Intermediary Frictions and Asset Pricing

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January 14, 2022

Abstract

We investigate the effect of intermediary frictions on asset pricing by examining the role of intermediaries in the convertible bond market. Buy-and-hedge intermediaries distribute new convertible issues but face costs in doing so. We demonstrate that these costs affect the price of intermediated securities as their price is decreasing in anticipated future hedging costs. Issue and after-market prices are related to arbitrageurs' hedging costs in both the cross-section and time series. Our findings demonstrate that trading frictions relevant to financial intermediaries are transmitted to asset prices.

Keywords: *intermediary asset pricing, convertible bond underpricing, convertible arbitrage, hedge funds, short-selling costs*

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1. Introduction

Intermediary asset pricing recognizes the role of financial intermediaries in the determination of asset prices (He and Krishnamurthy, 2013; 2018). Empirical studies on intermediary asset pricing have exploited the convertible bond market to show that intermediary capital affects convertible bond prices in times of crises. Mitchell, Pedersen, and Pulvino (2007) report that the large increase in convertible bond underpricing in 2005 was due to convertible bond funds being forced to sell convertibles to meet large capital redemptions by their investors. Mitchell and Pulvino (2012) report that discounts became large as a result of the 2008 global financial crisis when rehypothecation lenders to prime brokers sold the convertibles pledged as collateral to back their loans.[1]

In this paper, we ask whether intermediary frictions can affect pricing outside of crisis times by again exploiting the convertible bond market. The convertible bond market consists of two types of buyers. Outright "buy-and-hold" intermediaries, such as long-only convertible bond funds, invest in convertible bonds on behalf of investors seeking investment in securities with upside potential and downside protection. "Buy-and-hedge" intermediaries, such as convertible arbitrage hedge funds, invest only for as long as necessary to distribute the security, intermediating between firms that require capital quickly and investors requiring time to assess the security. After buy-and-hedge intermediaries purchase the initial convertible bond offering, the convertible's hybrid nature will usually continue until the convertible can be placed with an outright convertible bond holder who desires the associated risk-reward combination. So long as the arbitrage hedge fund retains ownership of the convertible, it hedges its equity exposure by combining its long position in the convertible with a short position in the stock of the company issuing the convertible.[2]

We find that intermediary frictions generally affect convertible bond prices. Convertible arbitrage funds will be willing to acquire and hedge a convertible when its price reflects the loan

[1] Those convertibles had earlier been pledged as collateral for loans from prime brokers to convertible arbitrage hedge funds. As a result, prime brokers were forced to reduce their lending to hedge funds and hedge funds were forced to reduce their holdings of convertible bonds.

[2] In some other cases, the convertible's debt-equity status will be crystallized while it is held by the convertible arbitrage hedge fund (Agarwal et al., 2011). If that crystallization is by conversion, the eventual outright holder is an equity investor and the convertible has provided delayed equity financing (Stein, 1992; Nyborg, 1995).

fees and search costs the fund will incur. For issue and after-market prices to reflect these costs, the convertible must be priced at a discount to the value of an otherwise equivalent package of stock and bonds. We document that discounts are largest when the security is first issued and decline as the distribution process proceeds. An arbitrageur's future hedging cost is the product of the per period cost of hedging a given principal amount, the total position to be hedged, and the anticipated life of the hedge. We show that the discount is sensitive to changes in these determinants of hedging costs.

Our sample contains 1,098 plain-vanilla convertible bonds issued between 2002 and 2018. We calculate the offering discount as the percentage difference between the offering price and the theoretical price calculated using the Tsiveriotis and Fernandes (1998) valuation model. The average estimated offering discount of 12.5% translates to an aggregate offering discount of 47 billion USD. We use the Trade Reporting and Compliance Engine (TRACE) database to track the pricing of these convertibles in the secondary market until the end of 2019. The average first-day return of convertible bonds is 1.5%, indicating that the bulk of the offering discount persists after the convertible bond begins trading on the secondary market.

We examine the relation between the size of discounts and measures of shorting costs. The first measure is the *Loan Supply*, defined as the number of stocks actively made available for borrowing scaled by total shares outstanding. The second measure is *Loan Fee*, which is the rate that an arbitrageur must pay the lender to borrow the stock. Both the ability to locate shares available for shorting and the size of loan fees are important frictions in the equity lending market (D'Avolio, 2002). Cross-sectionally, we find that convertible bonds issued by firms with lower *Loan Supply* and higher *Loan Fees* are issued with higher offering discounts. The effect of shorting costs on offering discounts is economically meaningful. For example, a one standard deviation decrease in *Loan Supply* is associated with an offering discount that is 2.1 percentage point larger.

Next, we study short-selling frictions and underpricing in the seasoned market. Over time, market prices converge gradually towards theoretical values. We use panel regressions that allow us to control for heterogeneity across issuers, bonds, and time. Our results show that short-selling costs explain time-series variation in underpricing, with post-issue convertible bond underpricing decreasing when the underlying stock becomes less costly to short. We further

investigate the relation between underpricing and the present value of anticipated future hedging costs by showing that the sensitivity of convertible bond underpricing to the *Loan Supply* and *Loan Fee* hedging-cost measures diminishes when a convertible bond's ownership is transferred from buy-and-hedge investors to buy-and-hold investors and when convertible arbitrageurs' intermediation activities become less important because of public registration.

In addition, we exploit that hedging would be infeasible if short selling were banned. Between September 18th and October 9th in 2008, the SEC banned short selling of most financial stocks. While the intention of the ban was to prevent excessive short selling by speculators, the ban introduced challenges for existing convertible arbitrageurs in maintaining their hedges and prevented new arbitrageurs from entering the market. We document a significant increase in underpricing for convertibles with banned underlying stock during the period of the ban. Placebo tests directly before and shortly after the short-sale ban show that discounts are not per se increasing for convertibles written on financial stocks.

Our study of intermediary frictions and convertible bond pricing contributes to the literature on intermediary asset pricing. Much of this literature concentrates on the health of dealers (e.g., Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017). We show that in addition to frictions related to financial health, frictions related to the intermediation process are relevant for asset pricing and are not only present in crisis periods. By examining the effect of intermediary frictions on the pricing of new offerings, our study connects the intermediary asset pricing literature to the corporate finance literature. We contribute to researchers' understanding of the determinants of firms' cost of capital by showing that intermediary hedging costs affect convertible bonds' offering discounts, which implies that intermediation frictions can impact borrowing costs and in turn corporate financing decisions.

The remainder of this paper is organized as follows. Section 2 reviews the literature on convertible bond underpricing and develops our predictions. Section 3 describes the data and methodology. Our results are documented in Section 4. Section 5 shows that our results are robust to different ways of measuring underpricing and Section 6 contains our conclusions.

2. Background Literature

2.1 Convertible bond underpricing

With over 160 billion USD of convertible debt outstanding in the U.S. in 2019, convertible bonds are an important source of financing for corporations. The academic literature on convertible bonds has primarily focused on issuance rationales (Green, 1984; Brennan and Kraus, 1987; Brennan and Schwartz, 1988; Constantinides and Grundy, 1989; Mayers, 1998; Stein, 1992; Lewis, Rogalski and Seward, 1999) and security design (Lewis, Rogalski and Seward, 1998; Dutordoir et al., 2014; Basak et al., 2020). Several studies have documented that convertible bonds are issued and traded at prices below their theoretical value (e.g., Chan and Chen, 2007; Mitchell, Pedersen, and Pulvino, 2007; Henderson and Tookes, 2012). The definition of underpricing in the convertible bond literature differs from that used in other parts of the literature. For example, the IPO literature defines underpricing as the difference between the offering price and the initial after-market price.[3] In the case of convertible bonds, underpricing refers to a difference between the offering price and a price estimated using a theoretical valuation model, with underpricing indicating a violation of an equality between the value of the convertible bond and the value of a portfolio of bonds and stocks that mimics the payoff to the convertible.

Two extant studies explicitly analyze determinants of convertible bond underpricing. Chan and Chen (2007) argue that underpricing may be driven by the risk that the firm might renegotiate the convertible's covenants. They show that in the absence of a rating downgrade, convertible bond prices converge to theoretical values after approximately two years. Henderson and Tookes (2012) show that offering discounts are lower when convertible bonds are issued to repeat investors via the network of the underwriter. Their findings demonstrate that frictions play an important role in the bargaining process between convertible issuers and buyers.

2.2 Convertible arbitrageurs and intermediary asset pricing

The buy-side of the convertible bond market is characterized by two different types of investors. Outright "buy-and-hold" investors, such as banks and mutual funds, invest in

[3] See Ljungqvist (2007) for a comprehensive review of theories of equity IPO underpricing.

convertible bonds so that their owners can profit from upside potential from the equity component while facing limited downside risk. "Buy-and-hedge" investors purchase convertible bonds and hedge the equity risk by shorting the underlying stock.[4] The arbitrageur typically determines the optimal short position to create a delta-neutral hedged portfolio. Following increases (declines) in stock prices, the optimal delta-neutral hedge ratio increases (decreases) and the optimal short position becomes larger (smaller). Thus, arbitrageur hedging provides liquidity to the equity market as additional stock is sold short after prices increase and short positions are reduced after prices decline (Choi, Getmansky, and Tookes, 2009).

Arbitrageurs play an important intermediary role in the convertible bond market. A substantial number of convertible bonds are privately placed under SEC Rule 144A, which restricts their purchase to Qualified Institutional Buyers such as convertible arbitrage hedge funds. This rule exempts newly-issued securities from some registration requirements and thus allows firms to raise capital quickly. Issuance through the SEC Rule 144A market is particularly popular among issuers in the high-yield segment of the market (Fenn, 2000). Convertible arbitrage hedge funds act as intermediaries between firms that require capital quickly and investors that require more time to assess the firm's growth potential and creditworthiness.[5] This hedge fund strategy can be profitable because the hedge funds benefit from the offering discounts and because the equity exposure of the convertible bond is effectively distributed to share investors via the short positions that the arbitrageurs take (Brown et al., 2012). After a period of typically 12 months, most privately issued securities are registered for sale to the public. Interestingly, this time frame coincides with the average holding period of convertible arbitrageurs (Van Marle and Verwijmeren, 2017). Convertible bonds can be traded freely after their public registration, allowing convertible bond ownership to gradually transfer from buy-and-hedge investors to buy-and-hold investors.

The traditional approach to asset pricing relates risk premia to household wealth and risk-aversion, and financial intermediation is assumed to be frictionless. The intermediary asset pricing approach recognizes that asset prices are also determined by the preferences and wealth

[4] Calamos (2003) provides a detailed practitioners' description of the convertible arbitrage strategy.

