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Arbitrage Crashes and the Speed of Capital

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Abstract

The imminent failure of large Wall Street prime brokerage firms during the 2008 financial crisis caused a sudden and dramatic decrease in the amount of financial leverage afforded hedge funds. This decrease in financing resulted from the *ex post* asymmetrical payoff to rehypothecation lenders—the ultimate providers of financing, through prime brokers, to hedge funds. Seemingly long-term debt capital became short-term capital creating a large mismatch in the duration of arbitrage opportunities on the left-hand side of arbitrageurs' balance sheet and liabilities on the right-hand side. A primary consequence of this withdrawal of financing was the inability of hedge funds involved in relative-value trades to maintain prices of substantially similar assets at substantially similar prices. The magnitudes of these mispricings, and the time required to correct them, provide an indication of the role played by arbitrageurs in maintaining rational prices during normal times.

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1. Introduction

Modern finance theory rests on the ability of arbitrageurs to ensure that substantially similar assets trade at substantially similar prices. When prices of related assets diverge, arbitrageurs sell short the expensive asset and simultaneously purchase the cheap asset. When the prices of the two assets converge, arbitrageurs unwind their trades and generate risk-free profits. As long as arbitrageurs can borrow, they can turn even small pricing discrepancies between two substantially similar securities into large profits. Although arbitrageurs may not cause absolute prices to equal fundamental values, they can ensure that assets are priced correctly on a relative basis.

If arbitrageurs lose access to debt capital, they may be unable to force prices of similar assets to the same level. When this occurs, substantially similar assets can trade at wildly different prices. In this paper, we measure the relative pricing errors that occurred during the 2008 financial crisis, when arbitrageurs were unable to borrow and were therefore financially constrained. We focus on arbitrage strategies involving corporate securities, including convertible debenture arbitrage, CDS-corporate debenture arbitrage, closed-end-fund arbitrage, merger arbitrage, and Special Purpose Acquisition Company (SPAC) arbitrage. None of these are truly arbitrage strategies—the securities underlying the trades are merely related rather than nearly identical. Nevertheless, we contend that the securities underlying the strategies are related closely enough to provide an estimate of the magnitude of relative mispricings eliminated by arbitrageurs in typical market environments.

In addition to documenting the level of mispricings, we document the time required for capital to flow into the void left by arbitrageurs. Seemingly risk-free arbitrage opportunities offering extraordinary expected returns were available for several months in the wake of the 2008 financial crisis, assuming of course, that an arbitrage investor could actually access equity or debt capital to invest in such opportunities. Even long-only investors with available capital did not rush to buy clearly mispriced securities. Furthermore, long-only investors were slow to replace economically equivalent securities in their portfolios with mispriced securities being sold by distressed arbitrageurs.

The paper is organized as follows. Section 2 briefly discusses related literature. Section 3 describes the source of debt financing for hedge funds, and the retraction of credit lines during the 2008 financial crisis. Sections 4, 5, and 6 describe the impact of the financial crisis on convertible arbitrage, CDS-corporate bond basis arbitrage, and SPACs, which were all directly affected by the withdrawal of debt capital from hedge funds. Section 7 describes the indirect impact of the financial crisis on other arbitrage strategies such as merger arbitrage and closed-end-fund arbitrage, and Section 8 concludes the paper.

2. Related Literature

Drawing on the earlier work of uninformed noise traders by DeLong, Shleifer, Summers, and Waldman (1990), Shleifer and Vishny (1997) provide a formal framework of limited arbitrage. In the Shleifer and Vishny model, performance-based investors redeem capital from arbitrageurs subsequent to negative performance, often the precise time when expected returns are highest. Consequently, rather than responding as predicted in textbooks by placing spread-compressing trades when spreads widen, arbitrageurs may be forced to do the opposite, reducing positions and destabilizing prices. The key assumption in the Shleifer and Vishny model is that investors are uninformed as to the actual trade undertaken by the arbitrageur and thus question the investment ability of the arbitrageur when losses are realized. Accordingly, arbitrageurs price idiosyncratic risk and do not fully exploit arbitrage opportunities. For this reason arbitrage spreads are wider than they would be in the absence of agency costs and information asymmetries. The prior work of Merton (1987) also explores how idiosyncratic risk affects expected returns to arbitrage. In particular, Merton proposes that both uncertainty about the distribution of returns from arbitrage investments and fixed costs associated with exploiting arbitrage opportunities impede arbitrage activity.

Whereas the initial research on limits to arbitrage focused on the asset side of the balance sheet (i.e., the fundamental value of the arbitrage opportunity) more recent theoretical research concentrates on the funding risk of arbitrage and the impact on investors. The basic story is that even if fund investors are fully

informed about the quality of the arbitrage investment, these investors may still rationally redeem capital if they expect withdrawals by other investors and/or an increase in the cost of financing from financial institutions. As a result, selling begets more selling and a vicious cycle of declining prices ensues, even in the face of increasingly attractive arbitrage investment opportunities. The downward price spiral escalates for the least liquid securities. See among others, theoretical research by Brunnermeier and Pedersen (2008), Garleanu and Pedersen (2009), Gromb and Vayanos (2002), and Liu and Mello (2009), all of which model the feedback mechanism between investors and arbitrage opportunities in light of market frictions.

Empirical work on limited arbitrage has focused on the left-hand side of the balance sheet showing that transactions costs and market frictions prevent arbitrageurs from forcing immediate price convergence of related securities. In some cases, so-called arbitrage opportunities disappear when the link between two related securities is severed, causing permanent losses to arbitrage investments. These losses create uncertainty regarding the distribution of arbitrage returns thereby limiting the amount of capital dedicated to convergence trades. See, for example, research by Baker and Savasoglu (2002), Lamont and Thaler (2003), Mitchell, Pulvino and Stafford (2002), Pontiff (1996), among others, all of which empirically document the limits of arbitrage. Overall, these papers provide substantial support for the influential theoretical work by Merton (1987) and Shleifer and Vishny (1997), namely that market frictions limit real-world arbitrage.

Most recently, empirical research has examined the right-hand side of arbitrageurs' balance sheets. The most comparable empirical research to this paper is recent work by Mitchell, Pedersen, and Pulvino (2007) who study merger arbitrage during the Crash of 1987 and convertible arbitrage in 2005, a time when the convertible market imploded following investor redemptions (i.e. the withdrawal of equity capital from hedge funds). As discussed in more detail in Section 4, Mitchell, Pedersen, and Pulvino show that major market dislocations can constrain arbitrage capital and force arbitrageurs, who are generally rewarded for providing liquidity, to themselves demand liquidity. In this paper, we extend the empirical literature by showing that a combination of (1) duration mismatch between long-term arbitrage investments on the left-hand-side of arbitrageurs' balance sheets and overnight debt financing on the right-hand side, and (2) an asymmetry in the speed of capital, namely the abrupt and immediate withdrawal of debt capital used to

finance arbitrage portfolios, and the lack of offsetting new capital from alternative suppliers, can greatly inhibit arbitrageurs' abilities to maintain relative prices at near-rational levels.

3. Withdrawal of Debt Capital from Hedge Funds

Hedge funds secure debt financing from prime brokerage operations of investment banks in order to increase the expected return on behalf of their fund investors. The two primary terms that define the borrowing arrangement are the fee charged to the fund by the prime broker and the amount of collateral required (also referred to as the "haircut"). Both terms vary with factors related to the portfolio's risk and size (i.e. portfolio concentration, liquidity, degree of hedging, recent performance, etc.). In recent years, prime brokers charged fees of roughly 35 basis points in excess of the federal funds rate (interest rate at which banks lend balances out of the Federal Reserve to loan to other banks) for their best hedge fund clients and the least-risky strategies. The amount of haircut required to post for each position is a function of the various factors indicated above. For example, a small convertible debenture where the current stock price is far lower than the debenture's conversion price and which trades infrequently requires a larger haircut than a large liquid convertible debenture with a stock price far above its conversion price. Likewise, a more credit-sensitive CDS-corporate debenture basis trade requires more collateral than an investment-grade CDS-corporate debenture basis trade. In the typical prime brokerage arrangement, terms are not fixed for a lengthy period, but are instead subject to daily adjustment depending on changes in the portfolio and overall economic conditions. Term financing is available, at a higher financing rate, but is typically of short duration (i.e. a few months) and contains numerous positive and negative covenants providing "outs" for the term lender. Prime brokers typically finance up to half of hedge fund borrowing via the rehypothecation market from lenders such as major European universal banks.[1] This chain of events is shown in Figure 1. As shown in this figure, hedge funds borrow money from prime brokers who in turn

[1] See Duffie (2010) for a comprehensive discussion of the mechanics of the repo market and dealer bank failures during the financial crisis of 2008.

borrow money from rehypothecation lenders. In each step of the process, securities purchased with the borrowed money are posted as collateral to the lender. From the perspective of the rehypothecation lender, there is little risk as the borrower is a well-financed Wall Street prime brokerage firm. The securities posted as collateral simply provide back-stop protection in the unlikely event that the counterparty fails.

The bankruptcy of Lehman Brothers on September 15, 2008 roiled the rehypothecation market. Although a long-short arbitrage trade where the two legs were directly linked may have had little risk, rehypothecation lenders were exposed only to the long leg of the trade. Their unhedged exposure typically had several times the volatility of the hedged position. As a result, following Lehman's bankruptcy, rehypothecation lenders of Lehman's prime brokerage began to quickly sell securities provided as collateral by Lehman's hedge fund clients. Consider for example, a high money, and thus high-delta, convertible debenture held by a convertible arbitrageur on a theoretical hedge. Because the convertible debenture is deep in the money, the hedged position has minimal fundamental risk as the arbitrageur is effectively long equity via the convertible debenture and short a similar amount of the same equity via the hedge. Even with the risk of an immediate jump to default, the prime broker would require only a small haircut, often less than 5% of the long position. Paradoxically, a deep-in-the-money convertible debenture is an extremely risky position for a rehypothecation lender—because of its high moneyness, the convertible debenture will behave like equity. Similarly, in the case of low-risk CDS-corporate bond basis trades, rehypothecation lenders received corporate bonds which were provided as collateral and in isolation had much greater risk than the risk of the basis-trade portfolio. Consequently, while the haircut previously posted was sufficient to protect Lehman rehypothecation lenders from realizing losses during a short period of time, haircuts in sharply deteriorating markets could potentially evaporate leaving rehypothecation lenders exposed to significant risk.[2] They responded by promptly selling collateral when Lehman filed for bankruptcy.[3]

[2] Note that in the weeks prior to the failure of Lehman, rehypothecation lenders began requiring larger haircuts on their loans, starting with the collapse of Bear Stearns in April 2008, to ensure they were adequately protected from downside risk. See Gorton and Metrick (2009) for an analysis of repo rates during the financial crisis of 2007 and 2008.

[3] As an alternative to immediately selling reposessed collateral, rehypothecation lenders could have partially hedged their positions by shorting equity and/or purchasing CDS protection. They likely chose not to do so given their lack of

As we describe later in this paper, the immediate selling of relatively illiquid securities by rehypothecation lenders led to sharply declining traded prices relative to fundamental values. This decline in the prices of illiquid securities, such as high-yield corporate bonds and convertible debentures, revealed the high risk of their collateral to rehypothecation lenders of other prime brokers. As a result, there was a widespread retraction of financing by rehypothecation lenders to all prime brokers. Prime brokers in turn required their hedge fund clients, particularly those with illiquid securities, to immediately delever their portfolios. In some cases, term-financing agreements between prime brokers and hedge funds delayed immediate forced liquidations. However, as mentioned above, term agreements did not account for a substantial amount of total lending by prime brokers to hedge funds.

Figure 2 displays the overnight LIBOR (London Interbank Offered Rates) rate and the difference between the overnight LIBOR and the 28-day U.S. Treasury bill rate during January 2001 through March 2010. Overnight LIBOR spiked during the week of the Lehman bankruptcy filing, rising from 2.1% on September 12, 2008 to a maximum of 6.4% on September 16, 2008, reflecting the high risk aversion of large banks making unsecured loans to each other during this week. Moreover, the financial markets experienced a flight to quality as investors shifted assets out of risky securities into U.S. Treasuries, causing the 28-day U.S. Treasury bill yield to move from 1.4% on September 12, 2008 to 0.1% on September 17, 2008. The movements in these short-term rates during the Lehman period are outside the distribution of the daily change in rates during the period January 1, 2001 through September 12, 2008.[4] As displayed in Figure 2, because of concerns about the stability of major financial institutions, spread widening between the overnight LIBOR rate and the 28-day U.S. Treasury bill rate continued over the following weeks. The spread did not return to normal levels until the second quarter of 2009.

