THE DYNAMICS OF INFORMATION FLOW ACROSS INDIVIDUAL STOCKS, OPTIONS AND CORPORATE BONDS

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Abstract

Taking advantage of a unique corporate bond transaction dataset from the National Association of Securities Dealers (NASD), this paper investigates the price adjustment of related securities, including stocks, bonds and options, to firm-specific information. Differing from previous studies, I find that lagged corporate bond returns have explanatory power for current stock price changes. This implies that information-based trading takes place in the corporate bond market, and both markets serve important roles in disseminating new information. The option market, however, contains valuable information about future movements in both the stock and the bond market, and these relations are unidirectional, suggesting that the option market is a preferred venue for informed trading. Furthermore, there is strong evidence that informed trading in the option market is distributed across different strike prices, with at-the-money options attracting investors who posses mild firm-specific information, and deep out-of-the-money options catching the attention of those who obtain extreme information.

JEL Classification: G14

Key-words: Market Microstructure, Price Discovery, Information-based Trading, Information-risk Premium, Firm Specific Information.

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1. Introduction

Even though debt and equity securities differ significantly from each other from various perspectives for both investors and issuing firms, both represent claims to the firm's underlying assets and future cash flows. Since the value of an option is derived directly from the price of its underlying stock, if financial markets are in equilibrium, information regarding the state of the individual firm should be reflected in all three related securities: debt, equity and its derivatives. While the direction of changes in the prices of these securities reflects the nature of the information, the speeds at which these prices adjust to new information are determined by the inherent risk-reward characteristics of different securities and the structure of the markets where these securities are traded. Therefore, a comprehensive study of inter-market linkages between the stock market, the corporate bond market and the option market are of extreme value as the direction of price movements in related securities reveals valuable information as to what kind of news is happening to the firm, which is essential for portfolio management, while knowledge about which market is leading the others in reflecting firm-specific information helps gain a deeper understanding of the price discovery process and thereafter allows for the development of successful trading strategies.

Following seminal work by Black (1975), there has been a huge literature studying inter-market relationships between equity and equity derivative markets. As suggested by Black (1975), the option market might be more attractive to informed traders than the market for the underlying stock because options offer higher financial leverage, and the option market is characterized with less stringent margin requirements, no uptick rule for short selling, and probably lower transaction costs. Whether the option market is leading the stock market in reflecting new information has been directly examined in numerous empirical studies[1]. Panton (1976) takes the first step in this direction, but he fails to demonstrate conclusively that call options are in general valid predictors of future stock price changes. Based on the Black-Scholes

1 The stock-option link and the role of the options market in the price discovery process have also been addressed indirectly from many perspectives. Early accounting research shows that current option prices reflect market anticipation of forthcoming earnings announcements and predict future stock price variability [Patell and Wolfson (1979, 1981)]. The informational role of options markets are further investigated in the financial markets literature. Jennings and Starks (1986) find that the stock prices of firms with listed options adjust to earnings announcements faster than those of nonoption firms and they conclude that options markets help to disseminate earnings news. Grossman (1988) argues that option trading reveals the future trading intentions of investors, and therefore helps to predict future price volatility. By comparing return patterns in contemporaneous stock and options, as well as options that are adjusted for contemporaneous changes in the price and volatility of the underlying asset, Sheikh and Ronn (1994) confirm informed trading in options markets. Figlewski and Webb (1993) show that options increase both transactional and informational efficiency of the market for the underlying stocks by reducing the effect of short selling constraints. A less-related literature examines hedging-related effects of option trading and their implications for inter-market linkages. When the complete market assumption under standard option pricing models is relaxed, introduction of options alters investors' hedging opportunities. The value of the underlying stocks increases while excess return volatility declines. This phenomenon has been documented in several empirical studies (Nabar and Park (1988), Skinner (1989), Conrad (1989)) and is subsequently formalized by DeTemple and Selden (1991) in a theoretical model. While most studies confirm the important role of options markets in the general price formation process, two exceptions stand out. Bhattacharya (1987) tries to compare implied bid and ask stock prices, which are derived from options quotes, to observed bid and ask stock prices to identify arbitrage opportunities. He fails to find any profitable trading strategies and hence cannot reject the null hypothesis that option prices bear no additional information than contemporaneous stock prices. By examining the depth and bid-ask spreads of the Chicago Board Options Exchange (CBOE), Vijh (1990) shows that the options market is not dominated by informed traders.

option pricing model, Latane and Rendleman (1976) and Beckers (1981) derive the volatility implied in option prices and show that it predicts future stock price variability. The leading role of the option market is strengthened by Manaster and Rendleman (1982), where they compare the implied and observed stock prices and demonstrate that the implied stock prices contain valuable information about the equilibrium prices of the underlying stocks that has not been revealed in the stock market. Furthermore, Fleming, Ostdiek and Whaley (1996) compare the transaction costs in the stock and the option markets, and show that for individual stocks, price discovery happens in the stock market as it offers lower spreads and higher liquidity. However, Vijh (1988) argues that the result of Manaster and Rendleman (1982) is questionable, since using daily closing prices introduces a bias associated with the bid-ask spread and nonsynchronous trading. After purging the effects of bid-ask spreads, Stephan and Whaley (1990) find that the stock market leads the option market. Nevertheless, Chan et al. (1993) argue that the stock lead is due to the relative smaller stock tick. If the average of the bid and ask is used instead of the transaction price, neither market leads the other.

While most work by middle 90s investigate the price relation between stocks and options, recently studies on the lead-lag relation have been focused more on trading volume[2]. Easley et al. (1998) show that "positive news option volumes" and

2 Trading volume relations in the stock and options markets have been explored by Anthony (1988) and Stephan and Whaley (1990). While Anthony (1988) finds weak evidence of the option lead based on a daily dataset, Stephan and Whaley (1990) use intraday transaction data and draw

"negative news option volumes" have predictive power for future stock price changes. The predictive ability of option trading volume is subsequently confirmed by Pan and Poteshman (2003), but not by Chan, Chung and Fong (2002). Cao, Chen and Griffin (2003) find that option volume imbalances are informative in the presence of pending extreme information events, but they fail to identify the same information role for option volume during normal periods. By measuring the relative share of price discovery occurring in the stock and options markets, Chakravarty, Gulen and Mayhew (2004) conclude that informed trading takes place in both stock and option markets, suggesting an important informational role for option volume. Following Chan, Chung and Fong (2002), who suggest that option quote revisions contain information about future price movements, this study uses bid-ask spreads for both ATM and deep OTM options. It finds that ATM option spreads have predictive power for future stock price changes, confirming the option lead found in the majority of work on stock-option relationships.

In contrast to the huge literature on the lead-lag relations between stocks and options, few studies have focused on the stock-bond relationship. Early research on the stock-bond linkages has been conducted on the aggregate level, looking at low-grade bonds [Blume, Keim and Patel (1991), Cornell and Green (1991)]. While both Cornell and Green (1991) and Blume, Keim and Patel (1991) find that speculative bonds are very sensitive to stock price movements, neither study is able to identify a significant impact of previous or future stock returns on current corporate bond

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an opposite conclusion. However, using total call option volume over a certain period of time is subject to question as its information content is hard to interpret.

returns. As the corporate bond market has become more transparent, two studies in the literature have explicitly examined the lead-lag relationship on the individual firm level. However, their results are contradictory. Using weekly quotes data from Merrill Lynch, Kwan (1996) finds that lagged stock returns have explanatory power for current bond yield changes, but not vice versa. Based on this finding, he concludes that 'stocks lead bonds in reflecting firm-specific information'. In contrast, Hotchkiss and Ronen (2002) analyze a transaction dataset for 55 high-yield bonds included on the NASD Fixed Income Pricing System (FIPS) [3] and reject the hypothesis that stocks lead bonds in reflecting firm-specific information. Instead, they argue that no causal stock-bond relationship exists, and the observed contemporaneous correlation between stock and bond returns only reveals their joint reaction to common factors.

The current paper argues that the conclusion of Kwan (1996) is subject to serious nonsynchronous trade effects as his sample might include inactive bonds. It also points out that the approach taken by Hotchkiss and Ronen (2002) is questionable. After correcting their methodology, I show that new information disseminates in both the stock market and the corporate bond market. Both markets serve an important role in the general price discovery process.

