag{8c}$$

(iv) At maturity, the possible payoff would be

$$CB(V,T) = \begin{bmatrix} \gamma V \;\; if \;\; \gamma V > P \\ P \;\; if \;\; \gamma V < P < \frac{V}{\omega} \\ \frac{V}{\omega} \;\; if \;\; \frac{V(T)}{\omega} < P \end{bmatrix} \tag{8d}$$

Therefore, the value of *non-callable discount convertible bond* satisfies the following PDE

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 CB}{\partial V^2} + rV\frac{\partial CB}{\partial V} - \frac{\partial CB}{\partial \tau} - rCB = 0 \tag{9}$$

In order to price *callable discount convertible bond*, boundary conditions (8a) and (8d) are still applicable. But (8b) and (8c) have to be modified to (10a) and (10b), respectively.

$$CB(V,0) = min\left(\frac{V}{\omega}, P\right) \qquad (10a)$$

$$CB(\bar{V}(t),t) = \kappa(t) \qquad (10b)$$

When issuer calls back the convertible bonds, the bondholders can decide either to surrender the convertible bonds at the call price or to convert the convertible bonds. Thus, the payoff upon call is given as,

$$CB(V,t) = max[\kappa(t), \gamma V] \qquad (11)$$

On the other hand, all the boundary conditions in (8) are applicable to determine the price of *non-callable coupon bearing convertible bond* that satisfies the following contingent claim equation.

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 CB}{\partial V^2} + (rV - \bar{C})\frac{\partial CB}{\partial V} - \frac{\partial CB}{\partial \tau} - rCB + \bar{C} = 0 \qquad (12)$$

Appendix A.3

Brennan and Schwartz's (1977) Structural Approach of Convertible Bonds Pricing Model

Brennan and Schwartz (1977) provide a numerical solution – finite difference method to the PDE, thus allowing for discrete coupon and dividend payments, early conversion, call restrictions and the investor's right to convert or redeem when the issuer calls the bond. But, the capital structure is assumed to consist only of convertible bond and equity, thus the possible payoffs at maturity are comparable to those in (8d).

Supplementary conditions that have to be satisfied in addition to the boundary conditions stated in (8) are as follows:

(i) An investor would only convert when the conversion value is higher than the value of convertible bond. Thus, the investor's conversion option ensures that

$$CB(V,t) \geq CV(V,t) = \gamma V \qquad (13a)$$

where CV is the conversion value, also a function of firm value and firm.

(ii) An issuer tends to limit the upside potential and minimises the value of convertible bond by calling back the security. Therefore, when the convertible bond is callable, the call constraint state that

$$CB(V,t) \leq \kappa(t) \qquad (13b)$$

But when issuer calls back the convertible bond, the payoff is as stated in Equation (11).

(iii) When the bond is not currently callable, the limiting firm value condition is

$$\lim_{V \to \infty} CB_V(V,t) = \gamma \qquad (13c)$$

in which the default risk is negligible for a sufficiently high value of V, this the convertibles can be regarded as a warrant to buy a fraction, γ of the firm with an exercise price equals to the present value of the riskless debt payments.

(iv) On the dividend date or an adverse change in conversion terms, the conversion condition is

$$CB(V,t^-) = max[CB(V-D,t^+), \gamma(t^- V)] \qquad (13d)$$

where D is the aggregate dividend payment, whereas t^- denotes the time immediately before the event and t^+ denotes the time immediately after the event. This condition gives the right to investors to convert immediately prior to the event.

(v) On the coupon date when the bond is not currently callable,

$$CB(V, t^-) = CB(V - I, t^+) + i \qquad (13e)$$

where *I* is the aggregate dividend payment on the outstanding convertible bonds at each periodic coupon date and I is the periodic coupon payment per convertible bond. Thus, the pre-coupon value is equal to post-coupon value plus the value of the coupon.

