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Arbitrage crashes and the speed of capital ☆

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ABSTRACT

The imminent failure of prime brokers during the 2008 financial crisis caused a sudden decrease in the leverage afforded hedge funds. This decrease resulted from the asymmetrical payoff to rehypothecation lenders—the ultimate financiers, through prime brokers, to hedge funds. Seemingly long-term debt capital became short-term capital creating a duration mismatch between left-hand side arbitrage opportunities and right-hand side liabilities. Consequently, arbitrageurs became unable to maintain similar prices of similar assets. Mispricing magnitudes, and the time required to correct them, reflect the role of arbitrageurs in maintaining accurate prices during normal times and offer an estimate of discounts at which assets transact during crises.

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 might 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, and if they are unable to replace the lost debt capital with new equity capital, they could be unable to force prices of similar assets to the same level. Furthermore, because the benefits from an orderly liquidation accrue to hedge fund investors and not to hedge fund lenders, hedge fund lenders could force rapid liquidations. Although doing so is unlikely to maximize liquidation proceeds, forced selling imposed by lenders to hedge funds could mitigate the probability of debt impairment associated with near-term deterioration in asset values. If the sudden rescission of debt capital simultaneously affects many arbitrageurs, asset sales could be made to non-arbitrageurs, possibly at fire sale prices (Shleifer and Vishny, 1992). As a result, 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 arbitrage hedge funds experienced a sudden loss of debt capital, causing arbitrage spreads to widen, inflicting losses and making it difficult for affected funds to raise equity capital.[1] Arbitrage funds responded by selling assets, often at significant discounts to fundamental values.

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[1] Hedge fund losses during the crisis were extraordinarily severe. According to Hedge Fund Research, hedge funds lost 19% in 2008, most

We focus on arbitrage strategies commonly employed by hedge funds involving corporate securities, including convertible debenture arbitrage, credit default swap (CDS)-corporate debenture arbitrage, closed-end fund (CEF) arbitrage, merger arbitrage, and Special Purpose Acquisition Company (SPAC) arbitrage. None of these is truly an arbitrage strategy; the securities underlying the trades are merely related, not identical. However, the underlying securities are similar enough to provide a reasonably reliable estimate of discounts to fundamental values at which assets were sold.

In addition to presenting the level of mispricings, we show the time required for capital to flow into the void left by hedge funds. Seemingly risk-free arbitrage opportunities offering extraordinary expected returns were available for several months in the wake of the 2008 financial crisis, assuming that an arbitrage investor could access equity or debt capital to invest in such opportunities. Even investors with available capital that were not directly affected by the rescission of debt financing were unable to offset the selling pressure from hedge funds. Furthermore, unconstrained 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, namely the off-balance sheet funding of investment bank's prime brokerage groups via rehypothecation of hedge funds' assets, and the rapid retraction of rehypothecation lending in the aftermath of the Lehman bankruptcy. Sections 4–6 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 that reduced debt financing to hedge funds had on other arbitrage strategies such as merger arbitrage and closed-end fund arbitrage. Section 8 concludes.

2. Related literature

Shleifer and Vishny (1992) examine effects of financial distress on asset liquidation values. According to their model, firms that respond to financial distress by selling assets risk doing so at fire sale prices. Fire sales are most likely to occur when the assets are industry-specific and when other industry-insiders are also distressed. In this situation, industry-insiders lack the financial resources necessary to purchase distressed firms' assets and the assets are instead sold to industry-outsiders. Because industry-outsiders do not employ the assets in their first-best use, they purchase the assets at prices below fundamental values. As discussed throughout this paper, a significant contributor to the dislocation across arbitrage markets during the 2008 crisis was the revocation of prime brokerage financing used by arbitrage hedge funds. When this short-term debt financing was revoked, hedge funds were placed into immediate financial distress, and they responded by selling assets. Because their peers were also financially distressed, hedge funds sold assets at steep discounts to their fundamental values.

Faced with the prospect of meeting margin calls by selling assets to industry-outsiders at steep discounts, hedge funds could have alternatively raised equity capital. Shleifer and Vishny (1997) discuss problems associated with this solution. In their model, performance-based investors redeem capital from arbitrageurs following negative performance, often the precise time when expected returns are highest. Consequently, instead of responding as predicted in textbooks by contributing additional capital to support spread-compressing trades, investors redeem capital and force arbitrageurs to reduce positions and destabilize 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 focuses on the asset side of the balance sheet (e.g., 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 could still rationally redeem capital if they expect withdrawals by other investors 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. Among others, theoretical research by Brunnermeier and Pedersen (2009), Garleanu and Pedersen (2011), Gromb and Vayanos (2002), and Liu and Mello (this issue) model the feedback mechanism between investors and arbitrage opportunities in light of market frictions.

Empirical work on limited arbitrage focuses 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. For example, research by Baker and Savasoglu (2002), Lamont and Thaler (2003), Mitchell, Pulvino, and Stafford (2002), and Pontiff (1996),

(*footnote continued*)
of which occurred during the aftermath of the Lehman Brothers bankruptcy in September 2008. During the prior 18-year period tracked by Hedge Fund Research, hedge funds had only one losing year, a small loss of 1% in 2002.

among others, empirically show limits of arbitrage. Overall, these papers provide substantial support for the influential theoretical work by Merton (1987) and Shleifer and Vishny (1992, 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 work by Mitchell, Pedersen, and Pulvino (2007), who study merger arbitrage during the stock market crash of 1987 and convertible arbitrage in 2005, a time when the convertible market imploded following investor redemptions (e.g., 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 in turn demand liquidity.

In this paper, we extend the empirical research on the right-hand side of arbitrageurs' balance sheets 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, can greatly inhibit arbitrageurs' abilities to maintain prices of similar assets at similar levels. For example, unlike the 2005 crisis in the convertible market when the negative price impact from rapid selling was at least partially internalized by parties causing the selling (e.g., redeeming investors), parties forcing convertible sales during the 2008 crisis (e.g., hedge fund lenders) had little incentive to maximize sale proceeds. Instead, because they were exposed to deterioration in asset values yet would not benefit from appreciation in asset values, hedge fund lenders forced quick and indiscriminant security sales. This forced deleveraging was particularly problematic in 2008, when, unlike the 2005 convertible crisis that was confined to the convertible market, capital constraints affected investors across asset classes. As a result, potential buyers of convertible bonds such as multi-strategy hedge funds that were close to first-best users of the assets were unable to fill the void left by selling arbitrageurs, and relative prices reached levels outside of the expected distribution.

3. Hedge fund capital structure

Unlike mutual funds and other highly regulated investment vehicles, hedge funds that engage in arbitrage investments as analyzed in this paper use significant leverage to increase the expected returns. In most cases, hedge funds obtain their debt financing from prime brokerage operations of large investment banks such as Goldman Sachs and Morgan Stanley.[2] This section describes the financing arrangement between hedge funds and prime brokers, particularly the role of rehypothecation, followed by a discussion of the impact of the Lehman bankruptcy in September 2008 on the prime brokerage financing of hedge funds.

3.1. Prime brokerage debt financing

Prime brokers provide a bundled package of services to hedge funds including capital introductions, clearing and custody, risk management, office space, securities lending, trading services, and, most notably, debt financing.[3] The primary terms that define the financing arrangement are the margin fee charged to the hedge fund by the prime broker, the amount of margin or collateral required (also referred to as the haircut), and the duration of the agreement.

In recent years, prime brokers charged margin fees of roughly 20–30 basis points in excess of the federal funds rate (interest rate at which banks lend balances out of the Federal Reserve to other banks) to their largest hedge fund clients.[4] The haircut associated with the margin loan varies considerably based on the risk of the security. For example, the haircut on Treasuries or investment-grade bonds is typically less than 5%. Conversely, haircuts up to 100% are not uncommon for small, illiquid equities or distressed corporate bonds. In a typical prime brokerage agreement, the terms are subject to daily adjustment depending on changes in the portfolio and overall economic conditions. Longer-term financing is available. However, it generally requires a substantially higher financing rate, is typically of short duration (e.g., a few months), and contains numerous positive and negative covenants providing outs for the lender. For example, a typical negative covenant violation is a significant decrease in the fund's net asset value resulting from poor fund performance. This negative covenant allows the lender to force a hedge fund to liquidate even when investment opportunities are attractive.

By granting the prime broker first lien on all securities and cash held by the prime broker (a practice known as hypothecation), hedge funds are able to obtain debt financing at rates slightly above the risk-free rate. An important feature of the standard prime brokerage agreement is that the hedge fund grants the prime broker the right to rehypothecate the hedge fund's securities as collateral for a loan to the prime broker by a third party. Specifically, Rule 15c3-2 of the 1934 Securities Exchange Act allows the prime broker to rehypothecate up to 140% of a margin customer's loan balance. Thus, if a hedge fund has $100 million in investor capital and borrows $200 million from the prime broker to purchase a total of $300 million in securities, Rule 15c3-2 permits the prime

[2] Alternatively, the hedge fund could issue long-term debt, but this form of debt financing is uncommon. An exception is the $2 billion investment-grade note offering by Citadel Investment Group in 2006.

[3] Hedge funds are not required to trade through their prime brokers but can trade through a multitude of executing brokers who in turn coordinate transactions with the prime brokers. In addition, hedge funds often have more than one prime broker.

[4] Given the unregulated nature of hedge funds, there is no official margin fee rate, and thus estimates are based on our conversations with officials of prime brokers and hedge funds.