To complete the examination of information flow across stocks, bonds and options, I check whether the option market contains valuable information about future bond

3 For more detailed information about FIPS, please see the NASD NtM 94-23, Alexander, Edwards, and Ferri (1999, 2000), and Hotchkiss and Ronen (2002).

price changes. Although the stock-option and the stock-bond relationships have both been explored in the financial market literature, a study on the bond-option relationship is lacking. Following Beckers (1981), who suggests that at-the-money (ATM) options contain most of the relevant information in predicting future stock price variability, most empirical studies on the links between options and equity markets focus on data for at- and near-the-money options. Chakravarty, Gulen and Mayhew (2004) find that on average, the information share of the price discovery process tends to be higher for OTM options than ATM options. Furthermore, as corporate bonds embed a short position in out-of-the-money (OTM) put options on credit risk, it is very natural to check the OTM option market. Using the bid-ask spreads in both OTM and ATM put options as a measure of information-based trading on the options market, I find that past deep OTM put option spreads are positively correlated with current bond returns, and current bond returns are in turn positively correlated with future ATM put option spreads. While the predictive power of current bond returns for future ATM put spread changes can be described as a reflection of hedging activities associated with bond trading, the finding that OTM put spreads help to predict future bond returns implies that investors trade OTM put options on some information that will also change the value of corporate bonds. Combined with the conclusion that ATM options spreads predict future stock returns, this conclusion implies that the option market as a whole is a preferred venue for information-based trading. Furthermore, the distribution of informed trading across different strike prices reveals the nature of the private information possessed by informed traders. with at-the-money options attracting investors who posses mild firm-specific information, and deep out-of-the-money options catching the attention of those who obtain extreme information.

The rest of the paper is organized as follows. Section 2 summarizes some recent developments in the corporate bond over-the-counter (OTC) market and the new Trade Reporting and Compliance Engine (TRACE) introduced by NASD. The stock, bond and options data are described in Section 3. Section 4 investigates pairwise lead-lag relationships between stocks, bonds and options. Whether these relationships are subject to infrequent trading in bonds and how they vary with firm size are addressed in Section 5. Section 6 concludes and points out some possible extensions.

2. The Corporate Bond Market and NASD's TRACE

The corporate bond market assumes roughly as important a role in corporate financing as the equity market, with approximately $4.4 trillion outstanding in 2004, which is larger than both the US treasury market ($3.8 trillion outstanding) and the municipal bond market ($2.0 trillion outstanding)[4]. The stock market is larger at about $15 trillion[5]. The total dollar volume of the market in 2003 is about $10 trillion, more than the trading volume on the NYSE[6]. About $18 billion in par value of corporate

4 NASD News Release, March 26th, 2004.

5 Business Times, Feb 8th, 2005

6 The Economist, Oct 14th, 2004

bonds turns over in roughly 22,000 transactions on a typical day[7]. As baby-boomers age and shift more of their assets from equity investments to debt investments, the corporate bond market will certainly grow in both size and importance.

However, transparency in this market has never been comparable to that of other securities markets. As Doug Shulman (NASD's President of Markets) said, the corporate bond market 'has been largely a mystery to retail investors[8]'. In the early 1990s, the opaqueness of the corporate fixed-income market, especially that of the high-yield bond market, became a really big concern for the U.S. Congress and the Securities and Exchange Commission (SEC) when investigations of the SEC and the U.S. Attorney's Office brought to light Drexel Burnham Lambert and its star trader Michael Milken's manipulation in the junk bond market. Subsequent low liquidity and investor confidence encouraged the SEC to put the enhancement of transparency of the high-yield bond market on its agenda. The Fixed Income Pricing System (FIPS) was the result of the SEC and the NASD's discussions on how to increase the transparency of the junk bond market and help regulators effectively monitor trading in high-yield debt. On April 11, 1994, The Nasdaq Stock Market, Inc., began operation of FIPS for members trading high-yield bonds. Under the FIPS system, NASD members are required to report all secondary market transactions on a selected

7 See a speech by Doug Shulman, NASD's President of Markets, on February 2nd, 2005 in New York, New York, 'Bond Market Association Legal and Compliance Conference Keynote Address', which is on the NASD's website.

8 Before that, in a Wall Street Journal article on September, 10th, 1998, Arthur Levitt, Chairman of the SEC, said that corporate bond traders 'do not enjoy the same access to information as a car buyer or a home buyer' or even 'a fruit buyer'.

set of high-yield bonds within 5 minutes of execution. Based on submitted transaction reports, hourly price and volume data on about 50 most frequently traded high-yield bonds are displayed on the FIPS terminal. Even though FIPS brought some transparency to the high-yield debt market, the corporate debt market as a whole still does not live up to regulators' expectation of a transparent market. In order to further increase the transparency of the corporate bond markets, NASD initiated a broader system know as TRACE (Trade Reporting and Compliance Engine) on July 1st, 2002, which incorporated the previous FIPS system. Under TRACE rules[9] , all NASD members were obligated to submit transaction reports for any secondary market transaction in TRACE-eligible securities[10] between 8:00PM and 6:30PM (EST) within one hour and fifteen minutes of the time of execution[11]. Transaction information on TRACE-eligible securities which are investment grade[12] and have an initial issuance of $1 billion or higher is subject to immediate dissemination. Additionally, 50 Non-Investment grade and most actively traded TRACE-eligible

9 Also known as the NASD Rule 6200 Series.

10 According to NASD Rule 6210(a), TRACE-eligible security 'mean all United States dollar denominated debt securities that are depository eligible securities under Rule 11310(d); Investment Grade or Non-Investment Grade; issued by United States and/or foreign private issuers; and: (1) registered under the Securities Act of 1933 and purchased or sold pursuant to Rule 144A of the Securities Act of 1933.' It does not include debt securities issued by government-sponsored entities (GSE), mortgage-backed or asset-backed securities, collateralized mortgage obligations and money market instruments.

11 For a detailed description of TRACE rules and their subsequent amendments, please refer to NASD Notice to Members NtM-02-76, NtM-03-12, NtM-03-22, NtM-03-36, NtM-03-45, NtM-04-39 and NtM-04-65.

12 Rated by a nationally recognized statistical rating organization (NRSRO) in one of its four highest generic rating categories. See NASD Rule 6210(h).

securities (TRACE 50 thereafter) are designated for dissemination. In the subsequent two and half years, major improvements to the TRACE system have focused on increasing dissemination and reducing reporting time. As of July 1st, 2002, only 540 securities are subject to dissemination. This number went up to 4,500 after NASD began distributing information on a third group of Investment Grade TRACE-eligible securities that are rated 'A3' or higher by Moody's or 'A-' or higher by S&P and have a $100 million or higher original issue size on March 3rd, 2003, and another group of 120'Baa/BBB' rated bonds on April 14th, 2003. After another two-stage implementation of the amendments to the TRACE Rules, which were approved by SEC on September 3rd, 2004, NASD started full dissemination of transaction information on all TRACE-eligible securities except those Section 4(2)/Rule 144A TRACE-eligible securities. Currently about 29,000 corporate bonds, another jump from 17,000 as of October 1st, 2004, have their transaction and price data spread to the market in real-time, and the corporate bond markets have never before been so transparent. Meanwhile, the time to report a trade of a Trace-eligible security has been declining. Starting from 75 minutes on July 1st, 2002, the reporting period went down to 45 minutes on October 1st, 2003 and further down to 30 minutes on October 1st, 2004. It will be shortened to just 15 minutes on July 1st, 2005.

TRACE improves on FIPS in several important ways. First, FIPS only covered non-convertible, non-investment grade and publicly offered debt which is not part of a medium-term note program[13], and only a set of 50 most actively traded bonds were

13 Nasdaq Stock Market, Inc., 1997, Rule 6210(i).

subject to dissemination. However, under TRACE rules, transaction information for any secondary market transaction in all TRAC-eligible securities are required to be reported to NASD, and starting February 7th, 2005, NASD has begun to fully disseminate transaction information on the entire universe of corporate bonds, which is considered by NASD as the most significant innovation for retail bond investors in decades. Second, for each debt security that is subject to dissemination, TRACE dramatically increase the amount of information distributed to the public. FIPS only published hourly summaries on the prices and total volume of transaction in a set of 50 bonds, while transaction and price data on each trade in TRACE-eligible securities are distributed to the market.

