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Book-to-Market, Mispricing, and the Cross Section of Corporate Bond Returns

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Abstract

Corporate bonds' book-to-market ratios predict returns computed from transaction prices. Senior bonds (even investment grade) with the 20% highest ratios outperform the 20% lowest by 3%–4% annually after non-parametrically controlling for numerous liquidity, default, microstructure, and priced-risk attributes: yield-to-maturity, bid–ask spread, duration/maturity, credit spread/rating, past returns, coupon, size, age, industry, and structural model equity hedges. Spreads for all-bond samples are larger. An efficient bond market would not exhibit the observed decay in the ratio's predictive efficacy with implementation delays, small yield-to-maturity spreads, or similar-sized spreads across bonds with differing risks. A methodological innovation avoids liquidity filters and censorship that bias returns.

I. Introduction

Three decades of research feature "book-to-market" as a predictor of equity returns. Because equities lack accurate models of risk premia, assessing whether risk or mispricing explains equity book-to-market's return correlation is a heroic

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task. By contrast, with corporate bonds, which we show exhibit a similar book-to-market correlation, assessment of the competing theories is far simpler. For one, fair prices are easier to infer for bonds than for equities. Indeed, bond dealers typically derive quotes and marks for bonds with "matrix pricing," in which a bond's fair price is a time-varying function of many bond characteristics that influence other bonds' prices.

Matrix pricing of a bond's fair value is only possible because the magnitude and timing of future cash flows are more transparent for bonds than for equities. For the senior bonds we focus on, only extreme and infrequent outcomes materially affect the likelihood of meeting payment promises. Discount rate variation thus has far more influence over these bonds' monthly returns than changes in cash flow projections, facilitating risk measurement compared to equities.

To this end, we define the "bond book-to-market ratio" ("BBM") as the bond's book value divided by its market price, which positively predicts a bond's return. (Book value, an amortizing issue price, linearly converges to the bond's face value at maturity.) BBM's 5% per year extreme-quintile return spread is almost as large as equity's historical spread and exhibits a greater Sharpe ratio (0.9). It is also larger than the quintiles' yield spread from bonds' *promised* payments, even for investment-grade (IG) bonds. Indeed, credit risk, which we control for, hardly alters BBM signal efficacy.

Abundant controls and tests cast additional doubt on risk mismeasurement as the source of BBM's significant raw and risk-adjusted spreads. For example, no risk story explains why the equity-hedged bond returns implicit in corporate bond structural models exhibit a BBM anomaly of the same magnitude as unhedged bond returns or why inclusion of a bond version of equity's book-to-market factor (BHML) leaves a significant alpha when adjusting BBM return spreads for factor risk.

Tax and liquidity premia cannot explain the anomaly either: High BBM bonds tend to be taxed less and traded more than low BBM bonds. Also, round-trip institutional trading costs are about the same (5 basis points (bp) higher for the highest BBM quintile), while regressions employing interactions between liquidity and BBM show that bonds with high versus low bid–ask spreads, trading volume, or number of trades exhibit similar degrees of BBM return predictability. However, bonds with more negative serial covariances ("gamma") at high return frequencies have greater BBM spreads.

BBM is 1 when a bond is issued, then rises above or falls below 1 due to changing economic forces or sentiment. If BBM broadly proxies for omitted controls, BBM signals should predict returns when implemented with modest delay. Because delays of a month or two torpedo BBM signal efficacy, BBM's anomaly cannot stem from BBM serving as an omitted control for most bonds within BBM's extreme quintiles. In this case, BBM evolves too slowly to render a

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delayed BBM signal so ineffective. Likewise, BBM cannot proxy for the omitted risk/liquidity controls of the few bonds that exit BBM's extreme quintiles each month, thus altering their premia. In this case, their changing risk/liquidity premia are far too large with no delay and change too rapidly to qualify as time-varying bond risk/liquidity premia.

By contrast, if sentiment distorts a bond's price, the effect is unlikely to persist, as arbitrage and mean reversion in sentiment force convergence to fair value. Hence, sentiment-driven low BBM ratios tend to rise, making risk-adjusted returns abnormally low; sentiment-driven high BBM ratios tend to fall, making returns abnormally high. Plausibly, sentiment's price distortions apply to only a few of BBM's extreme-quintile bonds, requiring distortions to be large to account for BBM's quintile spreads. In this case, BBM likely influences quintile returns only briefly because the vast majority of bonds caught up in the extreme quintiles' wide nets are priced fairly. Such bonds have no reason to share the quintile-exiting convergence to fair value of their grossly mispriced siblings.

Corporate bonds' thin trading has hindered research attempting to use transaction prices to measure monthly returns and strategy performance. We employ transaction prices from the relatively comprehensive Trade Reporting and Compliance Engine (TRACE) database. Prior studies employing TRACE focus mostly on its more liquid bonds.[1] Constructing monthly returns for bonds that trade nearly every day is straightforward. However, studies of such bonds cannot draw unbiased conclusions since liquidity could be correlated with bonds' returns or control variables.

To avoid liquidity filters, we impute monthly returns using the martingale property of fair risk-adjusted asset prices.[2] The property implies that the first and last transaction price of each month can substitute as unbiased estimates of the numerator (end-of-month price) and denominator (beginning-of-month price) of each bond's monthly return calculation. If a bond's current yield (interest earned/price) matched its expected return, TRACE's "flat" price (i.e., bond price excluding accrued due) is a martingale. In this case, bonds' imputed, unbiased beginning- and end-of-month flat prices generate noisy return estimates that have a small upward bias due to Jensen's inequality.

Current yields can differ from a bond's expected return. For example, riskless bonds issued at par can become discount bonds, generating higher BBMs when interest rates increase. Yet, riskless discount bonds have flat prices that converge to par at maturity. Such violations of the martingale property imply that our use of

[1]Chordia, Goyal, Nozawa, Subrahmanyam, and Tong (2017) use a mix of dealer quotes and bonds in TRACE that trade in the month's last 5 trading days. Bao, Pan, and Wang (2011) require a bond to trade on at least 75% of its relevant business days. Israel, Palhares, and Richardson (2018) select a monthly representative bond for each issuer based on seniority, maturity, age, and size. Schaefer and Strebulaev (2008) use prices contained in the most popular bond indices. Since bonds often do not trade for long periods, indices are partly built around mid-spread marks of traders' models that are divorced from nearby transactions. A more extensive literature review is in Appendix A of the Supplementary Material.

[2]Note that the martingale property holds only under the null of market efficiency. Behavioral-based return anomalies, the alternative hypothesis for which we present evidence, reject efficiency. However, the alternative hypothesis is irrelevant for classical statistical tests and has no bearing on whether the martingale assumption is appropriate here.

intra-month transactions to impute monthly prices and returns tends to understate high BBM bonds' full-month returns and overstate low BBM bonds' full-month returns. The same insight applies when market-wide credit spreads change after issuance. Hence, the BBM return spreads imputed with intra-month prices conservatively estimate the true (full-month) return spreads. A BBM effect in month-end trader quotes further supports our claim.

We adjust BBM trading profits for risk and liquidity with two approaches. The first uses cross-sectional Fama and MacBeth (FM) (1973) regressions. These control for the bond attributes listed in the article's abstract, as well as other premia attributes tied to liquidity and equity returns, such as equity beta, equity market capitalization, equity book-to-market, accruals, earnings surprise, earnings yield, gross profitability, past equity returns, and industry. The second adjusts for risk with time series factor models. The latter include Bai, Bali, and Wen's (2019) factor model, both with and without augmentation by a term structure factor, two versions of a 1-factor capital asset pricing model (CAPM) employing a bond market index, two versions of a 2-factor model that adds equity HML to the CAPM, and a 21-factor model subsuming Houweling and van Zundert's (2017) and Bektić, Wenzler, Wegener, Schiereck, and Spielmann's (2019) factors. BBM strategy profits remain significant with factor risk adjustments. Profits are also larger for "small bonds."

The monthly rebalancing strategy's risk-adjusted profits net of trading costs are insignificant. Such costs may deter arbitrageurs from exploiting BBM. Yet, buy-and-hold versions of the strategy survive the transaction costs incurred by larger trades, enhancing overall net performance if such trades avoid additional short sales constraints and costs.[3] Modest tilts of long-only portfolios toward high BBM and away from low BBM bonds can avoid short sales and enhance performance.

The adjusted profits are not contaminated by market microstructure biases or off-market pricing—offered to favored customers or from central dealers. They are also not due to long-term return reversals (Bali, Subrahmanyam, and Wen (2019)). Lastly, for the 20% of bonds that are closest to default, BBM has about the same efficacy as it does for the sample's complementary bonds. The irrelevance of default risk for BBM efficacy, as well as its similar efficacy for IG and non-IG bonds, casts doubt on omitted risk controls as the source of the BBM anomaly.

BBM does *not* predict U.S. Treasury returns. Our controls adequately capture term structure effects. We also show that imputing monthly returns for Treasuries, from their intra-month prices at the transaction dates of our sample's more thinly traded corporate bonds, leads to the same "non-result." Robustness tests show that BBM is a better predictor of the risk-adjusted returns of a universe of all corporate bonds—including the junior, secured, and puttable bonds that academic studies typically avoid—compared to bonds that are senior, unsecured, and lacking exotic options.

II. Data and Methodology

Prices for signals and bond returns employ TRACE's enhanced (pre-Apr. 2020) and standard databases. TRACE's daily data are from Jan. 2003 to Aug.

[3]Asquith, Au, Covert, and Pathak (2013) show that the cost of shorting corporate bonds is comparable to that of stocks.

2020 for trading signals and from Feb. 2003 to Sept. 2020 for returns, with July to Dec. 2002 used for the initial momentum control. We mostly focus on senior, unsecured, fixed-coupon bonds with no options other than (typically, make-whole) call provisions (e.g., Bai et al. (2019), Chung, Wang, and Wu (2019)). With filters, outlined below, this bond type covers an unbalanced panel of 8,925 different bonds (often existing for a portion of the sample period), 838 firms, and 458,139 bond-month observations.[4] One table studies all TRACE fixed-coupon bonds, covering 565,093 observations.

Both the senior unsecured and all-bond samples exclude trades reported to occur before the bond is issued or after it matures, as well as trades reported as canceled, attached to non-U.S. firms, denominated in non-U.S. currency, or issued by financial firms (SIC codes 60–69). We modify prices or other terms to their corrected values when TRACE indicates retroactive corrections. Like Bai et al. (2019), we remove transactions with prices below 1/20 or above 10 times their face amount, bonds with remaining maturity of less than 1 year, and bonds in default at the time of trade initiation.

Our samples are about 30% larger than similarly filtered samples from the Wharton Research Data Services (WRDS) Monthly Corporate Bond File. A WRDS return in month $t+1$ requires two bond trades, each in the last five days of months t and $t+1$. Our return requirement is less restrictive, so every (similarly filtered) WRDS return observation has a corresponding return in our sample. Robustness tests analyze returns from Merrill Lynch month-end trader marks, with the same start month as TRACE, but ending Dec. 2016, covering 140,808 observations.

We analyze month $t+1$ profits from trading signals known by month t's end. Imputed prices from month $t+1$ trades help estimate full-month $t+1$ returns. Unlike prior studies, we require a minimum 7-day gap between the transaction date of the bond price used for the signal and the return month's first day. The latter is the earliest transaction date we might use to impute month $t+1$'s return. As discussed later, this lengthy separation, an enhancement of measures used in equity studies (e.g., Bartram and Grinblatt (2018), (2021)) to avoid bid–ask bounce, prevents microstructure biases from distorting our findings. Note that the signal is known and assumed to be implemented at month t's end. It is merely the price inputs for the signal and estimated monthly return that require separate and distant transactions.

A. Return Construction

Unlike equities, bonds trade infrequently and often at large bid–ask spreads. To address these issues, we apply the martingale property. This property says that an unbiased estimate of an asset's price on some date is its transaction price at some other date adjusted for risk, the time value of money, and any payouts between the dates. These adjustments are small as trades are typically about 2–3 days from the prior or current month's end and largely approximated by interest earned.

[4]Few bonds exist throughout the full sample period, and cross-sectional regressions require non-missing values for all regressors. This requirement is uniformly imposed across all regression specifications to facilitate comparisons, generating an average of 1,149 bonds per month. Factor model regressions do not impose this requirement.

TRACE reports bond transactions' flat prices. Unless a bond is in default, a bond buyer pays the "full price," consisting of the flat price plus interest accrued. The full price change plus any coupon paid per dollar invested is an unbiased estimate of the bond's expected return. Thus, if earned interest per dollar invested (i.e., current yield)—the month's difference in accrued owed to sellers of the bond plus any paid coupon—completely captures the expected return, the flat price must be a martingale. While monthly changes in accrued interest plus distributions do not perfectly match the compensation for the time value of money and risk, they are close approximations, particularly for short periods. Portfolio diversification makes the approximation more innocuous. Finally, any failing of the martingale hypothesis implies our results are conservative, as this article's introduction explained. These insights validate substitution of flat bond prices from transactions at nearby dates for the month-end flat prices that would be observed if the data were available. Specifically, a bond's month $t+1$ return is its flat price change per dollar invested, as measured from month $t+1$'s first and last transactions, plus the current yield from holding the bond over the entire month. Details are provided below.

End-of-Month Flat Bond Prices. The martingale property implies that the imputed end-of-month flat bond prices, P^E, are the mid-market end-of-month flat prices at which the bonds would trade, plus noise. The noise depends on bond price volatility between the trade date used for imputation and the month's end, as well as the spread charged by the party providing liquidity. For bond j's end-of-month $t+1$ flat price, we use the flat price of its last month $t+1$ trade. For example, the Apr. 30, 2013 flat price might use the flat price of an Apr. 26, 2013 trade. If there is no month $t+1$ transaction for bond j, we treat the bond's month $t+1$ return as missing.

Beginning-of-Month Flat Bond Prices. A bond's beginning-of-month flat price estimate, P^B, is the flat price from its first trade that month. Thus, a Mar. 2013 beginning-of-month price comes from a Mar. 2013 trade. If there is only one transaction in a month, the flat price of that transaction serves both as its beginning and ending flat price, tying its return only to the full month's interest.

Monthly Returns. Using the end-of-month and beginning-of-month flat bond price estimates described previously, we construct each bond's month $t+1$ return as:

$$R_{t+1} = \frac{P^E_{t+1} + AI_{t+1} + C_{t+1}}{P^B_{t+1} + AI_t} - 1, \tag{1}$$

where $P^B{}_{t+1}$ and $P^E{}_{t+1}$ are the beginning- and end-of-month $t+1$ imputed flat prices, AI_t is accrued interest owed at the end of month t, and C_{t+1} is the coupon (if any) awarded for holding the bond in month $t+1$. We treat returns in consecutive months as missing if their product is less than -0.04 as it likely reflects error in recording the common price used in consecutive returns. Cumulated 6-month returns, a control, are computed analogously to equation (1), using a single beginning and single ending price over the 6-month horizon. As in equation (1), the 6-month return is adjusted for beginning and ending accrued interest, as well as coupons paid during the interval.

Bonds in Default. TRACE reports prices whenever bonds in default trade. We use these prices when assessing signal profitability. Our data also pinpoint the day each default occurs. To facilitate risk adjustment, we exclude bonds in default at the time a trading signal is implemented (end of month t) but include bonds that commence default while our strategies are invested in them (month $t+1$). The month t exclusion limits the fraction of defaulted bonds in our sample yet avoids all bias from sample selection because the only default filter is from a feasible trading strategy choice.

Defaulted bonds trade "flat," obviating the need for equation (1)'s accrued interest adjustments to convert flat prices into prices paid. Moreover, the coupons promised by defaulted bonds are never paid in month $t+1$. Unlike the flat prices of bonds that trade with accrued interest due, the flat prices of defaulted bonds cannot be martingales—motivating adjustment of their beginning- and end-of-month $t+1$ price estimates. The adjustment we apply deliberately underestimates defaulted bonds' returns.[5] This makes our return spread estimates conservative because we understate the returns of long positions in defaulted bonds and there are no defaulted bonds in our strategies' short positions. The conservatism is "overkill." Bonds commencing default in month $t+1$ are rare, even for the strategies' long positions. Defaulted bonds represent only 0.04% of BBM's long position investment.