[5] Convertible arbitrage hedge funds are known to make their decisions quickly, typically overnight, without requiring a discussion with the convertible issuing firm's management (Dong, Dutordoir and Veld, 2018).

of financial intermediaries, particularly so during crises (He and Krishnamurthy, 2013; 2018). Extant empirical studies demonstrate that the capital of intermediaries is an important factor in asset pricing tests across multiple asset classes (Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017). The large presence of arbitrageurs in the convertible bond market makes it an interesting setting to study the effects of frictions in financial intermediation. Prior to the financial crisis in 2008, arbitrageurs purchased on average around 75% of new convertible bond issues (Mitchell, Pedersen, and Pulvino, 2007; Choi et al., 2010; Brown et al., 2012). In subsequent years, this proportion has decreased somewhat, but remains substantial at around 50% (Song and Heavey, 2019).

The key prediction of our paper is that short-selling frictions play an important role in driving intermediary asset pricing effects in the convertible bond market. To maintain a delta-hedged portfolio, short sellers must locate stocks available for borrowing, pay loan fees, and post collateral (D'Avolio, 2002). The dynamic nature of convertible arbitrage requires short positions to be rebalanced frequently as stock prices move. Frequent portfolio rebalancing incurs additional transaction costs, especially so if the underlying stock is illiquid.[6] Thus, investing in a delta-hedged convertible bond strategy could require substantial discounts to compensate for these costs.

3. Data and Methodology

3.1 Convertible bond sample

The Mergent Fixed Income Securities Database (FISD) contains information on 1,226 plain-vanilla U.S. convertible bonds issued between July 2002 and December 2018, including details of design features and the bonds' credit ratings. The sample starts in July 2002 because this is when the TRACE database of the Financial Industry Regulatory Authority (FINRA) started reporting transaction-level bond data. The sample ends in 2018 to facilitate the analysis of

[6] The difficulty of locating stock to borrow and the costs of rebalancing are two elements of illiquidity. For unlisted convertibles locating a counterparty willing to trade can also be costly. Duffie, Garleanu, and Pedersen (2005; 2007) model the implications of search-and-bargaining frictions and conclude that illiquidity discounts are highest when counterparties are more difficult to locate, sellers have inferior bargaining power, and investors are not prepared to hold illiquid assets. Our analysis includes an examination of the relation between convertible bond liquidity and underpricing.

post-issuance underpricing up through 2019. The Mergent dataset is complemented with hand-collected information on put schedules and call prices from prospectuses available on the SEC Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system and online news announcements. We delete 128 convertibles for which we are unable to determine the call schedule or which we could not match with CRSP stock price information on the issuing firm, which we require to calculate the inputs to the pricing model. After applying these filters, our sample consists of 1,098 convertible bonds.

3.2 Underpricing

Most convertible bond pricing models rely on simulation- or iteration-based algorithms. Like most studies of convertible bond pricing, we obtain our baseline results using a binomial-tree adaption of the Tsiveriotis and Fernandes (1998) model (henceforth, the TF model). Zabolotnyuk, Jones, and Veld (2010) show that theoretical prices determined through the TF model predict out-of-sample market prices with a level of accuracy similar to that of the Ayache, Forsyth and Vetzal (2003) model, and with greater accuracy than the Brennan and Schwartz (1980) model. The TF model incorporates common design features like call and put provisions, which are redemption rights at the option of the issuer and the security-holder respectively, by adjusting the value function at nodes in a manner consistent with the call and put schedules at the node-date.

Our main variable of interest is the degree to which a convertible bond is underpriced. Following prior studies, we define convertible bond underpricing as the percentage difference between the actual price and the theoretical price of the convertible bond determined by the valuation model:

$$Underpricing = \frac{Theoretical\ Price_{TF} - Price}{Theoretical\ Price_{TF}}.$$

We test our predictions using regression analyses. The first analysis focuses on offering discounts and requires data on offering prices, which are collected from Mergent FISD. The second analysis focuses on underpricing in the secondary market. We use daily volume-weighted transaction prices to construct a daily measure of convertible bond underpricing. These estimates are then averaged per month to construct a panel of monthly underpricing.

Our sample starts in July 2002, when broker-dealers that are members of the FINRA began reporting information on secondary market OTC trades in fixed income securities, including in convertible bonds. The system was implemented in phases and completed by 2004. Beginning in 2014, the TRACE database started to also systematically cover transactions in bonds issued under SEC Rule 144A. We end our data collection from TRACE in December 2019, which allows us to obtain at least one year of trading activity for all new issues of convertible bonds in our sample. The TRACE data is cleaned following the data filters described by Dick-Nielsen (2009; 2014). These filters delete double-reporting, cancellations and corrections, reversals, and agency trades that would otherwise bias market liquidity upwards.

The main input parameters of the theoretical model are the risk-free rate, the credit spread, and the volatility of stock returns. The risk-free rate is set to the U.S. Treasury rate with maturity closest to the maturity of the convertible bond. The credit spread is determined using yields of U.S. corporate bonds matched by the convertible's most recently observed credit rating. Treasury rates and corporate bond yields are obtained from St. Louis Federal Reserve Economic Data (FRED). We follow prior studies (e.g., De Jong, Dutordoir and Verwijmeren, 2011) and assign the credit spread of BBB-rated bonds to unrated convertible bonds. For offering discounts, stock volatility is measured as the annualized standard deviation of daily stock returns measured over the year prior to the convertible's issue. For underpricing in the secondary market, we measure the realized stock volatility over the year prior to the valuation date. In Section 5, we show that our results are robust to using alternate estimates of volatility and credit spreads. We also show that our results are robust when using an alternative theoretical pricing model developed in Finnerty (2015).

3.3 Explanatory variables

3.3.1 Costs of short selling

The first prediction of our study is that convertible bond discounts compensate arbitrage investors for the cost of subsequently maintaining the short positions necessary to hedge their holding of convertibles. We focus on two stock-level variables as proxies for short-selling costs. The first variable is the active number of shares made available for borrowing scaled by total shares outstanding (*Loan Supply*). The second variable is *Loan Fee*, which is the rate that the

arbitrageur pays the lender for borrowing the stock. The ability to locate shortable shares and the loan fees are key frictions in the equity lending market (D'Avolio, 2002). These variables are calculated using equity lending market data from Markit.

An additional stock-level variable that we include in our models is the cost of buying and selling the underlying stock frequently as a consequence of managing a dynamically-hedged position (bid-ask *Spread*), as arbitrageurs' trading costs will depend on the illiquidity of the underlying stock. Various studies have documented a relation between stock liquidity and short-selling constraints (e.g. Hirshleifer, Teoh, and Yu, 2011). In a world without arbitrageurs, convertible bond underpricing would not be affected by illiquidity in the underlying stock since the theoretical price will incorporate the stock price and hence any illiquidity discount in that price. In a world with arbitrageurs, convertible bond underpricing could reflect the costs of the additional trade in illiquid stock that an arbitrage hedge fund must undertake in order to remain hedged compared to the trading level of investors in the underlying stock. We proxy stock liquidity with the CRSP bid-ask spread, which, as shown by Chung and Zhang (2014), provides an estimate of the TAQ-based spread useful in cross-sectional analysis.

3.3.2 Convertible bond liquidity

Even in a world without arbitrageurs, convertible bond underpricing might be affected by the illiquidity of the convertible relative to that of the underlying stock. Only the stock illiquidity effect is automatically built into the TF model price of a payoff-equivalent portfolio of stock and riskless bonds. Any greater illiquidity of convertible bonds relative to the underlying stock is not reflected in the model price. Our paper's second prediction is that offering discounts compensate convertible investors for holding the relatively illiquid convertible. The empirical measurement of convertible bond liquidity is complex, and the academic literature has proposed various measures of liquidity in corporate bond markets (Schestag, Schuster, and Uhrig-Homburg, 2016). Since the buy/sell indicator is often missing for bonds traded on the SEC Rule 144A market, we focus on measures that do not rely on this. First, we calculate several low-frequency liquidity measures using the filtered TRACE data. These measures are the number of trades, par value of bonds traded, the turnover ratio, and the probability that the bond is not traded on a given day. We denote this probability by *Zero* and estimate it as the fraction of trading days on which the convertible bond is not traded.

In addition, we estimate the actual transaction costs using the Imputed Roundtrip Costs (*IRC*) measure developed by Feldhutter (2012). Bid-ask spreads are derived from consecutive trades occurring within short time intervals and with identical par volumes. These trades typically represent pre-matched roundtrip trades between investors and dealers combined with interdealer trades. The *IRC* is then calculated as the difference between the highest and lowest price among the roundtrip trades, divided by the midpoint price.[7]

3.4 Sample characteristics

In Panel A of Table 1, we report bond-level summary statistics of our sample. Over 74% of convertible bonds in our sample are issued under SEC Rule 144A. Furthermore, only 42% of the convertibles have a credit rating and just 12% are investment-grade. This is consistent with SEC Rule 144A issuance being popular among lower-quality firms with limited financing alternatives and highlights the importance of the intermediary role that arbitrageurs play. The average convertible bond matures in 11 years and has a conversion premium of 38% and a 3.4% coupon. Although prior to 2002 most convertible bonds were callable, only 38% of the convertibles in our sample of post-2002 issues are callable. This is consistent with the post-2000 role of arbitrageurs as buyers of newly-issued convertibles and arbitrageurs' preference for protection from calls whose redistributive effect is to reduce the value of the long convertible bond side of a hold-and-hedge strategy while also inducing a loss on the short stock side of the hedge (Grundy and Verwijmeren, 2018).

[TABLE 1 ABOUT HERE]

We report firm-level summary statistics at the time of issuance in Panel B. The average supply of stocks available for shorting is 18% of the shares outstanding. The average loan fee is 1.11%. The average fee is substantially higher than the median fee of 0.375%, indicating that a small number of firms have stocks that are particularly costly to borrow. The average supply of shortable stocks for our sample of convertible issuers is similar to that for stocks in general as reported by Engelberg, Reed, and Ringgenberg (2018), but the loan fees appear to be higher.

[7] Feldhutter (2012) shows that most roundtrip trades consist of interdealer trades combined with either a buy or a sell transaction. Therefore, the estimated spread typically represents a half-spread and is multiplied by two.

Because data coverage by Markit was less extensive before 2006, the sample size becomes smaller in analyses involving the loan supply and fee variables. The average convertible bond issuing firm had a book value of 4.2 billion USD in total assets and a market-to-book ratio of 2.5. The average return-on-assets of a convertible-issuing firm is slightly negative, which is again consistent with convertible bond financing being used by distressed firms.

Table 1, Panel C contains descriptive statistics of monthly convertible bond market liquidity. TRACE contains trades of most publicly issued convertible bonds and, after 2014, trades in the majority of Rule 144A convertible bonds issued. This results in a total of 34,120 monthly observations of 838 unique convertibles. The average (median) convertible bond is traded 48 (25) times on a monthly basis. The average (median) monthly trading volume is 28.5 (13.0) million USD, corresponding with a turnover ratio of 7.6% (5.4%). The probability that a convertible bond does not trade on any given trading day is 47%. The average effective bid-ask spread estimated with the *IRC* measure is approximately 1.1%. Bid-ask spreads are higher on convertible bonds than on stocks. The average bid-ask spread of the issuing firm's stock is just 0.3% (see Panel B).