3. Data

Since high-yield bonds embed an equity component and are more sensitive to firm-specific information than investment grade bonds, transaction data for TRACE 50 are used to study the information flow across related securities. This dataset contains execution date and time (recorded to the second), price, yield, quantity, and some other information that can be used to purge invalid transaction reports for every trade in the TRACE 50 high-yield bonds from July 1st, 2002 to September 30th, 2004[14]. The TRACE 50 bonds are chosen by the NASD advisory committee based on criteria such as the security's volume, price, name recognition, amount of research attracted, a minimum amount of bonds outstanding, number of dealers that are making a market

14 On October 1st, 2004, NASD starts its second stage dissemination, and many more high-yield bonds are subject to dissemination. The concept of TRACE 50 does not exist any more.

in this security and the security's contribution to the TRACE 50's industry diversity. Similar to FIPS 50, the TRACE 50 are characterized by high trading volume, both in terms of number of transactions and number of block size trades, and similar trading patterns to the issue's stock. Over time, bonds with small trading volume were replaced with more active bonds. Transaction information on the first TRACE 50 bonds was released to the market on real-time basis for about one year since July 1st, 2002. Beginning on July 13th, 2003, the TRACE 50 list was updated every 3 month until September 30th, 2004. During this time period (July 1st, 2002 to September 30th, 2004), 177 high-yield bonds from 135 issuing firms were included in the TRACE 50 lists for dissemination.

Daily closing stock price and related options quotes data for the issuing firms are obtained from OptionMetrics INC for the period from July 1st, 2002 to April 15th, 2004. Only 129 bonds from 110 firms are subject to dissemination during this period. Since some companies are not public, and some are traded on the OTC market or the pink sheet market, stock price data do not exist for 18 of these firms. This reduces the sample to 92 firms. Furthermore, 15 out of the 92 firms do not have options traded on their common stock during this period. By excluding these 15 firms from my sample, I was left with 77 firms with 111 bonds.

To merge these data with the stock and options data, a daily time series dataset is formed by keeping the transaction price for the last valid trade before 6:30PM (EST) for each of these 111 bonds. As several firms have multiple bonds included in TRACE 50 list during certain periods of time, only the most active bond with the highest priority in payments is kept for inter-market analysis[15]. As a result, a panel of daily stock, bond and options data for 77 firms is employed for this study.

Table 1 contains summary characteristics for the 77 corporate bonds and their issuing firms at the time of their initial entry to the TRACE 50 list. Issuing firms are fairly large with median total asset value of 11471.1 million USD and characterized by high financial leverage, which is consistent with low credit ratings of these bonds. Also consistent with the high-yield nature, many bonds in the sample contain embedded options. Of the 77 bonds, 38 (49.35%) are callable prior to maturity and 14 (18.18%) are convertible. The bonds included in this study represent 7 different and they are concentrated in Manufacturing (38.96%), Servicing (31.17%) and Energy (11.69%). About half of the 77 bonds are senior unsecured notes. Senior notes and subordinated notes account for another 30 percent of the sample. Coupon payments are made twice per year for each of the 77 bonds, and all are all fixed plain vanilla coupons, except for one bond which has a variable coupon size. The average coupon rate is 7.48%. About 80% of the TRACE 50 bonds are rated no lower than B- by S&P and none of them defaulted during the sample period.

The use of option quotes data, instead of transaction data, deserves some comments. Information-based market microstructure models demonstrate that the bid-ask spread reflects a balancing of losses to the informed traders with gains from the uninformed traders and therefore contains information about the probability of trading on private

15 Examining the price behavior of different bonds issued by the same firm is another interesting topic for future research.

information in the market [See Copeland and Galai (1983), Glosten and Milgrom (1985) and Easley and O'Hara (1987, 1992)]. In addition, as shown by Chan, Chung and Fong (2002), because of generally larger bid-ask spread in the option market, as documented by Vijh (1999), informed traders might have an incentive to submit limit orders instead of market orders, and hence quote revisions contain valuable information about future market movements. Moreover, since corporate bonds embed a short position in puts on the value of the firm, call option data are eliminated from the sample. Finally, as will be shown in the next section, ATM options and OTM options carry different information about future movements in stocks and bonds. Therefore, both ATM and deep OTM put option spreads are kept for each firm.

4. Inter-Market Relationships between Stocks, Bonds and Options

If new information about the value of an individual firm exists in the market, it should be reflected in the prices of the firm's stocks, bonds and options. This section examines pair-wise relationships between stocks, bonds and options. Daily stock returns, $SR_{i,t}$, and daily bond returns, $BR_{i,t}$, are calculated using the end-of-day closing prices. For the options market, normalized spreads for both ATM and deep OTM puts are calculated by dividing the bid-ask spread by the midpoint of bid and ask quotes. These are denoted as $AS_{i,t}$ and $OS_{i,t}$ respectively.

In order to isolate interest rate risk, for each individual corporate bond I construct a corresponding default-free bond whose future cash flows match those of the corporate bond perfectly. The price of default-free bonds can simply be calculated by discounting the cash flows at corresponding default-free zero-coupon interest rates. These zero-coupon rates are estimated by employing a modified version of the extended Nelson-Siegel model (Bliss (1997)) on the observed on-the-run Treasury curve[16]:

$$\min_{\beta_0,\beta_1,\beta_2,\tau_1,\tau_2} \sum_{i=1}^{N_t} (w_i \varepsilon_i)^2 ,$$

subject to

$$r(m_{\min}) \geq 0 ,$$

$$r(m_{\max}) \geq 0 ,$$

and

$$\exp[-r(m_k)m_k] \geq \exp[-r(m_{k+1})m_{k+1}] ,\ \forall m_{\min} \leq m_k < m_{\max} ,$$

where

$$w_i = \frac{1/d_i}{\sum_{j=1}^{N_t} 1/d_j} ,$$

$$r(m) = \beta_0 + \beta_1 \left[\frac{1-e^{-m/\tau_1}}{m/\tau_1} \right] + \beta_2 \left[\frac{1-e^{-m/\tau_2}}{m/\tau_2} - e^{-m/\tau_2} \right] ,$$

$$\hat{p}_i = \sum c_{i,m} e^{-r(m)m} ,$$

16 Hotchkiss and Ronen (2002) calculate these default-free zero-coupon rates by using a method proposed by Fisher, Nychka, and Zervos (1994). However, based on a series of parametric and nonparametric tests, Bliss (1997) compares five distinct term structure estimation methods, including the smoothed and unsmoothed Fama-Bliss methods, the McCulloch model, the Fisher-Nychka-Zervos method and the extended Nelson-Siegel model, and concludes that the Fisher-Nychka-Zervos method does almost always poorly relative to the other four alternatives, in terms of both in-sample goodness-of-fit and out-of-sample performance.

and

$$\varepsilon_i = p_i - \hat{p}_i \, .$$

In this model, m represents time to maturity, $r(m)$ is the discount rate for coupon or principal payments at time m, d denote Macaulay duration, and c refers to cash flows. Based on the prices of the constructed default-free bonds, their returns, $DR_{i,t}$, can be readily calculated. Furthermore, to control for the effect of market-wide information, I include the S&P 500 index return, denoted as MR_t, in the model. Data for both the observed on-the-run Treasury curve and the S&P 500 index return are retrieved from the Center for Research in Security Prices (CRSP).