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necessary infrastructure and also the fact that they held sufficient collateral such that, even at sharply lower prices, they would not be impaired. In addition, as noted by Duffie (2010), money market funds in the U.S. are required by the SEC to immediately sell collateral in the case of counterparty failure. We have no knowledge that any of the Lehman repo lenders realized material losses as a result of the Lehman bankruptcy.

[4] For example, prior to the Lehman week, the largest one-day jump in the overnight LIBOR since the beginning of the sample period in January 2001 was 0.81% on March 17, 2008 when Bear Stearns was acquired by JPMorgan in a distressed transaction. In comparison, the overnight LIBOR increased 0.96% on September 15, 2008 and an additional 3.33% on September 16, 2008.

Even premier investment banks such as Goldman Sachs Group Inc. and Morgan Stanley, the two primary prime brokers in the U.S., were subject to considerable pressure. For example, the cost of insuring against a Morgan Stanley default increased so much during October 2008 that Morgan Stanley's CDS contracts began trading at "points up-front." This generally happens when credit spreads approach 1,000 bps reflecting a situation where the firm is considered to be financially distressed. On October 10, 2008, the 5-year CDS for Morgan Stanley traded at 28 points up-front. Thus, to insure $10 million of Morgan Stanley debt, an investor buying protection in the CDS market would be required to make an up-front payment of $2.8 million and would also be required to pay $500,000 annually over the next five years. Assuming this cost of insurance against Morgan Stanley's default and a recovery rate of 20%, the implied probability of default within one and five years was 16.4% and 59.2%, respectively.[5] Figure 3 displays the daily credit spread based on the 1-year CDS for Goldman Sachs and Morgan Stanley during January 2005 – March 2010. For both firms, the credit spread implied from the 1-year CDS was near zero (average credit spread < 20 basis points) during 2005-2007 implying that the likelihood of default was remote. As Wall Street began to experience difficulty in late 2007 (Bear Stearns in particular), CDS spreads for both Goldman Sachs and Morgan Stanley increased noticeably, but remained well below extreme levels experienced when Lehman failed.[6]

As default probabilities increased in the aftermath of the Lehman bankruptcy, rehypothecation lenders had no realistic alternative than to terminate financing arrangements with both Goldman Sachs and Morgan Stanley. Fees paid to rehypothecation lenders were small relative to the potential downside in case the prime brokers failed. In that scenario, rehypothecation lenders would be left with securities for which they lacked sufficient infrastructure to manage. Furthermore, if asset values continued to fall,

[5] Even at an assumed recovery rate of 0%, the implied default probabilities were high at Morgan Stanley, at 13.4% for one-year and 51.4% for five-year periods, respectively.

[6] On September 17, 2008 John Mack, CEO of Morgan Stanley, circulated a memo to employees stating that "there is no rational basis for the movements in our stock or credit-default spreads…..Its' very clear to me -- we're in the midst of a market controlled by fear and rumors, and short sellers are driving our stock down. You should know that the Management Committee and I are taking every step possible to stop this irresponsible action in the market." Interestingly, as the premier prime broker for many years, Morgan Stanley realized substantial profits by facilitating short selling of shares of thousands of firms.

rehypothecation lenders would have been left with insufficient collateral to cover their loans. Consequently, prime brokers such as Morgan Stanley and Goldman Sachs, which relied on external financing for a substantial portion of their prime brokerage business, required their hedge fund clients to quickly reduce leverage in their portfolios.

In a world in which the prime broker loss of financing is idiosyncratic, customers of the problem prime broker can simply transfer their portfolios to a competitor. This was the case in early 2008 as hedge funds removed their business en masse from Bear Stearns Securities Corp. However, in light of the financial turmoil across Wall Street, other prime brokers, even those with sufficient financing, were hesitant to accept additional securities, especially if there were concerns about the quality of the securities being transferred. Furthermore, the establishment of new prime brokerage relationships typically takes several weeks and was therefore not an option in terms of responding to the forced exit of other prime brokers. Left with no other choice, hedge funds were forced to sell securities, particularly illiquid securities like convertible and high-yield corporate debentures that did not provide attractive collateral for rehypothecation lenders.

4. Convertible Arbitrage and the Financial Crisis of 2008

Convertible arbitrageurs realized large losses in the fall of 2008 when financial markets collapsed. According to Hedge Fund Research, Inc. (HFR), a distributor of hedge-fund performance information, its index of convertible arbitrage funds realized losses of 34% in 2008, nearly all of which occurred during September-November 2008. By comparison, HFR reports that its convertible-arbitrage index lost only 2% in 2005 and 4% in 1994, the only two negative years for HFR's convertible arbitrage index since HFR began tracking convertible arbitrage funds in 1990.[7]

[7] Note that survivorship bias in the HFR index is potentially large during 2008 due to several forced liquidations in which it was highly unlikely that the respective funds reported their final returns. Unlike the HFR Index, the HFRX index is investable and is therefore free from survivorship bias. The HFRX convertible arbitrage index declined 58% in value during 2008, again nearly all of which occurred during September-November 2008.

Convertible debentures have been actively researched, both theoretically and empirically. This research has focused on firms' decisions to issue convertible debentures and the effectiveness of convertible securities in mitigating information asymmetry and agency costs.[8] This paper does not consider the underlying motivation for convertible issuance. Rather, it focuses on the market for convertible securities after they are issued. As discussed by Mitchell, Pulvino and Pedersen (2007), the convertible issuance process can literally take only a few days thereby allowing firms with immediate financing needs to access capital. Since the convertible debenture is a derivative security, its valuation is relatively straightforward and the arbitrageur can hedge most of the systematic risk by shorting the underlying stock. In effect, convertible arbitrageurs transform a convertible debenture into a security with far lower risk, and at the extreme, into a security absent of credit risk, equity risk, or interest rate risk. Because of their ability to timely strip the convertible debenture of its systematic risk, hedge funds engaging in convertible arbitrage can finance a firm's capital needs on extremely short notice. For instance, many convertible issues are priced overnight in that the issuer communicates to qualified institutional buyers, via an investment bank, a range of coupon rates and conversions premiums soon after the market close on one day, investors quickly respond with a demand schedule, and the offering is completed prior to the market open on the next day.[9] More commonly, the offering is completed two days after the issuer announces the range of terms of the new issue. This allows information contained in the announcement to be reflected in the stock price before the conversion price is determined. Overall, convertible arbitrageurs provide liquidity to corporations that find it expensive to issue straight debt or equity via the traditional lengthy road-show and registration process. In recent years, convertible-arbitrage hedge funds and multi-strategy hedge funds have dominated the trading and ownership of convertible debentures, accounting for up to 75% of the convertible market.

After the convertible debenture is stripped of most of its systematic risk, the expected return and volatility to the hedged convertible debenture is low relative to other securities. Consequently, leverage is

[8] See the often cited research by Brennan and Schwartz (1988), Green (1984), Mayers (1998), and Stein (1992) among numerous other theoretical papers on convertible debentures.

[9] In 1990, the SEC instituted Rule 144A which allows firms to issue unregistered securities to qualified institutional buyers (QIBs), thereby quickening the issuance of capital. QIBs can resell 144A securities to other QIBs prior to their registration which often can be months after the issuance date.

often used to increase the expected returns to the hedge fund. Defining leverage as long market value of convertible securities divided by the fund's NAV, leverage between 4 and 6 was considered normal in recent years for convertible arbitrage hedge funds. For very high-delta convertible debentures where the stock price traded well above the conversion price (and thus the hedged convertible had minimal systematic risk), leverage up to 20 times was possible.

4.1 Impact of Hedge Fund Deleveraging on Convertible Arbitrage

To assess the impact of the hedge fund deleveraging during the financial crisis of 2008 on convertible arbitrage, we examine the difference between theoretical prices and traded prices. If the forced deleveraging had an impact on the convertible market, then traded prices should fall relative to theoretical prices (i.e. bonds should "cheapen"). Because there are numerous market participants such as hedge funds and proprietary trading desks which actively search for mispricings in convertible securities, and because the derivative nature of the security provides for reasonably accurate estimates of theoretical prices, traded prices should be close to theoretical prices in unstressed markets.

We construct a sample of convertible debentures issued by U.S. publicly-traded firms which traded during the period January 1990 through March 2010. The sample consists of over 3,000 convertible debentures issues resulting in an average of more than 400 issues per month during the sample period. We obtain weekly prices of each convertible debenture from *Value Line Investment Surveys* during January 1990 through December 2006 and from various Wall Street trading desks from January 2007 through March 2010.[10] We record the details of the structure of each convertible debenture as of the issue date, including the conversion ratio, coupon rate, maturity date, call dates, and put dates and then track each convertible from the issue date through expiration date (i.e. scheduled maturity, issuer call, convertible holder put, cash merger, bankruptcy, corporate buy-back). There are numerous corporate events over the life of a convertible debenture which can alter the terms of the convertible and we account for those events

[10] *Value Line Investment Surveys* obtains its weekly convertible debenture prices from trading desks of Wall Street investment banks. For a period in which we have overlapping data from both *Value Line Investment Surveys* and directly from Wall Street trading desks, pricing differences are minimal and unbiased on average.

to increase the accuracy in estimating the fundamental value of the convertible. For example, conversion ratios are typically adjusted to stock splits and stock dividends. In a stock merger, a debenture convertible into the target company's stock is often transformed into a debenture convertible into the acquiring company's stock. The conversion ratio is adjusted to reflect the share ratio associated with the stock merger. Likewise, conversion ratios are typically adjusted for corporate reorganizations such as spin-offs or special dividends.

Based on the convertible debenture terms corresponding to each week during the sample period, we calculate a theoretical convertible debenture price using a finite difference model. A structural model such as the finite difference model allows us to account for various imbedded options in a convertible debenture such as the option of the issuer to call the bond or the option of the holder to redeem the bond for the par amount at certain times over the life of the bond. To obtain the theoretical value, we use input estimates corresponding to each convertible debenture and at every point in time. These inputs include the following: issuer stock price, issuer volatility estimates, issuer credit spread estimates, and term structure of interest rates. For issuer volatility, we use historical annualized volatility estimates calculated from daily stock returns of the trailing 200 trading days.[11] For issuer credit spreads, we obtain the issuer's respective S&P credit rating and then estimate the issuer's credit spread based on an aggregate credit rating and credit spread matrix provided by Credit Suisse corresponding to each credit rating. In cases in which the issuer does not have an S&P credit rating we estimate the credit rating based on an empirical model using both historical accounting and stock market data (see Shumway (2001) for a similar application to predicting default probabilities of corporate issuers).

To reduce estimation errors associated with our computation of the cheapness/richness of the convertible debenture universe on a time-series basis, we focus on equity-sensitive convertibles since they

[11] For the full sample period of 1990-2010, we have also assumed historical volatility estimates calculated from shorter and longer time periods than 200 trading days with having no substantive impact on the results. Similarly, for the 2004-2010 period, we also used volatility estimates implied from the equity option prices of the underlying issuer where such options actually traded, and likewise, these estimates did not have a substantial impact on the results in this paper. Finally, employing Barra estimates of individual issuer volatility which incorporates data from historical stock returns, equity option prices, and fundamental accounting data also does not have a substantive impact on the results.

are less sensitive to the model inputs, specifically to credit spreads.[12] For example, the S&P 500 dropped to as low as 752.4 in November 2008, a decrease of more than 50% from its high in October 2007. As a consequence of the sharp decrease in equity prices, a large portion of the convertible universe became credit-sensitive. For the full sample of convertible debenture prices over the sample period, we sort based on moneyness defined as stock price / conversion price for each convertible-debenture week. The median moneyness is 0.65, and we label convertible debentures with moneyness less than 0.65 as credit-sensitive bonds and convertible debentures with moneyness greater than 0.65 as equity-sensitive bonds. We then create a calendar time-series cheapness/richness estimate defined as the median of the difference between the theoretical value and market-traded value across all of the equity-sensitive convertible debentures corresponding to each week in the dataset.

Figure 4 displays the median cheapness/richness measure for convertible debentures over the time period, January 1990 through March 2010. On average, convertible debentures traded at prices 0.5% cheap relative to theoretical values.[13] The cheapness measure ranges from 3.3% rich in February 2003 to 10.9% cheap in November 2008. The November 2008 cheapness of 10.9% is 8.7 standard deviations from the average cheapness of 0.2% over the historical distribution of January 1990 – August 2008, illustrating the extreme level of convertible debenture dislocation during the financial crisis of 2008. Even within the entire sample period (January 1990 – March 2010), the November cheapness measure is nearly 5 standard deviations greater than the mean. As Figure 4 shows, convertible debentures began to cheapen considerably in July 2008 when they exceeded the maximum cheapness of the prior historical distribution, only to cheapen far more in the subsequent months and remain cheap for several months afterwards.