Interestingly, convertible bonds do not appear particularly illiquid when compared to non-convertible corporate bonds. Friewald, Jankowitsch, and Subrahmanyam (2012) report that the average corporate bond is traded around 73 times per month with a total volume of approximately 28 million USD. The estimated average effective bid-ask spread is 1.3%. Nevertheless, it seems unlikely that illiquidity of the convertible's equity constituent can fully explain an offering discount of 12.5%. On the other hand, we note that over 250 convertible bonds in our sample do not appear in the TRACE database at all. If these convertible bonds are omitted because they are rarely traded, it could be the case that the average convertible bond liquidity estimates in Table 1 are biased upwards.

4. Results

4.1 Descriptive statistics of offering discounts and secondary market underpricing

Table 2 contains summary statistics of convertible bond offering discounts and underpricing in the secondary market. The average offering discount is 12.5%. With an average

offering size of 279 million USD, this corresponds to 47 billion USD that could potentially be exploited by arbitrageurs in our sample only.[8]

[TABLE 2 ABOUT HERE]

In studies of equity IPOs, initial returns are frequently used to measure underpricing because high initial returns indicate that the market price lies above the offering price. If explanations of underpricing from the IPO literature are important for the pricing of bond issues, then we might expect to see that a large portion of convertible bond underpricing is resolved within the first few days of trading. Instead, if offering discounts reflect the costs of borrowing and trading the stock by convertible arbitrage funds, then we would expect underpricing to persist in the post-issue market. We define the initial return on a bond issue as the percentage difference of the first day or first week volume-weighted average transaction price and the offering price. The average first day (week) initial returns is 1.45% (1.92%). These numbers are higher than observed in the corporate bond market (Cai, Helwege, and Warga, 2007), but substantially lower than observed in the equity market (Corwin, 2003; Ljungqvist, 2007).

Most importantly, the magnitude of the initial returns is small compared to the average offering discount of 12.5%, which implies that a large portion of the offering discount persists in the secondary market. According to Chan and Chen (2007), underpricing decreases gradually as convertible bonds season. We find that underpricing is still substantial 12 months after issuance (8.24%) but has effectively vanished after 60 months (–0.28%). Figure 1 tracks monthly median underpricing of convertible bonds traded in the secondary market for 5 years after issuance. Market prices appear to converge gradually towards theoretical values, and median underpricing reaches zero approximately four years after issuance.

[FIGURE 1 ABOUT HERE]

4.2 Determinants of offering discounts

We start our analysis by examining the cross-sectional link between the cost of short selling and offering discounts on convertible bonds. The initial analysis resembles the

[8] The 47 billion USD represents the sum of the differences between the theoretical offering size and the actual offering size for all 1,098 convertibles in our sample.

conventional underpricing literature where (IPO or SEO) underpricing is regressed on a set of firm and offer characteristics. In subsequent analyses, we study the relation between short-selling costs and discounts where we, for example, focus on within-bond variation, or where we can exploit variation in hedge fund involvement. Explanations based on an information asymmetry underly much of the literature on why securities can be underpriced at issuance (Ljungqvist, 2007). We follow the conventional underpricing literature (e.g., Corwin, 2003; Cai, Helwege, and Warga, 2007) and control for information asymmetries and other determinants of security offering discounts by including the following firm-level control variables in our regression analysis: analyst coverage (from I/B/E/S), firm size (natural logarithm of total assets), the market-to-book ratio, and the return-on-assets (ROA). We also include the following bond characteristics to account for other features in the security that could affect pricing: time to maturity, callability, conversion premium, offering size, a dummy indicating whether the convertible is issued under SEC Rule 144A, and credit rating dummies. Year fixed-effects are included to control for heterogeneity in discounts across time, and standard errors are clustered at the issuance-year-level.[9] To limit the effects of outliers on our regression coefficients, we winsorize all variables at the 1% and 99% levels.

In Model 1 of Table 3, we test an implication of our observation that offering discounts compensate arbitrage investors for the cost of maintaining the short positions necessary to hedge their holdings prior to distribution. We predict that offering discounts are lower when it is easier for arbitrageurs to short stocks of the firm. We find that both the stock's loan supply and loan fees have a significant effect on offering discounts. A one standard deviation increase in *Loan Supply* is associated with an offering discount that is 2.1 percentage points (pp) smaller. A one standard deviation increase in *Loan Fee* is associated with an offering discount that is 0.9 pp larger. The effects are statistically significant at the 1% and 5% levels, respectively. These findings are consistent with arbitrageurs negotiating terms that reflect the supply of stocks available for borrowing and the level of short-selling fees. The liquidity of the underlying stock as proxied by its bid-ask spread also relates to the offer pricing of convertible bonds. The economic magnitude of the effect is larger than that of the shorting-related measures, as an

[9] Standard errors clustered at the firm- and industry-level are typically smaller. Hence, we have selected the more conservative approach. We continue this approach in the paper's other analyses and have confirmed that our conclusions are robust to alternative choices.

increase of one standard deviation in the bid-ask spread of the underlying stock is associated with a 2.7 pp increase in underpricing. Since the TF pricing model incorporates the market price of the underlying stock, convertible bond underpricing should not reflect any direct effect of stock illiquidity on the price of the underlying stock. Thus, the relation between the underlying stock's bid-ask spread and offering discounts reflects the impact of the cost of managing the short side of their hedge on a convertible arbitrageur's willingness to purchase a newly issued convertible.

[TABLE 3 ABOUT HERE]

A stock repurchase program at the time of a convertible bond issue can facilitate arbitrage-related short selling (De Jong, Dutordoir, and Verwijmeren, 2011).[10] More specifically, the concurrent stock repurchase allows arbitrageurs to sell their borrowed shares to the underwriter at a pre-agreed price. The underwriter then sells the shares back to the issuing firm, thereby completing the stock repurchase. In Model 2, we include a dummy that indicates whether a convertible bond issue was combined with a stock repurchase. We find that convertible bond offerings combined with stock repurchases have offering discounts that are 3.2 pp lower, an effect which is significant at the 5% level. The effect of the stock lending variables and the stock's bid-ask spread remains qualitatively unchanged by the control for concurrent stock repurchases.

In Model 3 of Table 3, we regress offering discounts on the post-issuance market liquidity measures of the convertible bond and the control variables of Model 1. Like Ellul and Pagano (2006), who examine the effect of expected liquidity on IPO underpricing, we use the convertible's realized post-issuance market liquidity estimated over a one-year period after issuance as a proxy for expected liquidity. The implicit assumption is that investors correctly anticipate secondary market liquidity and negotiate prices accordingly. A potential concern relates to reverse causality if higher offering discounts were to attract more investor attention and result in more trading activity. However, this mechanism implies a positive relation between underpricing and post-issuance liquidity, which would bias our estimates towards zero. In line

[10] Constantinides and Grundy (1989) consider a quite different rational for coupling a stock repurchase with a convertible bond issue, namely that issuing a convertible-like security while simultaneously repurchasing common stock can credibly signal the issuing firm's private information.

with our second prediction that convertible bond offering discounts compensate investors for holding the relatively illiquid security, we find significantly positive coefficients on *Zero* (at the 10% level) and *IRC* (at the 1% level). The economic magnitudes of these coefficients are also meaningful: A one standard deviation change in *Zero* (*IRC*) results in a change of 1.3 (1.0) pp in underpricing. Thus, expected illiquidity also appears to be incorporated into offering prices.

We test the effects of illiquidity and short-selling costs jointly in Model 4, which reduces our sample size to 632 observations. The coefficient of *Loan Supply* is almost unchanged and remains significant at the 1% level, whereas the coefficient on *Loan Fee* becomes smaller but remains significant at the 10% level. As such, our general conclusion concerning the effect of short-selling costs remains unchanged. Regarding the convertible bond liquidity variables, the coefficient on *IRC* remains significant at the 5% level, whereas the coefficient on *Zero* is still positive but statistically insignificant.

Overall, our findings highlight the link between frictions relevant to convertible arbitrageurs' trading strategy and offering prices. Convertible-issuing firms whose stocks are costlier to borrow grant higher offering discounts to the buyers of their convertible bonds.

The coefficients of the control variables indicate that firms with lower return-on-assets issue convertible bonds with higher offering discounts, even with credit rating dummies included in the model. This is consistent with distressed firms turning to arbitrage hedge funds as investors of last resort (Brophy, Ouimet, and Sialm, 2009). Larger offerings have lower offering discounts. Issuance size may serve as a proxy for the bond's liquidity (Longstaff, Mithal, and Neis, 2005) and this variant of liquidity need not be captured by our illiquidity measures. Convertibles with call provisions also have lower discounts, in line with theoretical models not fully capturing the potential benefits of call provisions, such as those related to a potential need to efficiently restructure by retiring a particular security (Lewis and Verwijmeren, 2014). Convertibles that are issued further out-of-the-money are also less underpriced, as in Loncarski, Ter Horst and Veld (2009). One way to interpret this result is that convertibles with higher moneyness require larger short positions to obtain delta-neutral positions and thus require a larger discount to offset these shorting costs.

Even though we control for a variety of firm and bond characteristics, a correlation between offering discounts and short-selling frictions is not necessarily evidence of causality. In the next sub-section, Section 4.3, we explore a panel dataset of monthly measures of secondary market underpricing and short-selling frictions. We investigate causality more closely in Section 4.4, where we explore a panel dataset of monthly changes in measures of secondary market underpricing and monthly changes in short-selling frictions, in Section 4.5, where we examine hedge fund involvement and the effect of disintermediation, and in Section 4.6, where we exploit the 2008 short-sale ban.

4.3 Determinants of secondary market underpricing

We construct a monthly panel of convertible bond underpricing using volume-weighted average daily underpricing estimates for the period 2002 to 2019. An analysis of monthly underpricing controls for movements in convertible bond prices driven by movements in equity prices, credit spreads, and interest rates after the issuance of the convertible. Our main explanatory variables are monthly measures of *Loan Supply* and *Loan Fee.* We also include the bid-ask spread of the stock and monthly measures of the convertible bond liquidity measures (*Zero* and *IRC*), bond age, stock volatility, and the conversion premium. In addition, we include credit rating and year-month dummies. Standard errors are clustered at the security-level to account for persistence in underpricing. The results are reported in Table 4.