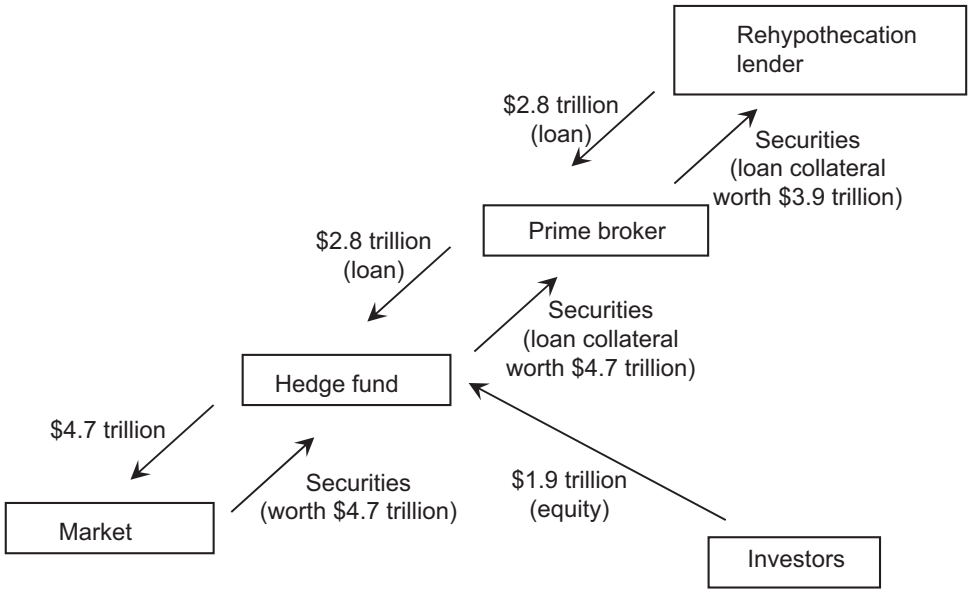

Fig. 1. Rehypothecation lending. This figure illustrates the rehypothecation lending process whereby hedge funds borrow from prime brokers and post securities as collateral to support the loan. Prime brokers, acting as intermediaries, in turn borrow funds from other banks and financial institutions, providing hedge funds' securities as collateral to secure the loans.

broker to rehypothecate up to $280 million (140% of the hedge fund's debit balance) of the total $300 million hedge fund assets. In aggregate, Rule 15c3-2 prohibits investment banks from obtaining financing in excess of the total financing provided to their prime brokerage clients, and this aggregate limit is the primary constraint on prime brokerage borrowing.

Prior to the financial crisis, virtually no mention is made of the role of rehypothecation in the financing of hedge funds, either in the financial press or academic research. Recent research by Singh and Aitken (2010) examines Securities and Exchange Commission (SEC) 10-Q reports from the seven largest US investment banks with prime brokerage operations and estimates that, as of the end of 2007, roughly $4.5 trillion of collateral (largely owned by hedge funds) at these investment banks was rehypothecated by their prime brokerage groups. Fig. 1 illustrates the important role of rehypothecation in the financing of hedge funds. According to Hedge Fund Research, roughly $1.9 trillion was invested in hedge funds as of year-end 2007. Assuming leverage [measured here as long value/net asset value (NAV)] of 2.5, hedge funds owned $4.7 trillion of securities at the end of 2007 and thus received debt financing of $2.8 trillion from their prime brokers.[5] Assuming that hedge funds hold all of their assets in margin accounts and that prime brokers rehypothecate the maximum 140% of customer debit balances pursuant to Rule 15c3-2, prime brokers are able to rehypothecate $3.9 trillion of securities and secure $2.8 trillion of debt on an off-balance sheet basis.[6] In summary, as illustrated by Fig. 1, investment banks do not use their own balance sheets to fund their prime brokerage operations. Instead, investment banks rely on off-balance sheet financing by rehypothecating client securities to finance their hedge fund customers.

According to various studies (Singh and Aitken, 2010; Gorton and Metrick, this issue; Hordahl and King, 2008), the amount of short-term financing obtained by US investment banks is roughly $10 trillion at the end of 2007. In particular, the investment banks rely on the interbank lending market and on the repo market to finance their assets, including securities held by their proprietary trading desks.[7] Like rehypothecation, a repo is a short-term (duration often less than 1 month) securitized loan whereby the investment bank posts securities as collateral to obtain cash. According to Hordahl and King (2008), in addition to the off-balance sheet financing of their prime brokerage clients, US investment banks funded half of their proprietary assets using repo markets. Most of the securities used to fund repos are Treasuries, although corporate securities are also used at higher levels of collateralization. Buyers of

[5] No reliable measure exists of hedge fund leverage, as estimates are largely based on surveys of hedge funds and of prime brokers. Because the larger hedge funds have multiple prime brokers, it is virtually impossible for an individual prime broker to know clients' actual leverage levels. We assume 2.5 leverage based on conversations with officials at hedge funds and prime brokers, but do not consider this estimate as highly accurate. Singh and Aitken (2010) assume leverage of 2.0 but do not disclose their source. Hedge Fund Research, in a special leverage report (*Hedge Fund Leverage Q1 2010*), estimates leverage of 2.6, on a value-weighted basis, as of the first quarter of 2010.

[6] As indicated above, investment banks are limited in aggregate to borrow only as much as they lend to prime brokerage clients.

[7] While Singh and Aitken (2010) refer to the aggregate securitized financing market as the shadow banking system, Gorton and Metrick (2011) label it securitized banking. In addition to the referenced work, see Duffie (2010) and Pozsar, Adrian, Ashcraft, and Boesky (2010) for comprehensive discussions of this marketplace.

repos, as well as funders of rehypothecated securities, include money market funds, banks, insurance companies, and corporate treasurers. These suppliers of capital find repo markets and rehypothecation lending to be an attractive place to store excess cash and realize a return in excess of the risk-free rate.

3.2. The failure of Lehman and hedge fund debt financing

The bankruptcy of Lehman Brothers on September 15, 2008 is the largest bankruptcy filing in US history. In addition to the parent company filing for protection from creditors, Lehman's UK subsidiary, Lehman Brothers International Europe (LBIE), whose primary business was prime brokerage services, also filed. However, Lehman's US broker–dealer did not seek bankruptcy court protection. This distinction is important because, unlike in the US, no statutory limits exist on the amount of customer securities that a UK prime broker can rehypothecate. Because of LBIE's unrestricted rehypothecation rights, LBIE could offer clients higher levels of leverage than the US broker–dealer that was subject to Rule 15c3-2's more stringent rehypothecation requirements. In the immediate aftermath of the Lehman bankruptcy filing, rehypothecation lenders to LBIE began to quickly sell securities provided as collateral by Lehman's hedge fund clients.[8] As a result, LBIE clients became general unsecured creditors of LBIE. Because Lehman's US broker–dealer did not seek bankruptcy court protection, its clients avoided a similar fate.

The motivation by LBIE's creditors to immediately sell rehypothecated securities was caused by two primary factors: (1) sharply increasing risk, and (2) lack of infrastructure to manage the securities. Portfolios managed by hedge funds had far lower risk than the actual securities rehypothecated by Lehman. Consider, for example, a deep in-the-money convertible debenture with a corresponding short position in the underlying stock. Because the convertible debenture is deep in the money, the hedged position has minimal fundamental risk as the hedge fund is indirectly long the underlying stock via the convertible debenture and short a similar amount of the underlying stock. Even the extinguishment of the entire conversion option would not expose the hedge fund to extraordinary losses and thus the prime broker would require only a small haircut, often less than 5% of the long position.[9] Whereas portfolios managed by hedge funds had low fundamental risk because of the hedges of linked securities, the hedged portfolios did not transfer to Lehman's rehypothecation lenders upon the bankruptcy filing. Instead, only the long positions that had been rehypothecated were transferred. Because of the delinking of the portfolio positions, previously hedged positions became unhedged and rehypothecation lenders received portfolios several times riskier than the underlying hedge fund portfolios. Given the resulting increase in risk, previously small haircuts became extraordinarily large.[10] Moreover, the news of the Lehman bankruptcy negatively impacted the stock market, with the Standard & Poor's (S&P) 500 declining 4.7%, thus reducing the cushion provided by the haircuts on the rehypothecated securities. The 4.7% decline in the S&P 500 would generally not have a noticeable effect on the risk of hedge funds' arbitrage portfolios, but because of the separation of the short and long positions, the market decline had an adverse effect on the performance of the collateral. Rehypothecation lenders that were used to dealing with financially strong counterparties and low-risk portfolios suddenly faced far greater risk. The default of Lehman removed the counterparty that separated rehypothecation lenders from their collateral, and as values fell, the lenders had no feasible alternative but to immediately sell the collateral.[11] As noted by Duffie (2010), money market funds in the US are required by the SEC to immediately sell collateral in the case of counterparty failure.[12]

In the wake of the Lehman failure, the cost of short-term financing increased substantially for investment banks. The normally highly liquid, and nearly risk-free, unsecured interbank market virtually shut down as LIBOR (London Interbank Offered Rates) spiked from 2.1% on September 12, 2008 to 6.4% on September 16, 2008.[13] As

[8] According to one Lehman hedge fund client we spoke with, the day following Lehman's bankruptcy, the hedge fund witnessed on its Bloomberg terminal the liquidation of its convertible debenture portfolio.

[9] An example is a convertible debenture issued by Alexion Pharmaceuticals with the following terms: 1.375% coupon, conversion ratio of 63.5828, conversion price of $15.73, and a maturity date of February 1, 2012. On Friday, September 12, 2008, Alexion's stock price closed at $41.53, and thus its convertible debenture is deep in the money. Based on quotations provided by Wall Street trading desks, the price of the Alexion convertible is $267.05 (convertible bonds are quoted based on $100 face value even though the actual face value is $1,000), slightly higher than its conversion value of $264.02. Based on a theoretical delta of 0.99, the value of the short position in the underlying stock is $261.42. Thus, even in the improbable case of an immediate jump to default and with zero recovery value on the convertible debenture or the outright collapse of the conversion option, the hedge fund would realize a maximum loss of 23% with leverage of 20.0 (5% haircut), and the rehypothecation lender would not be subject to any losses.