[12] Note that focusing on the equity-sensitive convertible debentures does not alter the results versus using the full sample of convertible debentures, rather we do so simply to mitigate the impact of the input estimates on the cheapness/richness measure.

[13] As indicated in the prior paragraph, the analysis focuses on equity sensitive bonds and thus the cheapness/richness estimate is not reflective of actual cheapness/richness across all convertible debentures. First, for extremely high stock prices relative to conversion prices, optionality is low and thus cheapness/richness truncates to zero. Second, the theoretical model assumes that companies follow a theoretically optimal call policy implying that issuers call convertible debentures as soon as the stock price is equal to or greater than the conversion price when the bond is callable. However, in practice, to avoid funding risk caused by a stock price decrease between the call announcement date and expiration of the call period (in which case bond holders would elect a par cash payment rather than stock) issuers delay calling a convertible debenture until the stock is trading at a substantial cushion to the conversion price. Assuming a 20% call cushion has the impact of increasing overall cheapness by up to 2 percentage points.

Convertible debenture cheapness hit a daily maximum of 13.7% on December 4, 2008. To convey the magnitude of this level of cheapness, we calculate the implied value of each of the inputs, ceteris paribus. On this date, there were 154 equity-sensitive (moneyness > 0.65) convertible debentures in the dataset with an average volatility estimate of 62% and an average credit spread estimate of 632 basis points. For cheapness to collapse to zero, credit spreads would have to triple to 1,900 basis points with no commensurate change in volatility. The level of volatility required to equate theoretical prices with market prices on December 4, 2008 was not computable. That is, even if one assumed that the underlying stock would have a volatility of zero, market prices were still below theoretical prices. Moreover, these scenarios hold all other inputs constant, an unrealistic assumption given the strong negative correlation between credit spreads and volatility.

By comparison, the convertible debenture market had experienced prior dislocations as analyzed by Mitchell, Pedersen and Pulvino (2007). However, as illustrated in Figure 4, prior dislocations were minor in comparison to the fall of 2008. Mitchell, Pedersen and Pulvino analyze the convertible arbitrage crash of 2005 when fund-of-funds and other large institutional investors redeemed their investments in convertible-arbitrage funds during 2005 because of low returns to convertible arbitrage. During the nine-year period, 1995-2003, annual returns to convertible arbitrageurs as measured by Hedge Fund Research was 12.9% with a minimum return of 7.8% over that period. Immediately following a relatively low return of 1.1% in 2004, investors redeemed in such large amounts that convertible arbitrageurs were forced to sell up to 40% of their holdings over the next year. This caused steep losses and forced numerous convertible arbitrage funds to shut down. It also caused proprietary trading desks of investment banks to greatly reduce exposure to convertible arbitrage. The widespread selling by convertible arbitrageurs and proprietary trading desks resulted in substantial convertible debenture cheapness relative to the historical distribution. The crux of the Mitchell, Pedersen and Pulvino analysis was that despite the extreme cheapness of convertible debentures and thus an obvious textbook arbitrage opportunity, it took several months before equilibrium was restored to the convertible market as investors, even multi-strategy firms which tactically allocate capital across strategies, were not able to absorb the enormous selling pressure from the convertible

arbitrage firms and convertible proprietary trading desks. The cheapness realized in 2008 was more than three times the level reached in 2005, and it took well over a year before convertible cheapness began to return to historical levels. Whereas in 2005, the cheapness resulted from a loss of hedge fund equity capital, the 2008 dislocation was caused primarily by the loss of hedge fund debt capital as prime brokers abruptly ceased lending to convertible arbitrage funds. A similar course of events occurred across various other arbitrage strategies as discussed subsequently in this paper.

4.2 High-Money Convertible Debenture Conversions

To illustrate the extreme cheapness reached in the convertible debenture market during the financial crisis of 2008, consider the Priceline.com Inc. convertible debenture issued in 2006 which paid an annual coupon of 0.50% and had a maturity date of September 30, 2011. On November 28, 2008, the capital markets desk at Merrill Lynch offered to sell, on behalf of a client, $25.0 million face value of Priceline convertible debentures at $166.56 per $100 face value with a total ask value of $41.6 million. As described below, the theoretical value of Priceline's convertible debenture at the time of the offer was $185.30 and thus Merrill Lynch offered the convertible at an 11.3% discount to theoretical value. [14]

To put the 11.3% cheapness in perspective, the stock price of Priceline.com was $67.66 as of the time that Merrill Lynch offered the convertible debentures for sale.[15] Given the conversion ratio of 24.7647, the offer price was actually one point less than the conversion value of 167.56 (24.7647 shares/bond x $67.66/share = $1,675.58 per $1,000 face value or $167.56 per $100 face value), and thus the

[14] For input estimates, we use a volatility of 75% (historical volatility was 74% and implied volatility from January 2010 equity options was 84%) and a credit spread of 662 basis points. Given the high moneyness of this convertible debenture, adjustments to these input estimates do not have a material impact on its theoretical price.

[15] Broker dealers such as Merrill Lynch quote convertible debentures relative to a specified stock price. Participants in the convertible market understand that the actual price paid for the bond will reflect an adjustment, based on the bond's theoretical delta, for any differences in the stock price between the time of the quote and the time of the transaction. For example, if Priceline.com's stock price increased to $68.00, Merrill's ask on the convertible debenture would automatically increase to 167.31 given the bond's conversion ratio of 24.7647 and theoretical delta of 0.89.

holder was willing to sell a valuable option at a negative price.[16] As an alternative to selling a bond for a price less than conversion value, a holder could direct their broker to forward their conversion request to the underlying company and receive conversion value by selling shares. There were two problems with this alternative approach in 2008. First, by converting the bond into the underlying equity, the holder would forgo accrued interest since the last coupon payment (the so-called "screw clause"). However, given the low coupon rate on the Priceline bond, this forgone interest was only $0.08 per $100 face value. The second, and in this case more important problem with converting the Priceline bond, is that would take approximately one month to convert the bond into equity.[17] Given that the convertible holder in this case chose to offer it for sale at less than conversion value is evidence that they had to sell the bond immediately, and importantly, that no other investors had sufficient financial resources to buy the Priceline convertible debenture even at its conversion value.

To determine if the Priceline.com example generalizes to a larger sample, we analyzed all convertible debentures which had a moneyness (stock price/conversion price) greater than 1.5 on at least five days during the period of October 1, 2008 through December 31, 2008 and had a minimum issue size of $100 million as of September 30, 2008. The resulting sample size is 17 convertible debentures, noticeably lower than in most prior periods—a result of the steep stock market decline over the prior twelve months. Panel A of Table 1 displays the Crisis-Period summary statistics, calculated on the day during the crisis when the difference between the debenture's market price and its conversion value was smallest, for these 17 convertible debentures. The average (median) moneyness for the sample is 1.78 (1.68). We obtain quoted convertible debenture prices from Deutsche Bank and compare the quoted prices to the bond's conversion value. The average quote is only 0.46 points (average quote of 173.60) greater than the

[16] Note that Merrill Lynch did not initially offer the convertible at one point under the conversion value, rather at 2 points above conversion value and continued to decrease the offer over a few days before the low offer described above.

[17] As specified in the convertible indenture, Priceline.com would have the option of satisfying the excess of the conversion value over principal value in either cash or stock. On the second trading day after the holder instructs their broker or conversion agent to facilitate the conversion price, Priceline.com will initiate a 20-day pricing period in which the VWAP will be calculated and used to determine the amount of cash or shares to deliver to the holder at the end of the pricing period.

corresponding conversion value and is not reliably different (p-value = 0.114) from the conversion value. The median quote is actually slightly less than the conversion value, also not statistically different from the conversion value. As in the case of Priceline.com, the fundamental values of these convertible debentures exceed their market prices by an average of 11.0 points (p-value < 0.001). Even though the underlying stock prices are well above the respective conversion prices, considerable optionality remains due to an expected remaining life of 2.2 years.

As discussed in the Priceline.com example, a holder would normally choose to convert the convertible debentures into shares if unable to sell for a higher price in the secondary market. But for the hedge fund without financing, if conversion were not immediate, they may be forced to sell even at prices below conversion value. To analyze the extent to which holders chose to actually convert their bonds to shares, we review the 10-Q filings associated with the sample of convertible debentures as described in Table 1. For seven of these 17 high-money convertible debentures, some holders chose to extinguish the bond's optionality via converting the bonds into shares, and the average (median) issue size of this sample declined by 3.1% (5.1%). In normal times, conversion of high-money bonds often occurs, but is typically induced by the issuer seeking to remove the convertible debentures from their balance. To induce conversion and extinguish optionality, issuers typically offer an incremental payment, either in cash or shares, in addition to the base conversion value. However, during the 4th quarter of 2008, holders largely chose to convert without any financial inducement from the issuers. There was only one case in which the issuer, Leucadia National Corp., induced conversion with cash. Even in this case, the amount paid (4.5 points) was far less than the value of the option embedded in the convertible debenture (16.3 points). Indeed, this particular debenture was trading at the highest level of the 17 debentures relative to conversion value, and had the issuer not actively attempted to induce conversion, it likely would have traded at much lower prices, similar to other high-money convertible debentures.[18]

[18] Based on our conversations with Wall Street trading desks, Leucadia National was offering cash inducements for early conversion. This is confirmed in their 10-K filing for the fourth quarter of 2008.

We create two control periods, one as of January 31, 2008 (Pre-Crisis Period in Panel B) and the other as of March 31, 2010 (Post-Crisis Period in Panel C). Unlike, the Crisis-Period, convertible debentures during the two control periods were quoted at prices economically and statistically higher than their respective conversion values. In addition, in the control periods, quoted prices were much closer to theoretical values, and indeed, the p-value is insignificant with respect to the Pre-Crisis median difference between theoretical value and quoted price.

These high-money convertible debenture conversions illustrate the difficulty hedge funds had in financing arbitrage positions, even those nearly free of fundamental risk.[19] It also suggests that markets were extremely segmented during the crisis period. That is, investors desiring equity exposure could simply have purchased these convertible debentures rather than the underlying stock, have the same upside potential, and in addition receive protection against the downside via owning a debenture with indenture rights stipulating repayment at maturity in case the stock price falls below the conversion price on the maturity date. Effectively, investors were being paid to accept downside protection. At a minimum, existing equity-holders could have replaced their stock holdings with convertible debentures. Based on observed conversions by the convertible holders, equity holders did not fully offset the selling pressure even with guaranteed arbitrage.[20]

4.3 Comparison of Convertible Debentures to Straight Debt

Whereas Section 4.2 compared high-money convertible debentures to their underlying equities, this section compares busted (trading at less than par) convertible debentures with the straight debt of the same issuer, specifically straight debt ranked pari passu with the convertible debentures. We exclude distressed

[19] The fundamental risk is not absolutely zero, but certainly close to it. Table 1 indicates the delta for this portfolio of high-money convertible debentures is 0.92. Assuming the arbitrageur constructed a portfolio with a delta of 0.92, he would begin to lose capital in a state of the world in which there is an immediate jump to default and the recovery value for the convertible debentures is 7%. Given that these convertible debentures are deep in-the-money, the issuing firms are far from being financially distressed. The likelihood of these stocks jumping to zero and the debentures receiving only seven cents on the dollar was remote.

[20] Whereas there is the theoretically potential downside to the convertible arbitrageur with unrealistic assumptions, there is no apparent incremental risk to the equity holder replacing shares with the convertible debentures.

convertible debentures, defined here as debentures with moneyness < 25% of conversion value since these bonds tend to trade infrequently resulting in potentially stale prices inducing noise in our direct comparisons. Of the 596 convertible debentures as of September 01, 2008, there are a total of 65 busted convertible debentures trading at less than par and with at least one year prior to a put date or maturity, for which there is also straight debt outstanding with similar maturity dates.

Although busted convertible debentures are more credit-sensitive than equity-sensitive, these bonds still have considerable optionality. For example, at the end of November 2008 when convertible debentures were at their most stressed levels, the typical convertible bond's embedded call option contributed roughly 12% ($7.97) of the overall busted convertible's value ($66.29 based on par value of $100).

The most interesting aspect of busted convertibles is the substantial contraction in the difference in yield between the straight debt and the convertible debenture. As displayed in Figure 5, prior to mid-September 2008 when Lehman failed, matched-pairs straight debt had yields 5.1 percentage points higher (5.6 percentage points higher based on median differences) than the convertible debt yield, a consequence of option embedded in the convertible debenture.[21] However, beginning in late September 2008 and accelerating in October 2008, the yield difference compressed and actually became negative for several days such that convertible debentures traded at higher yields than their comparable straight debentures. The standard deviation of the difference in yields prior to the Lehman failure was 0.28%, and thus the difference in yields during the crisis period was several standard deviations from the control period mean due to being far outside the prior distribution of differences. Note that this was not an extremely short-term phenomenon as it continued into early 2009. The arbitrage trade would be to buy the convertible debenture and simultaneously short the straight debenture, capturing a positive yield difference and a free call option.[22] Even in the absence of arbitrage, the convertible debenture should have a lower yield than the straight debenture. If, instead, convertible debentures carried a higher yield, straight debt holders would sell their

[21] We deleted observations in which the yield difference exceeded 1,000 basis points as such extremely large differences likely reflect bad debenture prices. Omitting these extreme outliers has no impact on the substantive results reported herein. The data source for the straight debt yields is Bloomberg.