To study information flow across different markets, the following panel Vector Auto-Regression (VAR) model with two controlling variables is estimated, and Granger causality tests are conducted to identify pairwise lead-lag relationships between stocks, bonds and options:

$$Y_{i,t} = \mathrm{A} + \sum_{j=1}^{J} B_{-j} Y_{i,t-j} + C_t X_t + E_{i,t} \, ,$$

where

$$Y_{i,t} = [SR_{i,t}, BR_{i,t}, AS_{i,t}, OS_{i,t}]' ,$$

$$X_t = [MR_t, DR_t]' ,$$

$$A = [\alpha_1, \alpha_2, \alpha_3, \alpha_4]' ,$$

$$B_{-j} = \begin{bmatrix} \beta_{11,-j} & \beta_{12,-j} & \beta_{13,-j} & \beta_{14,-j} \\ \beta_{21,-j} & \beta_{22,-j} & \beta_{23,-j} & \beta_{24,-j} \\ \beta_{31,-j} & \beta_{32,-j} & \beta_{33,-j} & \beta_{34,-j} \\ \beta_{41,-j} & \beta_{42-j,} & \beta_{43-j,} & \beta_{44,-j} \end{bmatrix},$$

$$C = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \\ \gamma_{31} & \gamma_{32} \\ \gamma_{41} & \gamma_{42} \end{bmatrix},$$

and

$$E_{i,t} = [\varepsilon_{i1,t} \quad \varepsilon_{i2,t} \quad \varepsilon_{i3,t} \quad \varepsilon_{i4,t}]'.$$

A, B and C contain parameters to be estimated, and E_t is the error vector. This model is estimated by generalized least squares (GLS) with error terms corrected for auto-correlation.

As individual corporate bonds tend to be less frequently traded than their corresponding stocks and options, even for TRACE 50 which are considered more active than other high-yield bonds [Hotchkiss and Nolen (2002)], this model is first estimated with data on 48 firms with relatively high bond volume to mitigate potential bias introduced by infrequent trading. Table 2 contains summary statistics about characteristics of the 48 bonds and their issuing firms.

3.1 Stock-bond relationships

According to the structural firm-value approach to the valuation of corporate debt (Merton (1974)), corporate bonds can be viewed as risk-free debt combined with a short position in a put on the value of the firm's assets. Since equity can be considered a call option on the assets, if financial markets are efficient, stock and bond prices should move simultaneously with no lead-lag relationship, and the direction of contemporaneous movements should reveal the nature of information in the markets: information about the mean value of the issuing firm's assets leads to positive correlation between stock and bond returns, while information related to changes in the volatility of the firm's asset returns causes negative correlation.

As found by previous studies [Kwan (1996), Hotchkiss and Ronen (2002)], stock returns are positively correlated with contemporaneous bond returns with a correlation coefficient of 0.169, suggesting that at the individual firm level, information that drives individual stock and bond returns is primarily related to the mean value of the firm's asset, not the volatility of asset returns. Also consistent with previous studies [Blume, Keim and Patel (1991), Cornell and Green (1991)], high-yield bonds are not sensitive to movements in interest rates (as the coefficient for DR_t is not significant) but are very sensitive to changes in stocks prices. The coefficient for MR_t is 0.136, and is significant at 1% level. As to the leads and lags, Table 4 shows that lagged stock returns have explanatory power for current bond returns, with the coefficients significant at 1% level back to day t-5 except for day t-4. The fact that the stock market closes two and half hours earlier than the TRACE makes the predictive power of previous stock returns even stronger. Additionally, Granger causality test rejects the null hypothesis that the coefficients for SR_{t-1} through SR_{t-5} are zero at 1% level. Therefore, there is strong evidence that the stock market contains valuable information about future bond returns. This result confirms the stock lead found in Kwan (1996).

What differentiates my study from previous ones is the finding that current stock returns are positively correlated with lagged bond returns (Table 3). Coefficients for lagged bond returns are both economically and statistically significant, not only for day t-1, but for day t-2 and day t-4, indicating that potential nonsynchronous trading brings little bias into the results. The F-value for testing that $\beta_{12,t-j}$ equals zero for j=1, 2, 3, 4 and 5 is 3.303, significant at 1% level. The reason that this relationship is not found in Kwan (1996) might be attributed to the quality of the data he uses. First, it is hard to identify active bonds using quotes data from a dealer, even though small issues that are subject to infrequent trading are eliminated from the sample. In fact, the use of inactive bonds to examine the lead-lag relations might bias his results toward the stock lead. Second, since information (especially publicly released information) is impounded into prices quickly, using data on weekly frequency to address the price discovery process is also questionable.

It is intriguing to notice that my results differ completely from those of Hotchkiss and Ronen (2002), as the quality of FIPS data they use is close to the TRACE 50 data in the current study. However, a closer look into their methodology reveals serious problems. In order to answer the question "Do stocks lead bonds in reflecting firm-specific information?", Hotchkiss and Ronen (2002) "construct a portfolio of the 20 most actively traded FIPS bonds which also have publicly traded equity", and conduct an analysis of Granger causality "between portfolios of the FIPS bonds and of the corresponding stocks". Obviously, aggregation across different bonds and stocks into portfolios will remove valuable information about informed trading in stocks and bond at the individual firm level. Therefore, unless there is trading based on portfolio or market related information, it is hard to identify any lead-lag relations between stocks and bonds. Not surprisingly, Hotchkiss and Ronen (2002) conclude that stock returns do not Granger cause bond returns, nor the other way around.

Moreover, the evidence that both lagged stock returns and lagged bond returns predict current prices movements implies that it takes time for new information to become incorporated into security prices. Compared to the corporate bond market, the stock market is more informationally efficient. According to the results reported in Table 3, lagged stock returns only for time t-1 is statistically significant at the 5% level, while lagged bond returns are statistically significant for time t-1, t-2 and t-4, with similar (albeit much less) magnitude. Even though coefficients for lagged stock returns are significant for almost all 5 days when $BR_{i,t}$ is used as dependent variable (Table 4), they drop significantly from 0.154 for time t-1 to 0.037 for time t-2, and remain at this level afterwards. On the contrary, the coefficient for $BR_{i,t-1}$ jumps in magnitude from -0.028 to -0.226 for $BR_{i,t-2}$. This indicates that information gets impounded in stock prices within one day, while it takes the corporate bond market much longer to adjust to the new information, a conclusion that differs from Hotchkiss and Ronen (2002) who they argue that market quality is no poorer for bonds than for their underlying stocks.

To summarize, even though the stock market and the bond market differ in degree of informational efficiency, informed traders trade in both markets on their information, hence both markets serve important informational roles in the price discovery process.

3.2 Stock-option relationships

Consistent with Chan, Chung and Fong (2002), this paper finds an informational role for option quote revisions. Table 3 shows that current stock returns are negatively correlated with ATM put spreads for the previous day, and lagged ATM put option spreads Granger cause current stock returns (F-value of 2.379, significant at 5% level). Since lagged stock returns have no explanatory power for current ATM put spreads, it is safe to conclude that trading in options leads trading in the underlying stocks, with a one-day lag. This conclusion complements the findings of a one-day lead of options by Manaster and Rendleman (1982) based on transaction price data, and that of Anthony (1988) with volume data. It also supports the argument that informed traders might submit limit orders in the option market to exploit their private information.

Interestingly, the leading role of option quote revisions can not be confirmed by deep OTM options. Lagged deep OTM put spreads do not predict current stock returns (Table 3), nor are lagged stock returns correlated with current OTM spreads (Table 6). This result contradicts that of Chakravarty, Gulen and Mayhew (2004), where they argue the average information share is significantly higher for OTM options for ATM options. If the higher information share for OTM options in the price discovery process can be attributed to their higher leverage, the superior predictive power of ATM option spreads might reside in their tighter bid-ask spreads compared to OTM options. However, this explanation is not very convincing as informed traders tend to submit limit orders in the option market to avoid higher options spreads relative to those of stocks.

The finding that current stock returns can be predicted by lagged spreads for ATM puts but not OTM puts can be explained by the kind of information investors trade on. Compared to deep OTM put options, ATM puts are more sensitive to changes in the mean value of a firm's assets, especially when the changes are not dramatic. Therefore, unless there is crash information about the firm's value, which will change the moneyness of the deep OTM put options, informed traders are more likely to trade ATM options. The clustering of informed trading on ATM options makes ATM option spreads capable of predicting future stock price changes, leading to the conclusion that the option market is leading the stock market in reflecting general firm-specific information. This explanation from the perspective of the nature of private information can be further strengthened by the lead-lag relations between options and bonds discussed in the following subsection.