[10] For example, the volatility of the hedged Alexion convertible discussed in note 9 is close to zero given the convertible was deep in-the-money and trading close to conversion value. In contrast, the long position, roughly equivalent to the underlying stock, experienced annual volatility of 40%.

[11] Starting with the collapse of Bear Stearns in April 2008, and especially in the weeks prior to Lehman's failure, rehypothecation lenders began requiring larger haircuts on their loans to ensure they were adequately protected. See Gorton and Metrick (2011) for an analysis of repo rates during the financial crisis of 2007 and 2008.

[12] As an alternative to immediately selling repossessed collateral, rehypothecation lenders could have partially hedged their positions by shorting equity or purchasing CDS protection. They likely chose not to do so given their lack of necessary infrastructure and the fact that they held sufficient collateral such that, even at sharply lower prices, they would not be impaired. Moreover, as pointed out by Duffie (2010), some rehypothecation lenders such as money market funds have restrictions per the Securities and Exchange Commission on the types of securities they can hold and thus would be required to immediately sell the collateral in case of counterparty failure. We have no knowledge that any of the Lehman rephypothecation lenders realized material losses as a result of the Lehman bankruptcy.

[13] Moreover, as investors greatly increased their exposure to US Treasuries, the 1-month Treasury yield moved from 1.4% on September 12, 2008 to 0.1% on September 17, 2008.

analyzed by Gorton and Metrick (2011), even secured short-term repo financing ceased during the crisis. Between 2007 and the period preceding Lehman's bankruptcy, repo haircuts increased from less than 1% to approximately 25%. Immediately following Lehman's bankruptcy repo haircuts increased to 45% (Gorton and Metrick, 2011). This dramatic increase in repo haircuts reflected the difficulty that Lehman's counterparties had selling illiquid securities, particularly convertible debentures and high-yield corporate bonds, without taking steep discounts from where these securities had previously traded. As a result, it became nearly impossible for investment banks to obtain repo financing on securities other than Treasuries.

The greatly increased costs of financing their operations and balance sheets, including those of their hedge fund clients, affected even premier investment banks such as Goldman Sachs and Morgan Stanley and brought these investment banks to the brink of failure. To illustrate the impact of losing short-term financing, 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 change in CDS pricing structure generally happens when credit spreads approach 1,000 basis points (bps) reflecting a situation in which the firm is near financial distress. On October 10, 2008, the 5-year CDS for Morgan Stanley traded at 28 points up-front, implying that 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 5 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 5 years was 16.4% and 59.2%, respectively.[14] Fig. 2 displays daily credit spreads, based on 1-year CDS, for Goldman Sachs and Morgan Stanley during January 2005–December 2010. For both firms, the credit spread implied from the 1-year CDS was near zero (average credit spread less than 20 basis points) during 2005–2007 suggesting 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 the extreme levels experienced in the wake of the Lehman failure.[15]

Not only were the investment banks unable to finance their own securities via the secured repo market, but investment banks were also subject to widespread retraction by rehypothecation lenders in financing their prime brokerage hedge fund clients. Given the increased risk of default by the investment banks, as proxied by the CDS market, the counterparty risk increased substantially to the rehypothecation lenders. Given their experience selling illiquid securities in a downward spiraling market following Lehman's bankruptcy, rehypothecation lenders terminated their financing lines with the investment banks. Investment banks were forced to use their limited access to the rehypothecation market to finance their own balance sheets. As a result, investment banks were unable to finance their hedge fund clients and, in turn, required their hedge fund clients to quickly reduce leverage. The amount of rehypothecation at the leading US investment banks was roughly $4.5 trillion at the end of 2007. By November 2008, according to Singh and Aitken (2010), the level of rehypothecation had plummeted to $2.1 trillion.[16] Moreover, based on our conversations with officials of prime brokers, rehypothecation lenders would no longer accept relatively illiquid securities such as convertible and high-yield corporate bonds as collateral. In addition, we learned from various prime brokerage officials that the forced deleveraging was immediate in many cases, resulting in portfolios being liquidated.[17] The prime brokers were also subject to considerable pressure from their less levered hedge fund clients. Whereas Rule 15c3-2 precludes US prime brokers from using hedge fund client assets as collateral to finance their own operations such as proprietary trading, it does allow the prime broker to use excess cash of less levered hedge funds to finance the assets of highly levered hedge funds. Consequently, less levered hedge funds began to sweep excess cash out of the prime brokerage accounts and into third-party custodial accounts, further restricting prime brokers' access to capital and contributing to the forced deleveraging of hedge funds by their prime brokers.[18]

Although prime brokers generally do not provide data showing the amount of debt financing provided to hedge fund clients, we obtain data for one large convertible

[14] Even with an assumed recovery rate of 0%, implied default probabilities were high at Morgan Stanley: 13.4% for a 1-year and 51.4% for a 5-year period, respectively.

[15] On September 17, 2008 John Mack, Chief Executive Officer (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….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.

[16] Notably, for Morgan Stanley, the largest participant in the rehypothecation market, the level of rehypothecation declined from roughly $950 billion at the end of 2007 to $300 billion in November 2008.

[17] 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 client exodus 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 relations typically takes several weeks and was therefore not an option in terms of responding to the forced exit of other prime brokers.

[18] Because the primary constraint on borrowing by prime brokers via rehypothecation is the aggregate borrowings by the prime broker's clients, the removal of excess cash by less levered hedge funds would normally not constrain the prime broker. But as repo haircuts to investment banks increased beyond 40% in the wake of the Lehman failure, investment banks were forced to use the excess cash of their less levered hedge fund clients to support their overall prime brokerage assets.

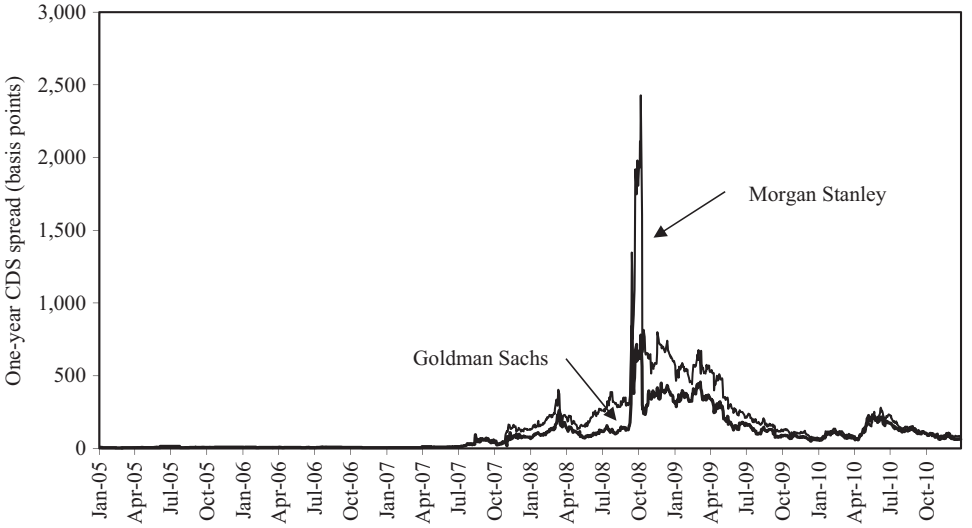

Fig. 2. Prime broker credit spreads. This figure displays the 1-year credit default swap (CDS) spreads (in basis points) for Goldman Sachs and Morgan Stanley on a daily basis during January 2005 through December 2010. CDS data provided by J.P. Morgan.

arbitrage hedge fund that used six prime brokers.[19] The data set consists of 588 convertible debentures with a total of 27,421 end-of-month haircuts over the period June 2008–December 2010. For each convertible debenture corresponding to each month during the sample period, we compute the median haircut across the six prime brokers by month. We then average the median prime broker haircut corresponding to each convertible debenture across all convertible debentures to generate a time series measure of available leverage (the inverse of haircut).[20] In addition, we compute average haircuts across convertible debentures in each month based on level of risk, proxied by the moneyness (stock price divided by conversion price) of the convertible. When hedged with a short position in the underlying equity, in-the-money convertible debentures have lower risk than out-of-the-money convertible debentures. To account for differences in risk, we separately analyze haircuts for debentures with moneyness between 0.0 and 0.5 (labeled "low-moneyness") and for debentures with moneyness greater than 1.0 (labeled "high-moneyness"). Finally, we invert all haircut measures to show the amount of available leverage.

Fig. 3 shows available leverage estimates for the full sample of convertible debentures and for the low-moneyness and high-moneyness subsamples. Leverage measures in Fig. 3 reveal that available leverage decreased (haircuts increased) substantially in the immediate aftermath of the Lehman failure and continued to decrease for the next few months. Between August 31, 2008 and November 30, 2008, prime brokers reduced the allowable leverage to the convertible arbitrage fund from 9.5 to 3.8. Available leverage for both low-money and high-money convertibles also declined considerably during the same 3-month period (6.6–3.2 for low-money convertibles and 15.2–9.8 for high-money convertibles). On average, haircuts nearly doubled and available leverage was halved for this convertible arbitrage fund during the midst of the financial crisis.[21]

4. Convertible arbitrage and the financial crisis of 2008

Convertible arbitrage hedge funds 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 the strategy in 1990.[22]

[19] The six prime brokers are Bear Stearns (acquired by J.P. Morgan), Citibank, Deutsche Bank, Merrill Lynch (acquired by Bank of America), Goldman Sachs, and Morgan Stanley.