(vi) On a coupon date when the bond is currently callable,

$$CB(V, t^-) = min[CB(V - I, t^+) + i, \kappa(t^-)] \qquad (13f)$$

Accordingly, the value of convertible bond satisfies,

$$\frac{1}{2}\sigma_V^2 V^2 \frac{\partial^2 CB}{\partial V^2} + rV\frac{\partial CB}{\partial V} - \frac{\partial CB}{\partial \tau} - rCB = 0 \qquad (14)$$

Solving by finite difference method, the differential equation can be approximated by

$$a_i CB_{i-1,j} + b_i CB_{i,j} + c_i CB_{i+1,j} = CB_{i,j-1}$$

where $i = 1, \dots\dots, (n-1), j = 1, \dots\dots m$

$$a_i = \frac{1}{2}rki - \frac{1}{2}\sigma_V^2 ki^2; \;\; b_i = 1 + rk + \sigma_V^2 ki^2; \;\; c_i = \frac{1}{2}rki + \frac{1}{2}\sigma_V^2 ki^2$$

$$CB(V,\tau) = CB\left(V_i,\tau_j\right) = CB(ih,jk) = CB_{i,j}$$

The symbols h and k are discrete increments in the value of the firm and in time to maturity, respectively. The symbols n and m represent the number of steps in the time dimension and the firm value dimension, respectively, the former is chosen to correspond to the maturity of the bond under consideration, while the latter must be sufficiently large for the limiting firm value condition (13c) to be well approximated at the maximum firm value considered.

Appendix A.4

Brennan and Schwartz's (1980) Structural Approach of Convertible Bonds Pricing Model

Brennan and Schwartz (1980) recommend a two-factor model that account for two stochastic factors, in particular the firm value and interest rates. Senior debt is also incorporated, thus convertible bondholders will only be paid after the senior debt holders, in the event of default. Both the firm value and the interest rate are assumed to follow stochastic processes. The dynamic of the firm value is shown in Equation (1), whereas the random process of interest rate is

$$dr = \alpha(\mu_r - r)dt + \sigma_r r dZ \tag{15}$$

where α is the speed of reversion. Since senior debt is added to the firm's capital structure, modifications to the boundary conditions are required because senior bondholders have priority of financial claims over convertible bondholders. Therefore, $CB(V,r,t)$ has to satisfy the following conditions.

(i) Conversion condition

$$CB(V,r,t) \geq \gamma[V - \sum B(V,r,t)] \tag{16a}$$

where $\gamma[V - \sum B(V,r,t)]$ is the conversion value, and $[V - \sum B(V,r,t)]$ is the total firm value after taking the aggregate value of senior debt into consideration.

(ii) Call condition

$$CB(V,t,t) \leq \kappa(t) \tag{16b}$$

(iii) At maturity, $t = T$, the possible payoffs would be

$$CB(V,r,T) = \begin{bmatrix} \gamma(V - \Sigma B(V,r,T) & \text{if} & \gamma[V - \Sigma B(V,r,T)] \geq P \\ P & \text{if} & \gamma[V - \Sigma B(V,r,T)] \leq P \leq (V - \Sigma BP_B)/\omega \\ (V - \Sigma BP_B)/\omega & \text{if} & P \geq (V - \Sigma BP_B)/\omega \geq 0 \\ 0 & \text{if} & V < \Sigma BP_B \end{bmatrix} \tag{16c}$$

where $\sum BP_B$ is the aggregate par value of the senior debt. The first two payoffs are the same as in (8d) of Brennan and Schwartz (1977). The third payoff states that in the event of default, convertible bondholders would receive the net firm value, which equals the total firm value minus total senior debt, if it is less than the par value. In brief, convertible bondholders can recover a fraction of the par value when the firm goes to bankruptcy. Meanwhile, the final payoff would be zero if the senior claims exhaust the firm value, so only senior debt holders are either fully or partially recovered.

(iv) Bankruptcy condition

$$CB(V,r,T) = \Lambda P \quad if\ V = \sum BP_B + \Lambda\omega P \tag{16d}$$

where Λ is the recovery rate for each convertible bond upon bankruptcy. Firm will go bankrupt if the firm value falls below the total redemption value to the senior debt holders and total recovery value to the convertible bondholders.

Referring to the boundary conditions in (16), the value of convertible bond contingent on the firm value and interest rate satisfies the following PDE.

$$\frac{1}{2}V^2\sigma_V^2\frac{\partial^2 CB}{\partial V^2} + \rho\sigma_V\sigma_r Vr\frac{\partial^2 CB}{\partial V\partial r} + \frac{1}{2}r^2\sigma_r\frac{\partial^2 CB}{\partial r^2} + [\alpha(\mu_r - r) - \vartheta r\sigma_r]\frac{\partial CB}{\partial r} + [rV - C]\frac{\partial CB}{\partial V} - rCB + cP + \frac{\partial CB}{\partial t} = 0 \quad (17)$$

where $\vartheta$is the market price of interest rate risk, P is the par value of the convertible bond and c is the coupon rate.