B. Signal Construction

Price measurement error shared by the month-end signal and subsequent return generates correlation between the two. Constructing end-of-month t signals from transaction prices at least eight calendar days before the first day of month $t+1$ avoids this pitfall. The multiday gap addresses trade splitting and workouts. Consider a 120 million U.S. dollar customer bond sale to one or more dealers, executed as three 40 million U.S. dollar sales on three consecutive days: Apr. 29, Apr. 30, and May 1. Such trades yield three daily price estimates at bid prices, assuming the bond lacks other trades. Bid prices artificially inflate any BBM signal employing them, as well as May's return if Apr. 30's (e.g., WRDS computation of the bond's return) or May 1's transaction provides the return's beginning price. Trade splitting at the ask or favorable pricing by dealers to trades straddling a month's end induce similar correlation. Scenarios that artificially induce correlation between BBM signals and subsequent returns become less likely the larger the gap between the prices used for signals and returns. Our 7-day gap ensures that correlations between estimated BBM and estimated returns stem from signals that truly predict returns rather than any microstructure bias.

Bond Book-to-Market Signal. Book value per \$100 face amount is a bond's amortized issue price. Panel A of Table 1 reports issue price distributions, sourced from Mergent (Fixed Income Securities Database (FISD)). For most bonds, the FISD issue price is near \$100. If the bond is issued at a discount or premium, we apply the accounting rule that linearly amortizes the premium or discount to maturity on month-end dates to arrive at the bond's (end-of) month t book value.

[5]Specifically, if the imputed beginning-of-month price is quoted flat due to default, equation (1) substitutes the flat price of the first transaction preceding the transaction used for the signal (hence, pre-default) as P^B, uses the end-of-month (hence, post-default) price for P^E, and omits accrued interest and coupons in the numerator, but not the denominator.

For the 30% of cases where FISD lacks the issue price, we omit the bond as a potential trade.

Month t's BBM signal is Book value/P^S. The signal's flat price per \$100 of face amount, P^S, is taken from the bond's most recent trade (excluding month t's last seven days). Even when signals employ stale trades, the signal represents information available at the end of month t and can direct trades at that instant in time. Moreover, signals based on stale prices are likely to be less effective and thus are conservative. Panel B of Table 1 reports the distribution of time between the trade dates used for P^S in the BBM signal and the beginning price P^B in month $t+1$'s bond return estimate. For the senior unsecured bonds that researchers traditionally study ("traditional bonds") and that we focus on in all but Table 8, the median difference between the signal date and that latter price is 11 days; the average is 16 days (Panel B's first row). About 10% of the differences exceed 25 days.

Figure 1's dots denote consecutive transactions in a bond. P^S is the transaction price used for month t's signal. P^B and P^E are intra-month flat transaction prices used as beginning and ending flat prices for month $t+1$'s return. The pair serves as the imputed flat prices at their nearest hashmarks, which separate months. Figure 1 shows P^S as originating in month t, but it could come from a prior month if the bond lacks a month t transaction.

C. Alpha Tests for Signal Efficacy and Control Variables

We sort bonds into quintiles at month t's end. Quintile 5 has the most value-oriented (highest BBM) bonds. We primarily analyze month $t+1$'s bond returns within these quintile portfolios, employing FM cross-sectional regressions as well as structural and factor models.

TABLE 1

Summary Statistics

Table 1 reports statistics on the offering price of corporate bonds (Panel A) and the time difference in calendar days between the transaction dates of the bond prices P^S used to construct the bond book-to-market signal in month t and bond prices used as beginning-of-month prices P^B to construct bond returns in month $t+1$ (Panel B). Panel A reports the distribution of offering prices per \$100 of face value, separately for the sample of senior, unsecured bonds ("Traditional bonds") and all bonds including junior bonds or bonds with embedded options ("All bonds"). Statistics are computed using bond-level panel data, separately for traditional bonds as well as all bonds. The return sample period is Feb. 2003 to Sept. 2020.

Panel A. Offering Price Statistics

				Percentiles									
	No. of Obs.	Mean	Minimum	1	5	10	25	50	75	90	95	99	Maximum
Traditional bonds	8,925	99.6	40.8	97.3	98.7	99.1	99.5	99.8	99.9	100.0	100.0	100.0	106.9
All bonds	12,643	99.6	25.0	97.6	98.9	99.2	99.6	99.9	100.0	100.0	100.0	100.0	112.6

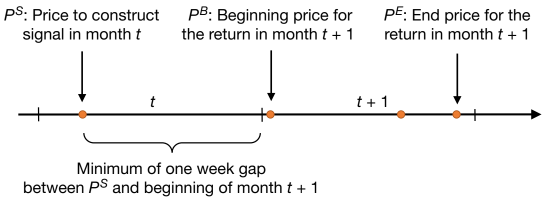
Panel B. Time Difference Between Trading Signals and Bond Return

			Percentiles								
	No. of Obs.	Mean	1	5	10	25	50	75	90	95	99
Traditional bonds	458,139	15.9	8.0	8.0	8.0	9.0	11.0	14.0	26.0	37.0	88.0
All bonds	565,093	19.3	8.0	8.0	8.0	9.0	11.0	18.0	34.0	51.0	133.0

FIGURE 1

Transaction Timing of Prices Used for Signal and Returns

Figure 1 shows a hypothetical example of how bond transactions are used to construct the signal and monthly bond returns. In particular, the bond price P^S in month t used to construct the signal is at least 1 week prior to the end of month t. To construct the bond return in month $t+1$, we use the first price of the bond in month $t+1$ as the beginning price P^B and the last bond price in month $t+1$ as the end price P^E.



FM Regression Coefficients on BBM. Here, the monthly regression's unit of analysis is the bond. We cross-sectionally regress month $t+1$'s bond returns (computed with Section II.A's procedures) on BBM quintile dummies or normal scores and quintile dummies for numerous controls. The coefficients on each regressor are then averaged across months. The controls consist of bond attributes and issuing firms' equity characteristics measured (in contrast to the signal's 7-day gap) as close to the end of month t as possible. These controls include each bond's yield-to-maturity (YTM),[6] credit spread, credit rating, value outstanding, time to maturity, duration, age, past 7-month return excluding the prior month ("bond momentum"), past 1-month return ("bond reversal"), bid–ask spread, and nearness to default. Equity characteristics include equity market beta, equity market capitalization, equity book-to-market, past 1-month stock return ("short-term reversal"), past 5-year stock return excluding the prior year ("long-term reversal"), past 12-month stock return excluding the prior month ("momentum"), accruals, earnings surprise ("SUE"), gross profitability, and earnings yield. These controls, detailed in Appendix B of the Supplementary Material, are rooted in past literature and textbooks.[7] Many controls are highly correlated, complicating inferences from their coefficients. Most FM regressions also include market microstructure/liquidity controls measured in the return month, $t+1$, as well as industry dummies.

We employ four main specifications of non-parametric regression controls. The first has industry controls; the second adds market microstructure controls; the third adds controls for bond characteristics; the fourth adds the bond issuer's equity characteristics. The many controls in category-oriented FM regressions represent a high dimensional classification of each bond, akin to the matrix pricing commonly

[6]BBM tends to rise and fall with YTM. Neither BBM nor YTM directly map into an expected return. However, YTM, deployed as a function of dummy variables for YTM ranks, better captures expected returns than the cruder BBM.

[7]Robustness tests explore parametric controls. In addition to papers cited earlier, Grinblatt and Titman ((2002), Chaps. 2, 23) discuss YTM, maturity, duration, and credit rating; Nozawa (2017) studies credit spread; Blume and Stambaugh (1983) study bid–ask spread; Jostova, Nikolova, Philipov, and Stahel (2013) focus on past returns; Warga (1992) relates bond age to returns; and Schaefer and Strebulaev (2008) analyze nearness to default. Bartram and Grinblatt's ((2018), (2021)) equity controls are the same as ours. Other research is cited in the introduction and Appendix C of the Supplementary Material.

used by Wall Street to mark YTMs and the prices of thinly traded bonds. Here, they represent attributes that likely predict bond returns. A robustness check with a necessarily shortened sample period and smaller cross section includes the bond's past long-term return.

Because equation (1)'s dependent variable R_j is bond j's true (but unobservable) full month return r_j less noise, e_j, regressing the imputed return R_j on an observable attribute X_j

$$r_j - e_j = c_0 + c_1 X_j + u_j$$

has a plim for c_1 equal to the slope coefficient that the unobserved true return would have, since

$$\mathrm{cov}\left(r_j - e_j, X_j\right)/\mathrm{var}\left(X_j\right) = \mathrm{cov}\left(r_j, X_j\right)/\mathrm{var}\left(X_j\right).$$

This illustrates that the c_1 estimate from intra-month flat prices is a consistent estimate of the unobservable true full month return's c_1. If X_j is a categorical dummy, c_1 is the return difference of 2 equal-weighted portfolios. Its noise component is diversified away in FM time series averaging.

Structural Models. Structural models view corporate bonds and equity as contingent claims on the firm's assets. One typically uses structural models to calculate bond prices, yields, or credit spreads, but past research has shown that they explain these poorly.[8] Such models also have implications for returns, showing that, over very short time periods, corporate bond returns should be close to perfectly correlated with a portfolio of riskless bonds and same-firm equity. Hedging out the equity component on the left-hand side of the FM regression adjusts for most of the risk premium linked to credit risk. We identify hedge ratios from a panel regression of bond returns on own-equity returns interacted with the control dummies used for the FM regression. This generates equity hedge ratios for each bond month from the panel's coefficients and bond attributes.

Factor Model Intercepts. Regressing the time series of excess returns (above 1-month LIBOR) of BBM quintile portfolios on factor portfolio returns is an alternative to FM regressions. Regression intercepts or spreads between intercepts represent alpha and should be zero in an informationally efficient bond market. We begin with Bai et al.'s (2019) 5 factors: the bond market, credit, value-at-risk, liquidity, and reversal factors. Factor construction in our article, using bond data from TRACE, follows Bai et al.'s (2019) procedures. We first calculate each bond's daily price as its volume-weighted average daily price, for all bonds in TRACE and Mergent FISD meeting Bai et al.'s (2019) filters. When TRACE shows trades in the last five business days of months t and $t+1$, we compute the bond's return from consecutive month-end daily prices (adjusting for accrued interest and coupons paid). If month t lacks a qualifying month-end daily price, we compute month $t+1$'s

[8]Eom, Helwege, and Huang (2004) fit the credit spreads of 182 bonds to structural models, finding poor matches with observed spreads. Huang and Huang (2012) conclude these models are deficient at pricing bonds, even at the ratings level. Huang, Shi, and Zhou (2020) document failures to fit credit default swaps data. Collin-Dufresne, Goldstein, and Martin (2001)'s bond-level regressions of credit spreads on stock returns and other control variables highlight structural models' poor fits.

return using the earliest daily price in the first five business days of month $t+1$. If neither approach is possible due to a lack of qualifying prices, we treat month $t+1$'s return as missing. Factors face-value weight these returns for specific subsets of bonds, as in BBW. Since we compute the factors ourselves based on BBW's descriptions, our analysis is not adversely affected by the computational issues that rendered their factors unreliable.

Data from Merrill Lynch are required for value-at-risk in the sample's first three years when the factor requires data that precede TRACE's initiation. In addition, we use an augmented BBW 6-factor model that adds a term structure factor to BBW's 5 factors, two versions of a 1-factor CAPM with a bond index as a factor, two versions of a 2-factor model, which adds equity HML to the CAPM factor, and a customized 21-factor model.

D. Summary Statistics for the Overall Sample

Panel A of Table 2 lists summary statistics for BBM and other attributes of the senior unsecured bonds and their issuing firms. Each row shows time series averages of the cross-sectional means of each variable using all traditional bonds (column 1) and all traditional bonds within each BBM quintile (columns 3–7). Q1 represents the 20% of bonds each month with the smallest BBM, averaging a BBM of 0.85; Q5 represents the highest BBM quintile, averaging a BBM of 1.09. Column 2 also reports the time series average of the cross-sectional correlations of the characteristic with BBM.

High BBM bonds tend to have poorer credit ratings (AAA = 1, …, D = 22, with 10 or less indicating investment grade) and are closer to default.[9] Such bonds also have higher bond betas, volatility, and value-at-risk (a downside risk measure). They also have higher YTMs, lower market value, higher bid–ask spreads, greater trading volume, larger numbers of trades, and been issued more recently and by firms with more bonds, higher equity betas, poorer past-year equity returns, larger equity book-to-market, and lower earnings/stock price ratios. By contrast, the lowest quintile of BBM bonds has the highest returns over the past 6 months (bond momentum) and the least negative serial covariance (bond gamma)[10] and comes from larger firms with the highest stock returns over the past year (equity momentum).[11] Bond maturity and duration, while concentrated in the 2 extreme BBM quintiles, are greatest within the 20% lowest BBM bonds. Combined with the

[9]Default risk is low. The highest BBM quintile averages an investment grade ("IG") rating. IG and non-IG bonds show a similar-sized BBM anomaly. We also control for nearness to default (Schaefer and Strebulaev's (2008) distance to default times minus 1), which is the z-value of the default probability from a Black–Scholes model adaptation. Nearness to and distance from default thus generate identical default probability quintiles. The firm is in default when nearness to default is positive infinity; default probability is below one-half with negative nearness to default.

[10]Bao et al.'s (2011) and Bai et al.'s (2019) bond gamma, based on Roll (1984), captures temporary price movements and illiquidity. Table 2 shows that gamma shares a similar correlation with BBM as our direct measure of a bond's effective bid–ask spread. Using gamma as a control in place of our direct measure of bid–ask spreads has little effect on our findings, as Appendix C of the Supplementary Material notes. However, its interaction effects with BBM are stronger, as the paper later documents.

[11]Chordia et al. (2017) and Nozawa (2017) show corporate bond issuers are mostly large (above NYSE median size).

TABLE 2

Portfolio Sorts by Bond Book-to-Market

Table 2 reports summary statistics of bond and firm characteristics by bond book-to-market (BBM) quintiles (Panel A); averages and selected test statistics of monthly portfolio returns from intra-month prices (Panel B); averages of monthly portfolio returns and current yields from inter-month prices by the number of month $t+1$ trades (Panel C); and statistics on beginning and end prices for returns (Panel D). Panel A's numbers are time series averages of equal weightings of each month's characteristics across all observations ("All"), observations for each BBM quintile (Q1, …, Q5) that month, and each month's cross-sectional correlation of BBM with the characteristic ("Correlation"). The panel also reports the time series average of the monthly difference between the average characteristics of the fifth and first BBM quintile as well as the associated t-statistic. Panel B reports time series averages of each month's equal- and value-weighted returns, the return spread between the BBM Q5 and Q1 portfolios, and the fraction of positive BBM Q5 – Q1 return spreads. It reports results separately for all bonds, as well as bonds below ("Small bonds") and above ("Large bonds") the monthly median bond value from sequential sorts on BBM and then bond value. Panel C's first 3 rows report equal-weighted average monthly returns, separately for all observations, as well as for bonds that trade never or only once in month $t+1$. Returns are based on Panel B's formula, found in the text, except that the price transacted just prior to the trade date of month t's signal's price is month $t+1$ return's beginning-of-month price, the price first transacted after month $t+1$ is the return's ending price, and the price change is scaled by the number of months (including fractional months) between the price pair. Panel C's bottom row reports the current yield (per month) of 1-trade bonds. Panel D reports the fraction of beginning and end prices for returns at bids, asks, and from dealer-to-dealer transactions by BBM quintiles. The fractions are scaled so that they sum to 100% for each quintile. The sample consists of nonfinancial firms with U.S. dollar-denominated, senior unsecured corporate bonds without embedded options other than call options.