[22] However, to implement the arbitrage trade, the investor incurs considerable recall risk as many debentures are relatively illiquid.

straight debentures and replace them with convertible debentures thereby receiving a higher yield and, in addition, getting a call option on the underlying equity. Just as in the high-money convertible conversion with equity described in Section 4.2, the lack of immediate arbitrage activity suggests markets remained segmented for a lengthy period of time.

4.4 Illiquidity and Convertible Debenture Cheapening

As described in Section 3, Lehman Brothers' rehypothecation lenders that aggressively sold securities provided as collateral experienced difficulties in selling convertible debentures, as well as certain corporate bonds and other illiquid securities, in a timely manner without moving prices. As discussed earlier, rehypothecation lenders to the other prime brokers increased margin requirements for convertible debentures, and in particular, convertibles which would be more difficult to sell quickly. Anecdotally, prime brokers increased margin requirements on illiquid convertible hedged positions, namely small and credit-sensitive issues, from 10-15% to 50-75%.

We examine whether the illiquid convertible debentures cheapened relatively more during the crisis period. The sample for this analysis consists of 486 convertible debentures which were outstanding as of August 31, 2008. We exclude convertibles for which the moneyness (stock price/conversion price) was less than 0.25 in order to eliminate distressed issues for which cheapness calculations vary substantially due to variations in credit spread estimates. We calculate the change in convertible debenture cheapness between August 31, 2008 and November 30, 2008 to capture the cross-sectional impact of the forced deleveraging on convertible cheapness. We chose the end of August since it was just prior to the Lehman bankruptcy and the end of November because it roughly corresponded to the peak cheapness for convertible debentures during the crisis. Based on our discussions with prime brokers regarding the increased margin requirements, we employ two measures of liquidity, size and credit quality. Small issues, defined as less than $250 million in par value outstanding, account for nearly 50% ((235 issues) of the sample. The average cheapness of these small issues increased from 10.6% on August 31, 2008 to 39.7% on November

30, 2008. Over the same time period, the cheapness of the larger issues (issue size > $250 million) increased from 7.2% to 27.4%. With respect to credit quality, we distinguish investment grade issues (77 issues) from high-yield and non-rated issues. The average cheapness of the more speculative issues increased from 9.8% on August 31, 2008 to 38.1% on November 30, 2008. Over the same time period, the average cheapness of the investment grade issues increased from 5.6% to 14.9%.

As previously discussed, the amount of cheapening that a bond can experience is limited by its conversion value—the market price of the bond will generally stay above the value that a holder could receive by converting the bond into equity.[23] To control for this, and also to control for changes in volatility and credit risk, we run the following cross-sectional regression:

$$\begin{aligned}\text{Change in Cheapness} = \alpha + \beta_1 \text{Change in Credit Spread} + \beta_2 \text{Change in Volatility} \\ + \beta_3 \text{Distance from Conversion Value} + \beta_4 \text{Illiquidity}\end{aligned} \quad (1)$$

Changes in bond cheapness, credit spreads and volatility are measured by taking differences between two dates, August 31, 2008 and November 30, 2008. Distance from Conversion Value is the difference between the bond's quoted price and its conversion value as measured on November 30, 2008. Illiquidity is a dummy variable defined one of two ways. The first definition is based on issue size—Illiquidity dummy takes the value of one if the issue size is less than $250 million. The second definition is based on credit ratings—Illiquidity dummy takes the value of one if the bond is rated below investment grade (i.e. high yield) or is not rated.

Table 2 displays results from estimating Equation 1. Column 1 presents results using issue size and column 2 presents results using bond rating to proxy for illiquidity. The coefficient for the credit spread variable is negative as expected, indicating that the larger the increase in credit spreads, the smaller the change in cheapness. The volatility variable has the predicted positive coefficient in that a larger increase

[23] This rule is generally true, although the Priceline example and related debentures described in Section 4.3 prove that it can be violated in times of stress.

in volatility causes a larger increase in cheapness. The Distance from Conversion Value variable has a positive coefficient reflecting the truncation in cheapness caused by the conversion option.

In the regression with issue size as the illiquidity variable (Column 1), the coefficient is 0.124 (t-statistic = 3.78). Thus, the change in cheapness for small issues is 12.4 percentage points greater than the change in cheapness for large issues. In the regression with credit quality as the illiquidity variable (Column 2), the coefficient is 0.198 (t-statistic = 4.52), indicating that the change in cheapness is 19.8 percentage points greater for speculative-grade issues than for investment-grade issues. Holding the control variables constant, these results indicate that illiquid bonds cheapened substantially more than liquid bonds, consistent with the hypothesis that forced hedge fund deleveraging had a larger impact on the prices of the less liquid convertible debentures.

4.5 Convertible Issuer's as Arbitrageurs of Last Resort

Despite a sharply declining economy, corporate issuers aggressively repurchased convertible debentures from hedge funds, paradoxically providing liquidity to their former liquidity providers. We track convertible debenture repurchases via reading issuer press releases as well as 10-Q and 10-K SEC filings corresponding to the 4th quarter of 2008 and the first quarter of 2009 for 501 convertible debentures issued by 406 corporations.[24] A total of 149 (37%) issuers repurchased convertible debentures of 161 (32%) issues during the October 2008 – March 2009 period. As of the quarter ending September 30, 2008, the 501 convertible debentures in the sample had an aggregate principal value of $180 billion. During the 4th quarter of 2008, these issuers repurchased 4.1% of the aggregate convertible issues and repurchased an additional 2.8% in the 1st quarter of 2009 for a total repurchase amount of nearly 7% during the financial crisis.

[24] We have to directly collect the repurchase data from the SEC filings since S&P Compustat does not track convertible debentures on the balance sheet at the quarterly level. We exclude convertible debentures under the following circumstances: (1) near-term cash merger which will extinguish the convertible, (2) intended call of the convertible, and (3) near-term put or maturity of the convertible.

To our knowledge, this repurchase activity of convertibles reflects the largest repurchase activity of any corporate security over a similar time frame. Academics have conducted substantial empirical research of share repurchases on both an individual and an aggregate level. Netter and Mitchell (1989) analyze stock repurchases around the Crash of October 1987 when 9.4% of NYSE/AMEX/NASDAQ companies announced a share repurchase in the aftermath of the crash. However, the subsequent follow-up of actual repurchase activity during the period October 19, 1987 – March 31, 1988 was only 0.9% of shares relative to the total amount of shares outstanding of NYSE/AMEX/NASDAQ firms. In a recent analysis of the time series of aggregate share repurchases, Dittmar and Dittmar (2007) document that the aggregate annual activity during the period 1985-2004 reached a maximum of roughly 2.5%. The maximum level occurred in 1987. Our search of the academic literature did not reveal any analysis of aggregate corporate debenture repurchase activity. Given that convertible debenture issuers are typically companies with unstable or low cash flow, and in light of the ongoing financial crisis and economic recession, the relatively high level of convertible repurchases during the crisis period provides further evidence about the extreme level of dislocation to the convertible debenture market.

5. CDS – Corporate Bond Basis during the Financial Crisis

Similar to convertibles, prime brokers substantially increased the margin required to hold corporate bonds, thereby negatively impacting the CDS-corporate bond basis arbitrage trade. A credit default swap (CDS) is a contract between two parties to swap the credit risk of an issuer (for this research, we assume the issuer is a corporation). The buyer purchases protection, via a series of payments, from the seller, and similar to insurance, receives a payment from the seller if a default event occurs. Since the CDS reflects the credit risk of a corporate issuer, it will trade in tandem with the issuer's bonds with similar ranking and maturity. The basis is the spread difference between the CDS and the corporate bond, and is computed as the CDS spread minus the corporate bond spread. To the extent that the basis becomes materially positive,

an arbitrageur will sell CDS protection and contemporaneously short the corporate bond.[25] Alternatively, if the basis became materially negative, the arbitrageur purchases the corporate bond and simultaneous buys CDS protection. Because of the similarities of the two instruments, the CDS – bond basis is mean reverting to zero. According to J.P. Morgan, haircuts on CDS-Corporate debt basis trades increased from 5% in June 2007, to 10% in June 2008 and to 20-25% in October 2008. Importantly, financing, even at the higher margin levels, was available only to select hedge funds. For many funds, financing was simply unavailable.

Figure 6 displays the weekly CDS-Bond Basis for U.S. investment-grade and high-yield corporate bonds during the period, January 2005 – March 2010. There are an average of 484 investment-grade issuers per week and 208 high-yield issuers per week represented in this data series. During the pre-crisis period (January 2005 – September 12, 2008), the average (median) basis for high-yield bonds was +2.4 (+12.7) basis points and was -6.8 (0.0) basis points for investment-grade bonds—essentially zero as expected given the ability to arbitrage the basis. The high-yield bond basis ranged from -146.7 basis points to +81.4 basis points during the pre-crisis period and the standard deviation of the basis was 40.0 basis points. Just prior to the financial crisis, the high-yield bond basis was negative and became much more negative during the financial crisis, reaching a peak of -677 basis points, more than four times that of the previous maximum level in absolute value, during the week ending December 5, 2008.[26] Conceptually, when the basis reached its minimum level, an arbitrageur could have purchased a basket of high-yield corporate bonds and simultaneously purchased CDS protection for the underlying issuers, thereby locking in an annual alpha of 6.8%. For several issuers, the arbitrageur could have locked in an annual alpha exceeding 10% on an unlevered basis. Given the eventual resolution of uncertainty, either when the bonds mature (and thus the basis goes to zero) or when bankruptcy occurs and the arbitrageur can collapse the two positions, the basis trade as described here is riskless at least on a fundamental basis. Rather, the problem with this arbitrage trade, just as in the convertible arbitrage trade described in Section 4, is financing risk. As displayed in Figure 6, the high-yield CDS-bond basis widened more than the investment grade CDS-

[25] See research by Duarte, Longstaff, and Yu (2007) and Nashkiiar, Subrahmanyam, and Mahanti (2009) for discussions of the CDS-corporate bond basis arbitrage.
[26] On a daily basis, the CDS – bond basis reached a level of -720 basis points on December 16, 2008.

bond basis due to the fact that the rehypothecation lenders to the prime brokers were more hesitant to accept relatively illiquid high-yield bonds as collateral for their loans.

In normal times, arbitrageurs employed leverage to increase the expected return in the CDS-bond basis arbitrage trade, posting as little as 5% equity capital. Of course, the basis was very tight prior to 2008 and thus the expected return was not especially high even with leverage of 20, after accounting for transactions and financing costs. For example, assuming that the arbitrageur sets an entry point at -30 basis points before putting on the trade, the expected alpha with leverage of 20 would be roughly 4%, not necessarily high in absolute amount, but a profitable trade given the lack of fundamental risk.[27] As described, during the aftermath of Lehman's bankruptcy filing, rehypothecation lenders to Lehman Brothers aggressively sold securities provided as collateral, including corporate bonds. The selling of corporate bonds did not simply end with the dumping by the Lehman rehypothecation lenders. Rehypothecation lenders to the other investment banks began to terminate financing agreements which led to widespread deleveraging by hedge funds, many of which were employing the CDS-bond basis trade. Moreover, investment banks themselves also had in place large CDS-bond basis trades, either through their proprietary trading desks attempting to capture the expected alpha from the trade or from the banking side which provided credit to corporations. In the latter case, banks that provided credit to corporations did not remove all of the credit from their balance sheets, but instead hedged their exposure by purchasing CDS protection as insurance. As these investment banks were forced to raise cash, they sold corporate bonds thereby exacerbating the widening of the negative CDS-bond basis.

An important feature of the dislocation in the CDS-Bond basis is the contemporaneous timing with the systematic cheapening of convertible debentures. Normally, there should be no relation between the CDS-bond basis and the cheapness of convertible debentures. Prior to the 2008 financial crisis, the correlation between the CDS-bond basis and convertible debenture cheapness was only -0.02 using weekly data from January 4, 2005 through September 12, 2008. The correlation spikes to 0.91 during the period

[27] This trade assumes financing at LIBOR and posting of 1% of capital with respect to the CDS and the interest rate swap, respectively. See various research reports from J.P.Morgan for commentary on the CDS-bond basis trade specifically and CDS generally.