Appendix A.5

McConnell and Schwartz's (1986) Reduced-form Approach of Convertible Bonds Pricing Model

McConnell and Schwartz (1986) suggest reduced-form pricing model to determine the price of convertible bonds that views convertible bonds as a contingent claim on the underlying stock price. Equally, the dynamic of stock price $S(t)$ is a stochastic process that is assumed to follow geometric Brownian motion with constant variance.

$$dS = [\mu_S S - D(S,t)]dt + \sigma_S S dZ \tag{18}$$

where μ_S and σ_S are the drift rate and standard equation, respectively, whereas $D(S,t)$ is the total rate of dividends paid to stockholders at time *t* that takes the general form of

$$(D,S) = d_y S + de^{g(t-t_0)} \tag{19}$$

where d_y is the issuer's dividend yield, *d* is the issuer's dividend rate, *g* is the constant growth rate of dividends, and t_0 is the issue date of the convertible bond. The equation allows for constant dividend yield when *d* = 0 or constant dividend growth rate when $d_y = 0$.

To begin with, McConnell and Schwartz (1986) determine the value of a *zero coupon callable and puttable convertible bond* $CB(S,t)$, in which the following boundary conditions have to be satisfied.

(i) The conversion condition ensures that

$$CB(S,t) \geq qS \tag{20a}$$

where q is the conversion ratio and qS is the conversion value.

(ii) The call condition states that

$$CB(S,t) \leq max[\kappa(t_c), qS] \tag{20b}$$

where $\kappa(t_c)$ is the call price at t_c because the pricing model allows for escalated call price through time.

(iii) The redemption or put price specifies that

$$CB(S, t_p) \geq P_p t_p \tag{20c}$$

where $P_p t_p$ is the put price at time t_p because the pricing model allows for escalated put price through time.

(iv) At maturity, the value of convertible bond will be

$$CB(S, t_p) = max(qS, P) \tag{20d}$$

Subject to these conditions, the value of a *zero coupon callable and puttable convertible bond (LYON)* contingent on the issuer's stock price satisfies the following PDE.

$$\frac{1}{2}\sigma_S^2 S^2 \frac{\partial^2 CB}{\partial S^2} + [r_a S - D(S,t)]\frac{\partial CB}{\partial S} + \frac{\partial CB}{\partial t} - rCB = 0 \qquad (21)$$

where r_a is the constant risk-adjusted interest rate, in which a constant credit spread is added to the flat risk-free rate, as the discounting rate to compensate for credit risk.

APPENDIX B

ESSAY TWO

PRICING CONVERTIBLE BONDS

Table B. 1
Trade Reporting and Compliance Engine (TRACE) Timeline

This 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 B. 2

Mean Comparison of Average Mispricing by Pricing Models for Subsample 1

This table reports the mean differences 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* 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. *SE* denotes the standard error. 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**	**CIR**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	10,116	-24.794	-23.800	-0.994	0.728	-2.422	0.434	-1.365
MPBuyer	6,654	-26.721	-26.374	-0.347	0.980	-2.269	1.574	-0.355
MPSeller	6,215	-26.459	-25.678	-0.781	1.027	-2.794	1.232	-0.761
MPDealer	4,761	-26.898	-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**	**TF**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	10,116	-24.794	-22.243	-2.551***	0.590	-3.708	-1.394	-4.322
MPBuyer	6,654	-26.721	-24.269	-2.452***	0.763	-3.947	-0.957	-3.215
MPSeller	6,215	-26.459	-23.717	-2.742***	0.786	-4.282	-1.202	-3.491
MPDealer	4,761	-26.898	-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**	**CEV beta=1**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	10,116	-24.794	-11.873	-12.921***	0.616	-14.129	-11.713	-20.967
MPBuyer	6,654	-26.721	-12.401	-14.320***	0.799	-15.886	-12.755	-17.927
MPSeller	6,215	-26.459	-12.545	-13.914***	0.829	-15.539	-12.289	-16.782
MPDealer	4,761	-26.898	-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**	**CEV beta=0**	**Mean difference**	**SE**	**95% Confidence interval**		**t-value**
MPAll	10,116	-24.794	-12.287	-12.507***	0.675	-13.830	-11.184	-18.529
MPBuyer	6,654	-26.721	-12.658	-14.064***	0.867	-15.763	-12.364	-16.225
MPSeller	6,215	-26.459	-13.419	-13.040***	0.917	-14.837	-11.243	-14.223
MPDealer	4,761	-26.898	-14.067	-12.831***	1.104	-14.996	-10.666	-11.619