Panel A. Bond and Firm Characteristics

			Bond Book-to-Market (BBM) Quintiles					Q5–Q1 (High-Low BBM)	
	All	Correlation	Q1 (Low BBM)	Q2	Q3	Q4	Q5 (High BBM)	Average	t-Statistic
Bond book-to-market	0.963	1.00	0.845	0.923	0.961	0.994	1.094	0.250	[35.9]
Bond mispricing	−0.001	0.29	−0.011	−0.005	−0.001	0.003	0.011	0.022	[34.3]
Bond coupon rate	5.513	−0.30	6.818	5.866	5.321	4.744	4.816	−2.002	[−30.5]
Bond yield	4.779	0.42	4.682	4.218	4.341	4.469	6.191	1.509	[9.9]
Bond credit spread	1.579	0.35	1.466	1.300	1.325	1.230	2.571	1.105	[8.3]
Bond value	532.2	−0.10	610.7	564.3	522.3	508.4	455.2	−155.5	[−14.5]
Bond face value	501.7	−0.03	508.0	517.5	500.2	503.2	479.8	−28.20	[−2.5]
Bond age	4.870	−0.16	7.268	5.083	4.373	3.702	3.926	−3.342	[−16.4]
Bond maturity	11.18	−0.10	16.41	10.184	8.832	8.445	12.02	−4.385	[−11.0]
Bond duration	6.984	−0.14	9.388	6.666	5.924	5.688	7.248	−2.140	[−10.2]
Bond rating	8.159	0.24	7.462	7.901	8.144	8.173	9.126	1.663	[17.2]
Bond reversal	0.685	−0.05	0.814	0.706	0.665	0.639	0.662	−0.152	[−1.2]
Bond momentum	3.421	−0.22	4.548	3.752	3.354	2.935	2.871	−1.677	[−3.2]
Bond volume	49.23	0.10	33.08	40.35	47.66	56.20	68.86	35.78	[13.5]
Bond volume institutions	47.93	0.09	32.45	39.10	46.18	54.68	67.25	34.80	[13.3]
Number of trades	103.1	0.14	56.94	93.42	111.1	118.9	135.1	78.17	[14.7]
Number of trade institutions	30.66	0.13	18.93	26.15	30.97	35.31	41.93	23.00	[14.6]

(continued on next page)

TABLE 2 (continued)

Portfolio Sorts by Bond Book-to-Market

Panel A. Bond and Firm Characteristics (continued)

	All	Correlation	Bond Book-to-Market (BBM) Quintiles					Q5–Q1 (High-Low BBM)	
			Q1 (Low BBM)	Q2	Q3	Q4	Q5 (High BBM)	Average	*t*-Statistic
Bond bid–ask spread	0.495	0.19	0.470	0.436	0.447	0.469	0.682	0.212	[10.8]
Bond bid–ask spread institutions	0.198	0.14	0.205	0.181	0.179	0.181	0.258	0.054	[8.4]
Bond gamma	0.003	0.17	0.003	0.002	0.003	0.003	0.007	0.003	[6.4]
Number of bonds outstanding	37.90	0.00	37.83	30.81	32.75	39.84	48.30	10.47	[3.2]
Number of days from beginning of month	2.907	−0.08	3.899	2.843	2.602	2.587	2.741	−1.158	[−9.9]
Number of days from end of month	2.743	−0.08	3.727	2.714	2.478	2.413	2.508	−1.219	[−10.6]
Bond volatility	0.006	0.02	0.006	0.005	0.004	0.006	0.009	0.003	[6.2]
Bond market beta	0.880	0.05	1.006	0.825	0.738	0.731	1.129	0.123	[5.1]
Bond value-at-risk	0.033	0.27	0.035	0.028	0.026	0.029	0.054	0.020	[11.0]
Bond institutional ownership	51.91	−0.20	58.37	54.99	51.25	47.57	46.29	−12.08	[−28.3]
Distance to default	9.488	−0.17	10.10	9.771	9.479	9.490	8.605	−1.492	[−15.9]
Nearness to default	−9.488	0.17	−10.10	−9.771	−9.479	−9.490	−8.605	1.492	[15.9]
Investment grade	0.863	−0.24	0.954	0.910	0.869	0.854	0.726	−0.227	[−19.3]
Non-investment grade	0.137	0.24	0.046	0.090	0.131	0.146	0.274	0.227	[19.3]
Bond offering price	99.49	0.05	99.23	99.49	99.55	99.61	99.56	0.331	[21.0]
Equity mispricing	0.080	0.00	0.049	0.074	0.088	0.080	0.129	0.080	[3.9]
Equity market capitalization	42,720	−0.06	48,318	39,548	40,351	45,811	39,560	−8,758	[−7.4]
Equity book-to-market	0.652	0.20	0.591	0.601	0.604	0.640	0.825	0.234	[8.3]
Equity beta	0.979	0.16	0.891	0.925	0.963	0.987	1.127	0.236	[16.3]
Standardized unexpected earnings surprise	−0.003	−0.10	0.001	0.001	0.000	0.000	−0.016	−0.017	[−4.3]
Gross profitability	0.226	−0.04	0.230	0.232	0.231	0.228	0.212	−0.018	[−5.2]
Earnings yield	0.012	−0.28	0.056	0.053	0.047	0.038	−0.134	−0.190	[−11.0]
Equity short-term reversal	1.028	−0.03	1.067	1.061	1.051	1.053	0.910	−0.156	[−0.5]
Equity momentum	10.59	−0.14	13.27	12.22	11.73	10.46	5.269	−8.002	[−10.6]
Equity long-term reversal	54.19	−0.10	58.54	58.03	56.28	54.01	44.13	−14.42	[−11.4]
Accruals	0.098	−0.03	0.093	0.105	0.112	0.107	0.077	−0.015	[−2.5]

(continued on next page)

TABLE 2 (continued)

Portfolio Sorts by Bond Book-to-Market

Panel B. Portfolio Returns

		All	Correlation	Bond Book-to-Market (BBM) Quintiles: Q1 (Low BBM)	Q2	Q3	Q4	Q5 (High BBM)	Q5–Q1 (High BBM to Low BBM): Fraction > 0	*p*-Value	Average	*t*-Statistic
All bonds	Equal-weighted bond return ($t+1$)	0.660	0.04	0.566	0.544	0.576	0.655	1.011	0.63	[0.00]	0.444	[3.86]
	Value-weighted bond return ($t+1$)	0.572	0.04	0.526	0.500	0.530	0.584	0.934	0.59	[0.01]	0.408	[3.58]
Small bonds	Equal-weighted bond return ($t+1$)	0.798	0.04	0.660	0.621	0.675	0.776	1.170	0.61	[0.00]	0.511	[3.42]
Large bonds	Equal-weighted bond return ($t+1$)	0.557	0.04	0.494	0.483	0.502	0.568	0.905	0.60	[0.00]	0.411	[3.67]

Panel C. Scaled Monthly Portfolio Returns from Inter-month Transactions and 1-Trade Bond Current Yield

No. of Trades in Month $t+1$		All	Correlation	No. of Obs.	Bond Book-to-Market (BBM) Quintiles: Q1 (Low BBM)	Q2	Q3	Q4	Q5 (High BBM)	Q5–Q1 (High BBM to Low BBM): Fraction > 0	*p*-Value	Average	*t*-Statistic
Any	Equal-weighted bond return ($t+1$)	0.576	0.06	517,353	0.510	0.495	0.481	0.505	0.889	0.58	[0.65]	0.379	[3.09]
Zero	Equal-weighted bond return ($t+1$)	0.450	0.09	64,705	0.363	0.385	0.296	0.267	0.902	0.54	[10.8]	0.539	[2.51]
One	Equal-weighted bond return ($t+1$)	0.511	0.04	5,512	0.340	0.377	0.703	0.694	0.611	0.57	[3.68]	0.268	[2.35]
	Equal-weighted current yield ($t+1$)	0.450	–0.24	5,512	0.469	0.454	0.428	0.418	0.441	0.24	[99.9]	–0.040	[–2.05]

Panel D. Fraction of Beginning and End Prices for Returns at Bid and Ask

Beginning Price of Bond Return in $t+1$	End Price of Bond Return in $t+1$	Bond Book-to-Market (BBM) Quintiles [%]: Q1 (Low BBM)	Q2	Q3	Q4	Q5 (High BBM)
Ask	Ask	9.4	9.4	10.2	11.1	12.0
Ask	Bid	10.7	9.4	9.0	9.1	9.3
Ask	Dealer	5.9	6.4	6.8	7.3	7.6
Bid	Ask	12.8	13.0	13.4	13.5	12.5
Bid	Bid	16.1	15.0	13.8	12.9	12.3
Bid	Dealer	10.2	11.0	10.9	10.6	9.6
Dealer	Ask	9.4	10.1	10.8	11.5	12.2
Dealer	Bid	13.9	12.8	11.8	11.1	11.2
Dealer	Dealer	11.6	12.9	13.2	12.9	13.2

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fact that lower credit risk tends to extend the effective maturity of actual bond payments and holding coupon rates the same (which has opposing duration and tax effects on expected returns), shifts in the risk-free term structure impose greatest risk on the 20% lowest BBM bonds.

The flat prices of BBM Q5 bonds (which typically trade at discounts) tend to appreciate, while Q1 bonds depreciate. Thus, Q5 bond purchasers tend to earn capital gains, while Q1 purchasers earn capital losses, even if both bond types earn identical returns. (The other return component, current yield, likely offsets expected shrinkage of flat price discounts and premiums.) When realized, the gains and losses will generally be taxed at lower rates and in the more distant future than accrued interest or amortization. Thus, tax considerations argue for negative Q5–Q1 (pre-tax) risk-adjusted return spreads. We now analyze raw return spreads before turning to adjustments for risk or illiquidity.

Panel B of Table 2 reports the average month $t+1$ returns of 5 BBM-sorted portfolios in the columns labeled Q1 to Q5. The panel's first 2 rows correspond to equal-weighted (EW) and value-weighted (VW) quintile portfolio returns, respectively. Both rows exhibit nearly monotonic increases across BBM quintiles. For example, the lowest BBM EW quintile portfolio earns 57 bp per month, while the highest earns 101 bp per month. Panel B also shows the average monthly return for the full sample (66 bp EW and 57 bp VW, a more than 1% annualized difference), the average monthly cross-sectional correlation between returns and BBM (0.04), the average monthly spread between the returns of the largest and smallest BBM quintiles (44 bp EW and 41 bp VW, both significant), and the fraction of months with a positive Q5–Q1 return spread (63% EW and 59% VW, both significant). The spread's *t*-statistics correspond to annualized Sharpe ratios of 0.92 (EW) and 0.85 (VW). Both exceed the 0.40 Sharpe ratio for equity HML (over a longer sample period) reported by Ehsani and Linnainmaa (2022).[12] Table 2 Panel B's last 2 rows stratify the top row (EW) by bond size. Small bonds have larger returns within each quintile and a larger BBM effect than large bonds. (The 2 sequentially sorted rows do not average to the top row because some bonds lack face value outstanding data.) The small bond BBM effect comes from Q5, for which the small minus large bond return is 27 bp per month—nearly twice the small minus large spread for Q1 and the largest size spread for any quintile.

Table 2 Panel B's return spreads are not temporary price changes that subsequently reverse. Percentage changes in flat prices from the return's ending price to the next price (from month $t+2$'s first trade or later) are -0.001 for EW Q5 and -0.090 for EW Q1 (table omitted for brevity.) Thus, returns formed from the prices of month $t+1$ and $t+2$'s initial transactions, rather than month $t+1$'s first and last trades, would increase BBM's extreme quintile spread by about 8 bp.

Panel B of Table 2 omits bonds lacking a month $t+1$ trade and assigns a flat price change of 0 to bonds trading just once in month $t+1$. Such choices inflate

[12]Correlation between the bond and equity HML factors, as well as correlations between the monthly return spreads of BBM and equity book-to-market sorted VW and EW quintile portfolios, range between 27% and 44% (Table IA.1 in the Supplementary Material), in line with the findings of Collin-Dufresne et al. (2001) and Choi and Kim (2018). BBM shows somewhat lower persistence compared to the equity book-to-market ratio (Table IA.2 in the Supplementary Material).

Panel B's spreads, albeit negligibly, if the unobserved full-month spreads of no-trade bonds are small or spreads in 1-trade bonds' flat price changes are negative. The opposite is true. Panel C of Table 2 reports each quintile's monthly return, measured from the trade just prior to the signal price's trade date to the first trade after month $t+1$. To address martingale violations, the returns shrink inter-month flat price changes by the number of months (a fraction exceeding 1) between the beginning and ending transactions generating each price pair, while each return's current yield component is over the full month $t+1$. Panel C shows a *larger* return spread for no-trade bonds than the full sample's spread and a *positive* spread in the flat price change for 1-trade bonds—the latter reflected by the difference in Panel C's two bottom rows.

Panel D of Table 2 reports each BBM quintile's joint distribution of beginning and ending price bid–ask pairs for month $t+1$'s returns. It lists the fraction of returns that come from the 9 pairings of bids (customer sale to a dealer), asks (customer buy from a dealer), and mids (dealer-to-dealer transaction) attached to beginning and ending prices. A bid beginning price tends to have a higher return, while a bid ending price tends to have a lower return, with the reverse for asks. Applying the bid–ask spread from each quintile (Panel A) to the joint distribution in Panel D implies that both Q1's and Q5's returns are upwardly biased by 1 bp and 3 bp, respectively. Their difference, 2 bp, is negligible. Hence, Table 2 Panel B's returns are not driven by their reliance on bid and ask prices for inputs.

III. Bond Book-to-Market and the Cross Section of Expected Bond Returns

Many return-influencing attributes correlate with BBM. We now analyze BBM's marginal effect, controlling for these attributes. Both cross-sectional FM regressions and time series factor model regressions show that BBM does not proxy for return-predicting attributes or factor betas.

A. Fama–MacBeth Cross-Sectional Regressions

The FM approach regresses next month's cross section of bond returns (in percent per month) on BBM and other bond and equity characteristics known at the time of trade initiation:

$$R_{j,t+1} = a_t + \gamma_t \mathrm{BBM}_{j,t} + \sum_{s=1}^{S} c_{s,t} X_{j,s,t} + e_{j,t+1}. \tag{2}$$

In equation (2), $\mathrm{BBM}_{j,t}$ is the month t BBM signal for bond j, and $X_{j,s,t}$ is the end-of-month t value of characteristic s of bond j (or its issuer) including industry fixed effects. The FM procedure averages the monthly coefficients over time and tests whether the average significantly differs from 0.

FM Specification. Table 3 Panel A's 4 odd-numbered specifications regress bond returns on BBM and controls, each expressed as dummy variables corresponding to Q2 through Q5, with Q1 omitted for the intercept. For brevity, Panel A of Table 3 only reports the coefficients for the Q5 dummy variables, which is Q5–Q1's return spread holding other regressors fixed. Specifications 2, 4, 6, and

8, which study parametric signals, replace the BBM quintile dummies with the BBM normal score, which is the BBM ratio transformed into a standardized normally distributed regressor.

Specifications 1 and 2 regress bond returns on BBM and industry dummies. Specifications 3 and 4 add (non-categorical) market microstructure/liquidity controls to specifications 1 and 2 that roughly proxy for the precision with which the martingale approach estimates month $t + 1$ returns. They include the number of bonds from the issuing firm in month $t + 1$, the percentage of the market value of the issuing firm's bonds with month t signals that trade in month $t + 1$, and a pair of controls for the (absolute value of the) number of calendar days between the first (last) day of the month and the transaction date used for beginning-of- (end-of-) month $t + 1$ prices. Specifications 5 and 6 add bond attribute controls to specifications 3 and 4. Finally, "kitchen sink" specifications 7 and 8 add equity and firm characteristics to specifications 5 and 6.

Specification 1 shows that BBM Q5 bonds outperform Q1 bonds by 44 bp per month ($t = 3.62$), controlling for industry fixed effects. The 0.14 coefficient on the parametric BBM signal is also significant ($t = 3.13$) as specification 2 shows. Specifications 3 and 4 illustrate that microstructure controls barely affect results: BBM's average coefficient is similar, whether comparing specification 3 with 1 or 4 with 2. Omitted for brevity, the relatively small effect of market microstructure also applies to the remaining two specifications. Thus, identifying returns with the martingale procedure does not distort inferences. Adding bond-specific controls (specifications 5 and 6) reduces BBM's influence on a bond's month $t + 1$ return by about 40%, but the BBM effect remains highly significant. Specifications 7 and 8's controls related to equity returns increase BBM Q5's coefficients compared to specifications 5 and 6 by about 20% and increase significance as well. Moreover, specifications 7 and 8 establish that equity book-to-market does not predict bond returns once BBM is controlled for.

Outliers. Results are also not driven by outliers. Eliminating observations that rely on the top 100 or bottom 100 bond prices negligibly alters our findings.

Callable Bonds. BBM Q5 does not outperform Q1 because bonds tend to be called when their fair value (in the absence of a call) exceeds the call price. Filtering out bond returns in months approaching call dates or adding controls for call dates has little effect on BBM's alpha spread.

Parametric Controls. Our use of quintile dummy control variables in Panel A of Table 3 to better proxy for a nonlinear relationship does not explain our findings. Column 1 in Panel B of Table 3 parrots Panel A specification 7's use of all FM controls but shows similar results with parametric versions of the control variables. This leftmost column reports a BBM quintile spread of 29 bp ($t = 4.52$).