September 19, 2008 – March 31, 2009, highlighting the crucial role that debt financing plays in arbitrage strategies that have little fundamental risk. Also, as with the cheapness of the convertible debentures, it took several months before the CDS-bond basis began to even approach historical levels, highlighting the slow movement of capital to arbitrage opportunities.

6. Special Purpose Acquisition Vehicles (SPACs)

Based on conversations with various prime brokers, SPACs were subject to high margin requirements, primarily for technical reasons related to shareholder voting procedures. SPACs, often called "blank check" companies, are publicly traded companies whose primary asset is a trust invested in short-term high-grade securities (typically Treasury bills). Managers of SPACs seek to buy operating companies using funds held in the trust account during a pre-specified period (typically two years). Once management decides on an acquisition candidate, they present the deal to the shareholders for approval. In nearly all cases, supra-majority shareholder approval (usually 70-80%) is required in order for management to proceed with the acquisition. If shareholders reject the acquisition proposal, management liquidates the trust account pro-rata to the shareholders. Importantly, if the acquisition receives approval, those shareholders voting against the deal are not forced to tag along and hold shares in the post-acquisition company. Rather, shareholders that vote against the acquisition and elect to "redeem" their shares receive cash representing their pro-rata portion of the trust value at the time of the acquisition.

Given the structure of SPACs, shareholders have a payoff that is equivalent to the payoff from holding a risk-free bond plus a call option. The option's expiration date corresponds to the end of the pre-specified deal period and the option strike price is equal to the expected per-share trust amount on the expiration date. This payoff is similar to that of a convertible debenture, but rather than bearing credit risk of the issuer, SPAC shareholders bear the risk of a trust account, largely invested in U.S. Treasury bills.

During late 2007 and early 2008, several billion dollars were raised in new SPAC issues and the primary holders were hedge funds. Figure 7 displays the median yield to maturity of SPACs and the

median excess yield over U.S. Treasury bills during January 2008 through September 2009. During the pre-Lehman failure, SPAC yields averaged 4.7 percent and 3.1 percent relative to Treasury bills. As a result of the financial crisis during the fall of 2008 and the revocation of debt financing by prime brokers, hedge funds that employed financial leverage aggressively sold SPACs as their expected return per dollar of equity capital was relatively low, a direct result of the high margin required by prime brokers. This aggressive selling occurred simultaneously with, and was a direct result of, reductions in financing of convertible debentures and the CDS-bond arbitrage trade described earlier. As displayed in Figure 7, the median annualized yield-to-trust of SPACs increased substantially reaching a peak close to 12% as hedge funds sold these relatively illiquid stocks in a market where there were no natural providers of liquidity. The primary risk to obtaining the high yields of SPACs is that the price could decline, and the holder, due to either a loss of equity capital or debt capital, would have to terminate the trade thereby realizing a loss. There are other risks associated with holding SPACs but these risks are largely miniscule. For example, there is no credit risk since the funds are held in U.S. Treasury bills or money market funds. There is the possibility that the trust funds could be impaired if the financial institution in which they are held fails. However, a number of SPACs had their trusts at Lehman Brothers at the time of Lehman's bankruptcy and none of these assets were impaired. Because the trust is not an asset of the financial institution holding the securities, creditors of the financial institution do not have a claim to the trust's assets. In the case of Lehman Brothers, the SPAC trusts were simply moved to other financial institutions. As the financial crisis ended and arbitrage capital returned to the SPAC market, SPAC yields eventually returned to lower levels, as shown in Figure 7, declining fairly continuously to roughly 3% at the end of the sample period, September 30, 2009. Given the extremely low risk in SPAC investments, they provide a direct estimate of the magnitude of mispricing that can occur when arbitrageurs are removed from the market.

7. Other Arbitrage Strategies Impacted by the Financial Crisis

Even arbitrage strategies that were not directly subject to substantially higher financing requirements were subject to selling pressure by hedge funds and proprietary trading desks attempting to generate cash to finance margin calls. This section describes the impact of the crisis on two such strategies, merger arbitrage and closed-end-fund arbitrage.

7.1. Merger Arbitrage

Upon the announcement of a merger, the stock price of the target firm appreciates considerably, yet typically trades at a small discount to the offer by the acquiring firm. Because of the substantial change in the expected distribution of returns associated with the target firm, many mutual funds and other holders of the target firm choose to sell their holdings soon after the merger announcement as the stock no longer fits their investment profile.[28] Merger arbitrageurs at hedge funds and Wall Street proprietary trading desks purchase the target shares after the merger announcement, thereby providing insurance against deal failure to the selling shareholders. In a cash merger, the arbitrageur simply buys the target shares and holds the shares until merger consummation. In the case of a stock merger, the arbitrageur also shorts the stock of the acquirer based on the exchange ratio in order to eliminate market risk.

Mitchell and Pulvino (2001) study a large sample of mergers over the period 1963-1998 and show that merger arbitrage is not immune to market risk in severely declining markets. Whereas Mitchell and Pulvino document a stock-market beta of roughly zero in most periods, they find that the beta to merger arbitrage increase to 0.50 during months in which the stock market declines by at least 4 percent. This increase in market risk is driven by cash mergers, particularly financing-contingent cash mergers, which are more subject to deal termination in the event of market downturns than are stock mergers. Mitchell, Pedersen and Pulvino (2007) discuss the impact of the October 1987 stock market crash on merger arbitrageurs. They show that deal spreads increased several-fold during the 1987 crash in response to

[28] Consider a mutual fund which invests in so-called growth stocks which have above-average growth potential. Once a cash merger has been announced or a stock merger with a non-growth acquirer, the target shares no longer offer the expected above-average growth potential, yet still bears substantial downside, albeit with low probability. Thus, the mutual fund manager will sell the target shares rather than hold a security inconsistent with the fund's mandate.

expectations of failed deals and negative re-pricings of deals. Using data on merger arbitrage holdings by Wall Street proprietary trading desks, Mitchell, Pedersen and Pulvino show that these desks were large sellers of target stocks in the aftermath of the 1987 crash, arguably exacerbating the increase in spreads due to the fact that these liquidity providers became liquidity demanders virtually overnight.

Given the previous empirical research on merger arbitrage and the extent of the widespread hedge fund deleveraging and intense pressure on the balance sheets of investment banks, it is natural to assume that merger arbitrage also realized a major dislocation during the 2008 financial crisis. Even though rehypothecation lenders to prime brokers were concerned with the illiquid securities such as high-yield corporate debentures and convertible debentures, merger arbitrage was a strategy in which hedge funds and investment banks could quickly reduce positions in and raise needed cash. To examine the impact of the 2008 financial crisis on merger arbitrage, we compute the median excess (relative to three month Treasury bills) spread of merger deals during the period January 2005 through March 2010 on a weekly basis. In light of the empirical research that the stock market beta to merger arbitrage is positive in severely declining equity markets and is driven largely by cash mergers, an analysis of stock mergers will better isolate the impact of hedge fund deleveraging and the shutdown of proprietary trading desks on merger arbitrage. Figure 8 displays median annualized spreads of stock deals using weekly data during January 2005 through March 2010. Despite the lower systematic risk, annualized spreads of stock mergers widened substantially during the financial crisis, and in particular the week of October 6-10, 2008 when the median spread for stock deals reached 14.2%, several standard deviations greater than the mean spread of 2.1% (standard deviation = 0.78%) for stock deals.[29] By comparison, the median spread on stock mergers in the aftermath of the October 1987 crash reached a maximum of 10.7% during the week of October 26-30, 1987, a period as described above when proprietary merger arbitrage desks suspended operations.

7.2. Closed-end-fund Discounts

[29] As a matter of anecdotal evidence, all of the 8 stock mergers with deal size in excess of $100 million which were pending as of September 15, 2008, the date of the Lehman bankruptcy, were consummated on the previously agreed terms.

Closed-end-fund (CEF) discounts have persisted for decades. Because they appear to violate the law-of-one-price, they have been widely studied. A host of papers provide various rational market and behavioral explanations for the CEF discount (among others, see the work by Malkiel (1977), Lee, Shleifer and Thaler (1991), Pontiff (1996), Gemmill and Thomas (2002), Ross (2002), and Berk and Stanton (2007)). A rational market explanation of the persistence of CEF discounts is based on agency costs, namely that the present value of the fees to CEF portfolio managers exceeds the value that they add as portfolio managers. A behavioral explanation of the CEF discount is that investor sentiment, specifically by noise traders who make irrational investment decisions, can cause closed-end-funds discounts to widen substantially. Because discounts may widen further, thereby imposing losses, rational investors are reluctant to attempt to force the discount to converge to zero.

Irrespective of the actual source of the discount, arbitrage in CEFs can be costly. Absent an explicit mechanism to force convergence, arbitrageurs have to passively wait until convergence occurs which can take an exceedingly long time and is a major risk in this type of arbitrage. During the 1990s, the SEC made several changes in proxy rules which decreased the costs of communication between shareholders and eventually led to attempts by activist hedge funds to force convergence of CEF discounts by taking action to convert CEFs to open-end funds. Bradley, Brav, Goldstein, and Jiang (2009) document that activist arbitrage activity has a substantial impact on CEF discounts.

Figure 9 displays the weekly median discount across equity CEFs during the period, January 2002 through March 2010. A minimum NAV of $100 million is required for inclusion in the sample resulting in an average of 77 CEFs in the sample at any given time. During the period, January 4, 2002 through September 12, 2008, the average discount was 7.5% with a standard deviation of 2.3%. As shown in Figure 9, the discount began to widen immediately after the Lehman bankruptcy, from 10.7% during the week of September 12 to 15.7% during the following week, and reached a maximum of 20.3% during the week of October 10. Recall from Section 3 that the week of October 10 is when Morgan Stanley reached its highest level of default probability during the financial crisis period. The 20.2% discount realized during the week of October 10, 2008 is considerably higher than the maximum discount of 13.0% during the pre-Lehman

period (January 2002 – September 12, 2008). The equity CEF discount remained high throughout the September 2008 – March 2009 financial crisis, eventually reverting to the historical levels as the financial crisis subsided.

We believe that the widening of the discount during the financial crisis was caused not so much by depressed equity markets, rather by hedge fund deleveraging. As hedge funds were forced to delever, they first unwound the relatively liquid securities in their portfolios—typically stocks such as CEFs and merger targets, and later sold illiquid securities such as corporate debt. In addition, because of their lack of capital, proprietary trading desks at Wall Street banks were forced to unwind convergence trades. Without buyers to offset the selling pressure by hedge funds and proprietary trading desks, CEF discounts widened and remained wide until financial markets stabilized.

8. Concluding Comments

In well-functioning capital markets, arbitrageurs ensure that differences in prices of substantially similar securities are small. By employing financial leverage, arbitrageurs are able to force even small pricing discrepancies to converge. One benefit of this activity is that it correctly sets relative prices thereby promoting the efficient allocation of resources in the economy. Periodically, however, market dislocations adversely affect arbitrageurs' abilities to force price convergence. An acute example occurred during the financial crisis of 2008 when debt financing was pulled from arbitrage hedge funds. As a result, rather than forcing prices of similar securities to converge, arbitrageurs were forced to liquidate existing positions causing the level of mispricing to increase. Clear mispricings on the order of 10-15% were commonplace, and in some markets, relative mispricings were far greater. Surprisingly, capital was very slow to flow into the void left by arbitrageurs resulting in persistent mispricings for months.

One of the byproducts of the 2008 market dislocation and the revocation of debt financing was the significantly negative performance of hedge funds. While many commentators view hedge funds as extremely risky investment vehicles, especially if they employ leverage, a closer examination of their

balance sheets suggest otherwise. Hedge funds which employ the strategies described in this paper buy securities which trade at a discount relative to directly-linked securities, and hedge via the linked security. Aside from the agency concerns discussed by Shleifer and Vishny (1997) regarding transparency of hedge fund trades, the risk on the left-hand side of the balance sheet is low, a direct result of the convergence nature of the portfolios' positions. For example, an unlevered convertible arbitrage (i.e. hedged with the underlying equity) portfolio has annualized volatility of 2%. This compares to a 15% volatility for the convertible long (i.e. without any hedge) portfolio and 30% for the portfolio of equities in the underlying issuers. Similarly, the CDS-corporate bond basis trade employed by many hedge funds has far less risk than a portfolio of corporate bonds.