3.3 Bond-option relationships

Compared to numerous studies on lead-lag relations between stocks and options, and a relatively smaller body of work on the stock-bond interrelation, literature on whether the option market contain important information as to future movements in the corporate bond market is literally blank. Table 4, 5 and 6 establish a very interesting relation between corporate bond returns and options spreads. Even though none of the coefficients for lagged deep OTM put spreads are significant in explaining current bond returns (Table 4), Granger causality tests do reject the null hypothesis that lagged OTM spreads, as a whole, have no explanatory power (with an F-value 2.550 and a significance level of 0.026). On the other hand, as shown by Table 6, when current deep OTM put option spreads are regressed on lagged bond returns, none of the coefficients are significant at any sensible level. Furthermore, Granger causality tests cannot reject that all coefficients are equal to zero.

This phenomenon can be explained by the same approach proposed in the last subsection. For delta-equivalent positions, deep OTM put options are more subject to a crash in a firm's value than ATM options. As a result, informed traders who obtain very bad news about a firm will prefer to buy OTM puts on the firm's stock, which will be reflected in the bid-ask spreads. On the other hand, since corporate bonds embed a short position in OTM puts, only information about a possible crash in the firm's value, and hence default in future interests and principal payments will affect the bond price. Therefore, the evidence of OTM put option spreads predicting future bond returns indicates that the option market is leading the bond market in reflecting extreme firm-specific information. Furthermore, the coefficients of lagged OTM spreads are negative for the first 2 days, confirming the informational effects of trading on the deep OTM put options. The identification of a unidirectional relation of OTM options leading bonds complements the finding that ATM options lead stocks in displaying how an informed trader's choice of options of different moneyness depends on the type of information she possesses. It also contributes to a strand of literature on how information based trading in the option market is allocated across strike prices [De Jong, Koedijk, and Schnitzlein (2001), Kaul, Nimalendran and Zhang (2002), Anand and Chakravarty (2003), Chakravarty, Gulen, Mayhew (2004)].

To complete the analysis on bond-option relationships, I turn to the lead-lag between bond returns and ATM put option spreads. Table 4 shows that lagged ATM put option spreads have no explanatory power for current bond returns. However, lagged bond returns do explain some changes in current ATM put option spreads. The coefficients for $BR_{i,t-1}$ and $BR_{i,t-4}$ are both economically and statistically significant (Table 5). The estimates for the coefficients are 0.443 and 0.440, with t-value of 2.274 and 2.270 respectively. The hypothesis that coefficients on all lagged bond returns are zero can be rejected at 5% level. Therefore, bond returns lead ATM spread changes, but not vice versa. This relation reflects hedging activities associated with trading in bonds. As argued by Cremers, Driessen, Maenhout and Weinbaum (2004), firm-specific information risk can to some extent be hedged by trading in options of the issuer. Furthermore, compared to way OTM options, ATM options are preferable in hedging as they are more sensitive to small changes in the value of the issuer's assets, and they tend to be more liquid.

4. Infrequent Trading and the Lead-Lag Relationships

In this section, the panel VAR model is re-estimated based on data for all 77 firms to examine whether the results in the previous section are subject to infrequent trading in corporate bonds. As shown by Table 1 and Table 2, firms with inactive bonds tend to be smaller than firms with active bonds. Reinserting those small firms and examining the pairwise lead-lag effects allows us to see how the dynamics of information flow across different securities varies with firm size. The results are presented in Table 7 through Table 10.

Stock returns are still positively correlated with contemporaneous bond returns at 0.155. The explanatory power of past bond returns remains, with $\beta_{12,-j}$ estimated at 0.034, 0.031, 0.015, 0.031 and 0.024 respectively for j=1, 2, …, 5. All estimates are statistically significant at 5% level except for that of time t-3. In addition, Granger causality tests confirm additional predictive power added by lagged bond returns, with an F-value 3.597, which is significant at 1% level. Since higher frequency of trading in stocks as compared to bonds tends to introduce a spurious stock lead, the fact that the predictive ability of previous bond returns for present stock prices changes remains even for firms with inactive bonds makes my results extremely strong.

The evidence of informed trading in the corporate bond market seems a little bit puzzling. According to a recent study released by the SEC (Edwards, Harris and Piwowar (2004)), average transaction costs for trades in corporate bonds are higher than in stocks. In particular, retail trading in a bond is at least four times more expensive as a typical retail trade in equities. Furthermore, unlike options, corporate bonds do not provide higher leverage than stocks. I conjecture that two reasons might explain the corporate bond market as a venue for informed trading. First, if investors are risk averse, even if they have access to some private information, they might choose to trade in bonds to stay away from down-side risk, as their aversion to risk cannot be fully eliminated by the piece of information they have, especially when they are not so sure about the quality of the information. While it is true that the down-side risk can be easily hedged in the options market, associated transaction costs might render direct trading in bonds a better choice. Secondly, for informed traders engaged in illegal insider trading, the choice of where to trade may be also affected by the perceived probability of being detected and prosecuted. According to Section 10(b) of the Securities and Exchange Act of 1934, it is unlawful for any person "to use or employ, in connection with the purchase or sale of any security registered on a national securities exchange or any security not so registered, any manipulative or deceptive device or contrivance in contravention of such rules and regulations as the SEC may prescribe"[17]. However, compared to the markets for equity securities and derivative securities, the debt securities market has been subject to much less scrutiny for insider trading. Therefore, the lower probability of detection and punishment

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17 To implement Section 10(b), the SEC adopted Rule 10b-5, which provides, in relevant part: It shall be unlawful for any person, directly or indirectly, by the use of any means or instrumentality of interstate commerce, or of the mails or of any facility of any national securities exchange,

a. To employ any device, scheme, or artifice to defraud,

b. To make any untrue statement of a material fact or to omit to state a material fact necessary in order to make the statements made, in the light of the circumstances under which they were made, not misleading, or

c. To engage in any act, practice, or course of business which operates or would operate as a fraud or deceit upon any person, in connection with the purchase or sale of any security.

might also encourage some informed traders to turn to the corporate bond market for higher expected profits.

The fact that investors might choose to trade on their private information in the corporate bond market has important implications for surveillance for illegal insider trading in market. While this study does not investigate whether corporate bond traders are trading on insider information unlawfully or aim at establishing a breach of fiduciary duty, it is likely that some of the information that informed traders exploit is illegal in nature. If prices of corporate bonds are sensitive to private information and the market for corporate bonds, especially high-yield bonds, includes some insider trading, then the concerns about insider trading as in any other securities market apply and it might be optimal for both policymakers and regulators to devote more efforts in monitoring the corporate bond market.

As to the relationships between stocks and options, ATM put option spreads continue to lead stock returns. However, with smaller firms included in the sample, there is some weak evidence that lagged deep OTM option spreads provide extra information about current stock returns. The F-value for testing coefficients for all prior OTM put spreads equal to zero is 1.865, which is a significant jump from 1.018 when only frequently traded bonds are examined, and is significant at 10% level. Since small firms generally have more skewed returns [Duffee (1995)], finding that current stock movements can be partially explained by changes in deep OTM options spreads confirms the argument that investors with extraordinary information prefer to trade OTM options. Additionally, if the one-day lead of the option market can be attributed to its later closing time than that for the stock market, including less frequently traded bonds should not change the conclusion as to whether OTM options contain valuable information regarding future stock price changes. The new evidence of informed trading in deep OTM options related to small firms thereafter makes the option lead less subject to the nonsynchronous trade effects.

Lastly, the result concerning the correlation between present bond returns and earlier way OTM option spreads is robust even when infrequently traded bonds are considered, making my conclusion on the option's lead even stronger. With less frequently traded bonds entering the sample, the finding that lagged bond returns help to predict current ATM options spread changes disappears. This might suggest that it is simply too expensive to hedge trading in inactive bonds.

5. Conclusions and Extensions

Taking advantage of a unique corporate bond transaction dataset from NASD, this paper studies where information based trading takes place and how information gets incorporated into securities prices. Differing from previous studies [Kwan (1996), Hotchkiss and Ronen (2002)], I find that informed traders do trade in the corporate bond market, and corporate bond returns contain important information about future stock price movements. Both the stock market and the bond market serve important informational roles in the price discovery process. Furthermore, compared to the stock and the bond markets, the option market is a preferred venue for informed trading. It is leading both the stock market and the corporate bond markets in reflecting firm specific information. In addition, there is strong evidence that an informed trader's choice of options with different strike prices depends crucially on what kind of information she has. Unless she is aware of some impending extreme event to a firm, in which case she rushes to buy deep OTM put options on the firm, she will trade ATM options if she obtains milder information.