[TABLE 4 ABOUT HERE]

The results of Model 1 indicate that short-selling costs are also relevant in the secondary market. The estimated economic magnitude of the effect of *Loan Fee* is larger than in the primary market, as a one standard deviation increase is associated with an increase in underpricing of 3.0 pp. The economic magnitude highlights the presence of convertible arbitrageurs in secondary markets. The economic effect of the *Loan Supply* variable is similar in the primary and secondary markets.

The effect of stock's bid-ask spread is smaller in the secondary market but remains significant at the 1% level. The *Zero* and *IRC* convertible bond liquidity measures possess significant explanatory power in both the primary and secondary markets. Underpricing is also particularly severe for firms with volatile stock prices and convertible bonds that are out-of-the-

money. Furthermore, the effect of bond age is significantly negative and implies that convertible bond prices converge slowly towards theoretical value over time, consistent with the pattern documented in Figure 1. Thus, the seasoning effect documented in Chan and Chen (2007) is not fully explained by changes in factors related to stock lending, bond liquidity, or the other characteristics included in our specification.

In Model 2, we include the offering discount in the regression, which controls for pricing errors due to misspecification of the TF model and other time-invariant factors relevant at issuance. Offering discounts have a significant positive effect on underpricing, highlighting their persistence in the secondary market. The other coefficients remain robust after controlling for offering discounts and become only slightly smaller in their economic magnitude. Model 3 includes bond fixed effects to further absorb heterogeneity across bonds. The effects of the stock lending variables *Loan Supply* and *Loan Fee* remain robust, indicating that stock lending factors also explain within-bond variation in underpricing. The effect of the *IRC* variable also remains statistically significant when including bond fixed effects. The coefficients of the stock's bid-ask spread and *Zero* become statistically insignificant. These two variables thus appear more effective in explaining cross-sectional variation in underpricing. In the next section, we put more emphasis on time-series variation of underpricing by examining the determinants of monthly changes in underpricing.

To confirm that our effects are not driven by the collapse of Lehman Brothers and the subsequent dislocation of the convertible bond market, we repeat the analysis from Models 2 and 3 when excluding the second half of 2008 from our sample period. The results of these regressions are presented in Models 4 and 5 and indicate that our conclusions remain unchanged. The effect of the 2008 short-sale ban on convertible bond prices is analyzed separately in Section 4.6.

4.4 Time-series variation in underpricing

The preceding analyses have largely examined cross-sectional variation in the level of underpricing related to cross-sectional differences in short-selling costs and convertible bond liquidity. We now investigate time-series variation in these measures by examining whether monthly changes in short-selling costs and convertible bond liquidity are effective in explaining

monthly changes in underpricing. The regression results are reported in Table 5, with standard errors clustered at the month-level.[11]

Model 1 of Table 5 regresses monthly changes in convertible bond underpricing on changes in the stock lending variables, stock liquidity, and the liquidity of the convertible bond. We also control for changes in the volatility of the underlying stock and the conversion premium. Changes in the *Loan Supply* and *Loan Fee* have significant effects on underpricing at the 1% significance level. When *Loan Supply* increases by one standard deviation in a month, underpricing decreases on average by 0.13 pp. A one standard deviation increase in loan fee is associated with a 0.19 pp increase in underpricing. The economic magnitude of the effect of *Loan Supply* changes is considerably smaller than that of *Loan Supply* levels in the cross-sectional analysis. One natural explanation is that both *Loan Supply* and underpricing are quite persistent. The unconditional monthly decrease in underpricing is just –0.12 pp.

[TABLE 5 ABOUT HERE]

The effect of changes in *IRC* on changes in underpricing is significantly positive, which echoes its significance in the levels analysis. The bid-ask spread of the stock and the *Zero* measure also obtain a positive coefficient, but as in Model 3 of Table 4 neither effect is a statistically significant determinant of changes in underpricing through time.

In Model 2, we include a further time-series control, namely the lagged rate of return on the Credit Suisse convertible arbitrage index. The index returns are likely to be correlated with the funding ability of the entire convertible arbitrage sector. Positive returns attract new fund flows from investors, whereas negative returns can lead to capital redemptions. By taking lagged index returns, we recognize that fund flows are not allocated instantly. Underpricing decreases significantly (at the 5% level) following profitable months in the convertible arbitrage industry. This finding highlights the connection between the capital availability of convertible arbitrageurs' and convertible bond prices (Mitchell, Pedersen, and Pulvino, 2007; Mitchell and Pulvino, 2012).

[11] The autocorrelation of monthly changes in underpricing is 3.1% over the entire sample. The results are robust to using Newey-West standard errors with various lags.

Following the collapse of Lehman Brothers in 2008, convertible arbitrage hedge funds suffered dramatic losses and convertible bond underpricing increased (Mitchell and Pulvino, 2012). To again confirm that our results are not driven by that period, we check the robustness of our findings when excluding the second half of 2008 from our sample period. The results are documented in Model 3 and confirm that the effects of intermediary capital and trading frictions on pricing exist outside the 2008 crisis period.

4.5 Hedge fund involvement and disintermediation

4.5.1 Hedge fund involvement and underpricing

Intermediary asset pricing predicts that convertible bond prices are dependent on the type of intermediary holding the convertible. When all convertible arbitrageurs have closed out their positions and the convertible is held by buy-and-hold investors only, its pricing should no longer reflect anticipated hedging costs and the convertible should trade closer to its theoretical value.

To analyze the direct relation between convertible arbitrage investors and pricing, we construct a dataset of convertible arbitrageurs' portfolio holdings using 13F filings of investment advisors representing convertible arbitrage hedge funds. For this purpose, we first identify convertible arbitrage hedge funds from the Lipper TASS, Hedge Fund Research (HFR), and Bloomberg databases. We then identify investment advisors that represent these funds through SEC EDGAR. We download the portfolio holdings of these investment advisors and use bonds' nine-digit CUSIP numbers to link the holdings information to the convertible bonds in our sample.

Based on the above procedure, we construct the variable *HF Holdings,* which represents the share of the convertible's offering amount held by convertible arbitrageurs. Because the 13F holdings are filed at a quarterly frequency, we interpolate the quarterly holdings to obtain a monthly estimate of *HF Holdings*. When we are unable to match the convertible with our holdings data, we assume *HF Holdings* to be zero. We then repeat the underpricing analysis of Section 4.3 with the inclusion of *HF Holdings* as an additional explanatory variable. The results are documented in Table 6.

[TABLE 6 ABOUT HERE]

In Model 1 of Table 6, the coefficient of *HF Holdings* is positive and statistically significant at the 5% level. The effect indicates that a one standard deviation increase in hedge fund involvement is associated with an increase in underpricing of 0.5 pp. A convertible bond that is fully intermediated through convertible arbitrageurs is 4.0 pp more underpriced, even after controlling for hedging costs and liquidity. Our measure seems more effective in explaining cross-sectional variation than time series variation in convertible bond pricing, as the effect loses its statistical significance when including bond fixed effects in Model 2, which could partly be due to the noise created by our use of interpolation for monthly changes. In Models 3 and 4, we use an alternative measure of hedge fund involvement, which we base on the number of investment advisors rather than the size of their holdings. This alternative measure is more robust to potential reporting errors in the size of holdings.[12] The regression coefficient of hedge fund involvement in Model 3 is positive and statistically significant. The size of the coefficient indicates that a one standard deviation increase in hedge fund involvement is associated with a 0.6 pp increase in underpricing. The effect remains significant after including bond fixed effects in Model 4.

Although the above analysis establishes a direct link between convertible arbitrage intermediation and underpricing in the convertible bond market, some caveats are in place, in addition to potential endogeneity concerns. Hedge fund data in Lipper TASS, HFR and Bloomberg is typically self-reported, so our constructed holdings dataset only covers a fraction of the convertible arbitrage universe. In addition, holdings data is available at the investment advisor-level and not at the fund portfolio-level, which means that some investment advisors could represent both convertible arbitrage hedge funds and long-only convertible bond funds. These factors increase the noise in our estimates of hedge fund involvement, which could potentially bias our regression coefficients towards zero.

4.5.2 The effect of disintermediation

We have shown that shorting costs help explain both cross-sectional and time-series variation in convertible bond underpricing. This result is consistent with the high level of

[12] Investment advisors can choose to report their holdings in "shares" or "principal amount". This approach seems to increase the likelihood of reporting errors, as sometimes unrealistically large positions are disclosed.

convertible arbitrage hedge fund involvement in the market for convertibles. A natural follow-up question indicative of a causal relation is what happens when a large fraction of convertible arbitrageurs close out their positions and their intermediary activities become less important.

When a convertible bond's ownership is transferred from buy-and-hedge investors to buy-and-hold investors, the impact of short-selling costs on underpricing should decrease. To test this prediction, we use the portfolio holdings of convertible arbitrage hedge funds as described in the previous sub-section. For each convertible bond reported in the 13F holdings of any of the investment advisors, we identify quarters where (i) at least one convertible arbitrage hedge fund that was also an initial buyer entirely closes out its position and (ii) no other convertible arbitrage hedge fund in our sample initiates a position in the convertible bond. We label these quarters as disintermediation quarters and create a dummy variable, *Disintermediation*, that equals one in quarters after disintermediation has taken place. When a convertible bond experiences multiple disintermediation quarters, we select the quarter in which the largest number of arbitrageurs closed out their positions.

To analyze the effect of disintermediation, we repeat the time-series analyses of Section 4.4 but this time allowing for heterogeneity in the sensitivity of monthly changes in convertible bond underpricing to changes in *Loan Supply* and *Loan Fee*. The *Disintermediation* dummy is interacted with the changes in *Loan Supply* and changes in *Loan Fee* variables. If the regression sensitivity of changes in convertible bond underpricing to changes in the short-selling variables is weaker after disintermediation, then the coefficients of the interaction variables will have opposite signs to those on the standalone equity-lending variables.

The results are documented in Model 1 of Table 7. The sample size decreases because we can only identify clear disintermediation quarters for 393 of 1,098 convertible bonds in our sample. The standalone coefficients of Δ *Loan Supply* and Δ *Loan Fee* remain significantly negative and positive, respectively. Although the interaction effect between the disintermediation dummy and Δ *Loan Supply* is not statistically significant, it suggests an offset of 84% of the standalone effect. The interaction effect between the disintermediation dummy and Δ *Loan Fee* is negative, statistically significant at the 5% level, and offsets 59% of the standalone effect.

[TABLE 7 ABOUT HERE]

Convertible arbitrage hedge funds are particularly important in the market for convertibles issued under SEC Rule 144A. Such issues lack SEC registration and can only be sold to qualified institutional buyers, i.e., institutions managing over 100 million USD. Approximately 12 months after issuance most 144A convertibles are then publicly registered, and the convertible can then be sold on to other investors. The public registration of a 144A convertible thus resembles a disintermediation event, and the intermediary role of buy-and hedge arbitrageurs becomes less critical afterwards. We investigate whether the sensitivity of convertible bond underpricing to equity lending conditions declines following public registration.