Prices from Month-End Trader Marks. The martingale assumption is also innocuous. End-of-month trader marks in the Merrill Lynch database instead of bond returns from transactions offer alternative returns for a smaller set of more liquid bonds. With Merrill data, BBM's (unreported) Q5–Q1 raw return spread is 44 bp ($t = 2.65$) for equal-weighted portfolios and 44 bp ($t = 2.85$) when value weighted. The associated alpha spread (column 2 in Panel B of Table 3) is 20 bp per month ($t = 2.52$). Using Merrill's marks for the prices of the BBM signal as well (column 3) generates a larger, more significant alpha spread of 50 bp per month

TABLE 3

Fama–MacBeth Cross-Sectional Regressions

Table 3 shows results from Fama and MacBeth (1973) regressions of monthly bond returns on bond and stock characteristics and control variables. Across different specifications, returns are regressed against prior month values for bond book-to-market, bond coupon rate, bond yield to maturity, bond credit spread, bond value, bond age, bond maturity, bond duration, bond bid–ask spreads, lagged bond returns, bond momentum, bond credit rating, nearness to default, equity market beta, equity market capitalization, equity book-to-market, equity short-term reversal, equity momentum, equity long-term reversal, accruals, standardized unexpected earnings (SUE) surprise, gross profitability, and earnings yield. Panel A employs quintile dummies for the characteristics as regressors except for bond book-to-market in even-numbered specifications, which employ the normal score of bond book-to-market. Each month's quintiles are determined from sorts of bonds with non-missing values for all characteristics. Market capitalization quintiles are based on NYSE break points. The regressions include dummy variables for quintiles 2, 3, 4, and 5 of each characteristic, but the table displays only the coefficients of the quintile dummy with the largest amount of the characteristic (Q5) for brevity. Additional controls are the number of outstanding bonds of a firm, the percentage of bond market capitalization of a firm that trades in a month, and the number of days from the beginning and end of the month of bond price data used to calculate the bond return. All regressions include industry dummy variables based on the 38 Fama and French industry classifications. Panel B shows results for various robustness tests. Panel B specification 1 uses parametric versions of the control variables, while specifications 2–6 use non-parametric controls as in Panel A. Panel B specification 2 uses the monthly bond return from trader marks provided by Merrill Lynch as a dependent variable, while specification 3 uses Merrill Lynch data to construct both the monthly bond return and bond book-to-market. In Panel B specification 4 the regressand is an unbiased estimate of each bond's equity hedged return using the equity of the bond issuer. We estimate hedge ratios as the predictions of hedonic panel regressions of each bond's return on interactions between the monthly equity return of the bond issuer in excess of LIBOR and 131 dummies representing the bond's 61 (non-collinear) characteristics, including 38 industry dummies. The bond return component from flat prices is rescaled to alleviate biases from thin trading. The dependent variable in Panel B specification 5 is the equity return of the bond's issuing firm. Panel B specification 6 uses the same regression model as Panel A specification 7 but restricts the sample to bonds that are investment grade ("Investment Grade Bonds"). The table shows average coefficients and test statistics as well as the average number of observations and average adjusted R^2. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Baseline Model

	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Bond book-to-market Q5	0.441	[3.62]***			0.445	[3.64]***			0.265	[3.21]***			0.320	[4.05]***		
Bond book-to-market (normal score)			0.139	[3.13]***			0.140	[3.15]***			0.096	[2.25]**			0.117	[3.13]***
Bond Characteristic Controls																
Bond coupon rate Q5									0.011	[0.16]	0.055	[0.67]	0.046	[0.74]	0.095	[1.25]
Bond yield Q5									0.416	[5.78]***	0.427	[5.96]***	0.433	[6.11]***	0.446	[6.27]***
Bond credit spread Q5									0.042	[0.64]	0.016	[0.26]	0.046	[0.69]	0.028	[0.44]
Bond value Q5									−0.049	[−0.89]	−0.036	[−0.66]	−0.070	[−1.43]	−0.056	[−1.16]
Bond age Q5									0.035	[0.87]	0.031	[0.75]	0.006	[0.14]	0.003	[0.07]
Bond maturity Q5									0.122	[0.64]	0.107	[0.59]	0.110	[0.61]	0.094	[0.54]
Bond duration Q5									0.129	[0.73]	0.157	[0.94]	0.108	[0.64]	0.139	[0.87]
Bond bid–ask spread Q5									0.076	[1.90]*	0.070	[1.86]*	0.070	[1.83]*	0.066	[1.78]*
Bond reversal Q5									−0.010	[−0.26]	−0.012	[−0.30]	−0.029	[−0.78]	−0.028	[−0.76]
Bond momentum Q5									0.005	[0.11]	0.002	[0.04]	−0.026	[−0.58]	−0.027	[−0.63]
Bond rating Q5									−0.242	[−3.35]***	−0.259	[−3.77]***	−0.219	[−2.61]***	−0.242	[−2.97]***
Nearness to default Q5									−0.010	[−0.19]	−0.017	[−0.33]	0.041	[0.54]	0.040	[0.54]
Stock Characteristic Controls																
Beta Q5													0.028	[0.37]	0.012	[0.16]
Market capitalization Q5													0.038	[0.54]	0.037	[0.52]
Book-to-market Q5													−0.003	[−0.04]	0.000	[0.00]
Short-term reversal Q5													0.281	[4.42]***	0.280	[4.47]***
Momentum Q5													−0.004	[−0.06]	0.003	[0.05]
Long-term reversal Q5													−0.011	[−0.19]	0.000	[0.00]
Accruals Q5													−0.068	[−1.20]	−0.077	[−1.40]

(continued on next page)

TABLE 3 (continued)

Fama–MacBeth Cross-Sectional Regressions

Panel A. Baseline Model (continued)

	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Standardized unexpected earnings surprise Q5													0.126	[2.40]**	0.131	[2.54]**
Gross profitability Q5													0.186	[2.39]**	0.186	[2.42]**
Earnings yield Q5													0.045	[0.67]	0.050	[0.77]
Microstructure Controls																
Number of bonds in $t+1$					0.000	[−0.45]	0.000	[0.07]	0.000	[−0.63]	0.000	[−0.79]	0.000	[−1.12]	0.000	[−0.97]
Percent of bond market cap traded in $t+1$					−0.182	[−1.66]*	−0.137	[−1.18]	−0.169	[−2.02]**	−0.164	[−2.04]**	−0.186	[−1.83]*	−0.178	[−1.81]*
Number of days from beginning of month $t+1$					0.005	[1.74]*	0.007	[2.13]**	0.002	[0.74]	0.002	[0.79]	0.001	[0.31]	0.001	[0.43]
Number of days from end of month $t+1$					0.015	[4.24]***	0.016	[4.68]***	0.012	[3.47]***	0.012	[3.65]***	0.010	[3.03]***	0.011	[3.17]***
Intercept	0.524	[3.35]***	0.620	[3.86]***	0.643	[3.41]***	0.695	[3.60]***	0.481	[3.04]***	0.540	[3.55]***	−0.239	[−0.55]	−0.208	[−0.46]
No. of obs.	1,149		1,149		1,149		1,149		1,149		1,149		1,149		1,149	
Adj. R^2	0.11		0.10		0.12		0.11		0.25		0.25		0.28		0.29	
Industry control	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	

Panel B. Robustness

			Non-parametric Controls									
	1		2		3		4		5		6	
	Regressions with Parametric Controls		Bond Return (Merrill Lynch)		BBM and Bond Return (Merrill Lynch)		Bond Return – Hedge Ratio × (Stock Return – LIBOR)		Stock Return		Investment Grade Bonds	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Bond book-to-market Q5	0.292	[4.52]***	0.202	[2.52]**	0.495	[5.03]***	0.316	[4.82]***	−0.082	[−0.71]	0.307	[5.97]***
Bond Characteristic Controls												
Bond coupon rate	0.028	[1.68]*	−0.018	[−0.27]	0.093	[1.31]	0.058	[1.10]	−0.203	[−1.71]*	0.141	[2.94]***
Bond yield	0.102	[2.48]**	0.333	[4.46]***	0.206	[2.88]***	0.448	[6.32]***	−0.252	[−1.54]	0.324	[4.88]***
Bond credit spread	−0.034	[−1.09]	0.075	[1.00]	0.137	[1.78]*	0.031	[0.46]	−0.054	[−0.41]	0.045	[0.69]
Bond value	0.000	[0.21]	0.006	[0.09]	0.060	[1.48]	−0.060	[−1.27]	−0.037	[−0.50]	−0.078	[−1.52]
Bond age	0.005	[1.19]	−0.050	[−1.07]	0.015	[0.33]	0.001	[0.03]	0.154	[1.95]*	0.078	[1.68]*
Bond maturity	0.006	[0.85]	0.226	[0.97]	0.025	[0.11]	0.061	[0.32]	0.482	[1.25]	0.047	[0.30]
Bond duration	−0.009	[−0.42]	−0.072	[−0.36]	0.174	[0.79]	0.099	[0.57]	−0.207	[−0.51]	0.174	[1.24]
Bond bid–ask spread	0.059	[2.42]**	0.038	[1.10]	0.002	[0.06]	0.065	[1.72]*	−0.147	[−2.47]**	0.033	[1.14]
Bond reversal	−0.010	[−1.50]	0.059	[1.55]	0.028	[0.71]	−0.020	[−0.54]	0.068	[0.97]	−0.092	[−2.24]**

(continued on next page)

TABLE 3 (continued)

Fama–MacBeth Cross-Sectional Regressions

Panel B. Robustness (continued)

			Non-parametric Controls										
	1		2		3		4		5		6		
	Regressions with Parametric Controls		Bond Return (Merrill Lynch)		BBM and Bond Return (Merrill Lynch)		Bond Return – Hedge Ratio × (Stock Return – LIBOR)		Stock Return		Investment Grade Bonds		
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	
Bond momentum	−0.004	[−0.76]	−0.072	[−1.39]	−0.050	[−1.10]	−0.014	[−0.35]	0.144	[1.24]	−0.068	[−1.78]*	
Bond rating	−0.034	[−3.56]***	−0.011	[−0.10]	−0.073	[−0.67]	−0.189	[−2.48]**	−0.334	[−1.26]	−0.128	[−1.69]*	
Nearness to default	0.011	[1.68]*	−0.084	[−1.05]	−0.093	[−1.08]	0.029	[0.36]	0.458	[1.58]	0.004	[0.06]	
Stock Characteristic Controls													
Beta	−0.011	[−0.29]	0.105	[1.33]	0.093	[1.27]	0.056	[0.78]	−0.145	[−0.45]	−0.064	[−0.89]	
Market capitalization	0.002	[0.14]	0.109	[1.31]	0.082	[1.05]	0.029	[0.47]	0.054	[0.21]	0.000	[0.00]	
Book-to-market	−0.041	[−1.79]*	−0.026	[−0.30]	−0.084	[−1.03]	−0.003	[−0.04]	−0.016	[−0.06]	−0.059	[−0.88]	
Short-term reversal	0.012	[6.15]***	0.260	[3.45]***	0.269	[3.50]***	0.347	[5.14]***	−0.498	[−2.08]**	0.123	[2.31]**	
Momentum	0.001	[2.26]**	0.108	[1.33]	0.113	[1.37]	0.092	[1.63]	−0.511	[−1.61]	−0.079	[−1.29]	
Long-term reversal	0.000	[−0.97]	−0.179	[−2.48]**	−0.081	[−1.27]	0.045	[0.80]	−0.097	[−0.39]	−0.057	[−0.97]	
Accruals	0.027	[0.75]	−0.026	[−0.39]	−0.006	[−0.08]	−0.042	[−0.75]	−0.195	[−1.04]	0.000	[0.00]	
Standardized unexpected earnings surprise	0.250	[0.62]	−0.020	[−0.38]	−0.016	[−0.29]	0.128	[2.14]**	−0.129	[−0.64]	0.024	[0.45]	
Gross profitability	−0.138	[−1.73]*	0.167	[1.48]	0.157	[1.60]	0.145	[1.90]*	0.224	[0.71]	0.187	[2.20]**	
Earnings yield	0.246	[1.35]	0.048	[0.71]	−0.010	[−0.18]	0.083	[1.25]	−0.203	[−0.96]	0.056	[0.92]	
Market Microstructure ontrols													
Number of bonds in $t+1$	0.000	[−2.10]**	0.000	[−0.68]	0.000	[−0.27]	0.000	[−0.60]	0.000	[−0.40]	0.000	[−0.06]	
Percent of bond market cap traded in $t+1$	−0.151	[−1.80]*	−0.124	[−0.87]	−0.199	[−1.39]	−0.145	[−1.48]	−0.286	[−0.83]	−0.009	[−0.09]	
Number of days from beginning of month $t+1$	0.004	[1.35]	−0.003	[−1.05]	−0.001	[−0.32]	0.001	[0.20]	−0.003	[−0.62]	0.002	[0.54]	
Number of days from end of month $t+1$	0.012	[3.35]***	−0.003	[−0.86]	0.000	[0.05]	0.011	[3.20]***	0.000	[0.02]	0.015	[4.35]***	
Intercept	0.269	[1.10]	0.083	[0.19]	−1.290	[−0.88]	−0.560	[−1.25]	2.417	[2.22]**	0.846	[1.27]	
No. of obs.	1,139		664		838		1,149		1,169		1,007		
Adj. R^2	0.31		0.53		0.53		0.26		0.58		0.28		
Industry control	Yes		Yes		Yes		Yes		Yes		Yes		

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(t = 5.03) but has bias from error in the price mark shared by both BBM and the return's beginning price.

Structural Models. Panel B of Table 3 also rebuts arguments that Table 3 Panel A's significant alpha spreads stem from failure to properly control for the implication that distressed bonds resemble equity. First, BBM Q5 bonds are not distressed because they exhibit negligible default rates, while Q1 bonds experienced no defaults. We also noted the extensive controls for credit spreads, bond rating, and default in Table 3's FM regressions. Punctuating our claim is column 4 in Panel B of Table 3, which reruns Panel A's specification 7 (all controls) with equity-hedged bond returns as the dependent variable. Bond j's month $t+1$ hedged return subtracts the product of its end-of-month t hedge ratio (described earlier) and the issuing firm's month $t+1$ equity return in excess of LIBOR from the bond's month $t+1$ return. The hedge eliminates the bond's asset risk premium component. Column 4's results here resemble Panel A of Table 3. BBM Q5's same-firm equity-hedged bond returns outperform Q1's by 32 bp per month (t = 4.82). The similar equity hedged and unhedged BBM quintile coefficients indicate that structural models are unlikely to play a successful role as supplements or replacements for Table 3's categorical regressors.

Finally, if BBM Q5 merely proxied for poor default controls, BBM should predict the firm's equity return. However, column 5 in Panel B of Table 3 shows that when the firm's equity return is the dependent variable, the BBM Q5 coefficient is −0.082 and insignificant (t = −0.71). In sum, BBM predicts bond returns and equity-hedged bond returns, but not same-firm equity returns. Later study of interaction effects supports this finding. Moreover, the equity premium associated with default reflects outcomes where equity is nearly wiped out. In unreported results, using a dummy for whether the equity return from month $t+1$ is below −75% as the dependent variable yields a BBM Q5 coefficient of 0.079 (t = 1.50).

Investment Grade Bonds. Table 3 Panel B's rightmost column studies the IG subsample of traditional bonds. After sorting IG bonds into BBM quintiles, the rightmost column reports specification 7 of Panel A of Table 3. The IG subsample's BBM Q5 coefficient, 0.307 (t = 5.97), is similar to Table 3 Panel A's coefficient, but more significant. With BBM dummies from an independent sort of IG and BBM, the (unreported) BBM Q5 coefficient is 0.321 (t = 5.01).

Long-Term Bond Return Reversals. Daniel and Titman (2006) and Gerakos and Linnainmaa (2017) link book-to-market's equity return predictability to the ratio's correlation with long-term past returns and, accordingly, changes in firm size. Bali et al. (2019) show that a bond's 3-year past return, measured from months $t-48$ to $t-13$, predicts return reversal. We omitted this past return control because its lengthy horizon halves the average number of bonds each month and cuts 42 months from the sample. Yet, in horse races between the 3-year past return and BBM, using Table 3 Panel A's key specifications (plus the 3-year past return), the 3-year past return's coefficient is never significant and always economically small. For example, in specifications analogous to Table 3 Panel A's specifications 5 and 7, BBM Q5's coefficients are 0.250 (t = 2.55) and 0.303 (t = 3.29), while the 3-year past return Q5 coefficients are 0.006 (t = 0.08) and −0.016 (t = −0.20), respectively. Thus, as a corporate bond return predictor, BBM subsumes the prediction power of the 3-year past return.

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Further Robustness Tests. Additional Table 3 robustness tests are in Appendix C of the Supplementary Material. It shows that adding controls for bond (1-factor) beta, volatility, and value-at-risk has little impact on our findings (Table IA.3 in the Supplementary Material). Similarly, replacing Table 3's bid–ask spread control with gamma illiquidity still leaves a significant BBM anomaly, but one that (with a comparable sample) is virtually identical in magnitude and significance to Table 3 (Table IA.4 in the Supplementary Material). Finally, it shows that the BBM signal is distinct and separate in its effects from a bond-centric implementation of the mispricing signal developed by Bartram and Grinblatt ((2018), (2021)) (Table IA.5 in the Supplementary Material).