[20] Haircuts are not available from every prime broker for each of the convertible securities as the fund did not hold a position in each security at all of the six prime brokers. Also, haircut data are not available for all 588 convertible debentures corresponding to each month as there are numerous new issuances, retirements, fund purchases, and fund sales during the sample period.

[21] While Fig. 3 illustrates that debt financing contracted quickly during the crisis period, this estimate of the change in available leverage is biased downward. Specifically, based on our conversations with prime brokers, some funds were required to reduce leverage much more than is indicated in Fig. 3, and many of these funds were forced to liquidate. In contrast, the convertible arbitrage fund depicted in Fig. 3 was not forced to liquidate and realized substantial inflows of investor capital during the crisis period.

[22] Survivorship bias in the HFR index is potentially large during 2008, a result of 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.

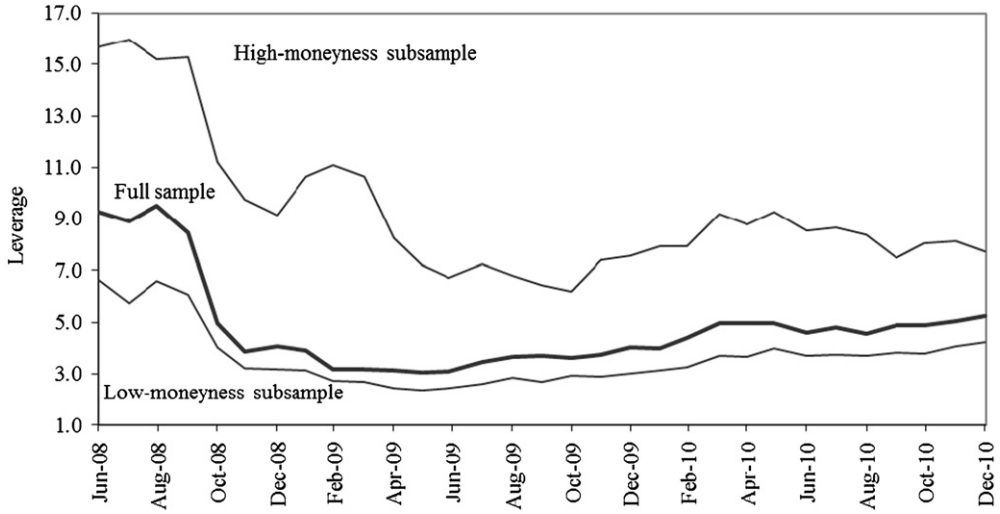

Fig. 3. Available prime broker leverage for a convertible arbitrage fund. This figure displays average monthly available leverage for a convertible arbitrage fund across six prime brokers during the period June 2008 through December 2010. Allowable leverage levels for the full sample of convertible debentures and subsamples of bonds with low-moneyness (high risk) and high-moneyness (low risk) are shown.

Convertible debentures have been actively researched, both theoretically and empirically. The prior research focuses on firms' decisions to issue convertible debentures and the effectiveness of convertible securities in mitigating information asymmetry and agency costs.[23] This paper does not consider the underlying motivation for convertible issuance but instead focuses on the secondary trading market for convertible securities after they are issued. As discussed by Mitchell, Pedersen, and Pulvino (2007), the convertible issuance process can take only a few days thereby allowing firms with immediate financing needs to access capital. Because the convertible debenture is a derivative security, its valuation is relatively straightforward and the arbitrageur can hedge most of the 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, and interest rate risk. Because of their ability to 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, often overnight. Issuers communicate to qualified institutional buyers, via investment banks, a range of coupon rates and conversions premiums soon after the market close. Investors quickly respond with a demand schedule, and the offering is completed prior to the market open on the following day.[24] More commonly, the offering is completed two days after the issuer announces the range of terms of the new issue, which 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 position is low relative to other securities. Consequently, leverage is often used to increase expected returns. 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, when the stock price traded well above the conversion price (and thus the hedged convertible had minimal 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 (e.g., bonds should cheapen). Because numerous market participants such as hedge funds and proprietary trading desks 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

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

[24] 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.

should be close to theoretical prices in unstressed markets.

We construct a sample of convertible debentures issued by US publicly traded firms that traded during the period January 1990–December 2010. The sample consists of more than three thousand convertible debentures resulting in an average of more than four hundred issues per month during the sample period. We obtain weekly prices of each convertible debenture from Value Line Investment Surveys during January 1990–December 2006 and from various Wall Street trading desks during January 2007–December 2010.[25] 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 (e.g., scheduled maturity, issuer call, convertible holder put, cash merger, bankruptcy, and corporate buy-back). Numerous corporate events over the life of a convertible debenture can alter its terms, and we account for those events to increase the accuracy in estimating fundamental values. For example, conversion ratios are typically adjusted for 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 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.[26] To obtain the theoretical value, we use input estimates corresponding to each convertible debenture as of each date in the sample period. These inputs include 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 the trailing 200 trading-day stock returns.[27] 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 or richness of the convertible debenture universe on a time series basis, we focus on equity-sensitive convertibles because they are less sensitive to model inputs, specifically to credit spreads.[28] For the full sample of convertible debenture prices over the sample period, we sort based on moneyness defined as stock price divided by 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 or 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 data set.

Fig. 4 displays the median cheapness or richness measure for convertible debentures over the period January 1990–December 2010. On average, convertible debentures traded at prices 0.6% cheap relative to theoretical values in the sample.[29] 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 dislocation in the convertible market during the financial crisis of 2008. Even within the entire sample period (January 1990–December 2010), the November cheapness

[25] 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.

[26] Specifically, the finite difference method that yields a numerical solution of Black-Scholes-Merton is more stable than the alternative binomial or trinomial tree methods of valuing convertible securities with various holder and issuer optionalities. However, none of the results presented in this paper is model dependent, and even the simple straight bond plus warrant valuation technique can illustrate the enormous change in convertible cheapness during the crisis period.

[27] For the full sample period of 1990–2010, estimates calculated using periods shorter or longer than two hundred trading days produce similar results. For the 2004–2010 period, we also use volatility estimates implied from the equity option prices of the underlying issuer. Likewise, these estimates do not have a substantial impact on the results. Finally, employing Barra estimates of individual issuer volatility that incorporates data from historical stock returns, equity option prices, and fundamental accounting data also does not significantly affect results.

[28] Focusing on equity-sensitive convertible debentures does not alter the results versus using the full sample of convertible debentures. We focus on equity-sensitive debentures simply to mitigate the impact of input errors on the cheapness or richness measure.

[29] The analysis focuses on equity sensitive bonds and thus the cheapness or richness estimate is not reflective of actual cheapness or richness across all convertible debentures. First, for extremely high stock prices relative to conversion prices, optionality is low and thus cheapness or 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%.

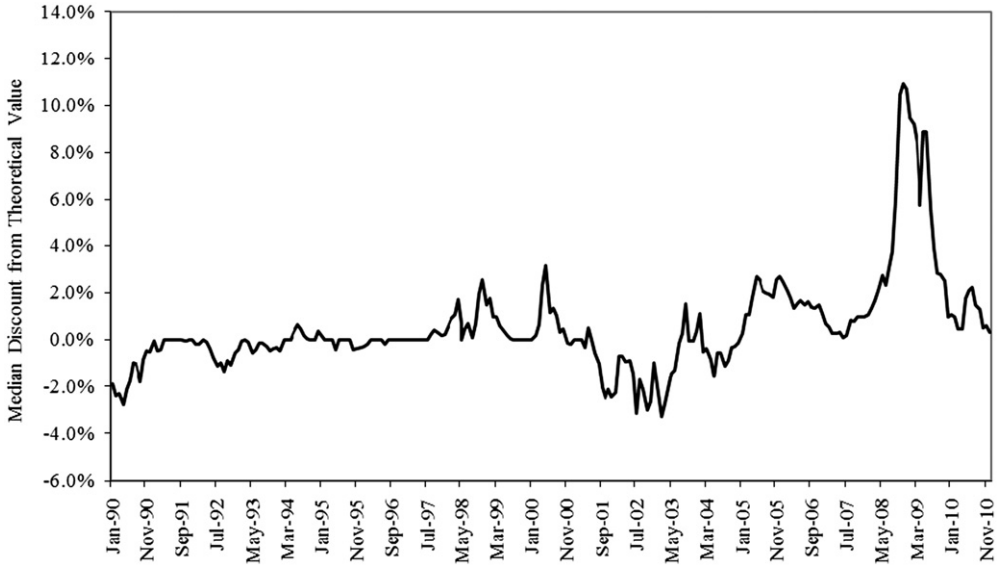

Fig. 4. Convertible debenture cheapness or richness. This figure displays the monthly median difference between the fundamental value of equity-sensitive convertible debentures and their traded prices during January 1990 through December 2010. We define equity-sensitive convertible debentures as convertibles with moneyness (ratio of issuer stock price to conversion price) greater than 0.65. Market prices are provided by Value Line Investment Surveys and various Wall Street investment banks. The fundamental or theoretical values of the convertible debentures are 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 on each date. On a given date, there are an average of 197 equity-sensitive bonds with a minimum of 39 (September 2002) and a maximum of 600 (June 2007). The minimum number of equity-sensitive bonds during the financial crisis was 158 in February 2009.

measure is nearly 5 standard deviations greater than the mean. As Fig. 4 shows, convertible debentures began to cheapen considerably in July 2008 when they exceed the maximum cheapness of the prior historical distribution, only to cheapen far more in the subsequent months and remain cheap for several months afterward.