We repeat the investigation using a *Disintermediation* dummy equal to one in months when a convertible that was initially issued under SEC Rule 144A is publicly registered and zero otherwise. We obtain information on public registration from Mergent FISD, which adds a separate entry to its database when a convertible initially issued under SEC Rule 144A is registered publicly. The regression result is documented in Model 2 of Table 7. We observe a pattern similar to that in Model 1. The relation between changes in short-selling cost measures and changes in underpricing is substantially weaker for 144A convertibles once they are publicly registered, which is consistent with short-selling costs being a particularly important element of the intermediation activities of convertible arbitrageurs.

Overall, our findings suggest that the aggregate sensitivity of convertible bond underpricing to hedging costs diminishes substantially after disintermediation. Again, these findings support the hypothesis that short-selling costs influence underpricing in markets in which convertible arbitrageurs are important players.

4.6 The 2008 short-sale ban

The financial crisis of 2008 severely impacted the convertible bond market, exacerbated by the extreme pre-crisis levels of hedge-fund leverage. Figure 2 illustrates our daily median underpricing estimate in the convertible bond market over the course of the crisis. Median underpricing oscillated around 0% in July and August of 2008, indicating that before the crisis convertible bonds traded close to their fundamental value. Median underpricing started to increase in September, when the Federal Housing Finance Agency placed Fannie Mae and

Freddie Mac under conservatorship and Lehman Brothers declared bankruptcy. Prices recovered somewhat by the end of October, but the convertible bond market remained stressed and volatile for months to come (Mitchell and Pulvino, 2012).

[FIGURE 2 ABOUT HERE]

In addition to the effect of deleveraging, convertible arbitrageurs were also hindered by restrictions placed on short selling during the crisis. Between September 18 and October 8 of 2008, U.S. regulators prohibited the short selling of the stock of most financial firms. The 2008 short-sale ban aimed to prevent speculators from driving down stock prices, but simultaneously introduced challenges for convertible arbitrageurs in implementing their hedging strategy. An implication of convertible bond discounts compensating arbitrage investors for the cost of maintaining short positions is that the underpricing of convertible bonds issued by financial firms would increase following the implementation of the ban. Figure 2 illustrates that underpricing increased notably during the period the ban was active.

To isolate the effect of the short-sale ban on convertible bonds issued by financial firms, we use a difference-in-differences regression to examine how the short-sale ban affected daily measures of convertible bond underpricing. In Model 1 of Table 8, we regress daily underpricing on the interaction of a short-sale ban dummy and a dummy that indicates whether the convertible was issued by a financial firm. The sample used in Model 1 starts on September 1, 2008 and ends on the last day of the short-sale ban, namely October 8, 2008. We include convertible bond fixed effects to account for heterogeneity across bonds, trading-day fixed effects to absorb general trends in underpricing in the convertible bond market, and a daily measure of the conversion premium as a control for firm-specific equity price movements. The interaction effect between the short-sale ban dummy and the financial industry dummy is significantly positive. The estimate indicates that the disruption of arbitrageurs' ability to short sell the stocks of financial firms coincided with a 2.4 pp increase in the underpricing of convertible bonds issued by financial firms.

[TABLE 8 ABOUT HERE]

A concern might be that our findings are driven by a general deterioration of asset prices among financial firms following Lehman's collapse. To examine whether this is the case, we

perform a placebo test using two different ten-trading day periods each containing a five-trading day pseudo-ban period. In Model 2, the sample ends immediately before the short-sale ban was implemented (i.e., on September 17, 2008). In Model 3, the sample starts after the actual ban. The hypothetical start dates of the five-trading day pseudo-ban windows are September 11, 2008 and October 20, 2008, respectively. We find no substantive effects of hypothetical ban periods on convertible bond underpricing. Therefore, the effect documented in Model 1 is likely driven by the short-sale ban, rather than other trends in the pricing of convertible bonds issued by financial firms.

5. Robustness

In the preceding analyses, we calculate underpricing using theoretical price estimates from the TF model. Our use of the TF model is motivated by its popularity among academic researchers and practitioners, as well as its accuracy relative to other pricing models (Zabolotnyuk, Jones, and Veld, 2010). Nevertheless, the output of the model is sensitive to methodological choices. In this section, we perform several robustness checks to demonstrate that our findings are not driven by our model specification choices.

Credit spreads and stock return volatility are two important input parameters of the TF pricing model. In the baseline analysis of Section 4, the credit spread is derived from bond yields matched to the credit rating of the convertible. These bond yields may not fully incorporate the effect of embedded options on the effective yield on a bond. We use the "Option-Adjusted Spread" (OAS) matched by credit rating as an alternative estimate of the credit spread. The OAS adjusts the credit spread for embedded options. It might thus be a more suitable input measure when valuing convertible bonds, being bonds that contain conversion rights, call provisions, and put provisions. We obtain OAS data from the St. Louis FRED.

In addition, in the baseline analysis, we measure stock return volatility using the historical standard deviation of stock returns over the year prior to the convertible's issue. An alternative volatility measure is the interpolated implied volatility of at-the-money stock options with the longest available maturity, typically between 6 months and 2 years, to provide the closest match with the maturities of convertible bonds. Implied volatility can be viewed as a gauge of investor beliefs about future volatility and is thus forward-looking. Option data is

obtained from OptionMetrics. A downside of using option-implied volatility is that the sample size is reduced, as some convertible issuing firms do not have listed options.

Table 9 contains summary statistics of underpricing calculated using alternative measures of theoretical prices. There is a significant offering discount across all specifications. Underpricing tends to be higher using the OAS rather than credit spreads derived from bond yields, and lower using option-implied volatility rather than historical volatility. Most importantly, the alternative measures of offering discounts and secondary market underpricing are highly correlated with our baseline measure, with correlation coefficients ranging between 0.906 and 0.996.

[TABLE 9 ABOUT HERE]

Finally, we use the theoretical model developed by Finnerty (2015) to estimate convertible bond underpricing. In Finnerty (2015), the value of the convertible bond is the sum of the value of a regular non-convertible bond and the option to exchange the bond into stocks. The model incorporates stochastic interest rates and credit spreads, whereas the TF model assumes these to be constant. Finnerty (2015) derives a closed-form solution for the value of the exchange option and uses iterative procedures to adjust the value of the convertible bond for call and put provisions. Table 9 shows that underpricing estimates with the Finnerty model prices are slightly higher than our baseline measure, but they remain highly correlated.

The conclusions drawn from the baseline analyses in Section 4 remain unchanged with these alternative measures of underpricing. The regressions results with alternative price measures are presented in Appendix B. Thus, our conclusions are robust to the methodological choices made in relation to the measurement of underpricing. Although these methodological choices affect the level of estimated underpricing, they do not appear to have an impact on the variation of the underpricing over time and its correlation with shorting costs and other firm-specific factors.

6. Conclusion

We investigate the importance of frictions in financial intermediation outside of crisis times by examining the pricing of convertible bonds. Buy-and-hedge convertible arbitrage hedge

funds are important players in the convertibles market. These convertible arbitrage funds invest only for as long as necessary to distribute the security, intermediating between firms that require capital quickly and investors requiring time to assess the security. We find that convertible bonds' prices reflect the loan fees, stock spreads, and search costs the arbitrageurs will incur when managing their positions. For instance, we show that the discount is sensitive to changes in the supply of stock available for borrowing by short sellers and stock loan fees. Panel regressions that control for heterogeneity across issuers, bonds and time indicate that post-issue convertible bond underpricing decreases when the underlying stock becomes less costly to short. Underpricing is higher when there is more convertible arbitrage involvement. Moreover, the sensitivity of convertible bond underpricing to hedging-cost measures diminishes when convertible arbitrageurs' intermediation activities become less important because of public registration or when a convertible bond's ownership is transferred from buy-and-hedge investors to buy-and-hold investors. The difference between market prices and theoretical values increases when short-selling restrictions limit convertible arbitrageurs in executing their strategy.

Besides adding to the underpricing literature, we add to the literature on intermediary asset pricing by showing that frictions related to hedge fund intermediation are relevant for asset pricing, and not just during crisis periods. Furthermore, by affecting the prices of newly issued securities, intermediation frictions can impact corporate financing decisions and the real economy.

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Figure 1: Post-Issuance Underpricing

This figure shows median monthly underpricing of convertible bonds traded in the secondary market. The graph tracks underpricing up to 60 months after issuance. The definition of underpricing is contained in Table A.1 in the Appendix. Monthly estimates of underpricing are calculated as volume-weighted averages of the daily estimates of underpricing within that month.

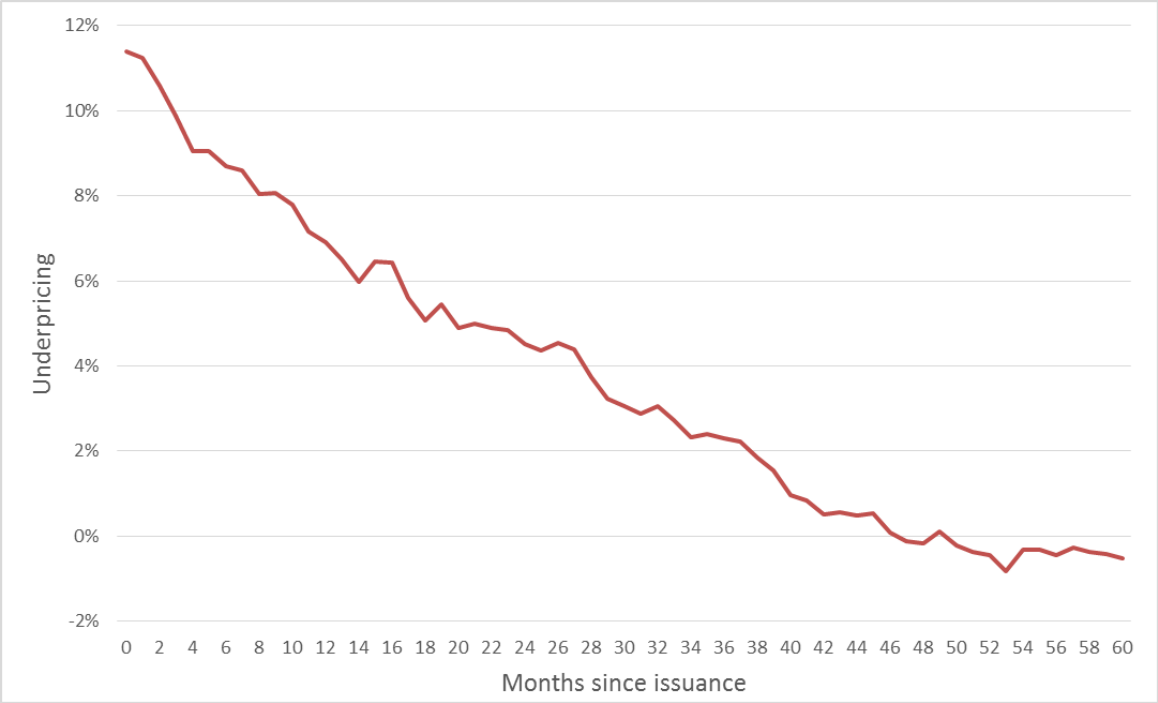

Figure 2: Underpricing during the 2008 Financial Crisis

This figure shows median daily underpricing of convertible bonds from July 2008 to October 2008. The definition of underpricing is contained in Table A.1 in the Appendix. The following significant events/periods are marked: the bankruptcy of Lehman Brothers (15 September) and the short-sale ban (18 September – 8 October).