Before the crisis, the low risk associated with arbitrage portfolios was reflected in both the amount and the cost of leverage afforded arbitrage portfolios. For some strategies such as convertible arbitrage, leverage levels exceeding 5:1 and borrowing rates similar to what is charged AAA corporate borrowers were not uncommon. The primary problem with hedge fund borrowing was not the amount or the cost, but the duration relative to the expected time to convergence of the arbitrage opportunities on the left-hand side of the balance sheet. Although market participants fully expected that overnight loans would be extended, rehypothecation lenders were under no obligation to do so. When the risk that Wall Street prime brokers would fail increased during the crisis (and when Lehman ultimately failed) rehypothecation lenders were protected not by the financial strength of their counterparty (Wall Street prime broker) but by the value of the pledged collateral. For liquid securities such as exchange-traded equities, this was not a problem as rehypothecation lenders had the ability to liquidate the collateral to cover loans. However, for slightly more illiquid and difficult-to-trade securities such as corporate bonds, where rehypothecation lenders lacked necessary infrastructure, they had no realistic choice but to temporarily cease lending to hedge funds. As a result, from an arbitrageur's perspective, seemingly long-term capital became truly short-term capital overnight. The rapid recall of debt capital prevented arbitrageurs from enforcing rational pricing of related securities and created enormous opportunities. Even for arbitrageurs with capital, there was substantial uncertainty regarding investor redemptions. For new investors contemplating an investment in a hedge

fund to capture these arbitrage opportunities, there was considerable uncertainty as to whether the crisis would continue to worsen causing short-term losses before gains could be realized. Because of this uncertainly on all fronts,[30] capital inflows to low-risk highly-profitable arbitrage strategies were very slow, causing prices of substantially similar securities to be substantially different for a long time.

[30] There was also the uncertainty created by the ban on shorting of financial institutions, which arguably was caused by panicked pleas from the premier investment banks to U.S. government officials. These bans created absolute havoc on the natural liquidity providers to corporations in need of capital. This ban dramatically increased the risk of the portfolio on the left-hand side of the balance due to delinking the arbitrage trades. We don't question the motives of the panicked pleas by the leaders of the Wall Street institutions as their job is to maximize shareholder wealth. The subsequent disruptions resulted in enormous arbitrage opportunities which they, ex-post, were able to capitalize on.

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Table 1: Summary Statistics for High-Money Convertible Debentures

Panel A: Crisis Period

	Average	*Median*
Moneyness	1.79	1.68
Difference between quoted price	0.46	-0.08
and conversion value	(0.114)	(0.404)
Difference between theoretical	11.03	11.04
value and quoted price	(<0.001)	(<0.001)
Expected remaining life (years)	2.21	1.70
Delta	0.92	0.92
Sample Size	17	17

Panel B: Pre-Crisis Period (January, 31, 2008)

	Average	*Median*
Moneyness	2.26	2.05
Difference between quoted price	4.67	3.86
and conversion value	(<0.001)	(<0.001)
Difference between theoretical	1.81	0.44
value and quoted price	(0.008)	(0.336)
Expected remaining life (years)	1.82	1.16
Delta	0.96	0.98
Sample Size	62	62

Panel C: Post-Crisis Period (March, 31, 2010)

	Average	*Median*
Moneyness	2.05	1.77
Difference between quoted price	5.71	1.83
and conversion value	(<0.001)	(0.002)
Difference between theoretical	3.88	1.55
value and quoted price	(<0.001)	(<0.001)
Expected remaining life (years)	1.91	1.52
Delta	0.96	0.96
Sample Size	46	46

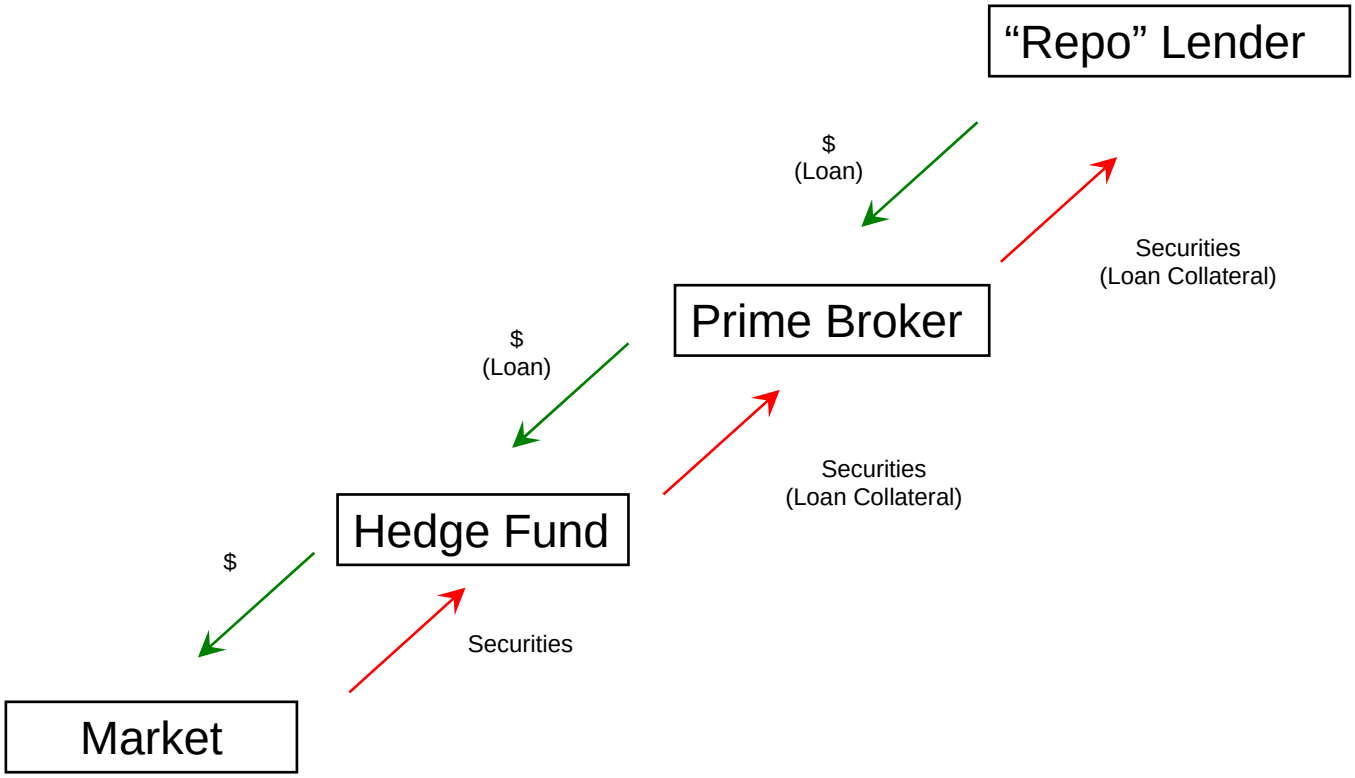
The Crisis Period panel displays summary statistics for 17 convertible debentures which had a moneyness (stock price / conversion price) greater than 1.5 on at least 5 days during the period, October 1, 2008 through December 31, 2008. The Pre-Crisis (Post-Crisis) Period panel displays summary statistics for 62 (46) convertible debentures which had a moneyness > 1.50 on January 31, 2008 (March 31, 2010). The statistics corresponding to each convertible debenture are calculated as of the date corresponding to the minimal difference between the quote price of the convertible debenture and the conversion value. P-values are displayed in parentheses (note, p-values for medians are based on bootstrapped estimates).

Table 2: Cross-Sectional Regression Analysis of Convertible Debenture Cheapness

	Column 1 Illiquidity Proxy = Issue Size	Column 2 Illiquidity Proxy = Credit Quality
Intercept	0.0315	-0.0460
	(0.74)	(-0.91)
Change in Credit Spread	-0.0001	-0.0001
	(-5.32)	(-5.78)
Change in Volatility	1.1687	1.1352
	(13.96)	(13.71)
Distance from Conversion Value	0.0068	0.0068
	(7.20)	(7.33)
Illiquidity Proxy	0.1244	0.1967
	(3.79)	(4.53)
Adjusted R-square	0.33	0.34
Number of Observations	465	465

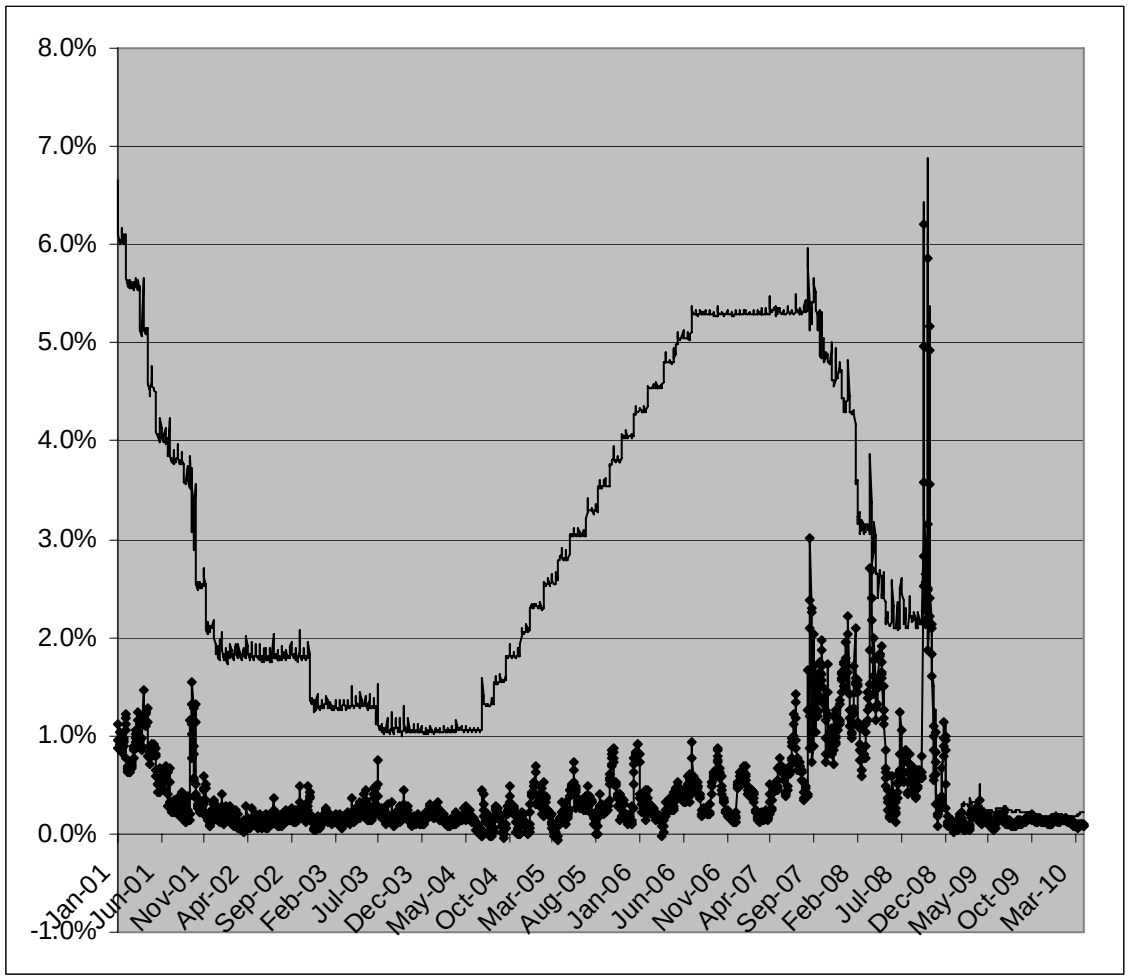
This table displays the results from a cross-sectional regression analysis of 465 convertible debentures where the dependent variable is the change in convertible debenture cheapness between August 31, 2008 and November 30, 2008. Change in credit spread is the difference in the credit spread (measured in basis points) between August 31, 2008 and November 30, 2008. Change in volatility is the difference in the volatility estimate between August 31, 2008 and November 30, 2008. The distance from conversion value is the difference between the quoted price and the conversion value of the convertible debenture as of November 30, 2008. The illiquid proxy is a dummy variable for small issues (< $250 million issue size) and for speculative issues (high-yield and non-rated).