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 are 164 equity-sensitive (moneyness >0.65) convertible debentures in the data set 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 had 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 is not computable. That is, even if one assumed that the underlying stock has a volatility of zero, market prices are 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 Fig. 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 because of low returns. During the 9-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%. 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 selling pressure caused steep losses and forced numerous convertible arbitrage funds to shut down, even causing 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 a textbook arbitrage opportunity, it took several months before equilibrium was restored to the convertible market as investors, even multi-strategy firms that 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 hedge funds, a result of the loss of financing from rehypothecation lenders. 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 pays an annual coupon of 0.50% and has 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 for $166.56 per $100 face value with a total ask value of $41.6 million. The theoretical value of Priceline's convertible debenture at the time of the offer is $185.30, and thus Merrill Lynch offered the convertible at an 11.3% discount to theoretical value.[30]

To put the 11.3% cheapness in perspective, the stock price of Priceline.com is $67.66 as of the time that Merrill Lynch offered the convertible debentures for sale.[31] Given the conversion ratio of 24.7647, the offer price is actually one point less than the conversion value of 167.56 (24.7647 shares/bond $\times$ $67.66/share = $1,675.58 per $1,000 face value or $167.56 per $100 face value), and thus the holder offered to sell a valuable option at a negative price. As an alternative to selling a bond for a price less than conversion value, a holder could direct its broker to forward its conversion request to the underlying company and receive conversion value by selling shares. Two problems arise with this alternative approach in 2008. First, by converting the bond into the underlying equity, the holder forgoes 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 is only $0.08 per $100 face value. The second, and in this case more important, problem with converting the Priceline bond is that it takes approximately 1 month to convert the bond into equity.[32] Given that the convertible holder in this case chose to offer it for sale at less than conversion value is evidence that it 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 analyze all convertible debentures that had a moneyness (stock price divided by conversion price) greater than 1.5 on at least five days during the period of October 1, 2008 through December 31, 2008 and 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 12 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 is the 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 with the bond's conversion value. The average quote is only 0.46 points (average quote of 173.60) greater than the corresponding conversion value and is not reliably different (p-value = 0.114) from the conversion value. The median quote is 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 is not immediate, the hedge fund could be forced to sell at prices below conversion value. To analyze the extent to which holders chose to convert their bonds to shares, we review the 10-Q filings associated with the sample of convertible debentures 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 is not uncommon but is typically induced by issuers seeking to remove the convertible debentures from their balance sheets. 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 fourth quarter of 2008, holders largely chose to convert without any financial inducement from the issuers. There is only one case in which the issuer, Leucadia National Corp., induced conversion with cash. Even in this case, the amount paid (4.5 points) is far less than the value of the option embedded in the convertible debenture (16.3 points). This particular debenture was trading at the highest level of the 17 debentures relative to conversion

[30] For input estimates, we use a volatility of 75% (historical volatility was 74% and implied volatility from January 2010 equity options is 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.

[31] 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 reflects 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.

[32] As specified in the bond's 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 its broker or conversion agent to facilitate the conversion, Priceline.com initiates a 20-day pricing period in which the value-weighted-average-price (VWAP) is calculated and used to determine the amount of cash or shares to deliver to the holder at the end of the pricing period.

Table 1
Summary statistics for high-money convertible debentures.

The crisis period panel displays summary statistics for 17 convertible debentures which had a moneyness (stock price divided by conversion price) greater than 1.5 on at least five days during the period October 1, 2008 through December 31, 2008. The pre-crisis (post-crisis) period panel displays summary statistics for 62 (57) convertible debentures which had a moneyness greater than 1.5 on January 31, 2008 (December 31, 2010). For the crisis period, statistics corresponding to each convertible debenture are calculated as of the date corresponding to the minimal difference between the quoted price of the convertible debenture and the conversion value. *p*-Values are displayed in parentheses (*p*-values for medians are based on bootstrapped estimates).

	Average	Median
Panel A: Crisis period		
Moneyness	1.79	1.68
Difference between quoted price and conversion value (points)	0.46	−0.08
	(0.114)	(0.404)
Difference between theoretical value and quoted price (points)	11.03	11.04
	(<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)		
Moneyness	2.26	2.05
Difference between quoted price and conversion value (points)	4.67	3.86
	(<0.001)	(<0.001)
Difference between theoretical value and quoted price (points)	1.81	0.44
	(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 (December 31, 2010)		
Moneyness	2.17	1.96
Difference between quoted price and conversion value (points)	6.60	4.41
	(<0.001)	(<0.001)
Difference between theoretical value and quoted price (points)	0.78	−0.09
	(0.364)	(0.797)
Expected remaining life (years)	1.93	0.96
Delta	0.96	0.98
Sample size	57	57

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.[33]

We create two control periods, one as of January 31, 2008 (pre-crisis period in Panel B) and the other as of December 31, 2010 (post-crisis period in Panel C). Unlike, the crisis-period, convertible debentures during the two control periods are quoted at prices economically and statistically higher than their respective conversion values. In addition, during the control periods, quoted prices are much closer to theoretical values.

High-money convertible debenture conversions illustrate the difficulty hedge funds had in financing arbitrage positions, even those nearly free of fundamental risk.[34] The forced conversions also suggest that markets exhibit extreme segmentation during the crisis period. That is, investors desiring equity exposure could simply have purchased convertible debentures rather than the underlying stock. Doing so would provide the same upside potential associated with increases in stock prices, yet would protect against stock price decreases via owning a debenture with indenture rights stipulating repayment at maturity. 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.[35]

4.3. Comparison of convertible debentures to straight debt

Whereas Section 4.2 compared high-money convertible debentures with their underlying equities, this subsection compares busted (trading at less than par) convertible debentures with the straight debt of the same

[33] Based on our conversations with Wall Street trading desks, Leucadia National Corp. was offering cash inducements for early conversion, confirmed by Leucadia's 10-K filing for the fourth quarter of 2008.

[34] The fundamental risk is not absolutely zero, but certainly close to it. Table 1 indicates that the theoretical 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 possibility of these stocks jumping

(*footnote continued*)
to zero and the debentures receiving only seven cents on the dollar is remote.

[35] 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.

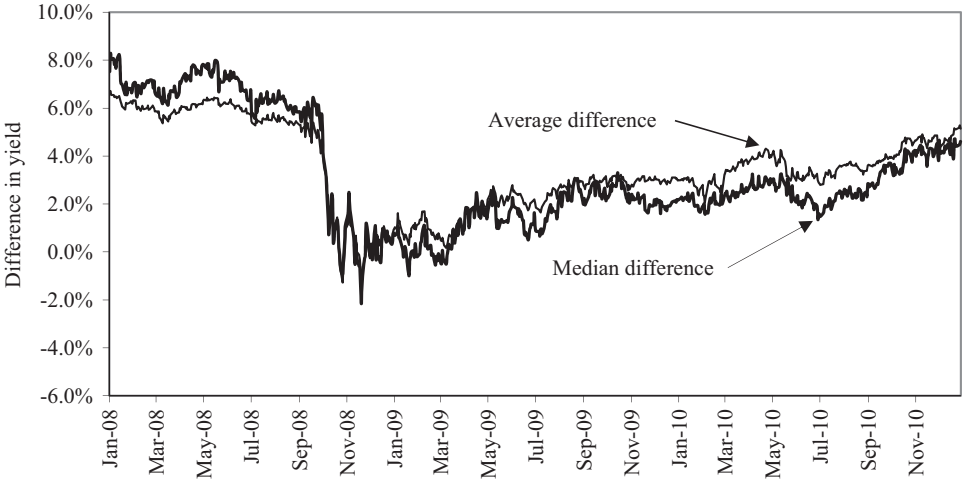

Fig. 5. Comparison of convertible yields and straight debt yields. This figure displays the average and median difference in yield between straight debt and busted (trading below par) convertible debt issued by the same company over the period January 2008 through December 2010.

issuer, specifically straight debt ranked pari passu with the convertible debentures. We exclude distressed convertible debentures, defined here as debentures with moneyness $<25\%$ of conversion value, because these bonds tend to trade infrequently, resulting in potentially stale prices. Of the 596 convertible debentures as of September 1, 2008, there are 65 busted convertible debentures trading below par, with at least one year of remaining life and with straight debt outstanding with a similar maturity date.

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) to the busted convertible's overall 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 Fig. 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 the option embedded in the convertible debenture.[36] However, beginning in late September 2008 and accelerating in October 2008, the yield difference compressed and 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 is 0.28%. Therefore, the near-zero difference in yields during the crisis period is several standard deviations from the difference in yields during the control period. This yield contraction is 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.[37] 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 straight debentures and replace them with convertible debentures thereby receiving a higher yield and, in addition, a call option on the underlying equity. Just as in the high-money convertible conversion 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 selling convertible debentures, as well as certain corporate bonds and other illiquid securities. As discussed in Section 3.2, rehypothecation lenders to the other prime brokers increased margin requirements for convertible debentures and, in particular, convertibles that would be more difficult to sell quickly.

We examine whether the illiquid convertible debentures cheapened relatively more during the crisis period. The sample for this analysis consists of 465 convertible debentures that are outstanding as of August 31, 2008.

[36] We delete observations in which the yield difference exceeded 1,000 basis points as such extremely large differences likely reflect bad prices. Omitting these extreme outliers has no impact on the substantive results reported. Straight debt yields are obtained from Bloomberg.

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

We exclude convertibles for which the moneyness (stock price divided by conversion price) is less than 0.25 to eliminate distressed issues for which cheapness calculations vary substantially because of 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 because it was just prior to the Lehman bankruptcy and the end of November because it roughly corresponds to the peak cheapness for convertible debentures during the crisis. Based on our discussions with prime brokers regarding 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 roughly 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%.

The amount of cheapening that a bond can experience is limited by its conversion value. The market price of the bond generally stays above the value that a holder could receive by converting the bond into equity.[38] To control for the distance from conversion value, and also to control for changes in volatility and credit model inputs, we run the following cross-sectional regression:

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

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; the *illiquidity* dummy takes the value of one if the issue size is less than $250 million. The second definition is based on credit quality; the *illiquidity* dummy takes the value of one if the bond is rated below investment-grade (e.g., high yield) or is not rated.