Table B.2 *Continued*

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

	Obs	Risk Neutral	GARCH (1,1)	Mean difference	SE	95% Confidence interval		t-value
MPAll	10,116	-24.794	-11.638	-13.155***	0.612	-14.354	-11.953	-21.508
MPBuyer	6,654	-26.721	-12.296	-14.426***	0.795	-15.985	-12.867	-18.138
MPSeller	6,215	-26.459	-12.668	-13.792***	0.827	-15.413	-12.171	-16.676
MPDealer	4,761	-26.898	-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	$CEV_{\beta=1}\,TF$	Mean difference	SE	95% Confidence interval		t-value
MPAll	10,116	-18.971	-8.551	-10.420***	0.599	-17.416	-15.069	-27.127
MPBuyer	6,654	-19.215	-9.214	-10.001***	0.779	-19.034	-15.981	-22.478
MPSeller	6,215	-18.468	-9.289	-9.179***	0.808	-18.753	-15.587	-21.263
MPDealer	4,761	-17.389	-9.174	-8.214***	0.924	-19.536	-15.912	-19.175

Table B. 3

Mean Comparison of Average Mispricing by Pricing Models for Subsample 2

This 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* 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. *SE* denotes the standard error. 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	CIR	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-17.195	0.097	0.282	-0.456	0.651	0.344
MPBuyer	20,102	-16.668	-16.794	0.126	0.324	-0.510	0.761	0.388
MPSeller	18,505	-15.767	-16.039	0.271	0.329	-0.373	0.916	0.826
MPDealer	14,873	-14.391	-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	TF	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-15.716	-1.382***	0.275	-1.922	-0.843	-5.022
MPBuyer	20,102	-16.668	-15.203	-1.466***	0.309	-2.072	-0.859	-4.736
MPSeller	18,505	-15.767	-14.427	-1.341***	0.314	-1.957	-0.725	-4.266
MPDealer	14,873	-14.391	-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	CEV beta=1	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-7.160	-9.938***	0.278	-10.483	-9.392	-35.717
MPBuyer	20,102	-16.668	-6.456	-10.212***	0.311	-10.822	-9.602	-32.809
MPSeller	18,505	-15.767	-6.058	-9.709***	0.314	-10.326	-9.093	-30.879
MPDealer	14,873	-14.391	-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	CEV beta=0	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-7.059	-10.039***	0.278	-10.584	-9.493	-36.062
MPBuyer	20,102	-16.668	-6.034	-10.634***	0.311	-10.940	-9.719	-33.165
MPSeller	18,505	-15.767	-9.818	-5.949***	0.315	-10.435	-9.202	-31.206
MPDealer	14,873	-14.391	-5.438	-8.954***	0.338	-9.616	-8.292	-26.519

Table B.3 *Continued*

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

	Obs	Risk Neutral	GARCH (1,1)	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-9.373	-7.725***	0.280	-8.275	-7.176	-27.545
MPBuyer	20,102	-16.668	-8.990	-7.678***	0.315	-8.295	-7.061	-24.389
MPSeller	18,505	-15.767	-8.577	-7.190***	0.318	-7.814	-6.566	-22.594
MPDealer	14,873	-14.391	-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	$CEV_{\beta=1}TF$	Mean difference	SE	95% Confidence interval		t-value
MPAll	31,608	-17.098	-5.588	-11.510***	0.275	-12.049	-10.970	-41.817
MPBuyer	20,102	-16.668	-4.911	-11.757***	0.306	-12.358	-11.156	-38.362
MPSeller	18,505	-15.767	-4.437	-11.331***	0.310	-11.937	-10.724	-36.609
MPDealer	14,873	-14.391	-4.194	-10.197***	0.332	-10.848	-9.547	-30.721

Table B. 4
Mean Comparison of Average Mispricing between the Stochastic Volatility Models for Subsample 1

This 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. *SE* denotes the standard error. 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 (β)

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

Panel B: Mean comparison between the $CEV_{\beta=1}$ and GARCH(1,1) models

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

Panel C: Mean comparison between the $CEV_{\beta=0}$ and GARCH(1,1) models

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

Table B. 5
Mean Comparison of Average Mispricing between the Stochastic Volatility Models for Subsample 2

This 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. *SE* denotes the standard error. 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 (β)

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

Panel B: Mean comparison between the $CEV_{\beta=1}$ and GARCH(1,1) models

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

Panel C: Mean comparison between the $CEV_{\beta=0}$ and GARCH(1,1) models

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