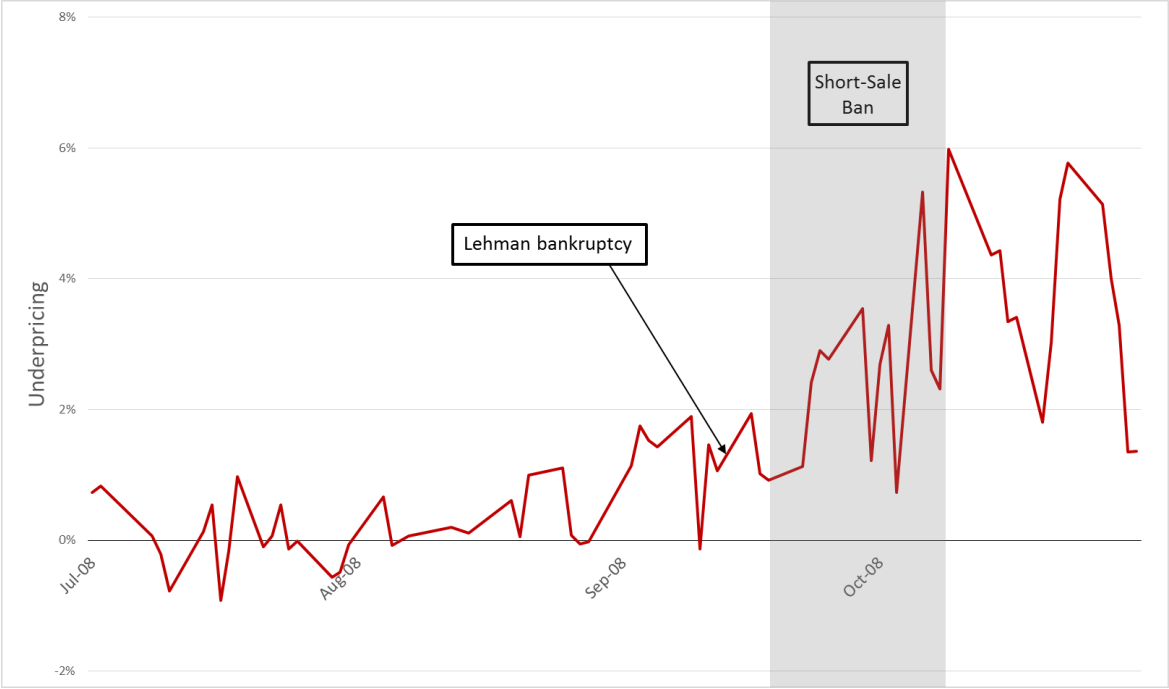

Table 1: Sample Summary Statistics

This table shows summary statistics of our sample of 1,098 convertible bonds. Panel A contains bond-level variables: a dummy for whether the convertible bond is issued under Rule 144A, a dummy for whether the convertible bond has a credit rating, the years to maturity at issuance, whether the convertible bond is callable, the conversion premium at issuance, and the coupon rate. The firm-level variables in Panel B are *Loan Supply*, *Loan Fee*, total assets (in USD millions), market-to-book ratio, and return-on-assets (EBIT/Total assets). Panel C contains monthly summary statistics of convertible bond liquidity, including number of trades, trading volume, the turnover ratio, *Zero*, and *IRC*. Variable definitions are contained in Table A.1 in the Appendix.

Variable	**Mean**	**Std. Dev.**	**Median**	**$Q_{0.05}$**	**$Q_{0.95}$**	**N**
Panel A: Bond-level						
Rule 144A	0.742	0.438	1	0	1	1,098
Rated	0.423	0.494	0	0	1	1,098
Investment Grade	0.121	0.326	0	0	1	1,098
Maturity (Years)	11.3	8.3	7	4	30	1,098
Callable	0.383	0.486	0	0	1	1,098
Conversion Premium (%)	38.0	127	30.0	10.0	60.0	1,098
Coupon (%)	3.41	2.08	3.13	0.75	7.00	1,098
Panel B: Firm-level						
Loan Supply	0.145	0.117	0.145	0.001	0.342	930
Loan Fee (%)	1.109	3.867	0.375	0.250	3.500	936
$\text{Spread}^{\text{Stock}}$ (%)	0.302	0.438	0.145	0.040	1.198	1,098
Total Assets ($M)	4,218	12,064	1,205	133	17,637	1,098
M/B Ratio	2.541	2.745	1.646	0.911	8.048	1,098
ROA (%)	–0.285	23.24	4.544	–40.32	19.10	1,098
Panel C: Bond-month-level						
# Trades	48	64	25	2	162	34,120
Volume ($M)	28.5	54.7	13.0	0.450	104	34,120
Turnover	0.076	0.084	0.054	0.003	0.221	34,120
Zero	0.472	0.323	0.478	0	0.952	34,120
IRC (%)	1.052	1.158	0.733	0.142	2.907	30,284

Table 2: Descriptive Statistics of Convertible Bond Underpricing

This table shows statistics of convertible bond underpricing at various points in time. Variable definitions are contained in Table A.1 in the Appendix. Initial returns are the percentage difference between the average transaction price in the first day or week after issuance and the offering price. Underpricing is defined as volume-weighted average of daily underpricing over all the months, during the 12th month of a convertible's life, and during the 60th month of a convertible's life.

Variable	Mean	Std. Dev.	Median	5th	95th	N
Offering Discount	12.5%	13.0%	11.2%	–7.00%	34.8%	1,098
Initial Returns (1D)	1.45%	2.15%	0.78%	–0.74%	5.38%	410
Initial Returns (1W)	1.92%	3.15%	1.17%	–1.42%	7.70%	430
Underpricing	4.37%	16.0%	2.20%	–12.7%	29.3%	34,120
Underpricing (12M)	8.24%	14.2%	5.94%	–7.34%	33.3%	594
Underpricing (60M)	-0.28%	16.0%	–0.21%	–16.8%	17.4%	238

Table 3: Regression Results of Offering Discounts

This table shows the results of multivariate regressions of convertible bond offering discounts on various measures of the cost of short-selling and of liquidity. Variable definitions are contained in Table A.1 in the Appendix. Standard errors are clustered at the issuance-year-level. *, **, and *** indicate significance at the 10% level, 5% level, and 1% level, respectively.

	(1)	(2)	(3)	(4)
Loan Supply	–0.180***	–0.170***		–0.177***
	(0.046)	(0.046)		(0.052)
Loan Fee	0.232**	0.269**		0.168*
	(0.094)	(0.093)		(0.095)
Zero			0.043*	0.014
			(0.023)	(0.022)
IRC			1.166***	0.848**
			(0.362)	(0.368)
$\text{Spread}^{\text{Stock}}$	6.217***	6.222***	8.464***	6.960***
	(1.309)	(1.304)	(1.834)	(2.053)
ln(Nr. Analysts)	–0.010*	–0.009*	–0.009*	–0.007
	(0.005)	(0.005)	(0.005)	(0.006)
ln(Total assets)	0.006	0.005	0.009	0.005
	(0.004)	(0.004)	(0.006)	(0.005)
M/B Ratio	–0.004*	–0.004*	0.000	–0.003
	(0.002)	(0.002)	(0.002)	(0.003)
ROA	–0.145***	–0.135***	–0.136***	–0.129***
	(0.015)	(0.016)	(0.017)	(0.017)
Rule 144A	–0.009	–0.005	–0.024***	–0.017
	(0.008)	(0.008)	(0.007)	(0.010)
ln(Par value)	–0.029***	–0.028***	–0.024**	–0.029***
	(0.006)	(0.006)	(0.009)	(0.008)
ln(Maturity at issuance)	0.002	0.001	–0.023*	–0.004
	(0.013)	(0.012)	(0.013)	(0.013)
Callable	–0.050***	–0.050***	–0.021	–0.038**
	(0.015)	(0.015)	(0.016)	(0.015)
Conversion Premium	–0.162***	–0.166***	–0.213***	–0.182***
	(0.023)	(0.023)	(0.018)	(0.017)
Stock Repurchase		–0.032**		
		(0.011)		
Rating dummies	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	930	930	722	632
R^2	0.604	0.610	0.563	0.591

Table 4: Regression Results of Secondary Market Underpricing

This table shows the results of multivariate regression of monthly convertible bond underpricing in the secondary market. Variable definitions are contained in Table A.1 in the Appendix. Model 2 includes the offering discount as an independent variable. Model 3 includes bond fixed effects. Models 4 and 5 mirror Models 2 and 3 and exclude the second half of 2008 from the analysis. Standard errors are clustered at the convertible bond-level. ** and *** indicate significance at the 5% level, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)
				Excl. crisis	
Loan Supply	–0.147***	–0.059**	–0.133***	–0.057**	–0.141***
	(0.026)	(0.028)	(0.032)	(0.028)	(0.033)
Loan Fee	0.534***	0.505***	0.373***	0.502***	0.366***
	(0.055)	(0.057)	(0.053)	(0.057)	(0.051)
Zero	0.046***	0.027***	0.009	0.023**	0.008
	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)
IRC	1.160***	1.126***	0.910***	1.079***	0.858***
	(0.159)	(0.157)	(0.111)	(0.155)	(0.114)
$\text{Spread}^{\text{Stock}}$	4.221***	3.148**	0.528	4.488***	0.751
	(1.531)	(1.254)	(0.623)	(1.361)	(0.807)
ln(Age)	–0.040***	–0.036***	–0.014***	–0.036***	–0.015***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)
Volatility	0.085***	0.071***	0.051***	0.072***	0.053***
	(0.008)	(0.008)	(0.006)	(0.008)	(0.006)
Conv. Premium	0.006***	0.008***	0.009***	0.008***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Offering Discount		0.340***		0.337***	
		(0.042)		(0.042)	
Rating dummies	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	Yes	No	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	27,886	27,886	27,879	26,861	26,854
R^2	0.412	0.460	0.709	0.465	0.715

Table 5: Regressions of Changes in Secondary Market Underpricing

This table shows the results of multivariate regressions of monthly changes in convertible bond underpricing on changes in hedging costs, liquidity, and stock-related variables. Variable definitions are contained in Table A.1 in the Appendix. Model 2 also includes the lagged rate of return of the Credit Suisse convertible arbitrage index. Model 3 includes the lagged rate of return of the Credit Suisse convertible arbitrage index and excludes the second half of 2008 from the analysis. Standard errors are clustered at the month-level. *, **, and *** indicate significance at the 10% level, 5% level, and 1% level, respectively.