The analysis of the dynamics of information flow across individual stocks, options and corporate bonds can be extended in several important ways. First, it is interesting to extend this study in both cross-sectional and time-series frameworks. What this study establishes is a world with symmetric information arrival, with the option market leading the others. It would be interesting to know whether this relationship extends to each individual firm, and if not, how it varies with firm-specific characteristics. Furthermore, how the relative speed of adjustment to new information in different markets changes with contemporaneous market conditions and over time, and whether it differs dramatically between event days and non-event days are of no less interest. Answers to these questions will definitely provide deeper understanding of the price discovery process. An example of work in this direction is Chakravarty, Gulen and Mayhew (2004).

Second, as this study focus on the lead-lag interrelationships between three closely related securities markets in terms of price, it is equally important to explore the information role of volume. Easley and O'Hara (1992) show that volume contains some information that is not reflected in the price. Blume, Easley and O'Hara (1994) emphasize the role of volume as a statistic for technical analysis. It is interesting to check whether transaction volume in different markets provides additional insights into where informed traders trade and where price discovery takes place. Furthermore, an investigation of the pattern of trading volume in corporate bonds and its time-series variation would contribute to the new area of corporate bond market microstructure.

Lastly, the identification of informed trading ingthe corporate bond market suggests a market microstructure approach to corporate bond pricing. Traditional structural models of default, built on the original insights of Black and Scholes (1973) and Merton (1974), provide an intuitive framework for identifying the determinants of credit spread changes of debt securities. However, these models are not successful in rationalizing credit spreads observed in the market. Furthermore, even after accounting for liquidity effects, it is still challenging to explain credit spread changes solely based on credit-risk factors (see for example, Collin-Dufresne, Goldstein and Martin (2001), Eom, Helwege and Huang (2003), Duffie and Singleton (2003) and Huang and Huang (2003)). One inherent assumption under all these models, however, is that the market is complete. If information is asymmetric and it is incorporated into prices by trading, as shown by the current study, the high-yield spreads observed in the market might embed an information premium that is left out in traditional structural models. Correct pricing of information risk in the corporate bond market brings a more ambitious goal into agenda. As posited by Titman (2002), if the markets for debt, equity and derivatives are not integrated, then the required return premium associated with any risk differs across markets. This directly affects how firms raise capital and hedge. The complete transaction dataset for debt, equity and derivative securities, as well as an accurate pricing model for different risks, allow direct tests of whether the markets for these securities are perfectly integrated, and hence help us to gain a deeper understanding of the Modigliani and Miller (1958) theorem.

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Table 1

Characteristics of 77 TRACE 50 Bonds and Their Issuing Firms

Panel A:

Variable	*Mean*	*Median*	*Minimum*	*Maximum*	*Std Dev*
Assets	11471.1	8394	523.8	63545	10195.2
Leverage	0.7819	0.7773	0.3586	1.9119	0.2128
Coupon Rate	7.4812	7.875	1.25	11	2.2228
Time to Maturity	6.369	5.8344	2.0862	26.705	3.3646

Panel B:

Bond Type	SRDEB	SRNT	SRSECNT	SRSUBNT	SRUNNT	SUBDEB	SUBNT	UNNT
Number of Bonds	1	12	2	8	38	1	10	4
Percentage	1.32	15.79	2.63	10.53	50	1.32	13.16	5.26

PanelC:

S&P Rating	BBB	BB	B	CCC	CC	C	NR
Number of Bonds	7	24	29	7	1	1	7
Percentage	9.21	31.58	38.16	9.21	1.32	1.32	9.21

Panel D:

Coupon Type	Variable	Fixed Plain Vanilla Fixed Coupon
Number of Bonds	1	76
Percentage	1.3	98.7

Panel E:

Payment Frequency	Semiannually
Number of Bonds	77
Percentage	100

Panel F:

Industry	CG	ENGY	FIN	MANU	SERV	TELE	TRANS
Number of Bonds	1	9	7	30	24	5	1
Percentage	1.3	11.69	9.09	38.96	31.17	6.49	1.3

Panel G:

Callable	Yes	No
Number of Bonds	38	39
Percentage	49.35	50.65

Panel H:

Convertible	Yes	No
Number of Bonds	14	63
Percentage	18.18	81.82

This table contains summary characteristics for the 77 corporate bonds and their issuing firms at the time of their initial entry to the TRACE 50 list. Firm characteristics are based on data from COMPSTAT, while bond characteristics are determined from the TRACE 50 dataset. Most of these descriptive bond data were obtained from NASD, with the remainder provided by the issuing firms. The following abbreviations are used in this table: for bond type, SRDEB (Senior Debenture), SRNT (Senior Note), SRSECNT (Senior Secured Note), SRSUBNT (Senior Subordinated Note), SRUNNT (Senior Unsecured Note), SUBDEB (Subordinated Debenture), SUBNT (Subordinated Note) and UNNT (Unsecured Note); for industry, CG (Consumer Goods), ENGY (Energy), FIN (Financial), MANU (Manufacturing), SERV (Services), TELE (Telecommunications) and TRANS (Transportation).

Table 2

Characteristics of 48 Most Frequently Traded TRACE 50 Bonds and Their Issuing Firms

Panel A:

Variable	*Mean*	*Median*	*Minimum*	*Maximum*	*Std Dev*
Assets	14259.7	10709.7	1613	63545	11564.6
Leverage	0.7963	0.7843	0.4444	1.5206	0.1946
Coupon Rate	7.4121	7.75	1.25	11	2.247
Time to Maturity	6.721	5.8344	2.0862	26.705	4.0662

Panel B:

Bond Type	SRDEB	SRNT	SRSECNT	SRSUBNT	SRUNNT	SUBDEB	SUBNT	UNNT
Number of Bonds	1	7	2	4	24	0	7	3
Percentage	2.08	14.58	4.17	8.33	50.00	0.00	14.58	6.25

PanelC:

S&P Rating	BBB	BB	B	CCC	CC	C	NR
Number of Bonds	4	16	17	5	1	0	5
Percentage	8.33	33.33	35.42	10.41	2.08	0.00	10.42

Panel D:

Coupon Type	Variable	Fixed Plain Vanilla Fixed Coupon
Number of Bonds	1	47
Percentage	2.08	97.92

Panel E:

Payment Frequency	Semiannually
Number of Bonds	48
Percentage	100.00

Panel F:

Industry	CG	ENGY	FIN	MANU	SERV	TELE	TRANS
Number of Bonds	1	7	4	16	15	5	0
Percentage	2.08	14.58	8.33	33.33	31.25	10.42	0.00

Panel G:

Callable	Yes	No
Number of Bonds	23	25
Percentage	47.92	52.08

Panel H:

Convertible	Yes	No
Number of Bonds	12	36
Percentage	25.00	75.00

This table contains summary characteristics for the 48 most frequently traded TRACE 50 bonds and their issuing firms at the time of their initial entry to the TRACE 50 list. Firm characteristics are based on data from COMPSTAT, while bond characteristics are determined from the TRACE 50 dataset. Most of these descriptive bond data were obtained from NASD, with the remainder provided by the issuing firms. The following abbreviations are used in this table: for bond type, SRDEB (Senior Debenture), SRNT (Senior Note), SRSECNT (Senior Secured Note), SRSUBNT (Senior Subordinated Note), SRUNNT (Senior Unsecured Note), SUBDEB (Subordinated Debenture), SUBNT (Subordinated Note) and UNNT (Unsecured Note); for industry, CG (Consumer Goods), ENGY (Energy), FIN (Financial), MANU (Manufacturing), SERV (Services), TELE (Telecommunications) and TRANS (Transportation).