Figure 1: Rehypothecation Lending



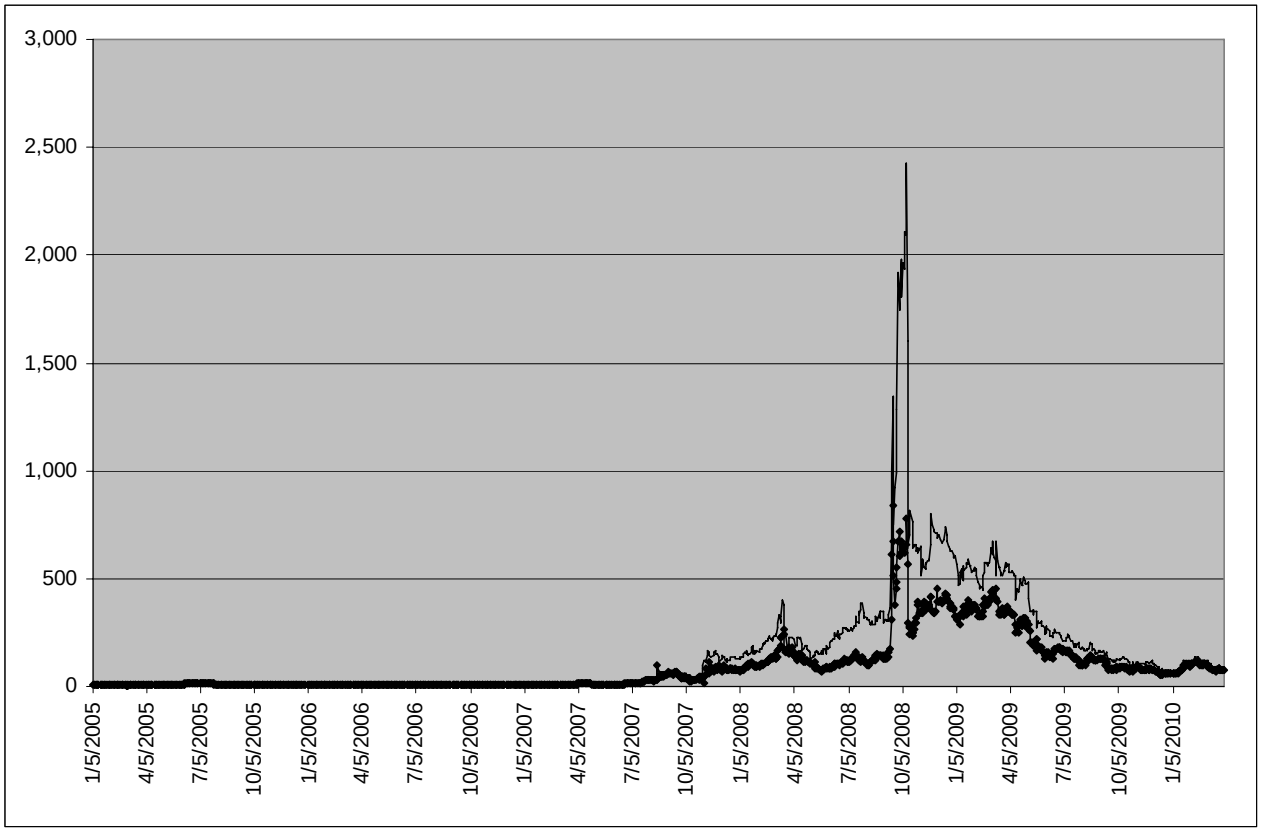
This Figure illustrates the rehypothecation lending process whereby the hedge fund borrows funds from the prime broker and posts securities as collateral to support the loan. The prime broker, acting as the intermediary, in turns borrows funds from another bank, providing the hedge fund's securities as collateral to secure its loan.

Figure 2: Overnight LIBOR Rates (January 2001- March 2010).



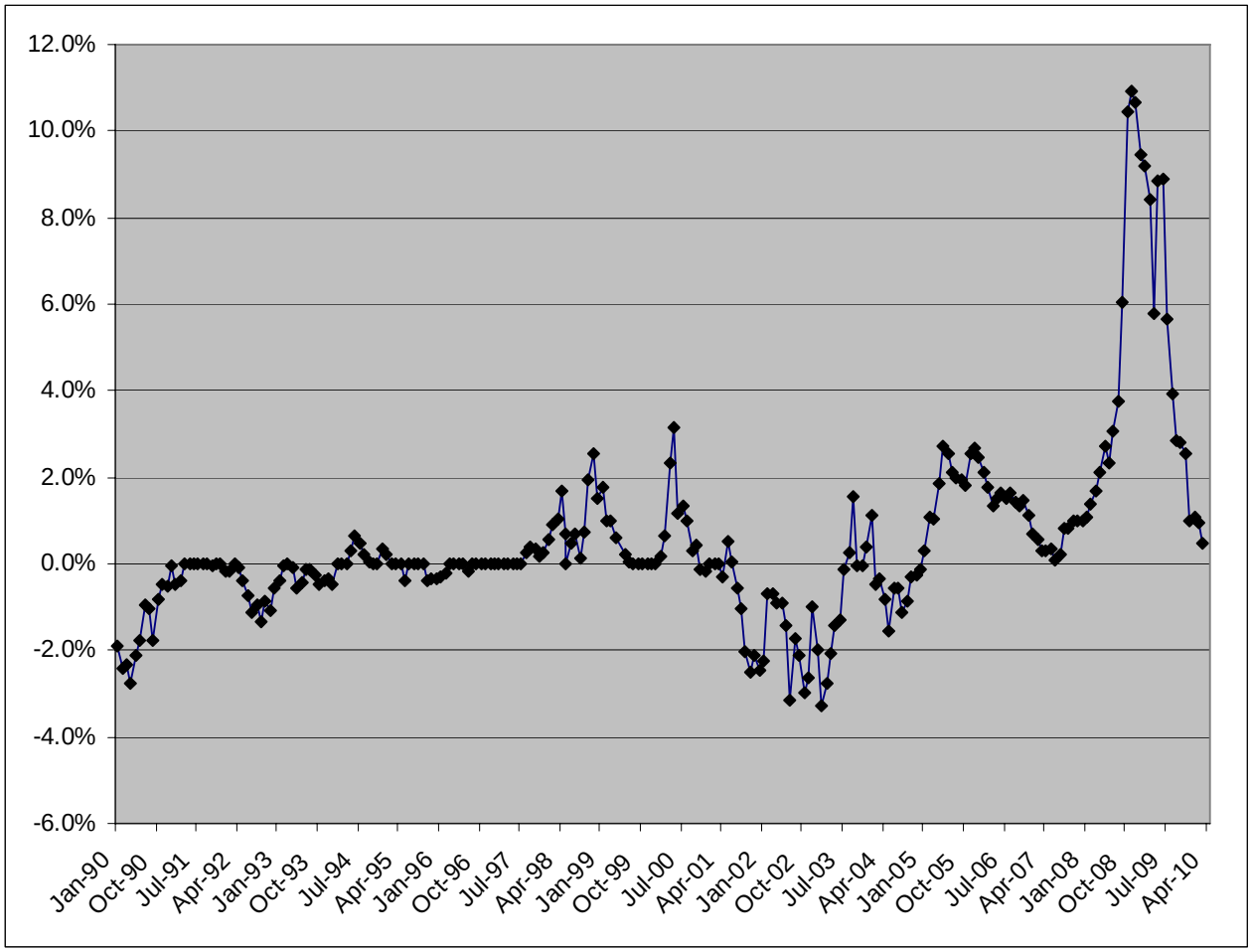
This figure displays the overnight LIBOR rate (single line) on a daily basis during January 2, 2001 through March 31, 2010, and the daily difference (line with diamonds) between the overnight LIBOR rate and the 28-day U.S. Treasury bill rate.

Figure 3: Credit Default Swap Spreads for Goldman Sachs and Morgan Stanley (January 2005 – March 2010)



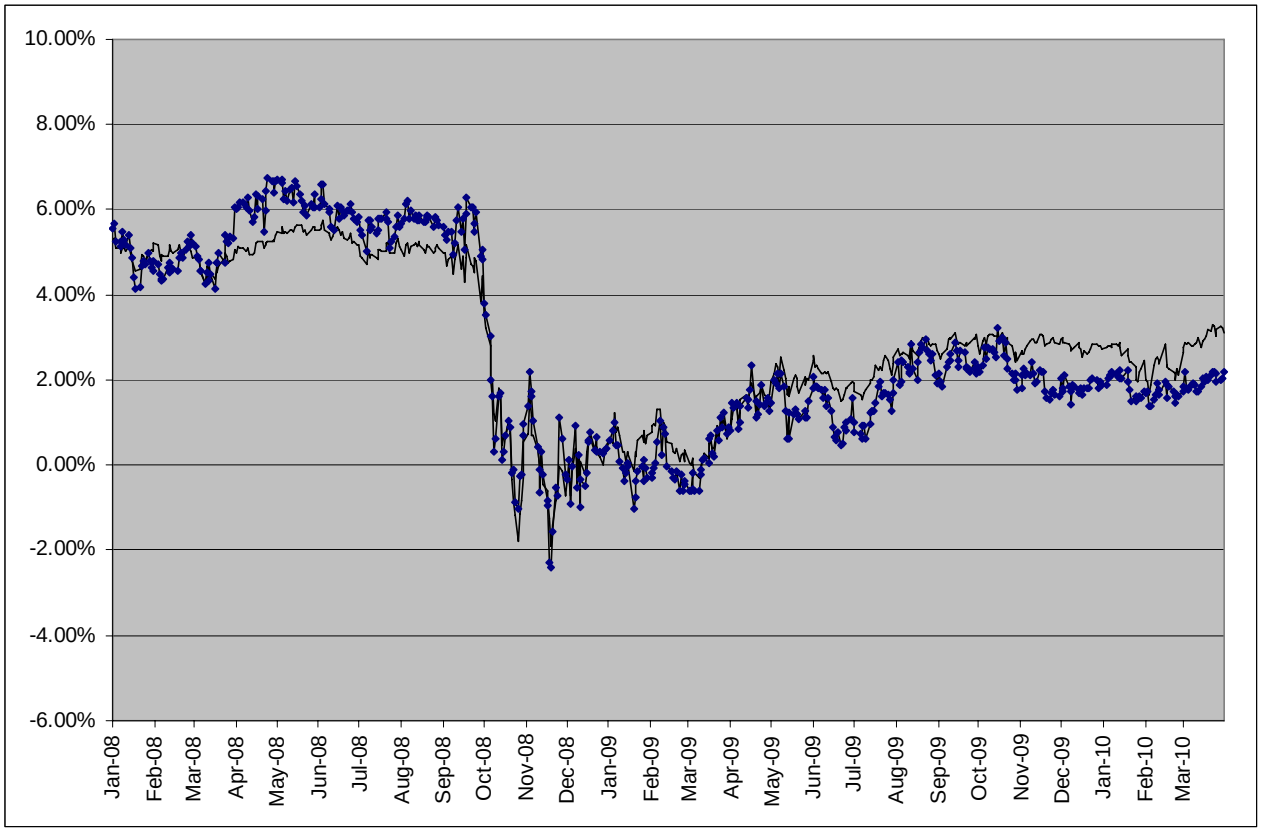
This figure displays the one-year CDS spreads (in basis points) for Goldman Sachs (line with diamonds) and Morgan Stanley (straight line) on a daily basis during January 2005 through March 2010. The CDS data was provided by J.P. Morgan.

Figure 4: Convertible Debenture Cheapness/Richness (January 1990 - March 2010)