	(1)	(2)	(3)
			Excl. crisis
Δ *Loan Supply*	–0.056***	–0.058***	–0.059***
	(0.015)	(0.015)	(0.016)
Δ *Loan Fee*	0.064***	0.067***	0.064**
	(0.024)	(0.025)	(0.025)
Δ *Zero*	0.002	0.002	0.003*
	(0.002)	(0.001)	(0.001)
Δ *IRC*	0.152***	0.141***	0.132***
	(0.032)	(0.029)	(0.030)
Δ $\text{Spread}^{\text{Stock}}$	0.251	0.297	0.118
	(0.244)	(0.267)	(0.242)
Δ Volatility	0.002	0.001	0.000
	(0.003)	(0.003)	(0.003)
Δ Conv. Premium	0.008***	0.008***	0.007***
	(0.002)	(0.002)	(0.002)
C.A. Returns		–0.001**	–0.002***
		(0.001)	(0.000)
Constant	–0.002***	–0.001*	-0.001**
	(0.001)	(0.001)	(0.001)
Observations	24,429	24,429	23,585
R^2	0.052	0.060	0.055

Table 6: Secondary Market Underpricing and Hedge Fund Involvement

This table shows the results of multivariate regression of monthly convertible bond underpricing in the secondary market. The key independent variable in Models 1 and 2 is *HF Holdings*, which represents the share of the convertible held by convertible arbitrageurs. The key independent variable in Models 3 and 4 is the natural logarithm of one plus the number of hedge funds holding the convertible bond. Definitions of the remaining variables are contained in Table A.1 in the Appendix. Models 2 and 4 include bond fixed effects. Standard errors are clustered at the convertible bond-level. ** and *** indicate significance at the 5% level, and 1% level, respectively.

	(1)	(2)	(3)	(4)
HF Holdings	0.040**	0.020		
	(0.018)	(0.017)		
ln(Nr. HFs+1)			0.011***	0.007**
			(0.004)	(0.003)
Loan Supply	–0.142***	–0.150***	–0.145***	–0.149***
	(0.025)	(0.034)	(0.025)	(0.035)
Loan Fee	0.491***	0.326***	0.492***	0.327***
	(0.059)	(0.054)	(0.059)	(0.054)
Zero	0.047***	0.009	0.055***	0.011
	(0.010)	(0.010)	(0.010)	(0.010)
IRC	1.128***	0.846***	1.170***	0.853***
	(0.165)	(0.117)	(0.161)	(0.117)
$\text{Spread}^{\text{Stock}}$	3.730**	0.374	3.793**	0.392
	(1.576)	(0.654)	(1.584)	(0.646)
ln(Age)	–0.043***	–0.016***	–0.043***	–0.017***
	(0.003)	(0.005)	(0.003)	(0.005)
Volatility	0.082***	0.050***	0.082***	0.050***
	(0.008)	(0.007)	(0.008)	(0.006)
Conv. Premium	0.007***	0.010***	0.007***	0.010***
	(0.001)	(0.001)	(0.001)	(0.001)
Rating dummies	Yes	Yes	Yes	Yes
Bond FE	No	Yes	No	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	24,457	24,450	24,457	24,450
R^2	0.428	0.704	0.428	0.704

Table 7: Regression Analysis of Effect of Disintermediation

This table shows the results of multivariate regressions of monthly changes in convertible bond underpricing. Changes in the equity lending variables, Δ *Loan Supply* and Δ *Loan Fee*, are interacted with a dummy variable, *DI*, that indicates whether a convertible arbitrage-related disintermediation event has taken place. In Model 1, *DI* equals 1 when at least one convertible arbitrage hedge fund that purchased the convertible at issuance has closed all of its position. In Model 2, *DI* equals 1 if the convertible bond was initially issued under SEC Rule 144A but is publicly registered at the time of the monthly change in underpricing. Standard errors are clustered at the year-month-level. Definitions of all variables are contained in Table A.1 in the Appendix. ** and *** indicate significance at the 5% level, and 1% level, respectively.

	(1) Ownership transfer	(2) Public registration
Δ *Loan Supply*	–0.051**	–0.083***
	(0.023)	(0.021)
DI × Δ *Loan Supply*	0.043	0.048*
	(0.040)	(0.029)
Δ Loan Fee	0.181***	0.097***
	(0.061)	(0.035)
DI × Δ *Loan Fee*	–0.106**	–0.076**
	(0.052)	(0.033)
Δ *Zero*	0.004*	0.003
	(0.002)	(0.002)
Δ *IRC*	0.155***	0.150***
	(0.044)	(0.032)
Δ $\text{Spread}^{\text{Stock}}$	-0.059	0.258
	(0.388)	(0.243)
Δ Volatility	0.003	0.002
	(0.004)	(0.003)
Δ Conv. Premium	0.007***	0.008***
	(0.003)	(0.002)
DI	0.000	–0.001
	(0.001)	(0.001)
Constant	–0.002**	–0.002**
	(0.001)	(0.001)
Observations	11,254	24,429
R^2	0.049	0.053

Table 8: The 2008 Short-Sale Ban and Underpricing

This table shows the results of multivariate regression of daily underpricing around the time of the 2008 short-sale ban. Model 1 involves daily observations over the September 1 through October 8 period of 2008. The main independent variable in Model 1 is the interaction of the short-sale ban dummy (Ban) with a dummy that indicates whether the issuing firm is a financial firm (Financial). The *Ban* dummy in Model 1 equals 1 between September 18 and October 8. In Model 2 (3), the sample consists of a ten-trading day window starting on September 4, 2008 (October 13, 2008), and the main independent variable is replaced with a "placebo" 5-trading day short-sale ban dummy variable that starts on September 11, 2008 (October 20, 2008). The conversion premium is included as a control variable. The regressions include convertible bond and day fixed effects. Standard errors are clustered at the bond-level. *** indicates significance at the 1% level, respectively.

	(1)	(2)	(3)
		Placebo	
Ban × Financial	0.024***	0.004	0.010
	(0.009)	(0.006)	(0.013)
Conv. Premium	0.001***	0.011	0.004
	(0.000)	(0.009)	(0.004)
Bond FE	Yes	Yes	Yes
Day FE	Yes	Yes	Yes
Observations	2,418	875	761
R^2	0.938	0.981	0.929

Table 9: Robustness of Convertible Underpricing to Alternative Theoretical Prices

This table shows statistics of the distribution of convertible bond underpricing measures calculated using alternative theoretical price estimators. Definitions of all variables are contained in Table A.1 in the Appendix. In the upper panel, theoretical prices are estimated using the Tsiveriotis and Fernandes (1998) model with option-adjusted spread. In the center panel, theoretical prices are estimated using the Tsiveriotis and Fernandes (1998) model with the option-implied volatility. In the lower panel, the model of Finnerty (2015) is used to determine theoretical prices. ρ is the correlation of the alternative underpricing measures with the baseline underpricing measure.

Variable	Mean	Std. Dev.	Median	5th	95th	N	ρ
OAS:							
Offering Discount	15.0%	12.8%	13.9%	–3.19%	36.8%	1,098	0.991
Secondary Market Underpricing	5.84%	16.0%	3.29%	–10.3%	31.5%	34,120	0.996
IVOL:							
Offering Discount	9.88%	11.5%	9.03%	–8.14%	29.4%	769	0.906
Secondary Market Underpricing	2.91%	15.2%	1.80%	–13.0%	24.7%	27,421	0.951
Finnerty:							
Offering Discount	13.8%	12.8%	12.3%	–5.50%	35.6%	1,098	0.982
Secondary Market Underpricing	6.07%	15.5%	3.55%	–10.0%	31.1%	34,120	0.971

Appendix A – Variables Definitions

Table A.1: Variable definitions

This table contains definitions of the underpricing, short-selling costs, liquidity, and control variables that are used throughout the paper. Panel A contains bond-level variables. Panel B contains firm-level variables.

Variable	Definition
Panel A: Bond-level	
Offering Discount	The difference between the convertible's theoretical value determined using the Tsiveriotis and Fernandes (1998) model and the offering price, divided by the theoretical value
Underpricing	The difference between the convertible's theoretical value determined using the Tsiveriotis and Fernandes (1998) model and the market price, divided by the theoretical value
Rule 144A	A dummy indicating whether the convertible is privately placed under SEC Rule 144A
Rated	A dummy indicating whether the convertible is rated by a credit rating agency
Investment Grade	A dummy indicating whether the convertible is rated BBB/Baa or higher
Par value	Total par value of the convertible bond at issuance
Maturity	The number of years to maturity of the convertible bond at issuance
Callable	A dummy indicating whether the convertible can be called at the discretion of the issuer
Conversion Premium (%)	The percentage difference between the conversion price and the stock price
Coupon (%)	The annual coupon rate that the issuer must pay to the holder of the convertible
Age	Number of months that have elapsed since the bond was issued
# Trades	The number of times a convertible bond was traded over a given time period

Volume ($M)	The par trading volume of a convertible bond over a given time period
Turnover	The par trading volume of a convertible bond over a given time period divided by the offering amount
Zero	The number of trading days that the convertible remained untraded over a given time period, expressed as a percentage of the total number of trading days
IRC (%)	The imputed roundtrip costs measure of the bid-ask spread proposed by Feldhutter (2012)
Panel B: Firm-level	
Loan Supply	The number of stocks actively made available for lending divided by total stocks outstanding
Loan Fee (%)	The rate that the short seller must pay to the lender in return for borrowing the stock
$\text{Spread}^{\text{Stock}}$ (%)	The CRSP quoted bid-ask spread of the stock
Nr. Analysts	The number of analysts in the I/B/E/S database that are covering the firm
Total Assets ($M)	Total book value of assets
M/B Ratio	Total book value of assets minus the book value of equity plus the market capitalization, divided by the total book value of assets
ROA (%)	EBIT divided by total book value of assets
Volatility	The annualized standard deviation of daily stock returns over a given period