Table 2 displays results from estimating Eq. (1). The coefficient for the *change in credit spread* variable is negative, indicating that the larger the increase in credit spread estimates, the smaller the change in cheapness. The *change in volatility* variable has a positive coefficient in that a larger increase in the volatility estimate 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.

Table 2
Cross-sectional regression analysis of convertible debenture cheapness.

This table displays results from a cross-sectional regression analysis of 465 convertible debentures in which the dependent variable is the change in convertible 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. *Distance from conversion value* is the difference between the quoted price and the conversion value of the convertible debenture as of November 30, 2008. *Illiquidity* is a dummy variable for small issues ($<$$250 million issue size) and for speculative issues (high-yield and nonrated).

	Illiquidity proxy = issue size	Illiquidity proxy = credit quality
Intercept	0.0315	−0.0460
	(0.74)	(−0.91)
Change in credit spread	−1.3018	−1.4047
	(−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	0.1244	0.1967
	(3.79)	(4.53)
Adjusted R^2	0.33	0.34
Number of observations	465	465

In the regression with issue size as the *illiquidity* variable, 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, 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. Response by convertible mutual funds and convertible issuers

Unlike arbitrageurs that use short selling and leverage to profit from small pricing discrepancies, convertible mutual funds typically do not short underlying stocks and do not employ financial leverage. As a result, buying and selling activity by convertible mutual funds is driven primarily by capital contributions and redemptions. Similarly, issuers of convertible bonds are not directly affected by arbitrageurs' portfolio leverage constraints. In this subsection, we show that both convertible mutual funds and issuers of

[38] 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.

convertible securities reacted opportunistically to the crisis in the convertible market by purchasing convertibles at distressed prices.

We identify 13 open-end mutual funds that held at least 80% of their holdings in convertible securities and had net asset values of at least $100 million at the end of 2007. For each of the 13 convertible mutual funds, we obtain monthly NAVs and investor flows from the Simfund Mutual Fund Database over the period June 2003–December 2010. In addition, we obtain monthly returns of the 13 convertible

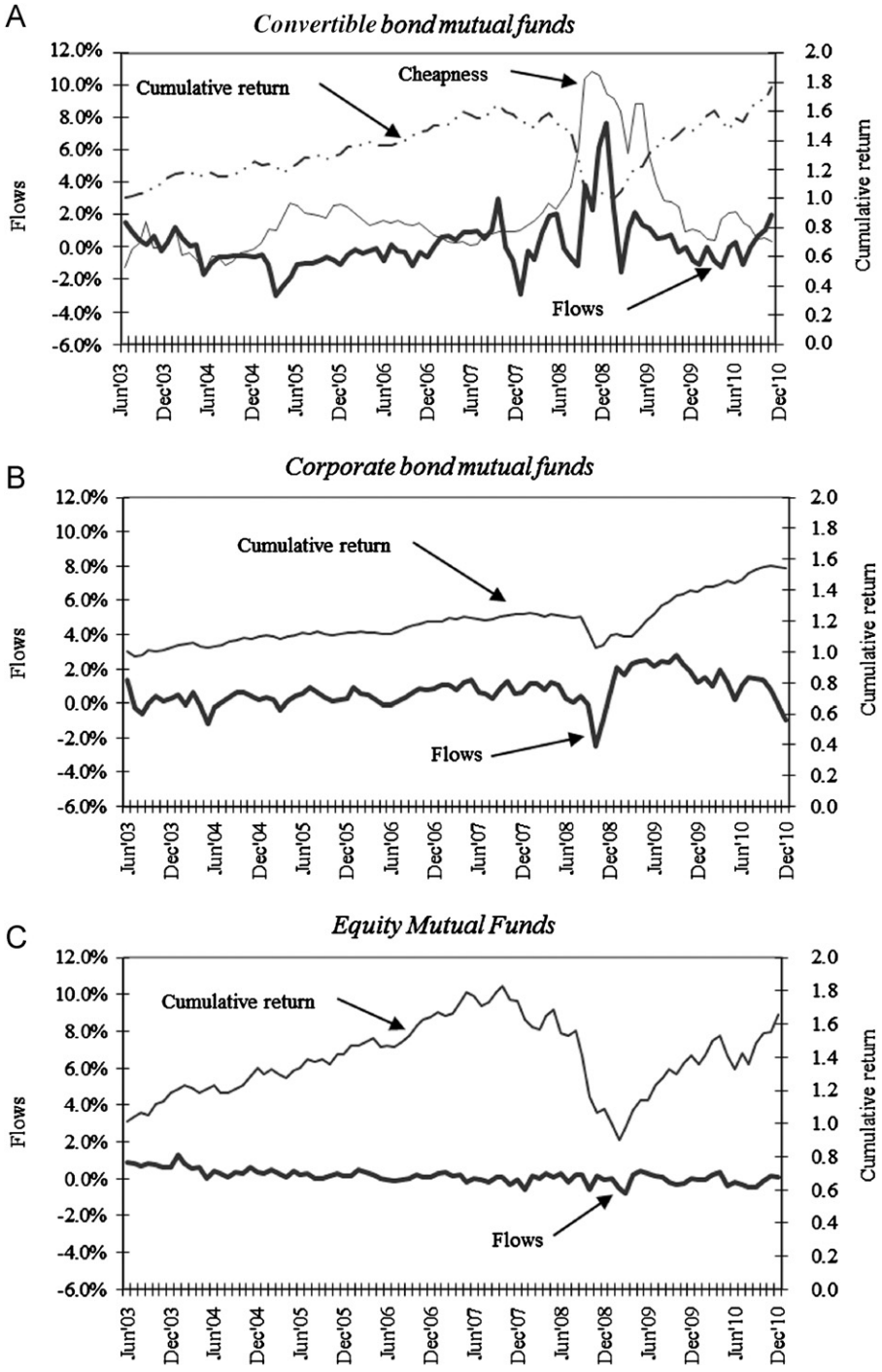

Fig. 6. Mutual fund flows into convertible bonds, corporate bonds, and equities. This figure displays monthly fund flows as a percent of fund net asset value (left scale) and cumulative return index (right scale) for convertible securities (Panel A), corporate bonds (Panel B), and equities (Panel C) over the period June 2003 through December 2010. Panel A also includes the cheapness measure (from Fig. 4) for convertible securities.

mutual funds from Bloomberg. As of August 2008, these 13 funds had an aggregate NAV of $9.7 billion, roughly 4% of the $225 billion US convertible market.[39]

For the combined 13 convertible mutual funds, Fig. 6 Panel A shows monthly investor flows as a percentage of the preceding month NAV. In addition, as measures of the opportunity facing convertible mutual funds, the convertible cheapness measure from Fig. 3 and the convertible mutual funds' cumulative total return index are included in Fig. 6 Panel A. During the pre-crisis period (June 2003–August 2008), the 13 mutual funds experience small redemptions that average –0.2% of the prior month's NAV. Redemptions to the convertible mutual funds are particularly high in 2005 with monthly redemptions averaging 1.3%. As discussed in Section 4.1, convertible debentures cheapened considerably in 2005 when large institutional investors redeemed their investments in convertible arbitrage funds following a period of poor returns. Thus, rather than responding proactively to the cheapened convertible debentures, mutual funds also are net sellers during the 2005 dislocation, a response to their own redemptions. In contrast to the 2005 convertible market dislocation, Fig. 6 Panel A shows that convertible mutual funds receive substantial inflows during the 2008 financial crisis. For example, during the 5 months of October 2008–February 2009 when convertible cheapness average in excess of 10%, monthly inflows to convertible mutual funds average 4.5%. Each of these monthly inflows is more than 2 standard deviations greater than the pre-crisis period mean flow.

Inflows to convertible mutual funds during the extreme cheapness period occur despite losses that exceed 30% between July and November of 2008. Whereas negative returns usually induce outflows, the extreme cheapening of convertibles, apparent even in the absence of a formal pricing model (per the discussion in Sections 4.3 and 4.4 of convertible prices relative to straight debt and stock of the same issuer), resulted in large inflows and a commensurate buying wave by convertible mutual funds. For comparison, Panel B and Panel C of Fig. 6 show flows and returns for corporate debt mutual funds (consisting of both investment grade and high-yield) and equity mutual funds over the June 2003–December 2010 sample period. During the extreme 5-month period (October 2008–February 2009) of convertible cheapness, monthly flows to corporate debt mutual funds and equity mutual funds average 0.2% and −0.2%, respectively, far less than flows into convertible mutual funds.

Like convertible mutual funds, corporations that had previously issued convertible securities are less capital constrained than the convertible arbitrage funds during the crisis and, thus are in a good position to repurchase their own debt at a discount to fundamental value. We track convertible debenture repurchases via press releases and SEC filings corresponding to the fourth quarter of 2008 and the first quarter of 2009 for 501 convertible debentures issued by 406 corporations.[40] A total of 149 (37%) issuers repurchase 161 (32%) convertible 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 fourth quarter of 2008, issuers repurchase 4.1% of this amount and repurchase an additional 2.8% in the first quarter of 2009 for a total repurchase amount of nearly 7% during the financial crisis.

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, and NASDAQ companies announced share repurchases in the aftermath of the crash. However, actual purchases were far less. During the period October 19, 1987–March 31, 1988, only 0.9% of NYSE, AMEX, and NASDAQ shares outstanding were repurchased. In a recent analysis of the time series of aggregate share repurchases, Dittmar and Dittmar (2007) show that the aggregate annual activity during the period 1985–2004 reached a maximum of roughly 2.5%, and this maximum level occurred in 1987. Our search of the academic literature does not reveal any analysis of aggregate corporate debt repurchase activity. Given that convertible 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 that the level of dislocation in the convertible debenture market was extreme. Paradoxically, corporate issuers provided liquidity to their former liquidity providers and thus were arbitrageurs of last resort.