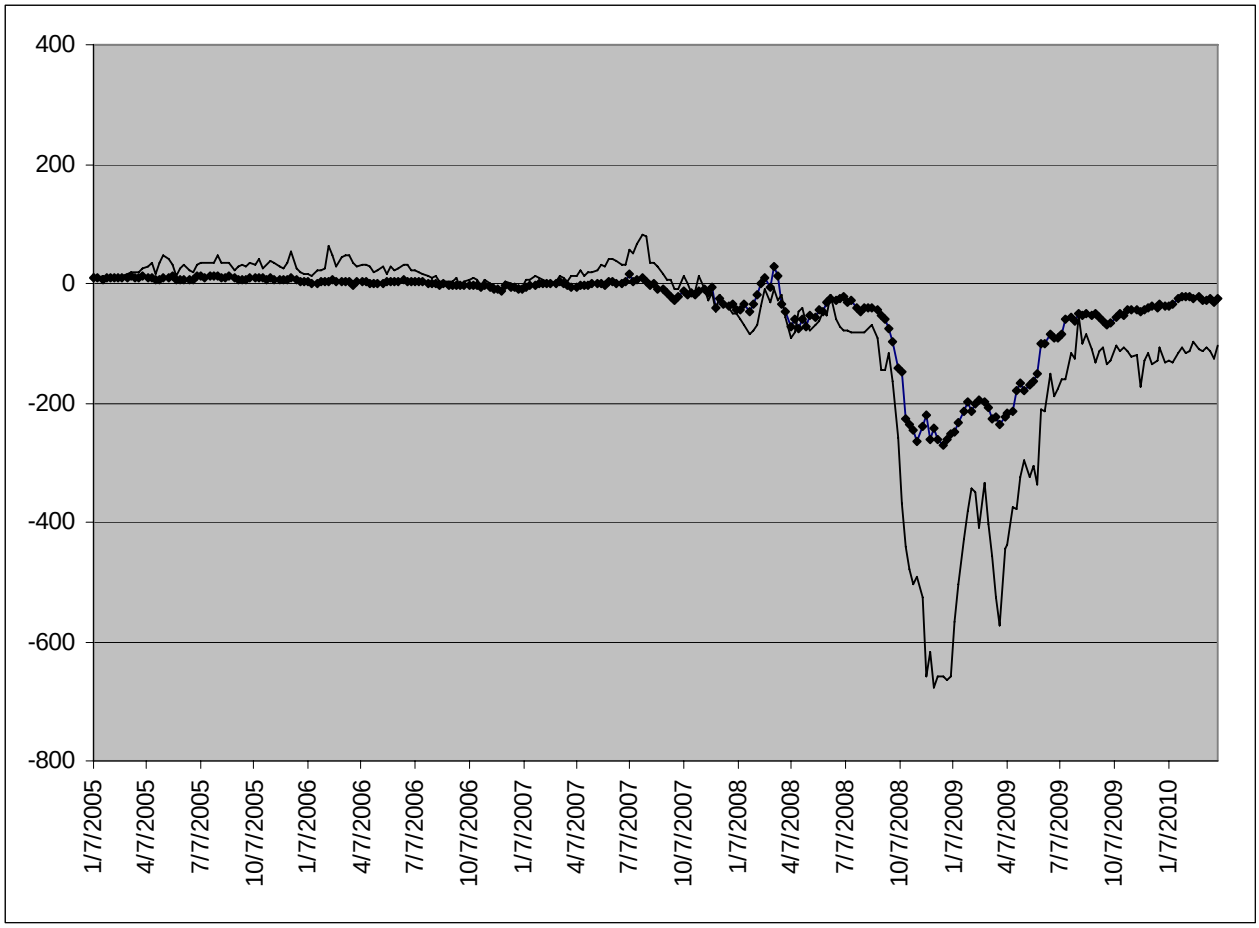
This figure displays the monthly median difference between the fundamental value of equity-sensitive convertible debentures and their traded prices during January 1990 through March 2010. We define equity-sensitive convertible debentures as convertibles with moneyness (ratio of issuer stock price to conversion price) > 0.64. Data on traded prices provided by *Value Line Investment Survey*s and various Wall Street investment banks. The fundamental or theoretical value of the convertible debentures is calculated using a finite difference model and input estimates (stock price, equity volatility, credit spread, and term structure of interest rates) corresponding to each convertible debenture at every point in time.

Figure 5: Comparison of Convertible Yields versus Straight Debt Yields



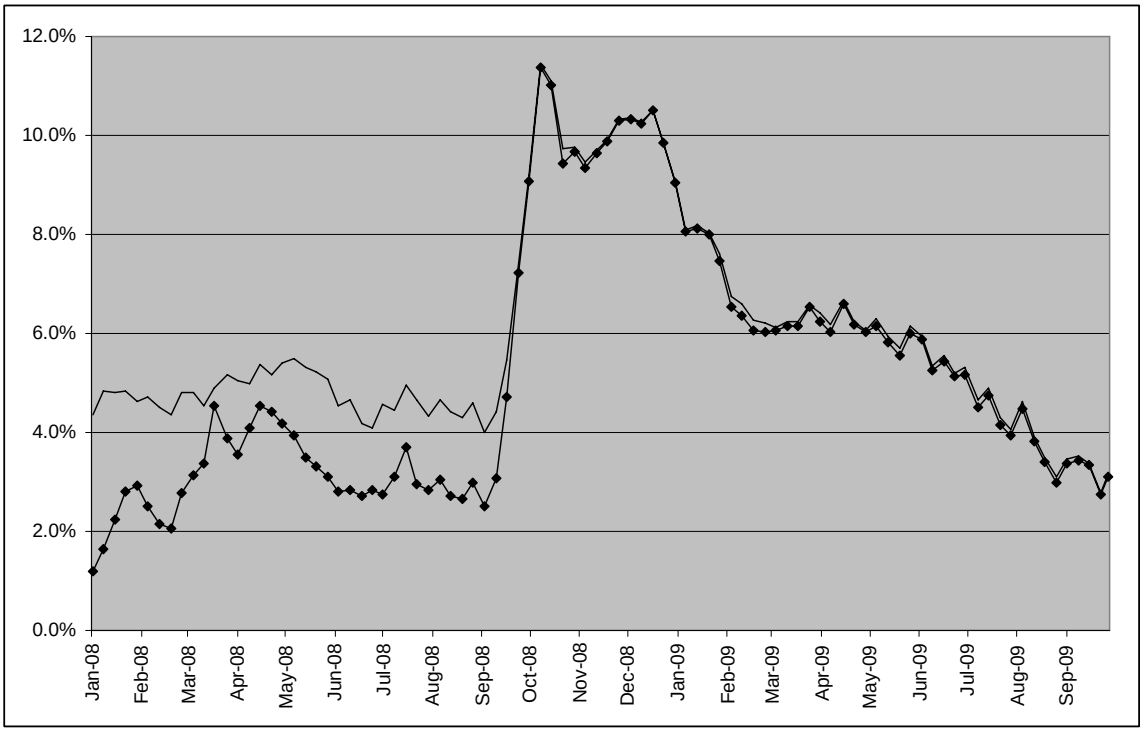
This figure displays the average (straight line) and median (line with diamonds) difference in yields between straight debt and busted (trading below par) convertible debentures of the same issuers.

Figure 6: CDS – Corporate Bond Basis (January 2005 – March 2010)



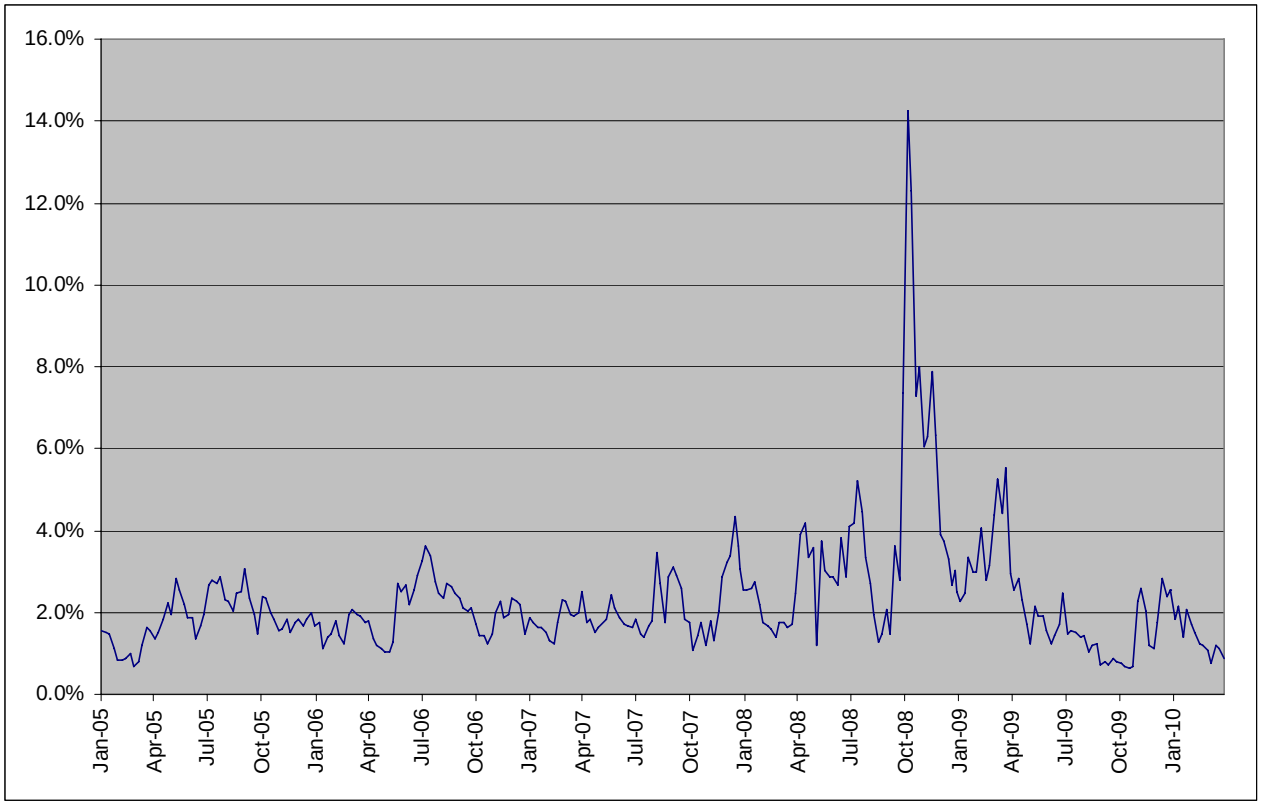
This figure displays the CDS – Corporate Bond Basis (in basis points) for High-Yield Issues (average of 204 issues per week) and Investment-Grade Issues (average of 491 issues per week) during January 2005 through March 2010. A positive (negative) basis is when the implied spread from the CDS exceeds (is less than) the implied credit spread from the corporate bond. Data is provided by J.P. Morgan.

Figure 7: SPAC Yields (raw and excess to Treasury Bills)



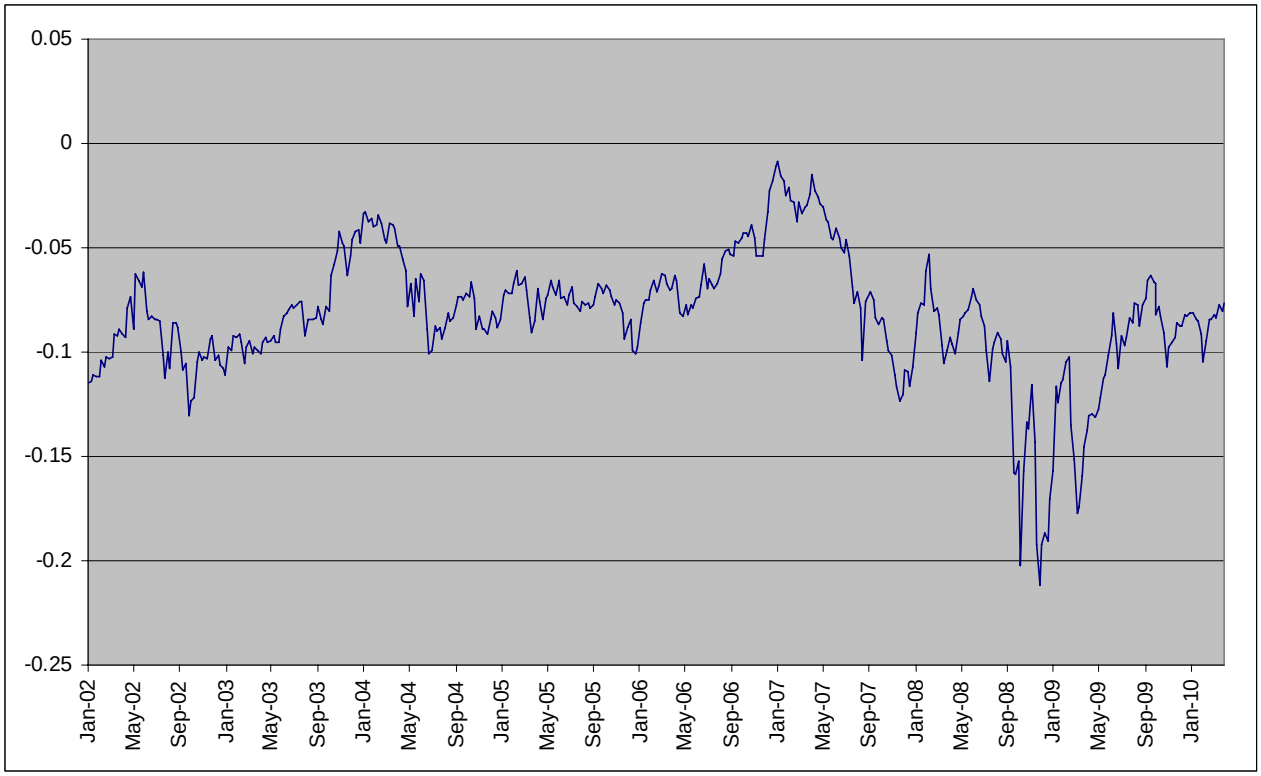
This figure displays the yields of Special Purpose Acquisition Vehicles (SPACs – straight line) and the difference between SPAC yields and U.S. Treasury bills (line with diamonds) during January 2008 through September 2009.

Figure 8: Median Excess Spreads of Stock Merger Deals (January 2005 – March 2010).



This figure displays the median excess (relative to U.S. Treasury bill yields) spread (percentage difference between the offer by the acquirer and the stock price of the target firm) of stock merger targets during January 2005 through March 2010.

Figure 9: Median Discounts for Equity Closed-End-Funds (January 2002 – March 2010)



This figure displays the median discount for equity closed-end-funds during January 2002 through March 2010. When the discount is negative, the NAV of the underlying assets of the fund exceeds the traded value of the fund.