Table 3

Regression of current stock returns on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 48 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0016	2.3428	0.0192
2	DR	-0.1667	-1.9273	0.0540
3	MR	1.2975	32.2153	0.0000
4	SR{1}	0.1791	15.8183	0.0000
5	SR{2}	-0.0080	-0.6889	0.4909
6	SR{3}	-0.0138	-1.1747	0.2401
7	SR{4}	-0.0182	-1.5732	0.1157
8	SR{5}	0.0196	1.7123	0.0869
9	BR{1}	0.0567	3.4094	0.0007
10	BR{2}	0.0337	1.9672	0.0492
11	BR{3}	0.0241	1.3949	0.1631
12	BR{4}	0.0392	2.3012	0.0214
13	BR{5}	0.0248	1.5353	0.1248
14	AS{1}	-0.0027	-2.5172	0.0119
15	AS{2}	0.0006	0.4478	0.6543
16	AS{3}	0.0013	1.0453	0.2959
17	AS{4}	0.0017	1.3406	0.1801
18	AS{5}	-0.0004	-0.3705	0.7111
19	OS{1}	-0.0551	-0.8946	0.3710
20	OS{2}	-0.0006	-0.0083	0.9933
21	OS{3}	0.0208	0.2953	0.7678
22	OS{4}	-0.0058	-0.0826	0.9342
23	OS{5}	0.0070	0.1139	0.9093
24	Adjusted R-Square	0.1634		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
BR: Lag 1 to Lag 5	3.3035	0.0056
AS: Lag 1 to Lag 5	2.3787	0.0364
OS: Lag 1 to Lag 5	1.0177	0.4053

Panel A presents the results from estimating the following model:

$$SR_{i,t} = \alpha_1 + \gamma_{11} MR_t + \gamma_{12} DR_{i,t} + \sum_{j=1}^{5} \beta_{11,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{12,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{13,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{14,-j} OS_{i,t-j} + \varepsilon_{i1,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{12}, β_{13}, and β_{14} are equal to zero.

Table 4

Regression of current bond returns on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 48 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0016	3.8044	0.0001
2	DR	0.0238	0.3843	0.7008
3	MR	0.1357	4.6362	0.0000
4	SR{1}	0.1541	18.0473	0.0000
5	SR{2}	0.0368	3.9583	0.0001
6	SR{3}	0.0492	5.2450	0.0000
7	SR{4}	0.0071	0.7771	0.4372
8	SR{5}	0.0292	3.4068	0.0007
9	BR{1}	-0.0282	-2.2662	0.0235
10	BR{2}	-0.2261	-18.2410	0.0000
11	BR{3}	-0.0765	-6.0553	0.0000
12	BR{4}	-0.0607	-4.9194	0.0000
13	BR{5}	-0.0325	-2.6867	0.0072
14	AS{1}	-0.0005	-0.5827	0.5601
15	AS{2}	0.0000	-0.0335	0.9733
16	AS{3}	0.0008	0.6944	0.4874
17	AS{4}	-0.0001	-0.1314	0.8955
18	AS{5}	0.0003	0.3740	0.7085
19	OS{1}	-0.0742	-1.6055	0.1084
20	OS{2}	-0.0189	-0.3163	0.7518
21	OS{3}	0.0486	0.8240	0.4100
22	OS{4}	0.0412	0.6933	0.4882
23	OS{5}	-0.0241	-0.5244	0.6001
24	Adjusted R-Square	0.1635		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
SR: Lag 1 to Lag 5	102.2204	0.0000
AS: Lag 1 to Lag 5	0.3946	0.8529
OS: Lag 1 to Lag 5	2.5503	0.0259

Panel A presents the results from estimating the following model:

$$BR_{i,t} = \alpha_2 + \gamma_{21} MR_t + \gamma_{22} DR_{i,t} + \sum_{j=1}^{5} \beta_{21,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{22,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{23,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{24,-j} OS_{i,t-j} + \varepsilon_{i2,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{21}, β_{23}, and β_{24} are equal to zero.

Table 5

Regression of current ATM put option spreads on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 48 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0569	9.6744	0.0000
2	DR	-0.4843	-0.5199	0.6031
3	MR	1.2883	2.9091	0.0036
4	SR{1}	-0.1385	-1.0321	0.3021
5	SR{2}	-0.0638	-0.4197	0.6747
6	SR{3}	0.0445	0.2867	0.7743
7	SR{4}	-0.1201	-0.8002	0.4236
8	SR{5}	0.0857	0.6387	0.5230
9	BR{1}	0.4431	2.2741	0.0230
10	BR{2}	0.2097	1.0795	0.2804
11	BR{3}	-0.0051	-0.0251	0.9800
12	BR{4}	0.4396	2.2697	0.0233
13	BR{5}	-0.2616	-1.3816	0.1671
14	AS{1}	1.0294	82.7690	0.0000
15	AS{2}	-0.3683	-20.6481	0.0000
16	AS{3}	0.2143	11.7187	0.0000
17	AS{4}	-0.0905	-5.0392	0.0000
18	AS{5}	0.0572	4.5531	0.0000
19	OS{1}	-0.1615	-0.2240	0.8227
20	OS{2}	0.2244	0.2263	0.8210
21	OS{3}	0.7483	0.7619	0.4461
22	OS{4}	-1.1026	-1.1183	0.2635
23	OS{5}	1.1094	1.5430	0.1229
24	Adjusted R-Square	0.4857		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
SR: Lag 1 to Lag 5	0.5494	0.7389
BR: Lag 1 to Lag 5	2.5140	0.0279
OS: Lag 1 to Lag 5	6.9518	0.0000

Panel A presents the results from estimating the following model:

$$AS_{i,t} = \alpha_3 + \gamma_{31} MR_t + \gamma_{32} DR_{i,t} + \sum_{j=1}^{5} \beta_{31,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{32,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{33,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{34,-j} OS_{i,t-j} + \varepsilon_{i3,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{31}, β_{32}, and β_{34} are equal to zero.

Table 6

Regression of current OTM put option spreads on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 48 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0002	1.8701	0.0615
2	DR	-0.0120	-0.7745	0.4387
3	MR	0.0162	2.1917	0.0284
4	SR{1}	0.0030	1.3113	0.1898
5	SR{2}	0.0028	1.0463	0.2955
6	SR{3}	0.0006	0.2183	0.8272
7	SR{4}	0.0022	0.8399	0.4010
8	SR{5}	0.0015	0.6532	0.5136
9	BR{1}	-0.0018	-0.5497	0.5825
10	BR{2}	0.0004	0.1204	0.9042
11	BR{3}	-0.0034	-0.9722	0.3310
12	BR{4}	-0.0019	-0.5778	0.5634
13	BR{5}	0.0003	0.0869	0.9308
14	AS{1}	0.0001	0.3150	0.7528
15	AS{2}	-0.0002	-0.6327	0.5270
16	AS{3}	0.0003	0.8038	0.4215
17	AS{4}	0.0001	0.1632	0.8704
18	AS{5}	0.0000	0.1984	0.8427
19	OS{1}	1.0070	82.2091	0.0000
20	OS{2}	-0.3433	-19.8042	0.0000
21	OS{3}	0.3323	19.2645	0.0000
22	OS{4}	-0.1377	-7.9880	0.0000
23	OS{5}	0.1316	10.7617	0.0000
24	Adjusted R-Square	0.9254		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
BR: Lag 1 to Lag 5	1.6781	0.1361
AS: Lag 1 to Lag 5	0.3417	0.8878
OS: Lag 1 to Lag 5	0.8776	0.4951

Panel A presents the results from estimating the following model:

$$OS_{i,t} = \alpha_4 + \gamma_{41} MR_t + \gamma_{42} DR_{i,t} + \sum_{j=1}^{5} \beta_{41,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{42,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{43,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{44,-j} OS_{i,t-j} + \varepsilon_{i4,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{41}, β_{42}, and β_{43} are equal to zero.