Although these opportunistic buyers purchase approximately $15 billion of convertible securities during the fourth quarter of 2008 and first quarter of 2009, their substantial buying activity is not nearly enough to offset the estimated $75 billion of selling by hedge funds, the primary holders of convertible securities.[41] As a result, convertible arbitrage hedge funds sold convertible bonds to non arbitrage buyers at prices well below fundamental values, consistent with Shleifer and Vishny (1992).

[39] The combined open-end and closed-end convertible mutual funds from the Simfund Mutual Funds Database had $15.3 billion in NAV, but we do not analyze closed-end funds given the absence of investor flows.

[40] Because S&P Compustat does not track convertible debentures on the balance sheet at the quarterly level, we directly collect repurchase data from SEC filings. We exclude convertible debentures under the following circumstances: near-term cash merger, intended issuer redemption (call), and near-term put or maturity.

[41] There was roughly $200 billion in aggregate value of US convertible securities during the crisis period and based on conversations with officials of prime brokers, investment banking trading desks, and hedge funds, 75% of convertibles were held by hedge funds. Based on the greater than 50% estimated reduction in available rehypothecation lending by Singh and Aitken (2010) and the evidence from the haircut data from six prime brokerage firms on a surviving convertible arbitrage fund, we assume that hedge funds were forced to sell half of their convertible securities holdings.

5. CDS–corporate bond basis during the financial crisis

Similar to convertibles, rehypothecation lenders refused to accept corporate bonds as collateral, which led prime brokers to substantially increase the margin required to hold corporate bonds, thereby negatively impacting another common hedge fund strategy, the CDS–corporate bond basis trade. A 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. Because the CDS reflects the credit risk of a corporate issuer, it trades 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 it is computed as the CDS spread minus the corporate bond spread. To the extent that the basis becomes materially positive, an arbitrageur sells CDS protection and contemporaneously shorts the corporate bond.[42] Alternatively, if the basis becomes materially negative, the arbitrageur purchases the corporate bond and simultaneously 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 hedge funds, financing was simply unavailable.

Fig. 7 displays the weekly CDS–bond basis for US investment-grade and high-yield corporate bonds during the period January 2005–December 2010. An average of 491 investment-grade issuers per week and 204 high-yield issuers per week are represented in this data series. During the pre-crisis period (January 2005–September 12, 2008), the average (median) basis for high-yield bonds is $+2.4$ ($+12.7$) basis points and is -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 range from -146.7 basis points to $+81.4$ basis points during the pre-crisis period and the standard deviation of the basis is 40.0 basis points. Just prior to the financial crisis, the high-yield bond basis is negative. It became much more negative during the financial crisis, reaching a peak of -677 basis points in early December 2008, more than four times that of the previous maximum level in absolute value.[43] 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 excess return of 6.8%. For several issuers, the arbitrageur could have locked in an annual excess return 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 has little fundamental risk. However, like the convertible arbitrage trade described in Section 4, the CDS–bond basis trade has financing risk. As displayed in Fig. 7, the high-yield CDS–bond basis widened more than the investment grade CDS–bond basis, a direct result of rehypothecation lenders' reluctance to accept relatively illiquid high-yield bonds as collateral.

In normal times, arbitrageurs employ leverage to increase the expected return in the CDS–bond basis trade, posting as little as 5% equity capital. 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, the expected excess return with leverage of 20 would be roughly 4%. Although 4% is not a remarkably high expected return, it is an attractive investment given the lack of fundamental risk.[44] However, in the aftermath of Lehman's bankruptcy, rehypothecation lenders to Lehman Brothers aggressively sold securities provided as collateral, including corporate bonds. In addition, rehypothecation lenders reduced lending to other investment banks, causing a retraction of leverage provided to hedge funds that were employing the CDS–bond basis trade. In addition, investment banks themselves had placed large CDS–bond basis trades, either through their proprietary trading desks attempting to capture the expected excess return 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 risk 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 and unwound CDS positions, 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, no relation should exist 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 is -0.02 using weekly data from January 4, 2005 through September 12, 2008. However, the correlation spikes to 0.91 during the period September 19, 2008–March 31, 2009, highlighting the crucial role that debt financing plays in arbitrage strategies that have little fundamental risk. Like convertible cheapness, it took several months for the CDS–bond basis to approach historical levels,

[42] See research by Duarte, Longstaff, and Yu (2007), Fontana (2010), and Nashkiiar, Subrahmanyam, and Mahanti (forthcoming) for discussions of CDS–corporate bond basis arbitrage.

[43] On a daily basis, the CDS–bond basis reached a level of -720 basis points on December 16, 2008.

[44] 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.

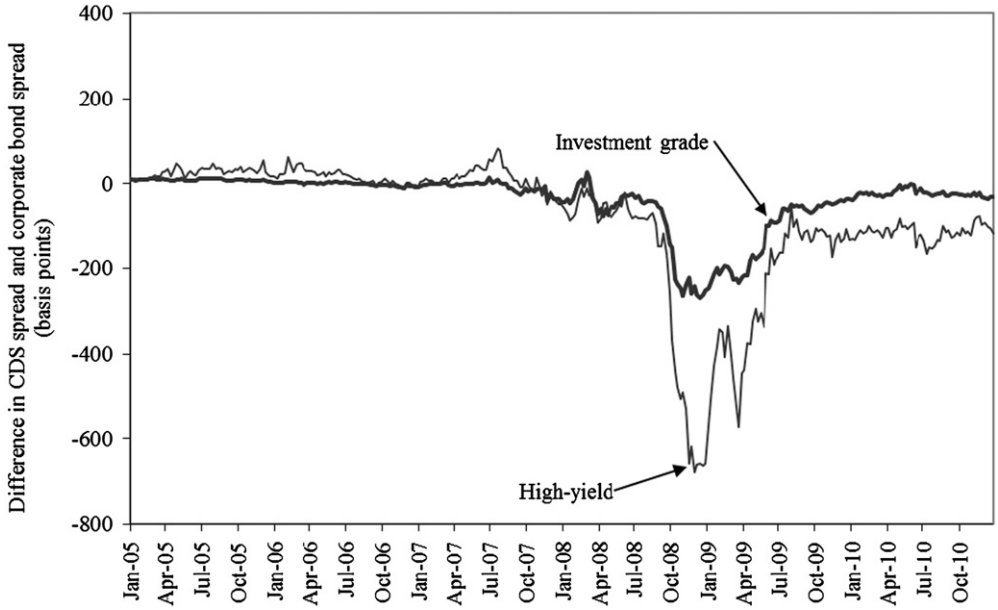

Fig. 7. Credit default swap (CDS)–corporate bond basis. This figure displays weekly CDS–corporate bond basis (in basis points) for high-yield issues (average of 204 issues per week) and investment-grade issues (average of 491 issues per week) during January 2005 through December 2010. A positive (negative) basis is when the implied spread from the CDS exceeds (is less than) the implied credit spread from the corporate bond. Data provided by J.P. Morgan.

highlighting the slow movement of capital to extraordinary arbitrage opportunities.

6. Special purpose acquisition companies (SPACs)

Based on conversations with various prime brokers, we find that 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 US Treasury bills). Managers of SPACs seek to buy operating companies using funds held in the trust account during a pre-specified period (typically 2 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 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. Instead, 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 instead of bearing the credit risk of the issuer, SPAC shareholders bear the risk of a trust account, largely invested in US Treasury bills.

During late 2007 and early 2008, several billion dollars were raised in new SPAC issues and the primary holders were hedge funds. Fig. 8 displays the median yield-to-trust of SPACs and the median excess yield over US Treasury bills during January 2008–September 2009. During the pre-Lehman failure, SPAC yields average 4.7% and 3.1% 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 is a direct result of, reductions in financing of convertible debentures and the CDS–bond arbitrage trade. As displayed in Fig. 8, 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 with 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. Other risks are associated with holding SPACs, but these risks are largely miniscule. For example, there is no credit risk because the funds are held in US Treasury bills or money market funds. 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 was impaired. Because

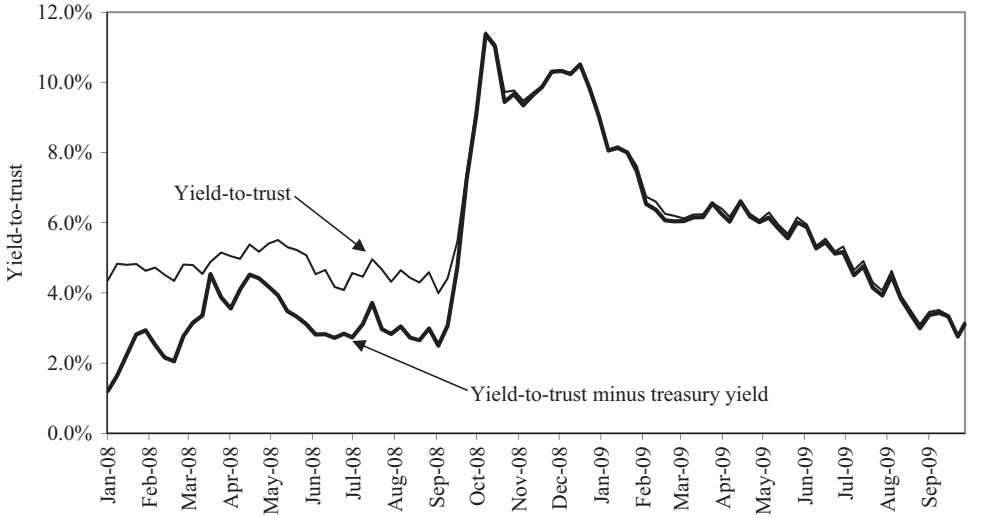

Fig. 8. Special Purpose Acquisition Company (SPAC) yield-to-trust. This figure displays weekly yields-to-trust of SPACs and the weekly difference between SPAC yields and US Treasury bill yields during January 2008 through September 2009 (after which the population of SPACs became too small to calculate reliable yield-to-trust estimates).