B. Factor Model Time Series Regressions

As an alternative to FM regressions, Table 4 reports factor model alphas and factor betas of EW and VW quintile portfolios sorted on the BBM signal using several factor models. Compared to Table 3 Panel A's FM cross-sectional analysis, Table 4's time series factor model regressions include bond observations that lack data on the control characteristics. They also facilitate alpha analysis of each of the BBM quintile portfolios and the use of both equal and value weighting.

For BBM quintile portfolio q, Panels A and B of Table 4 run time series regressions of the quintile portfolio's returns (in excess of 1-month U.S. dollar LIBOR) on 5 or 6 risk factors,

$$r_{q,t+1} = a_q + \sum_{l=1}^{6} \beta_{q,l} F_{l,t+1} + \varepsilon_{q,t+1}. \tag{3}$$

The intercept a_q is the risk-adjusted return or "alpha" of the quintile portfolio. All factor model regressions report test statistics derived from Newey and West (1987) standard errors. If systematic risk factors explain differences in bond returns for portfolios stratified by BBM, the risk-adjusted returns α_q of the BBM quintile portfolio should be indistinguishable from 0. Panels A and B of Table 4 report the alphas and factor betas, as well as the spread in the Q5-Q1 risk-adjusted returns.

BBW Factors. The BBW 5-factor model controls for overall bond market, credit, value-at-risk, liquidity, and short-term bond return reversal factors; the augmented BBW 6-factor model adds a term structure factor. The first row of each of Panel A's top half (EW portfolios) and bottom half (VW portfolios) shows each quintile's BBW risk-adjusted returns. Table 4 Panel A's EW 19 bp alpha spread is smaller than the alpha spread (BBM Q5 coefficient) from any of Table 3 Panel A's odd-numbered (non-parametric) specifications. The VW spread, 12 bp per month, is smaller than the EW spread and statistically insignificant. The small EW and VW alpha spreads in Panel A of Table 4 may stem from the 5-factor model's lack of a term structure control; bonds with similar maturity tend to covary more with each other than with different maturity bonds. To control for term structure risk, Panel B of Table 4 supplements BBW's factors with a term structure factor created in the spirit of BBW. We independently triple-sort bonds into 125 face-value-weighted portfolios based on maturity, coupon, and credit rating. We then take the simple average of returns across the 25 portfolios of the top 20% highest maturity

TABLE 4

Factor Model Time Series Regressions

Table 4 shows results from time series regressions of monthly portfolio returns (in excess of 1-month USD LIBOR) on bond factor models. Bonds are sorted each month into quintiles based on BBM and combined into equal- or value-weighted portfolios. The table reports intercepts, slope coefficients, t-statistics, the number of observations, and R^2 separately for each of the five portfolios (Q1, Q2, Q3, Q4, Q5) and for the return spreads between the highest bond book-to-market (Q5) and lowest bond book-to-market (Q1) quintiles. Regressors for the Bai et al.'s (2019) factor model in Panel A are the excess return on the bond market portfolio, return spreads based on value-at-risk (the second worst returns in the previous 3 years), rating (credit rating), illiquidity (Bao et al.'s (2011) measure), and reversal (past 1-month return). The augmented BBW factor model in Panel B further adds a term structure factor, constructed from independent triple sorts of bonds into 125 face value-weighted portfolios based on maturity, coupon, and credit rating. We take the simple average of returns across the 25 portfolios of the top 20% of bonds in terms of maturity for the long position and do the same for the bottom 20%. The difference in returns between these 2 extreme maturity quintiles is our term structure factor. Panel C shows intercepts of equal-weighted portfolios for the BBW factor model and the augmented BBW factor model separately for small and large bonds (from sequential sorts on BBM and size based on the median monthly bond value). In addition, it reports alphas from a 1-factor CAPM (alternatively from the WRDS returns of a value-weighted index of all corporate bonds and the martingale returns of the bonds in our sample), as well as 2-factor versions that add equity HML to the CAPM factor. Standard error estimates use the Newey and West (1987) procedure. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. BBW Factor Model

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High-Low BBM)	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Equal-Weighted Portfolios												
Intercept	0.207	[2.92]***	0.153	[2.72]***	0.173	[4.48]***	0.185	[4.76]***	0.400	[4.63]***	0.193	[2.17]**
Bond market factor (t + 1)	0.829	[6.56]***	0.834	[8.90]***	0.792	[16.9]***	0.875	[20.5]***	0.908	[9.44]***	0.078	[0.64]
Bond value-at-risk factor (t + 1)	0.044	[0.76]	−0.054	[−0.98]	−0.085	[−2.43]**	−0.172	[−6.80]***	−0.135	[−2.30]**	−0.180	[−1.94]*
Bond rating factor (t + 1)	−0.139	[−3.30]***	−0.071	[−2.63]***	−0.068	[−3.80]***	−0.036	[−2.63]***	0.213	[5.01]***	0.352	[4.91]***
Bond illiquidity factor (t + 1)	−0.257	[−1.66]*	−0.173	[−1.11]	−0.113	[−1.25]	0.013	[0.24]	0.153	[2.37]**	0.411	[2.19]**
Bond reversal factor (t + 1)	−0.024	[−0.51]	0.013	[0.35]	0.042	[1.82]*	0.060	[2.45]**	−0.019	[−0.49]	0.006	[0.10]
R^2	0.74		0.82		0.89		0.88		0.79		0.60	
No. of obs.	212		212		212		212		212		212	
Value-Weighted Portfolios												
Intercept	0.149	[2.26]**	0.093	[2.16]**	0.085	[2.99]***	0.080	[2.45]**	0.272	[3.42]***	0.123	[1.44]
Bond market factor (t + 1)	0.985	[8.35]***	0.936	[12.6]***	0.927	[33.9]***	1.010	[25.9]***	1.061	[11.7]***	0.077	[0.61]
Bond value-at-risk factor (t + 1)	0.060	[1.22]	−0.088	[−2.18]**	−0.131	[−4.66]***	−0.202	[−6.18]***	−0.167	[−2.55]**	−0.226	[−2.42]**
Bond rating factor (t + 1)	−0.190	[−4.33]***	−0.108	[−5.05]***	−0.110	[−7.82]***	−0.070	[−3.88]***	0.146	[3.21]***	0.336	[4.38]***
Bond illiquidity factor (t + 1)	−0.292	[−2.55]**	−0.130	[−1.19]	−0.041	[−0.72]	0.053	[0.99]	0.155	[1.10]	0.447	[2.12]**
Bond reversal factor (t + 1)	−0.063	[−1.46]	−0.006	[−0.19]	0.032	[1.72]*	0.042	[1.82]*	0.012	[0.24]	0.074	[1.17]
R^2	0.80		0.88		0.94		0.93		0.82		0.58	
No. of obs.	212		212		212		212		212		212	

(continued on next page)

TABLE 4 (continued)

Factor Model Time Series Regressions

Panel B. Augmented BBW Factor Model

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Equal-Weighted Portfolios												
Intercept	0.128	[2.38]**	0.122	[2.45]**	0.158	[4.59]***	0.181	[4.75]***	0.358	[4.35]***	0.230	[2.55]**
Bond market factor ($t+1$)	0.639	[5.76]***	0.761	[8.45]***	0.755	[14.5]***	0.864	[18.8]***	0.807	[6.58]***	0.167	[1.13]
Bond value-at-risk factor ($t+1$)	−0.092	[−1.54]	−0.107	[−1.70]*	−0.112	[−2.52]**	−0.180	[−5.00]***	−0.208	[−3.10]***	−0.116	[−1.53]
Bond rating factor ($t+1$)	−0.070	[−1.76]*	−0.045	[−1.62]	−0.055	[−2.44]**	−0.032	[−1.69]*	0.250	[4.30]***	0.320	[3.86]***
Bond illiquidity factor ($t+1$)	−0.062	[−0.42]	−0.098	[−0.62]	−0.075	[−0.81]	0.024	[0.45]	0.257	[3.45]***	0.320	[1.72]*
Bond reversal factor ($t+1$)	−0.013	[−0.30]	0.018	[0.47]	0.044	[1.86]*	0.061	[2.42]**	−0.013	[−0.33]	0.000	[0.00]
Bond term structure factor ($t+1$)	0.255	[5.40]***	0.099	[2.77]***	0.050	[1.74]*	0.015	[0.50]	0.136	[1.93]*	−0.120	[−1.42]
R^2	0.79		0.83		0.90		0.88		0.80		0.61	
No. of obs.	212		212		212		212		212		212	
Value-Weighted Portfolios												
Intercept	0.059	[1.33]	0.064	[1.78]*	0.073	[2.95]***	0.079	[2.56]**	0.236	[3.06]***	0.177	[2.11]**
Bond market factor ($t+1$)	0.764	[7.91]***	0.865	[12.7]***	0.898	[25.0]***	1.009	[21.6]***	0.972	[9.27]***	0.208	[1.55]
Bond value-at-risk factor ($t+1$)	−0.099	[−2.06]**	−0.139	[−2.80]***	−0.152	[−4.31]***	−0.203	[−5.28]***	−0.231	[−3.16]***	−0.132	[−1.61]
Bond rating factor ($t+1$)	−0.110	[−2.76]***	−0.082	[−3.67]***	−0.100	[−5.46]***	−0.070	[−3.23]***	0.178	[3.14]***	0.288	[3.43]***
Bond illiquidity factor ($t+1$)	−0.066	[−0.66]	−0.057	[−0.54]	−0.011	[−0.19]	0.054	[0.94]	0.247	[1.71]*	0.312	[1.48]
Bond reversal factor ($t+1$)	−0.049	[−1.35]	−0.001	[−0.05]	0.034	[1.72]*	0.042	[1.81]*	0.017	[0.35]	0.066	[1.08]
Bond term structure factor ($t+1$)	0.297	[6.30]***	0.095	[2.81]***	0.039	[1.62]	0.001	[0.06]	0.120	[2.27]**	−0.177	[−2.52]**
R^2	0.85		0.88		0.94		0.93		0.83		0.60	
No. of obs.	212		212		212		212		212		212	

Panel C. Robustness

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic
BBW Factor Model												
Small bonds	0.339	[4.29]***	0.263	[3.64]***	0.312	[5.69]***	0.343	[5.20]***	0.608	[4.67]***	0.269	[2.21]**
Large bonds	0.113	[1.57]	0.072	[1.57]	0.069	[2.16]**	0.067	[1.97]**	0.261	[3.17]***	0.148	[1.59]
Augmented BBW Factor Model												
Small bonds	0.275	[4.01]***	0.231	[3.49]***	0.294	[5.84]***	0.331	[5.05]***	0.553	[4.99]***	0.277	[2.56]**
Large bonds	0.021	[0.41]	0.041	[1.03]	0.052	[1.91]*	0.066	[2.07]**	0.225	[2.82]***	0.204	[2.22]**

(continued on next page)

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TABLE 4 (continued)

Factor Model Time Series Regressions

Panel C. Robustness

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic	Intercept	*t*-Statistic
CAPM and CAPM + HML Models												
Equal-Weighted Portfolios												
Bond market index (own sample)	0.052	[0.85]	0.053	[1.25]	0.109	[4.03]***	0.149	[4.16]***	0.362	[3.44]***	0.310	[2.11]**
Bond market index (WRDS)	0.170	[2.52]**	0.154	[3.41]***	0.201	[5.85]***	0.248	[6.08]***	0.480	[4.83]***	0.311	[2.39]**
Bond market index (own sample) and equity HML	0.053	[0.89]	0.057	[1.65]*	0.110	[4.84]***	0.152	[4.28]***	0.381	[3.61]***	0.328	[2.23]**
Bond market index (WRDS) and equity HML	0.164	[2.36]**	0.152	[3.53]***	0.197	[5.76]***	0.245	[5.95]***	0.492	[4.96]***	0.328	[2.55]**
Value-Weighted Portfolios												
Bond market index (own sample)	−0.055	[−0.85]	−0.030	[−1.22]	0.009	[0.54]	0.027	[0.78]	0.237	[2.72]***	0.292	[2.09]**
Bond market index (WRDS)	0.083	[1.13]	0.084	[2.28]**	0.114	[3.86]***	0.137	[3.70]***	0.371	[4.22]***	0.288	[2.29]**
Bond market index (own sample) and equity HML	−0.058	[−0.91]	−0.032	[−1.38]	0.005	[0.33]	0.027	[0.78]	0.245	[2.81]***	0.304	[2.19]**
Bond market index (WRDS) and equity HML	0.071	[0.93]	0.074	[1.92]*	0.104	[3.55]***	0.129	[3.83]***	0.369	[4.42]***	0.298	[2.44]**

bonds for the long position, then do the same for the 20% lowest maturity bonds for the short position. The difference in returns between these 2 extreme maturity quintiles is our term structure factor. Table 4 Panel B's augmented BBW factor model shows that adding this term structure factor increases the EW alpha spread to 23 bp and the VW spread to 18 bp, both statistically significant. The latter spreads are closer to the pair of comparison spreads obtained from Table 3 Panel A's FM regressions.

Return biases due to bid and ask distributions, as well as Jensen's inequality, prevent assessment of whether Table 4's observed spreads stem more from the long or the short end. However, if the bias was the same across all quintile portfolios and the true alphas of the 5 EW quintile portfolios averaged to 0, the respective EW alphas in Panels A and B would be 22 bp and 19 bp lower than reported. Reducing each alpha in Panel A by the 22 bp would generate Q1 and Q5 intercepts of −0.02 and 0.18, respectively. Panel B's alpha reduction of 19 bp implies Q1 and Q5 intercepts of −0.06 and 0.17, respectively. Based on these transformations, alpha spreads largely come from the long end (Q5).

Bond Size. BBM's effects may also differ across risk-adjustment methodologies because Table 4 lacks factors for many other controls in Table 3 Panel A's FM regression, like bond size. Table 4 Panel C's top 4 rows illustrate the effect of bond size on factor model EW alpha with the BBW 5-factor and augmented 6-factor models.[13] With both models, bonds with less than intra-quintile median market capitalization have larger and more significant alpha spreads than bonds with larger value outstanding. With the 5-factor model, EW portfolios of "large bonds" exhibit no significant alpha spread. With the augmented 6-factor model (third and fourth rows), the small-bond alpha spread is a significant 28 bp and lies between the 27 and 32 bp alpha spreads from specifications 5 and 7 in Panel A of Table 3. However, the 20 bp large-bond spread, while significant, is far smaller. If mispricing accounts for BBM alpha spreads, this finding, along with the VW finding for the BBW 5-factor model, suggests that large bonds may be more efficiently priced than small bonds. BBM's greater efficacy at predicting small-bond risk-adjusted returns mirrors equity's parallel finding.

Alternative Factor Models. As an alternative to the BBW factor models, Panel C of Table 3 also reports alphas and alpha spreads from two versions of 1-factor (CAPM) and 2-factor (CAPM + HML) models. The 1-factor model spreads are intercepts from regressing returns on a value-weighted index of either the WRDS returns of all WRDS bonds or of the martingale-based intra-month returns of all bonds used in our sample of traditional bonds; 2-factor models add equity HML as a second factor. The alternative models show significant and similar alpha spreads (about 30 bp).

Robustness. Further robustness tests of the raw returns and factor model alpha spreads are found in Appendix C of the Supplementary Material. These tests find significant alpha spreads with a 21-factor model described in Table IA.6 in the Supplementary Material. They also find that BBM's CAPM alphas are larger for investment grade bonds (Table IA.7 in the Supplementary Material), and that

[13]The "Small bonds" and "Large bonds" rows do not average to Table 4 Panel A's EW alphas because some bonds lack data on their size.

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neither volatility, individual bond market betas, value-at-risk, nor bond institutional ownership materially influence BBM spread magnitude (Table IA.8 in the Supplementary Material).

IV. Understanding the BBM Alpha Spread: Risk or Mispricing?

A. Signal Delay

Figure 2 plots alpha spreads (BBM's Q5 dummy coefficients from specification 7, Panel A of Table 3) for signal delays ranging from 0 to 11 months. Unlike Table 3, Figure 2's returns always commence Jan. 2004, ensuring apples-to-apples comparisons across differing lags. Its 30 bp per month alpha spread with no delay (i.e., first signal from Dec. 2003), approximates the 32 bp coefficient from Panel A of Table 3 despite a shorter return series. Figure 2 indicates an alpha spread decline to 9 bp when signal delay is 2 months, losing about 70% of its efficacy. The spread meanders with further delay, ranging from 2 to 12 bp with a slow downward trend.

Figure 2's rapid decay rules out omitted risk or liquidity controls as the source of the BBM anomaly. Bonds with extreme BBM ratios may ultimately exhibit less extreme BBM. However, BBM is a slowly evolving attribute, and generally, large price changes are required to move a bond out of an extreme BBM quintile. Most extreme quintile bonds remain in their quintiles for several months and, for some, even years.[14] BBM's slow evolution implies that if BBM *broadly* proxies for omitted attributes, stale BBM signals should predict bond returns, which is inconsistent with Figure 2.