Table 7

Regression of current stock returns on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 77 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0014	3.0483	0.0023
2	DR	-0.1266	-2.0124	0.0442
3	MR	1.2423	46.9327	0.0000
4	SR{1}	0.1704	20.9229	0.0000
5	SR{2}	-0.0106	-1.2751	0.2023
6	SR{3}	-0.0001	-0.0127	0.9898
7	SR{4}	-0.0239	-2.8696	0.0041
8	SR{5}	0.0134	1.6358	0.1019
9	BR{1}	0.0338	2.8857	0.0039
10	BR{2}	0.0312	2.5724	0.0101
11	BR{3}	0.0148	1.2012	0.2297
12	BR{4}	0.0312	2.5792	0.0099
13	BR{5}	0.0241	2.0771	0.0378
14	AS{1}	-0.0023	-3.2685	0.0011
15	AS{2}	0.0008	0.9517	0.3413
16	AS{3}	0.0013	1.4601	0.1443
17	AS{4}	0.0003	0.3366	0.7364
18	AS{5}	0.0004	0.5828	0.5601
19	OS{1}	-0.0151	-1.0158	0.3097
20	OS{2}	0.0075	0.4501	0.6527
21	OS{3}	-0.0042	-0.2524	0.8007
22	OS{4}	0.0044	0.2637	0.7920
23	OS{5}	-0.0176	-1.1834	0.2367
24	Adjusted R-Square	0.1666		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
BR: Lag 1 to Lag 5	3.5972	0.0030
AS: Lag 1 to Lag 5	3.1894	0.0070
OS: Lag 1 to Lag 5	1.8653	0.0968

Panel A presents the results from estimating the following model:

$$SR_{i,t} = \alpha_1 + \gamma_{11} MR_t + \gamma_{12} DR_{i,t} + \sum_{j=1}^{5} \beta_{11,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{12,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{13,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{14,-j} OS_{i,t-j} + \varepsilon_{i1,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{12}, β_{13}, and β_{14} are equal to zero.

Table 8

Regression of current bond returns on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 77 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0019	4.8320	0.0000
2	DR	0.0357	0.7360	0.4618
3	MR	0.1120	5.5325	0.0000
4	SR{1}	0.1338	21.3473	0.0000
5	SR{2}	0.0907	14.2621	0.0000
6	SR{3}	0.0671	10.4983	0.0000
7	SR{4}	0.0111	1.7480	0.0805
8	SR{5}	0.0261	4.1321	0.0000
9	BR{1}	-0.3837	-42.5804	0.0000
10	BR{2}	-0.2432	-25.1523	0.0000
11	BR{3}	-0.1423	-14.4930	0.0000
12	BR{4}	-0.0749	-7.7620	0.0000
13	BR{5}	-0.0375	-4.2087	0.0000
14	AS{1}	-0.0005	-0.9931	0.3207
15	AS{2}	-0.0001	-0.2151	0.8297
16	AS{3}	0.0004	0.5967	0.5507
17	AS{4}	-0.0003	-0.5078	0.6116
18	AS{5}	0.0006	1.1009	0.2709
19	OS{1}	-0.0127	-1.1130	0.2657
20	OS{2}	-0.0086	-0.7072	0.4795
21	OS{3}	-0.0017	-0.1379	0.8903
22	OS{4}	0.0039	0.3237	0.7462
23	OS{5}	-0.0052	-0.4547	0.6493
24	Adjusted R-Square	0.1485		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
SR: Lag 1 to Lag 5	155.6577	0.0000
AS: Lag 1 to Lag 5	0.5409	0.7454
OS: Lag 1 to Lag 5	2.2486	0.0468

Panel A presents the results from estimating the following model:

$$BR_{i,t} = \alpha_2 + \gamma_{21} MR_t + \gamma_{22} DR_{i,t} + \sum_{j=1}^{5} \beta_{21,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{22,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{23,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{24,-j} OS_{i,t-j} + \varepsilon_{i2,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{21}, β_{23}, and β_{24} are equal to zero.

Table 9

Regression of current ATM put option spreads on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 77 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0538	12.9468	0.0000
2	DR	0.3628	0.5095	0.6104
3	MR	1.5335	4.9712	0.0000
4	SR{1}	-0.0915	-0.8827	0.3774
5	SR{2}	-0.0031	-0.0265	0.9789
6	SR{3}	0.1174	0.9694	0.3324
7	SR{4}	-0.0848	-0.7249	0.4685
8	SR{5}	0.0487	0.4725	0.6366
9	BR{1}	0.2741	1.8595	0.0630
10	BR{2}	0.0425	0.2852	0.7755
11	BR{3}	-0.0454	-0.2908	0.7712
12	BR{4}	0.2149	1.4392	0.1501
13	BR{5}	-0.1742	-1.1943	0.2324
14	AS{1}	1.0764	120.5697	0.0000
15	AS{2}	-0.4472	-34.1534	0.0000
16	AS{3}	0.2963	21.9894	0.0000
17	AS{4}	-0.1363	-10.3707	0.0000
18	AS{5}	0.0678	7.5582	0.0000
19	OS{1}	0.2721	1.4542	0.1459
20	OS{2}	-0.0389	-0.1530	0.8784
21	OS{3}	0.2040	0.8028	0.4221
22	OS{4}	0.2097	0.8265	0.4085
23	OS{5}	-0.0817	-0.4365	0.6625
24	Adjusted R-Square	0.5000		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
SR: Lag 1 to Lag 5	0.4812	0.7906
BR: Lag 1 to Lag 5	1.4282	0.2105
OS: Lag 1 to Lag 5	10.2521	0.0000

Panel A presents the results from estimating the following model:

$$AS_{i,t} = \alpha_3 + \gamma_{31} MR_t + \gamma_{32} DR_{i,t} + \sum_{j=1}^{5} \beta_{31,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{32,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{33,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{34,-j} OS_{i,t-j} + \varepsilon_{i3,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{31}, β_{32}, and β_{34} are equal to zero.

Table 10

Regression of current OTM put option spreads on current default-free debt returns, market returns, lagged bond returns, lagged ATM put option spreads, and lagged deep OTM put option spreads for the 77 firms with frequently traded bonds

Panel A: Estimation Results

	Variable	Estimated Coefficient	t-value	Significance Level
1	Constant	0.0013	6.7536	0.0000
2	DR	0.0601	1.8574	0.0633
3	MR	0.0202	1.4308	0.1525
4	SR{1}	0.0088	1.7948	0.0727
5	SR{2}	-0.0027	-0.4707	0.6379
6	SR{3}	0.0033	0.5573	0.5773
7	SR{4}	0.0035	0.6186	0.5362
8	SR{5}	0.0006	0.1321	0.8949
9	BR{1}	-0.0029	-0.4212	0.6737
10	BR{2}	-0.0014	-0.1936	0.8465
11	BR{3}	-0.0047	-0.6215	0.5343
12	BR{4}	-0.0044	-0.6229	0.5334
13	BR{5}	-0.0002	-0.0249	0.9801
14	AS{1}	-0.0001	-0.2911	0.7710
15	AS{2}	-0.0005	-0.7080	0.4789
16	AS{3}	0.0009	1.3769	0.1686
17	AS{4}	-0.0011	-1.7883	0.0738
18	AS{5}	0.0015	3.5755	0.0004
19	OS{1}	1.0016	113.9680	0.0000
20	OS{2}	-0.4848	-39.0331	0.0000
21	OS{3}	0.4500	35.9626	0.0000
22	OS{4}	-0.1772	-14.2858	0.0000
23	OS{5}	0.1616	18.3628	0.0000
24	Adjusted R-Square	0.6804		

Panel B: Granger Causality Tests

Null Hypothesis : The Following Coefficients Are Zero	F-value	Significance Level
BR: Lag 1 to Lag 5	1.0194	0.4042
AS: Lag 1 to Lag 5	0.2341	0.9477
OS: Lag 1 to Lag 5	4.1887	0.0008

Panel A presents the results from estimating the following model:

$$OS_{i,t} = \alpha_4 + \gamma_{41} MR_t + \gamma_{42} DR_{i,t} + \sum_{j=1}^{5} \beta_{41,-j} SR_{i,t-j} + \sum_{j=1}^{5} \beta_{42,-j} BR_{i,t-j} + \sum_{j=1}^{5} \beta_{43,-j} AS_{i,t-j} + \sum_{j=1}^{5} \beta_{44,-j} OS_{i,t-j} + \varepsilon_{i4,t}$$

SR and BR represent daily stock return and bond return, calculated from end-of-day closing prices. MR is the S&P 500 index return, and DR denotes return on a default-free debt with future cash flows matched perfectly with the high-yield corporate bond. AS and OS stand for ATM put options spreads and OTM put options spreads respectively. They are normalized by dividing the bid-ask spreads by the average of bid and ask quotes.

Panel B contains the results from Granger Causality tests on whether all β_{41}, β_{42}, and β_{43} are equal to zero.