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, 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, 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 and forced to sell to industry outsiders.

7. Other arbitrage strategies impacted by the financial crisis

As hedge funds were forced to delever in response to increased haircuts and the resulting margin calls, they moved to generate cash by selling more liquid securities, thereby mitigating the sale of illiquid securities at fire-sale prices. In this section, we examine the impact of the forced deleveraging on other hedge fund strategies such as merger arbitrage and closed-end fund arbitrage, strategies with considerably more liquidity than the convertible arbitrage and CDS–bond arbitrage strategies.

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.[45] 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 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 show a stock market beta of roughly zero in most periods, they find that the beta to merger arbitrage increases to 0.50 during months in which the stock market declines by at least 4%. This increase in market risk is driven by cash mergers, particularly financing-contingent cash mergers, which are more likely to be terminated during market downturns. 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 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 are large sellers of target stocks in the aftermath of the 1987 crash, exacerbating the increase in spreads.

[45] Consider a mutual fund that invests in growth stocks. Once a cash merger or a stock merger with a non growth acquirer has been announced, the target shares no longer offer above-average growth potential. Yet they still have substantial downside risk, albeit with low probability. Thus, the growth stock fund manager often sells the target shares rather than hold a security inconsistent with the fund's mandate.

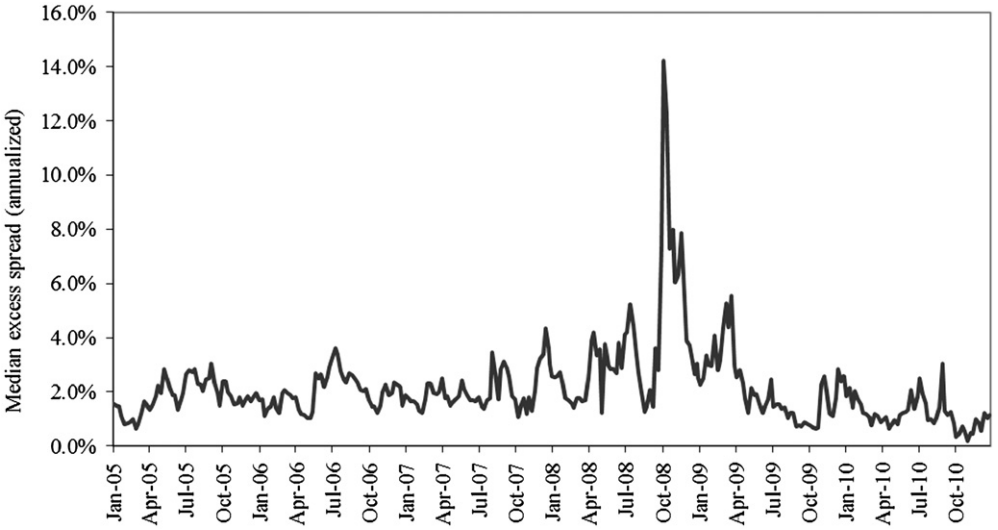

Fig. 9. Median excess spreads of stock merger deals. This figure displays the weekly median excess (relative to US Treasury bill yields) spread (percentage difference between the acquirer's offer and the target's stock price) for stock mergers during January 2005 through December 2010.

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, another strategy commonly employed by hedge funds, also realized a major dislocation during the 2008 financial crisis. To examine the impact of the 2008 financial crisis on merger arbitrage, we compute the median excess (relative to 3 month US Treasury bills) spread of merger deals during the period January 2005–December 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 more effectively isolates the impact of hedge fund deleveraging and the shutdown of proprietary trading desks on merger arbitrage. Fig. 9 displays median annualized spreads of stock deals using weekly data during January 2005–December 2010. Despite the lower systematic risk, annualized spreads of stock mergers widened substantially during the financial crisis and, in particular, during the week of October 6–10, 2008. The median spread for stock deals reached 14.2%, several standard deviations greater than the time series mean of 2.1% (standard deviation = 0.78%).[46] Anecdotally, all of the eight stock mergers with deal size in excess of $100 million that were pending as of September 15, 2008, the date of the Lehman bankruptcy, were consummated on the previously agreed terms.

7.2. Closed-end fund discounts

Closed-end fund 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; 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 management fees exceed the value added by CEF portfolio managers. A behavioral explanation of the CEF discount is that noise traders who make irrational investment decisions can cause closed-end funds discounts to widen substantially. Because discounts can 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 that 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 (2010) show that activist arbitrage activity has a substantial impact on CEF discounts.

Fig. 10 displays the weekly median discount across equity CEFs during the period January 2002 through December 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 is 7.5% with a standard deviation of 2.3%. As shown in Fig. 10, the discount begins to widen immediately after the Lehman bankruptcy, from 10.7% during the week of September 12 to 15.7% during the following week, and reaches a maximum of 20.3% during the week of October 10, the week when Morgan Stanley's default probability peaked. The 20.3%

[46] 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 when several proprietary merger arbitrage desks suspended operations.

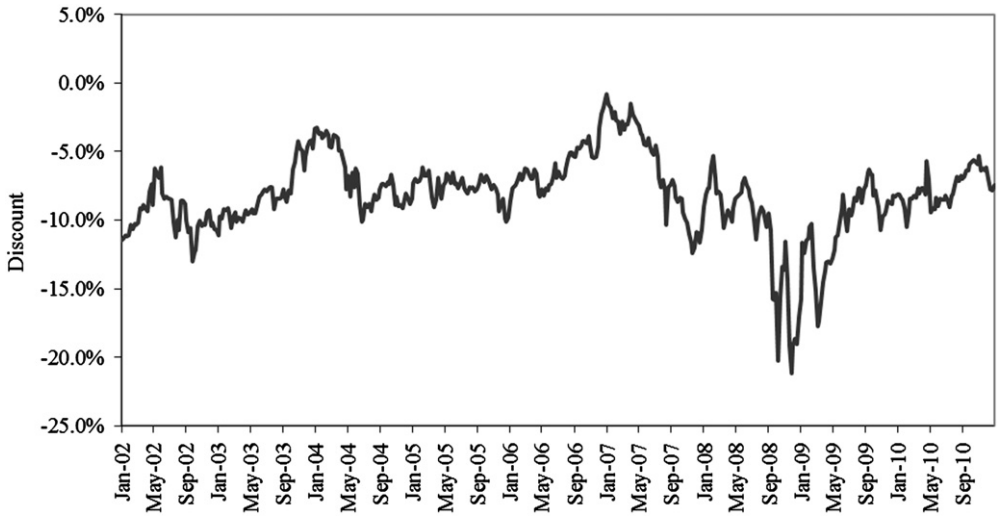

Fig. 10. Median discounts for equity closed-end funds. This figure displays the weekly median discount for equity closed-end funds during January 2002 through December 2010. When the discount is negative, the net asset value of the fund's underlying assets exceeds the fund's market value.

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 than 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. Later, hedge funds sold illiquid securities such as corporate bonds. 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.[47] As a result, instead of forcing prices of similar securities to converge, arbitrageurs had 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, opportunistic capital was unable to offset the void left by arbitrageurs, and industry-outsiders, as in Shleifer and Vishny (1992), became the eventual purchasers. As a result, mispricings persisted for months.

One of the by-products 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 that 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 (e.g., hedged with the underlying equity) portfolio has annualized volatility of 2%. This low volatility estimate compares with 15% volatility for the convertible long (e.g., without any hedge) portfolio

[47] While this paper has focused on the loss of debt capital to hedge funds, we note that investor capital did decline in 2008 from $1.87 trillion to $1.41 trillion, most of which was caused by losses. Based on data compiled by Hedge Fund Research, investor net flows were −$0.15 trillion in 2008 and −$0.13 trillion in 2009. Investor redemptions certainly contributed to the dislocation but not nearly as much as the loss of debt capital. Specifically, it was not just the relative size of the loss of debt capital to investor capital, but also the notification period. Prime brokers removed financing immediately. Conversely, investors must give redemption notices in advance, often 90 days, which gives the hedge fund more time to delever without adversely affecting prices. In addition, many hedge funds can (and, in fact, did) erect gates so as to delay investor redemptions.

and 25% 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 managed by hedge funds. For some strategies such as convertible arbitrage, leverage levels exceeding 5:1 and borrowing rates similar to what is charged AAA corporate borrowers were common. 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 and, importantly, collateral without an accompanying hedge, thereby exacerbating the risk to the rehypothecation lender. For liquid securities such as exchange-traded equities, the Lehman failure did not pose a problem as rehypothecation lenders had the ability to liquidate 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 similar 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, considerable uncertainty existed as to whether the crisis would continue to worsen causing short-term losses before gains could be realized (as in Merton (1987), uncertainty about the distribution of returns mitigated immediate opportunistic investments). Because of this uncertainly on all fronts,[48] 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.

[48] 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 US government officials. These bans created havoc on the natural liquidity providers to corporations in need of capital by dramatically increasing the risk of the portfolio on the left-hand side of the balance sheet due to delinking the arbitrage trades. We do not question the motives of the panicked pleas by the leaders of the Wall Street institutions as their job is to maximize shareholder wealth. However, the subsequent disruptions resulted in enormous arbitrage opportunities that they, ex post, were able to capitalize on.

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