Calibrating delay's effect on quintile membership supports a view that BBM cannot broadly proxy for risk or liquidity. More than 85% of the extreme quintiles' bonds persist in those quintiles the next month, yet signal efficacy diminishes by 42%. With a 2-month lag, alpha declines by 70%, but more than 80% of this stale strategy is dedicated to bonds that remained in quintiles 1 and 5. Moreover, as time evolves, bonds leaving extreme quintiles generally move to adjacent quintiles. Adjacent quintiles have tighter alpha spreads with their more extreme neighbors than the 2 extreme BM quintiles have with each other. Indeed, unreported coefficients on BBM quintiles 2–5 are monotonically increasing and significant in all of Table 3 Panel A's odd-numbered specifications.

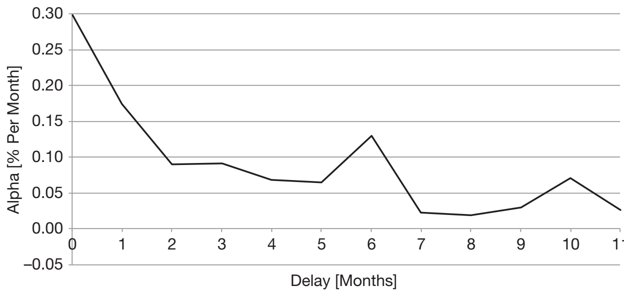
The alpha decay pattern and extreme-quintile spread size also rule out BBM as a *narrow* proxy for the omitted risk/liquidity attributes of a small proportion of these quintiles' bonds. As a narrow proxy, the omitted risk or liquidity attributes must earn implausibly large premia to account for the extreme quintile alpha spread and

[14]BBM changes slowly, just as Gerakos and Linnainmaa (2017) document for equity book-to-market. To prove that these features make BBM's quintiles stable, we computed survival rates: the percentage of each BBM quintile's month t investment remaining in the quintile's month t bonds at the end of months $t+1$, $t+2$, and $t+3$. With 1-month delay, the time series averages of the percentages of "old bond" investment are 89%, 73%, 67%, 67%, and 82% for Q1, Q2, Q3, Q4, and Q5, respectively. Thus, the 1-month survival rates for bonds in the 2 extreme BBM quintiles exceed those of the 3 interiors quintiles. For Q1 and Q5, the 2-month survival rates are 85% and 76%, respectively: only an additional 4% and 6% of bonds leave Q1 and Q5 in the subsequent month, respectively.

FIGURE 2

Signal Delay

Figure 2 shows average coefficients from Fama and MacBeth (1973) regressions of monthly bond returns on bond book-to-market, controlling for other bond and equity characteristics (specification 7 in Panel A of Table 3). Book-to-market quintile dummies are lagged by 1 to 12 months. The table employs quintile dummies for quintiles 2, 3, 4, and 5 of each characteristic as regressors, but the figure displays only the coefficient on the quintile 5 dummy for bond book-to-market.



then have the premia shrink once the bonds exit their BBM quintile. With alpha spreads about twice the spread in YTM, the hidden risk or liquidity attributes would have to earn at least 20 times the Q5–Q1 spread in *promised* yields if BBM proxied for the omitted controls of 20% of the BBM Q5 bonds. An omitted attribute earns just one-sixth of the needed spread if it earns a 5% per year spread for this narrow set of bonds. A traditional bond typically earned 5% over Treasury bills during our sample period without controls, while the narrow proxy hypothesis says BBM captures many times this premium *as a spread.* Default's rarity and a similar-sized BBM anomaly for our investment grade subsample turn this hypothetical, enormous, yet rapidly declining risk/liquidity premium into pure fantasy.

Unlike risk or liquidity premia, mispricing can both be distributed unevenly and be large for a few bonds within BBM's extreme quintiles. Consistency with Figure 2's rapid decay pattern requires only price convergence to fair value within a couple of months for such highly mispriced bonds. Finance teaches that savvy traders exploit large arbitrage opportunities quickly. The fact that illiquid markets with large trading costs prevent instant price convergence to fair value of small pricing mistakes is no surprise. It takes time for the mispricing of some extreme quintile bonds to build to sufficiently attractive levels to warrant the attention of capital-constrained arbitrageurs.

In sum, a few highly mispriced bonds within BBM's extreme quintiles explain Table 3 Panel A's results even when the remaining bonds are at fair value. When savvy market participants force the prices of highly mispriced bonds to converge to fair value, the formerly mispriced bonds tend to depart their quintiles. Whether they depart or stay, other bonds remaining in the extreme BBM quintile will largely consist of bonds that are close to fair valuations, rendering a delayed BBM signal useless. As a back of the envelope calculation, if only 10% of the BBM Q5 bonds are underpriced by 3%, and 10% of the Q1 bonds are overpriced by 3%, 50% of these mispriced bonds converging to fair value each month is sufficient to generate a 30 bp alpha spread with no delay (= 3% × 10%/2 + 3% × 10%/2), a 15 bp alpha

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spread with 1-month delay (= 3% × 10%/4 + 3% × 10%/4), and a 7.5 bp alpha spread with 2-month delay (= 3% × 10%/8 + 3% × 10%/8).

B. Signal Efficacy as a Function of Default Risk and Liquidity

Table 3 Panel A's extensive controls for credit ratings, default, and liquidity make it unlikely that omitted controls explain the BBM anomaly. Prior YTM discussion, expanded here, reinforces our credit risk argument. A default prone Q5 bond's YTM should exceed its expected return because payments in default fail to meet the bond contract's promises. The Q5 difference implies that the YTM difference between Q5 and no-default Q1—less than 13 bp in Panel A of Table 2—should also exceed the spread in their risk-related expected returns. Yet, BBM's EW return spread, averaging 44 bp (Panel B of Table 2), is 3.5 times larger than the spread in the quintiles' promised yields. Even Table 2 Panel A's 32 bp (all control) alpha spread is more than twice YTM's spread.

If BBM proxied for inadequate credit risk or liquidity controls, the BBM anomaly may be stronger for bonds that are nearer to default or less liquid. Table 5 adds interactions to Table 3 Panel A's regressors, multiplying each BBM quintile dummy or normal score by a dummy for the 20% of bonds that are nearest to default (Panel A's top half) or the 20% that have the lowest credit rating (Panel A's bottom half). Panel B correspondingly multiplies each BBM quintile dummy by dummies for either the 20% of bonds with the lowest trading volume, 20% with the lowest number of trades, 20% with the largest bid–ask spread, or 20% with the largest bond gamma (Panel B, appearing top to bottom, respectively). For brevity, reported BBM quintile interactions are only with BBM Q5, representing BBM's Q5–Q1 alpha spread. A positive coefficient here indicates larger BBM spreads for the top 20% of bonds based on default or illiquidity compared to BBM spreads for the bottom 20% of default or illiquidity.

All of Table 5 Panel A's specifications have significant BBM Q5 coefficients, implying the BBM anomaly remains for the 80% of bonds least likely to default. However, the interaction dummies are insignificant. For example, in specification 7's top half, bonds in the quintile nearer to default have a 10 bp per month *lower* alpha spread than bonds further from default. In all specifications, the 20% most likely to default bonds and the 80% least likely have statistically indistinguishable BBM effects.

Panel B of Table 5 shows similar findings for the first 3 illiquidity measures. Here, all but 2 of BBM's 24 interaction terms with the 20% least liquid bonds are insignificant. The exceptions are specifications 2 and 4's marginally significant volume interaction, for which the least liquid bonds exhibit stronger BBM normal score predictability, but only with limited regressor controls. With bond gamma as the liquidity proxy (bottom quarter of Panel B), low liquidity bonds earn significantly greater BBM alpha spreads than high liquidity bonds. The significant interaction here is consistent with illiquidity increasing the returns of some bonds and decreasing the returns of others, depending on the BBM quintile. This is not a liquidity premium per se, which raises the returns of similarly illiquid BBM Q1 and Q5 bonds by similar amounts. We would detect such a premium from a significant

TABLE 5

Default Risk and Liquidity Interactions

Table 5 shows results from Fama and MacBeth (1973) regressions of monthly bond returns on bond and stock characteristics with BBM interaction variables for bonds with the 20% highest default risk (Panel A) or 20% lowest liquidity (Panel B). In Panel A, in addition to the regressors employed in Panel A of Table 3, all regressions include the fifth quintile dummy for nearness to default (top) or bond credit rating (bottom), as well as interactions of these worst credit indicator variables with the 4 quintile dummies for bond book-to-market (odd-numbered columns) or normal score of bond book-to-market (even-numbered columns), respectively. In Panel B, all regressions include the fifth quintile dummy for the negative of volume, the negative of the number of trades, the bond bid–ask spread, or the bond gamma as well as interactions of these illiquidity indicator variables with the 4 quintile dummies for bond book-to-market (odd-numbered columns) or normal score of bond book-to-market (even-numbered columns), respectively. Volume and the number of trades are multiplied by minus one so that the fifth quintile of all 4 liquidity measures identify bonds with the lowest degree of liquidity. The table shows average coefficients and test statistics as well as the average number of observations and average adjusted R^2. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Default Risk

	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Nearness to Default																
Bond book-to-market Q5 × nearness to default Q5	−0.047	[−0.30]			−0.023	[−0.15]			−0.071	[−0.48]			−0.100	[−0.73]		
Bond book-to-market (normal score) × nearness to default Q5			0.111	[1.29]			0.114	[1.32]			0.047	[0.63]			0.080	[1.12]
Bond book-to-market Q5	0.397	[3.82]***			0.396	[3.77]***			0.278	[4.04]***			0.317	[4.31]***		
Bond book-to-market (normal score)			0.103	[2.90]***			0.106	[2.95]***			0.095	[3.22]***			0.107	[3.80]***
Nearness to default Q5	0.019	[0.16]	−0.039	[−0.52]	0.011	[0.09]	−0.035	[−0.47]	−0.009	[−0.09]	−0.097	[−1.90]*	0.101	[0.82]	−0.043	[−0.51]
No. of obs.	1,149		1,149		1,149		1,149		1,149		1,149		1,149		1,149	
Adj. R^2	0.13		0.13		0.14		0.14		0.26		0.26		0.29		0.29	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Bond Rating																
Bond book-to-market Q5 × bond rating Q5	−0.036	[−0.26]			−0.032	[−0.23]			−0.100	[−0.78]			−0.006	[−0.05]		
Bond book-to-market (normal score) × bond rating Q5			0.084	[0.89]			0.086	[0.91]			0.031	[0.37]			0.082	[1.11]
Bond book-to-market Q5	0.411	[3.96]***			0.411	[3.93]***			0.275	[4.06]***			0.293	[4.08]***		
Bond book-to-market (normal score)			0.108	[3.09]***			0.111	[3.13]***			0.096	[3.30]***			0.102	[3.62]***
Bond rating Q5	−0.088	[−0.92]	−0.070	[−0.84]	−0.075	[−0.80]	−0.063	[−0.76]	−0.201	[−2.18]**	−0.306	[−3.70]***	−0.222	[−2.51]**	−0.314	[−3.46]***
No. of obs.	1,149		1,149		1,149		1,149		1,149		1,149		1,149		1,149	
Adj. R^2	0.14		0.14		0.14		0.14		0.26		0.26		0.29		0.29	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	

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TABLE 5 (continued)

Default Risk and Liquidity Interactions

Panel B. Liquidity

	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Bond Volume																
Bond book-to-market Q5 × bond volume Q5	0.091	[1.13]			0.081	[0.95]			0.011	[0.13]			−0.025	[−0.31]		
Bond book-to-market (normal score) × bond volume Q5			0.067	[2.10]**			0.065	[1.93]*			0.045	[1.41]			0.026	[0.84]
Bond book-to-market Q5	0.394	[3.28]***			0.401	[3.31]***			0.262	[3.09]***			0.306	[3.73]***		
Bond book-to-market (normal score)			0.127	[2.91]***			0.129	[2.93]***			0.105	[2.34]**			0.124	[2.99]***
Bond volume Q5	0.112	[2.32]**	0.169	[5.08]***	0.063	[1.31]	0.120	[3.99]***	−0.002	[−0.03]	0.031	[0.76]	−0.031	[−0.57]	−0.002	[−0.05]
No. of obs.	1,383		1,383		1,383		1,383		1,383		1,383		1,383		1,383	
Adj. R^2	0.10		0.10		0.11		0.10		0.22		0.23		0.25		0.25	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Number of Trades																
Bond book-to-market Q5 × number of trades Q5	0.021	[0.25]			0.006	[0.07]			−0.034	[−0.46]			−0.032	[−0.44]		
Bond book-to-market (normal score) × number of trades Q5			0.008	[0.25]			0.000	[0.00]			0.000	[0.00]			−0.005	[−0.20]
Bond book-to-market Q5	0.412	[3.28]***			0.412	[3.27]***			0.272	[3.15]***			0.312	[3.75]***		
Bond book-to-market (normal score)			0.141	[3.05]***			0.141	[3.02]***			0.115	[2.51]**			0.133	[3.14]***
Number of trades Q5	0.075	[1.81]*	0.120	[4.43]***	−0.002	[−0.06]	0.025	[0.91]	−0.063	[−1.29]	−0.046	[−1.33]	−0.091	[−1.80]*	−0.064	[−1.81]*
No. of obs.	1,383		1,383		1,383		1,383		1,383		1,383		1,383		1,383	
Adj. R^2	0.10		0.09		0.10		0.10		0.22		0.23		0.25		0.25	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Bond Bid–Ask Spread																
Bond book-to-market Q5 × bid–ask spread Q5	0.037	[0.29]			0.046	[0.36]			−0.003	[−0.03]			0.027	[0.28]		
Bond book-to-market (normal score) × bid–ask spread Q5			0.065	[1.13]			0.068	[1.22]			0.027	[0.60]			0.036	[0.90]
Bond book-to-market Q5	0.365	[3.12]***			0.368	[3.12]***			0.252	[3.40]***			0.295	[3.86]***		
Bond book-to-market (normal score)			0.101	[2.48]**			0.102	[2.50]**			0.097	[2.77]***			0.111	[3.51]***
Bid–ask spread Q5	0.157	[2.67]***	0.204	[4.32]***	0.152	[2.64]***	0.196	[4.15]***	0.081	[1.48]	0.041	[1.23]	0.062	[1.07]	0.038	[1.07]
No. of obs.	1,149		1,149		1,149		1,149		1,149		1,149		1,149		1,149	
Adj. R^2	0.13		0.12		0.13		0.13		0.26		0.26		0.29		0.29	

(continued on next page)

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TABLE 5 (continued)

Default Risk and Liquidity Interactions

Panel B. Liquidity (continued)	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Bond Gamma																
Bond book-to-market Q5 × bond gamma Q5	0.159	[1.56]			0.150	[1.50]			0.182	[1.89]*			0.177	[1.89]*		
Bond book-to-market (normal score) × bond gamma Q5			0.072	[1.88]*			0.071	[1.88]*			0.069	[2.21]**			0.070	[2.43]**
Bond book-to-market Q5	0.394	[3.27]***			0.390	[3.22]***			0.151	[1.64]			0.189	[2.35]**		
Bond book-to-market (normal score)			0.123	[2.92]***			0.122	[2.87]***			0.072	[1.55]			0.091	[2.35]**
Bond gamma Q5	0.029	[0.47]	0.145	[3.17]***	0.033	[0.54]	0.138	[2.99]***	−0.096	[−1.37]	−0.005	[−0.14]	−0.081	[−1.12]	−0.006	[−0.17]
No. of obs.	1,096		1,096		1,096		1,096		1,096		1,096		1,096		1,096	
Adj. R^2	0.13		0.12		0.13		0.13		0.27		0.27		0.31		0.31	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	

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coefficient on the standalone gamma regressor, but gamma is insignificant in all regressions with bond controls.

Each of Table 5 Panel B's 32 regressions imply that all bonds, irrespective of liquidity quintile, exhibit significant BBM effects, even when liquidity and its interactions are controlled for. Hence, while some forms of illiquidity may enhance the BBM effect, for reasons we will explore later, the enhancement is not because BBM proxies for an omitted or poorly measured liquidity control. Next, we study whether omitted controls tied to the riskless term structure might explain our findings.