Appendix B – Robustness Checks

Table B.1: Analysis of Offering Discounts with Alternative Theoretical Prices

This table shows the results of multivariate regressions of convertible bond offering discounts on various measures of the cost of short-selling and of liquidity. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate the offering discount. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate the offering discount. In Model 3, the Finnerty (2015) pricing model is used to calculate the offering discount. Variable definitions are contained in Table A.1 in the Appendix. Standard errors are clustered at the issuance-year-level. *, **, and *** indicate significance at the 10% level, 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Loan Supply	–0.170***	–0.194***	–0.171***
	(0.044)	(0.032)	(0.039)
Loan Fee	0.224**	0.162	0.234**
	(0.094)	(0.125)	(0.099)
$\text{Spread}^{\text{Stock}}$	6.039***	6.908***	6.017***
	(1.268)	(1.836)	(1.208)
ln(#Analysts)	–0.011*	–0.017**	–0.012**
	(0.005)	(0.008)	(0.005)
ln(Total assets)	0.005	0.001	0.007
	(0.004)	(0.004)	(0.004)
M/B Ratio	–0.004*	–0.007***	–0.004*
	(0.002)	(0.001)	(0.002)
ROA	–0.140***	–0.145***	–0.149***
	(0.014)	(0.023)	(0.014)
Rule 144A	–0.008	–0.013*	–0.012
	(0.008)	(0.006)	(0.008)
ln(Par value)	–0.027***	–0.023**	–0.032***
	(0.006)	(0.008)	(0.007)
ln(Maturity at issuance)	0.009	0.005	–0.006
	(0.012)	(0.014)	(0.012)
Callable	–0.059***	–0.048**	–0.036**
	(0.014)	(0.017)	(0.015)
Conv. Premium	–0.145***	–0.146***	–0.134***
	(0.023)	(0.034)	(0.025)
Rating dummies	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	930	731	930
R^2	0.620	0.605	0.580

Table B.2: Analysis of Secondary Market Underpricing with Alternative Theoretical Prices

This table shows the results of multivariate regression of monthly convertible bond underpricing in the secondary market. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. In Model 3, the Finnerty (2015) pricing model is used to calculate underpricing. Variable definitions are contained in Table A.1 in the Appendix. ** and *** indicate significance at the 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Loan Supply	–0.151***	–0.159***	–0.134***
	(0.025)	(0.030)	(0.025)
Loan Fee	0.522***	0.352***	0.518***
	(0.054)	(0.055)	(0.054)
Zero	0.041***	0.042***	0.055***
	(0.010)	(0.013)	(0.010)
IRC	1.218***	0.975***	1.296***
	(0.153)	(0.171)	(0.158)
$\text{Spread}^{\text{Stock}}$	4.100***	9.009***	4.117***
	(1.481)	(1.193)	(1.524)
ln(Age)	–0.045***	–0.040***	–0.037***
	(0.003)	(0.003)	(0.003)
Volatility	0.084***	0.067***	0.081***
	(0.008)	(0.010)	(0.008)
Conv. Premium	0.007***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)
Rating dummies	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	27,886	23,549	27,886
R^2	0.435	0.336	0.420

Table B.3: Analysis of Secondary Market Underpricing Changes with Alternative Theoretical Prices

This table shows the results of multivariate regressions of monthly changes in convertible bond underpricing on changes in hedging costs, liquidity, and stock-related variables. Variable definitions are contained in Table A.1 in the Appendix. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. In Model 3, the Finnerty (2015) pricing model is used to calculate underpricing. Standard errors are clustered at the month-level. *, **, and *** indicate significance at the 10% level, 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Δ *Loan Supply*	–0.059***	–0.033*	–0.045***
	(0.014)	(0.017)	(0.016)
Δ *Loan Fee*	0.059**	–0.022	0.061**
	(0.024)	(0.045)	(0.024)
Δ *Zero*	0.003*	0.004*	0.004**
	(0.002)	(0.002)	(0.002)
Δ *IRC*	0.155***	0.123***	0.173***
	(0.033)	(0.041)	(0.035)
Δ $\text{Spread}^{\text{Stock}}$	0.243	0.342	0.271
	(0.236)	(0.378)	(0.221)
Δ Volatility	0.002	0.017***	0.003
	(0.003)	(0.005)	(0.003)
Δ Conv. Premium	0.008***	0.011***	0.008***
	(0.002)	(0.002)	(0.002)
Constant	–0.002***	–0.002***	–0.002**
	(0.001)	(0.001)	(0.001)
Observations	24,429	20,670	24,429
R^2	0.055	0.054	0.055

Table B.4: Analysis of Hedge Fund Involvement with Alternative Theoretical Prices

This table shows the results of multivariate regression of monthly convertible bond underpricing in the secondary market. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. In Model 3, the Finnerty (2015) pricing model is used to calculate underpricing. The key independent variable is *HF Holdings*, which represents the share of the convertible held by convertible arbitrageurs. Definitions of the remaining variables are contained in Table A.1 in the Appendix. Standard errors are clustered at the convertible bond-level. ** and *** indicate significance at the 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
HF Holdings	0.034*	0.054**	0.028*
	(0.018)	(0.021)	(0.017)
Loan Supply	–0.148***	–0.162***	–0.134***
	(0.024)	(0.030)	(0.024)
Loan Fee	0.478***	0.305***	0.475***
	(0.058)	(0.064)	(0.058)
Zero	0.042***	0.046***	0.053***
	(0.010)	(0.013)	(0.009)
IRC	1.191***	1.000***	1.240***
	(0.158)	(0.179)	(0.164)
$\text{Spread}^{\text{Stock}}$	3.594**	8.596***	3.782**
	(1.515)	(1.273)	(1.593)
ln(Age)	–0.048***	–0.044***	–0.040***
	(0.003)	(0.004)	(0.003)
Volatility	0.081***	0.061***	0.078***
	(0.008)	(0.010)	(0.008)
Conv. Premium	0.008***	0.008***	0.007***
	(0.001)	(0.001)	(0.001)
Rating dummies	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	24,457	24,457	24,457
R-squared	0.455	0.347	0.435

Table B.5: Analysis of Disintermediation with Alternative Theoretical Prices

This table shows the results of multivariate regressions of monthly changes in convertible bond underpricing. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. In Model 3, the Finnerty (2015) pricing model is used to calculate underpricing. Changes in the equity lending variables, Δ *Loan Supply* and Δ *Loan Fee*, are interacted with a dummy variable, *DI*, that indicates whether a convertible arbitrage-related disintermediation event has taken place. *DI* equals 1 when at least one convertible arbitrage hedge fund that purchased the convertible at issuance has closed all of its position. Standard errors are clustered at the year-month-level. Definitions of all variables are contained in Table A.1 in the Appendix. ** and *** indicate significance at the 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Δ *Loan Supply*	–0.058***	–0.064***	–0.055**
	(0.021)	(0.023)	(0.022)
DI × Δ *Loan Supply*	0.053	0.095	0.064
	(0.039)	(0.058)	(0.045)
Δ Loan Fee	0.174***	0.108***	0.174***
	(0.059)	(0.037)	(0.058)
DI × Δ *Loan Fee*	–0.103**	–0.147**	–0.101**
	(0.049)	(0.073)	(0.049)
Δ *Zero*	0.004**	0.007***	0.005**
	(0.002)	(0.002)	(0.002)
Δ *IRC*	0.162***	0.175***	0.174***
	(0.045)	(0.049)	(0.047)
Δ $\text{Spread}^{\text{Stock}}$	–0.011	0.550	–0.021
	(0.375)	(0.528)	(0.349)
Δ Volatility	0.004	0.017***	0.005
	(0.003)	(0.005)	(0.004)
Δ Conv. Premium	0.007***	0.012***	0.008***
	(0.003)	(0.002)	(0.003)
DI	0.000	–0.001	0.000
	(0.001)	(0.001)	(0.001)
Constant	–0.002***	–0.002*	–0.002**
	(0.001)	(0.001)	(0.001)
Observations	11,254	9,888	11,254
R^2	0.054	0.063	0.057

Table B.6: Analysis of Public Registrations with Alternative Theoretical Prices

This table shows the results of multivariate regressions of monthly changes in convertible bond underpricing. In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. In Model 3, the Finnerty (2015) pricing model is used to calculate underpricing. Changes in the equity lending variables, Δ *Loan Supply* and Δ *Loan Fee*, are interacted with a dummy variable, *DI*, that indicates whether a convertible that was initially issued under SEC Rule 144A is publicly registered. Standard errors are clustered at the year-month-level. Definitions of all variables are contained in Table A.1 in the Appendix. ** and *** indicate significance at the 5% level, and 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Δ *Loan Supply*	–0.085***	–0.069***	–0.078***
	(0.020)	(0.024)	(0.021)
DI × Δ *Loan Supply*	0.047*	0.068**	0.061**
	(0.028)	(0.032)	(0.028)
Δ Loan Fee	0.091***	-0.050	0.096***
	(0.034)	(0.066)	(0.033)
DI × Δ *Loan Fee*	–0.073**	0.059	–0.080**
	(0.032)	(0.055)	(0.032)
Δ *Zero*	0.003*	0.004*	0.004**
	(0.002)	(0.002)	(0.002)
Δ *IRC*	0.154***	0.123***	0.172***
	(0.033)	(0.041)	(0.034)
Δ $\text{Spread}^{\text{Stock}}$	0.249	0.342	0.278
	(0.235)	(0.378)	(0.220)
Δ Volatility	0.002	0.017***	0.003
	(0.003)	(0.005)	(0.003)
Δ Conv. Premium	0.008***	0.011***	0.008***
	(0.002)	(0.002)	(0.002)
DI	–0.000	–0.001*	–0.000
	(0.001)	(0.001)	(0.001)
Constant	–0.002***	–0.002**	–0.001*
	(0.001)	(0.001)	(0.001)
Observations	24,429	20,670	24,429
R^2	0.056	0.055	0.056

Table B.7: Analysis of the 2008 Short-Sale Ban with Alternative Theoretical Prices

This table shows the results of multivariate regression of daily underpricing around the time of the 2008 short-sale ban. The main independent variable is the interaction of the short-sale ban dummy (*Ban*) with a dummy that indicates whether the issuing firm is a financial firm (Financial). In Model 1, the Tsiveriotis and Fernandes (1998) pricing model with the option-adjusted spread instead of a credit spread based on corporate bond yields as input parameter is used to calculate underpricing. In Model 2, the Tsiveriotis and Fernandes (1998) pricing model with implied volatility instead of historical volatility as input parameter is used to calculate underpricing. The conversion premium is included as a control variable. The sample contains daily observations over the September 1 through October 8 period of 2008. The regressions include convertible bond and day fixed effects. Standard errors are clustered at the bond-level. *** indicates significance at the 1% level, respectively.

Pricing Model:	(1) *TF-OAS*	(2) *TF-IVOL*	(3) *Finnerty*
Ban × Financial	0.022**	0.030**	0.018**
	(0.009)	(0.012)	(0.009)
Conv. Premium	0.001***	0.006	0.001**
	(0.000)	(0.014)	(0.000)
Bond FE	Yes	Yes	Yes
Day FE	Yes	Yes	Yes
Observations	2,418	1,873	2,418
R^2	0.941	0.936	0.941