C. BBM and Lower Risk Treasury Notes and Bonds

If BBM's anomaly stems from BBM better capturing duration or related interest rate risk measures than our controls, Treasuries should exhibit a BBM anomaly. Using CRSP's U.S. Treasury Database (excluding T-bills, TIPS, and Treasuries with special tax provisions) instead of corporate bonds, Table 6 repeats Table 3 Panel A's regressions with the returns of U.S. Treasuries as the dependent variable, dropping regressors that do not apply to Treasuries. Panel A covers the period from July 1961 to Sept. 2020, Panel B covers the period prior to the period we study with TRACE, and Panel C studies the return period over which we study corporate bond returns with TRACE – Feb. 2003 to Sept. 2020. The coefficient on the BBM Q5 dummy is insignificant for all specifications and all time periods. By contrast, YTM is a significant predictor of U.S. Treasury returns. This finding is consistent with our controls for duration and term risk being adequate, leaving other risks or, more likely, mispricing as the better explanation for the BBM anomaly in the corporate bond market.

A placebo test, which censors most Treasury transactions, assesses whether our martingale procedure artificially induces a BBM anomaly when trading is infrequent. Here, we force trades in Treasuries to mimic the distribution of trading frequencies in the corporate bond market. At the end of each month t, Treasury security j is randomly assigned a corporate bond (with replacement) from the universe of corporate bonds that belong to one of our end-of-month t BBM quintiles. If the martingale procedure for the assigned corporate bond employs the bond's last transaction on day d_1 to compute its month t signal, a day d_2 transaction for the beginning price of its month $t+1$ return, and a day d_3 transaction for the end price of that return, we compute Treasury security j's month t signal and $t+1$ return using the latter security's end-of-day prices from days d_1, d_2, and d_3, respectively. Other transactions in the Treasury security are ignored, forcing it to exhibit the same illiquidity as its assigned corporate bond. We remove observations if day d_1 is before the bond's issuance or day d_3 falls after the bond's maturity date. After similar assignments to all qualifying Treasury securities in each month, we estimate Table 6 Panel C's regression using the censored Treasury transaction data.

Panel D of Table 6 reports the average values for Table 6 Panel C's regression coefficients across 1,000 Monte Carlo simulations. Panel D's results are virtually identical to Panel C. For example, with specification 5, Panel D's coefficient on BBM Q5 is an insignificant 0.029, whereas Panel C's coefficient is −0.032. The similarity of Panels C and D validates the martingale procedure as an appropriate methodology to assess the BBM anomaly when trading is thin. In work not reported

TABLE 6

Sample of Treasury Bonds

Table 6 shows results from Fama and MacBeth (1973) regressions of monthly Treasury bond returns on Treasury bond characteristics. Treasury bond returns are regressed on bond book-to-market (BBM), coupon rate, yield to maturity, market value, age, time to maturity, duration, bid–ask spreads, lagged returns, and cumulative returns from $t-6$ to $t-1$ of Treasury bonds. The regressions include dummy variables for quintiles 2, 3, 4, and 5 of each characteristic, but the table displays only the coefficients of the quintile dummy with the largest amount of the characteristic (Q5) for brevity. Panels A–C use all daily observations to construct monthly returns, while in Panel D, we randomly match each Treasury security that is used in a BBM quintile in a month to a corporate bond. We then use the signal date, beginning-of-month date, and end-of-month date for the matching corporate bond to calculate BBM for the Treasury security and run regressions using this simulated data set. We simulate the data 1,000 times and report the average of the coefficients, t-statistics, adjusted R^2, and number of observations across simulations in Panel D. The table also shows the average number of observations and average adjusted R^2. $*$, $**$, and $***$ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	1		2		3		4		5	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Panel A. 1961.7–2020.9										
Bond book-to-market Q5	−0.083	[−1.61]	−0.029	[−1.05]					−0.036	[−1.56]
Bond coupon rate Q5			0.021	[0.82]			0.010	[0.40]	−0.013	[−0.74]
Bond yield Q5					0.295	[3.67]***	0.213	[4.34]***	0.190	[4.23]***
Bond value Q5			−0.041	[−1.34]			−0.053	[−2.47]**	−0.018	[−1.61]
Bond age Q5			−0.013	[−0.30]			−0.057	[−1.93]*	−0.046	[−1.79]*
Bond maturity Q5			0.128	[1.25]			0.021	[0.73]	0.026	[1.02]
Bond duration Q5			0.039	[2.18]**			0.009	[0.88]	0.010	[0.97]
Bond bid–ask spread Q5			0.014	[0.71]			0.012	[0.69]	0.006	[0.36]
Bond reversal Q5			−0.083	[−2.08]**			−0.081	[−2.59]***	−0.075	[−2.48]**
Bond momentum Q5			−0.023	[−1.08]			0.028	[1.12]	−0.013	[−0.79]
Intercept	0.589	[9.21]***	0.605	[8.03]***	0.377	[9.93]***	0.418	[7.91]***	0.518	[9.77]***
No. of obs.	150		150		150		150		150	
Adj. R^2	0.29		0.78		0.58		0.78		0.79	
Panel B. 1961.7-2003.1										
Bond book-to-market Q5	−0.050	[−0.89]	−0.026	[−0.76]					−0.039	[−1.51]
Bond coupon rate Q5			0.014	[0.42]			−0.002	[−0.05]	−0.034	[−1.60]
Bond yield Q5					0.21	[2.46]**	0.256	[4.34]***	0.227	[4.26]***
Bond value Q5			−0.056	[−1.20]			−0.074	[−2.30]**	−0.019	[−1.18]
Bond age Q5			0.025	[0.43]			−0.050	[−1.37]	−0.024	[−0.95]
Bond maturity Q5			0.086	[1.16]			0.021	[0.67]	0.016	[0.53]
Bond duration Q5			0.026	[1.52]			0.003	[0.20]	0.001	[0.04]
Bond bid–ask spread Q5			0.009	[0.40]			0.014	[0.65]	−0.001	[−0.07]
Bond reversal Q5			−0.087	[−1.67]*			−0.080	[−2.07]**	−0.077	[−2.08]**
Bond momentum Q5			−0.049	[−1.67]*			0.031	[0.89]	−0.030	[−1.40]
Intercept	0.635	[9.44]***	0.758	[7.32]***	0.472	[9.02]***	0.490	[6.84]***	0.633	[9.00]***
No. of obs.	117		117		117		117		117	
Adj. R^2	0.28		0.73		0.52		0.74		0.73	

(continued on next page)

TABLE 6 (continued)

Sample of Treasury Bonds

	1		2		3		4		5	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Panel C. 2003.2-2020.9										
Bond book-to-market Q5	−0.162	[−1.43]	−0.033	[−0.73]					−0.032	[−0.72]
Bond coupon rate Q5			0.038	[1.08]			0.036	[1.02]	0.034	[0.97]
Bond yield Q5					0.495	[2.76]***	0.033	[0.57]	0.040	[0.61]
Bond value Q5			−0.013	[−0.99]			−0.013	[−1.14]	−0.016	[−1.27]
Bond age Q5			−0.080	[−1.55]			−0.070	[−1.40]	−0.081	[−1.53]
Bond maturity Q5			0.186	[0.83]			0.020	[0.39]	0.041	[0.90]
Bond duration Q5			0.070	[1.56]			0.025	[1.41]	0.031	[1.70]*
Bond bid–ask spread Q5			0.023	[0.63]			0.009	[0.29]	0.019	[0.49]
Bond reversal Q5			−0.073	[−1.30]			−0.083	[−1.56]	−0.071	[−1.35]
Bond momentum Q5			0.027	[1.00]			0.022	[0.83]	0.021	[0.78]
Intercept	0.479	[3.31]***	0.246	[4.05]***	0.151	[5.92]***	0.248	[4.76]***	0.247	[4.01]***
No. of obs.	229		229		229		229		229	
Adj. R^2	0.31		0.88		0.73		0.88		0.89	
Panel D. 2003.2-2020.9, Simulated Data Accounting for Infrequent Transactions										
Bond book-to-market Q5	−0.146	[−1.44]	0.030	[0.54]					0.029	[0.52]
Bond coupon rate Q5			0.112	[2.21]**			0.099	[2.04]**	0.111	[2.15]**
Bond yield Q5					0.392	[2.69]***	0.200	[1.65]*	0.197	[1.57]
Bond value Q5			−0.025	[−1.07]			−0.020	[−0.88]	−0.024	[−1.00]
Bond age Q5			−0.059	[−1.03]			−0.057	[−1.07]	−0.058	[−0.98]
Bond maturity Q5			0.019	[0.08]			0.050	[0.81]	0.032	[0.53]
Bond duration Q5			0.049	[0.96]			0.021	[0.54]	0.023	[0.60]
Bond bid–ask spread Q5			0.013	[0.34]			0.008	[0.25]	0.014	[0.36]
Bond reversal Q5			−0.055	[−0.83]			−0.047	[−0.74]	−0.047	[−0.73]
Bond momentum Q5			−0.006	[−0.09]			−0.013	[−0.18]	−0.016	[−0.23]
Intercept	0.454	[3.70]***	0.186	[2.29]**	0.182	[9.25]***	0.192	[3.15]***	0.167	[1.99]**
No. of obs.	204		204		204		204		204	
Adj. R^2	0.21		0.52		0.44		0.51		0.51	

in a table, we repeat Panel D of Table 6 but randomly perturb the Treasury prices on the 3 days d_1, d_2, and d_3 by a randomly assigned positive or negative 20 bp, each with equal probability. This procedure mimics the impact of a 20 bp half bid–ask spread. Results with the randomly perturbed prices are highly similar.

D. Does BBM Factor Risk Explain the BBM Alpha?

Davis, Fama, and French (2000) argue that HML factor betas account for both equity's book-to-market return anomaly and its book-to-market ratio. Here, we construct a bond version of HML and show it has only modest ability to diminish the BBM effect. To create an HML-like factor, we parrot Fama and French's (1993) procedure. Each month, we divide bonds into one of 6 categories based on 2 bond size categories (market value outstanding) and 3 BBM categories. Within each of the 2 bond size groups (large and small), we compute each month's return spread between a value weighting (proportional to each bond's market capitalization) of the top- and bottom-third BBM bonds. Averaging the "large" and "small" bond return spreads generates that month's bond HML factor (BHML).

Table 7 repeats Table 4's primary factor regressions, adding BHML factor returns. Table 7's top half corresponds to Panel A of Table 4 (the BBW factor model); its bottom half corresponds to Panel B of Table 4 (the augmented BBW factor model). For brevity, Table 7 only reports intercepts and factor betas on BHML. Its rightmost column shows significant differences in Q5–Q1 BHML factor betas with both factor models. The first row of the rightmost column also displays a significant alpha spread of 15 bp per month ($t = 3.11$) – 4 bp below Table 4 Panel A's 19 bp spread. Including the term structure factor yields a similar, significant alpha spread (14 bp, $t = 3.17$).

It is not surprising that Table 7's alpha spreads are smaller than Table 4's. If we had constructed the BHML factor as an equal weighting of the top and bottom BBM quintile returns, mathematics would ensure a *zero* alpha spread. The modestly differing design of BHML similarly leads to a downward bias in the alpha spreads, albeit a less dramatic one. Such a bias makes the significance of the Q5–Q1 intercepts, even at 14 to 15 bp per month, quite telling. It suggests that it would be conservative to argue that factor risk does not fully explain the BBM anomaly.

V. Junior Bonds, Trading Frequency, and Transaction Costs

A. BBM's Return Predictive Ability for All Bonds

Prior analysis studied only senior unsecured bonds with no options other than simple calls. Table 8 repeats Tables 3, 4, and 7's regressions, but for all TRACE bonds, including junior and puttable bonds. Panel A of Table 8, which parrots Table 3's FM regressions for the all-bond sample, reports selected coefficients of interest for brevity. Panel B and C's factor regressions study EW quintiles using Tables 4 and 7's factors, respectively, but report only the intercepts and, for Panel C, BHML betas as well.

Table 8 supplements the traditional sample with corporate bonds that trade less frequently and are riskier than the original sample's senior unsecured bonds. With

TABLE 7

Factor Model Time Series Regressions with Bond HML Factor

Table 7 shows results from time series regressions of monthly portfolio returns (in excess of 1-month USD LIBOR) on bond factor models augmented with a high-minus-low factor based on bond book-to-market (BHML). Bonds are sorted each month into quintiles based on bond book-to-market (BBM) and combined into equal-weighted portfolios. The table reports intercepts, slope coefficients, *t*-statistics, the number of observations, and R^2 separately for each of the five portfolios (Q1, Q2, Q3, Q4, Q5) and for the corresponding times series of return spreads between the highest (Q5) and lowest (Q1) BBM bond quintiles. To form the BHML factor, each month, we independently sort bonds into 2 categories based on bond size (bond market value outstanding) and 3 based on the BBM ratio. For bonds within each of the 2 size categories, we value-weight returns (based on bond size) in the 2 extreme BBM terciles and calculate month $t+1$'s return spread of the portfolio. We then average the 2 value-weighted return spreads to form BHML. Regressors for the Bai et al.'s (2019) factor model are the excess return on the bond market portfolio, return spreads based on value-at-risk (the second worst returns in the previous 3 years), rating (credit rating), illiquidity (the Bao et al. (2011) measure), and reversal (past 1-month return). The augmented BBW factor model further adds a term structure factor. Standard errors are estimated using the Newey and West (1987) procedure. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
BBW Factor Model												
Intercept	0.230	[4.34]***	0.169	[4.61]***	0.177	[5.18]***	0.183	[4.63]***	0.380	[4.58]***	0.150	[3.11]***
BHML factor ($t+1$)	−0.580	[−9.33]***	−0.423	[−5.45]***	−0.111	[−1.74]*	0.068	[1.79]*	0.505	[5.00]***	1.085	[15.1]***
R^2	0.848		0.89		0.90		0.88		0.83		0.86	
No. of obs.	212		212		212		212		212		212	
5 factors (see Panel A of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	
Augmented BBW Factor Model												
Intercept	0.171	[4.29]***	0.157	[4.74]***	0.166	[5.70]***	0.174	[4.66]***	0.309	[4.48]***	0.138	[3.17]***
BHML factor ($t+1$)	−0.512	[−8.78]***	−0.408	[−4.87]***	−0.097	[−1.40]	0.078	[2.08]**	0.587	[5.35]***	1.100	[15.1]***
R^2	0.87		0.89		0.90		0.88		0.84		0.87	
No. of obs.	212		212		212		212		212		212	
6 factors (see Panel B of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	

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TABLE 8

Sample of All Corporate Bonds

Table 8 shows results for regressions using the sample of all bonds including junior bonds and bonds with embedded options. Panel A shows results from Fama and MacBeth (1973) regressions of monthly bond returns on bond and stock characteristics for the same regression specifications as in Panel A of Table 3. The regressions include dummy variables for the remaining quintiles of each characteristic, but the panel displays only the coefficients of the quintile dummy with the largest amount of bond book-to-market (Q5) or the normal score of bond book-to-market for brevity. The panel also shows average coefficients and test statistics as well as the average number of observations and average adjusted R^2. Panel B shows results from time series regressions of monthly equal-weighted portfolio returns (in excess of 1-month USD LIBOR) on bond factor models as in Table 4. For brevity, the panel only displays coefficients and *t*-statistics for the regression intercept as well as the number of observations and R^2. Panel C shows results from time series regressions of monthly equal-weighted portfolio returns (in excess of 1-month USD LIBOR) on a risk model augmented with a high-minus-low factor based on bond book-to-market (BHML), following Table 7. The panel reports intercepts, slope coefficients, *t*-statistics, the number of observations, and R^2 separately for each of the five portfolios, Q1–Q5, and for the return spreads between the highest bond book-to-market (Q5) and lowest bond book-to-market (Q1) quintiles. For brevity, the panel only displays coefficients and *t*-statistics for the regression intercept and the BHML factor, as well as the number of observations and R^2. Standard errors are estimated using the Newey and West (1987) procedure. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Fama–MacBeth Cross-Sectional Regressions

	1		2		3		4		5		6		7		8	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Bond book-to-market Q5	0.575	[4.79]***			0.569	[4.72]***			0.336	[3.64]***			0.384	[4.26]***		
Bond book-to-market (normal score)			0.192	[4.28]***			0.189	[4.19]***			0.152	[3.47]***			0.171	[4.22]***
No. of obs.	1,315		1,315		1,315		1,315		1,315		1,315		1,315		1,315	
Adj. R^2	0.11		0.10		0.12		0.11		0.23		0.24		0.26		0.26	
Bond characteristic controls (see Table 3)	No		No		No		No		Yes		Yes		Yes		Yes	
Stock characteristic controls (see Table 3)	No		No		No		No		No		No		Yes		Yes	
Market microstructure controls (see Table 3)	No		No		Yes		Yes		Yes		Yes		Yes		Yes	
Industry controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	

Panel B. Factor Model Time Series Regressions

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
BBW Factor Model												
Intercept	0.203	[3.11]***	0.219	[3.91]***	0.308	[6.76]***	0.473	[8.29]***	0.636	[6.82]***	0.433	[5.13]***
R^2	0.77		0.82		0.86		0.76		0.82		0.65	
No. of obs.	212		212		212		212		212		212	
5 factors (see Panel A of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	
Augmented BBW Factor Model												
Intercept	0.137	[2.60]**	0.187	[3.86]***	0.300	[6.90]***	0.464	[8.78]***	0.616	[6.77]***	0.478	[5.67]***
R^2	0.80		0.83		0.86		0.76		0.82		0.67	
No. of obs.	212		212		212		212		212		212	
6 factors (see Panel B of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	

(continued on next page)

TABLE 8 (continued)

Sample of All Corporate Bonds

Panel C. Factor Model Time Series Regressions with Bond HML Factor

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
BBW Factor Model												
Intercept	0.269	[5.11]***	0.261	[6.27]***	0.310	[7.46]***	0.447	[8.12]***	0.547	[7.16]***	0.278	[5.70]***
BHML factor ($t+1$)	−0.397	[−6.16]***	−0.251	[−3.06]***	−0.016	[−0.24]	0.155	[2.81]***	0.530	[3.40]***	0.927	[8.36]***
R^2	0.83		0.86		0.86		0.77		0.87		0.88	
No. of obs.	212		212		212		212		212		212	
5 factors (see Panel A of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	
Augmented BBW Factor Model												
Intercept	0.212	[5.25]***	0.235	[7.44]***	0.302	[8.00]***	0.428	[8.89]***	0.495	[7.96]***	0.283	[6.25]***
BHML factor ($t+1$)	−0.351	[−5.04]***	−0.230	[−2.59]**	−0.009	[−0.14]	0.170	[2.86]***	0.573	[3.32]***	0.924	[7.86]***
R^2	0.85		0.86		0.86		0.77		0.87		0.88	
No. of obs.	212		212		212		212		212		212	
6 factors (see Panel B of Table 4)	Yes		Yes		Yes		Yes		Yes		Yes	

full controls (specifications 7 and 8), Table 8 Panel A's results are stronger than those from Panel A of Table 3. For example, the BBM Q5 dummy's coefficient in specification 7 of Panel A is 38 bp per month (t = 4.26); the corresponding coefficient from Panel A of Table 3, specification 7 is 32 bp (t = 4.05). Likewise, factor model alpha spreads between BBM Q5 and Q1—43 and 48 bp per month for Panel B, 28 and 28 bp per month for Panel C, all significant—exceed those from the traditional sample's factor models, as outlined in Tables 4 and 7, respectively. Thus, the BBM anomaly is stronger for the all-bond sample.

B. Off-Market Prices

The literature is ambiguous about whether dealers offer key customers different prices than others or whether central dealers offer bid–ask spreads at discounts or premia when providing liquidity. TRACE prices bias inferences if the BBM signal selects time-clustered off-market prices below or above mid-market prices. For brevity, the arguments below assume key customers get better prices and oligopolistic central dealers offer worse spreads. The arguments merely reverse (e.g., bids become asks and vice versa, better becomes worse, higher is lower, etc.) if off-market prices imply key customers get wider rather than narrower spreads or central dealers offer narrower rather than wider spreads.

Suppose key customers receive better pricing, and their better prices frequently impute TRACE's beginning price for returns. Then customer–dealer trades would earn higher BBM alpha spreads than dealer-to-dealer return-initiating trades. Table 9 uses Table 3 Panel A's FM regression methodology to analyze this conjecture. It adds interaction terms to the BBM quintile dummies for a return-beginning price that is from a customer buy or sell transaction. Column 1's 0.328 coefficient on BBM quintile 5 represents the Q5–Q1 alpha spread when a dealer-to-dealer trade generates the return's beginning price. The interaction with the customer beginning-price dummy is insignificant in both specifications. This refutes the hypothesis that customer groups receiving favorable off-market bid and ask prices induce spurious BBM correlation with alpha spreads.

The minimum 7-day gap between the signal and the trade used for the return's beginning price makes it unlikely that the key customer hypothesis can explain our results. If a high BBM signal (which comes from trades at both bids and asks) selects bonds that favored customers are buying at the transaction date of the bond return's beginning price (with the reverse for low BBM signals), the minimum 7-day gap should be sufficient to mitigate the signal's ability to predict the trade direction of specific customer types receiving favored (or disfavored) pricing. Below-market ask prices that inflate both BBM and the return's beginning-of-month price are theoretically possible. However, with a 7-day gap, it seems unlikely to be the source of a 44 bp return spread between Q5 and Q1, let alone the alpha spread observed when controlling for the most recent bid–ask spread.

Further evidence against the key customer hypothesis comes from gap shortening, which should increase the spread if favored customers concentrate trades in short time intervals. Instead, the spread decreases to 43 bp if the gap is reduced by 5 trading days. When increasing the 7-day gap, even by 16–20 trading days, extreme quintile monthly return spreads still exceed 40 bp.

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TABLE 9

Off-Market Prices

Table 9 shows results from Fama and MacBeth (1973) regressions of monthly bond returns on bond and stock characteristics. BBM quintile dummies have interaction variables for dealer–customer bond transactions with the omitted dummy reflecting a dealer-to-dealer transaction. In addition, the regression includes the control variables used in specification 7 of Table 3 Panel A. The table employs quintile dummies for the characteristics as regressors except for bond book-to-market in specification 2, which employs the normal score of bond book-to-market. All regressions include an indicator variable for customer transactions, defined as cases where the beginning bond price used to construct the return in month $t+1$ comes from a customer transaction. The customer transaction indicator is also interacted with the quintiles and the normal score for bond book-to-market. The table shows average coefficients and test statistics of selected regressors as well as the average number of observations and average adjusted R^2. ∗, ∗∗, and ∗∗∗ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	1		2	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Customer transaction	0.006	[0.24]	0.019	[1.00]
Bond book-to-market Q2 × customer transaction	0.017	[0.51]		
Bond book-to-market Q3 × customer transaction	0.019	[0.53]		
Bond book-to-market Q4 × customer transaction	0.041	[1.21]		
Bond book-to-market Q5 × customer transaction	−0.018	[−0.31]		
Bond book-to-market (normal score) × customer transaction			0.005	[0.23]
Bond book-to-market Q5	0.328	[4.69]***		
Bond book-to-market (normal score)			0.101	[3.18]***
No. of obs.	1,104		1,104	
Adj. R^2	0.27		0.28	
Bond characteristic controls (see Table 3)	Yes		Yes	
Stock characteristic controls (see Table 3)	Yes		Yes	
Market microstructure controls (see Table 3)	Yes		Yes	
Industry controls	Yes		Yes	

The irrelevance of gap lengthening and shortening also refutes claims that the BBM anomaly is explained by off-market prices transacted with a central dealer offering liquidity at unfavorable terms to its counterparties. According to the central dealer hypothesis, liquidity-providing dealers concentrate their trades for periods as long as a month at below-market bid prices for Q5 bonds and at above-market ask prices for Q1 bonds. As with favored customers, clustering of central dealer trades could inflate Q5 signals and returns, while deflating Q1 signals and returns.

For the key customer and central dealer hypotheses to hold, off-market prices must also persist for no more than 13–15 trading days. If persistence was longer, biases in month-end prices (typically 13–15 trading days after the beginning-price trade) would offset the bias in the beginning-of-month transaction price, negating return bias. Hence, evidence showing that gap lengthening by up to 16–20 trading days scarcely affects return spreads helps refute off-market price hypotheses.

C. Buy-and-Hold Returns

Many institutional investors rebalance their bond portfolios infrequently, reducing transaction costs. Table 10 reports factor model alphas (computed as in Panel A of Table 4) of 5 yearly rebalanced BBM quintiles and the long–short BBM strategy. These yearly rebalanced BBW and augmented BBW factor models yield extreme quintile alpha spreads of 12 bp ($t = 2.05$) and 16 bp ($t = 2.67$) per month, respectively.[15] This suggests that yearly rebalancing approximately halves BBM's risk-adjusted profits.

[15]To address statistical pitfalls from 12-month returns that roll over each month, we apply Jegadeesh and Titman's (1993) technique. They construct an independent monthly return series that mimics a buy-

TABLE 10

Buy-and-Hold Returns

Table 10 shows results from time series regressions of monthly bond portfolio returns (in excess of 1-month USD LIBOR) on risk factors. Following Jegadeesh and Titman ((1993), (2001)), the table measures the monthly performance of a portfolio held for 12 months with the following non-overlapping returns methodology. Bonds are sorted each month into 12 sets of quintiles based on BBM that is delayed from 0 to 11 months and combined into equal-weighted portfolios within the same signal delay cohort. The monthly return that is used in the regression equally weights the 12 portfolios that belong to the same quintile. The table reports intercepts and associated *t*-statistics separately for each of the five portfolios (Q1, Q2, Q3, Q4, Q5) and for the corresponding time series of return spreads between the highest book-to-market (Q5) and lowest book-to-market (Q1) bond quintiles. Regressors for the Bai et al. (2019) factor model are the excess return on the bond market portfolio, return spreads based on value-at-risk (the second worst returns in the previous 3 years), rating (credit rating), illiquidity (the Bao et al.'s (2011) measure), and reversal (past 1-month return). The augmented BBW factor model further adds a term structure factor. Standard errors are estimated using the Newey and West (1987) procedure. $*$, $**$, and $***$ indicate significance at the 10%, 5%, and 1% levels, respectively.

	Q1 (Low BBM)		Q2		Q3		Q4		Q5 (High BBM)		Q5–Q1 (High–Low BBM)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Alpha BBW factor model	0.208	[3.11]***	0.151	[2.83]***	0.165	[4.54]***	0.195	[5.23]***	0.332	[4.75]***	0.124	[2.05]**
Alpha augmented BBW factor model	0.141	[2.63]***	0.117	[2.43]**	0.148	[4.51]***	0.182	[5.77]***	0.298	[4.72]***	0.157	[2.67]***

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D. Transaction Costs

BBM's extreme quintile pre-transaction cost alpha spread assesses market efficiency, but a BBM trading strategy is unprofitable if transaction costs exceed gross profits. Corporate bond market transaction costs are generally high (Chen, Lesmond, and Wei (2007), Edwards, Harris, and Piwowar (2007), Bao et al. (2011), and Feldhütter (2012)), which might deter exploitation of BBM signals as stand-alone "arb strategies." Appendix D of the Supplementary Material details how TRACE is used to estimate trading costs from turnover and effective half spreads per dollar trade for every BBM quintile in each month. Month t 2-way turnover is twice the sum of the portfolio weights of the bonds leaving the portfolio in month $t + 1$, thus accounting for both purchases and sales. Equation (4) in Appendix D of the Supplementary Material computes trading costs from 2-way turnover.

While dealers meeting customer liquidity needs execute on the profitable side of the bid–ask midpoint, customers can bilaterally negotiate prices with a dealer. Hence, costs may depend on the type of investor, the type of trade, and the relative market power dealers have over the customer (Bessembinder, Kahle, Maxwell, and Xu (2009)). Consistent with this, Bao et al. (2011) show that large bond transactions face lower trading costs. Accordingly, we compute 2 alternative sets of transaction costs. The first includes all dealer–customer transactions in TRACE-sourced bonds; the second is limited to dealer–customer transactions with volumes of at least \$100,000. The latter captures trades that incur tighter bid–ask spreads due to larger customers' greater bargaining power.

Figure 3 graphs monthly bid–ask spreads for all trades (Graph A) and for large trades (Graph B). It displays the average bid–ask spreads for an equal weighting of all BBM quintiles as well as for bonds in Q1 and Q5. The overall bid–ask spread patterns are consistent with Choi, Huh, and Shin's (2023) findings. Figure 3 also shows bid–ask spreads spiking during the 2008–2009 financial crisis.

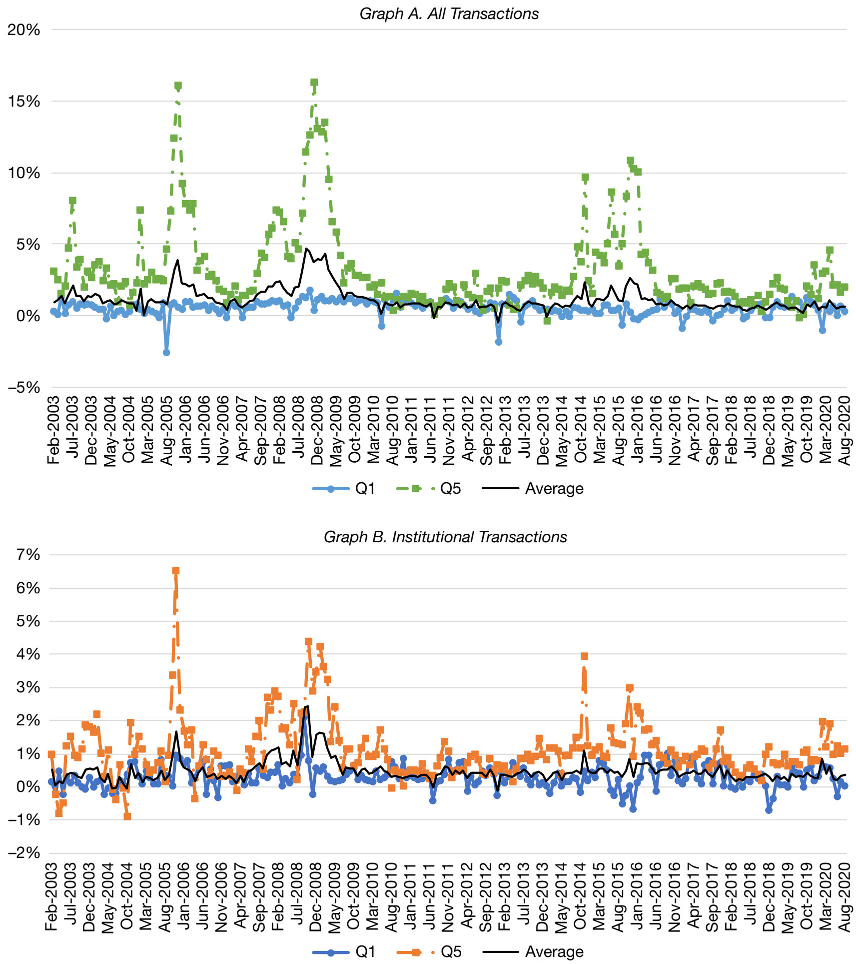
Table 11 reports average turnover and transaction costs as well as gross and net performance for trades within BBM's extreme quintiles. Net performance is the intercept from regressing quintile portfolio excess returns net of trading costs on factors. Subtracting these costs monthly alters factor betas, so Table 11's net performance is not exactly equal to the difference between Table 4 and Table 10's average gross alpha and average transaction costs. Panel A and B's alpha columns reproduce Tables 4 and 11's monthly and yearly rebalanced factor model alphas, respectively. With monthly rebalancing, the long–short BBM strategy has a pre-transaction-cost BBW factor model alpha of 19 bp per month. The transaction cost associated with its turnover of 31% amounts to 50 bp for all investors, which exceeds the alpha spreads computed for the strategy. Even applying the (more than

and-hold outcome. Their 12-month buy-and-hold series equally weighs the same-month returns from 12 partially overlapping strategies that simultaneously buy bonds based on slightly differing signals. Each quintile employs 12 same-quintile indicator signals, differing by signal-delay lags ranging from 0 to 11 months. This yields a single monthly return series for each quintile that approximates the true buy-and-hold quintile portfolio's returns. Time series averaging of the difference between quintile 5 and 1's time series vectors is BBM's buy-and-hold alpha spread.

FIGURE 3

Monthly Bid–Ask Spreads for Bond Book-to-Market Quintiles

Figure 3 shows monthly bid–ask spreads by bond book-to-market quintiles, separately for all transactions (Graph A) and institutional transactions (Graph B). Every day, we take the average of buy transactions and sell transactions for all bonds in each quintile. We take the average of daily prices in a month separately for buys and sells and compute the quintile-level bid–ask spreads from the average buys and sells for the month. The figure shows the spreads for quintile 1 (lowest BBM), quintile 5 (highest BBM), and the average of all quintiles.



50%) lower transaction costs of 19 bp for large trades to the same gross alpha offers no consolation, yielding an insignificant 2 bp per month net alpha. Augmented BBW factor model alphas net of transactions costs are an insignificant 7 bp per month for large trades.

Buy-and-hold (i.e., yearly rebalanced) strategies reduce turnover—as borne out in Panel B, with turnover of 7% and monthly transaction costs of 11 bp and 4 bp for all investors and institutions (i.e., trades of $100,000 or more), respectively. While these strategies earn lower risk-adjusted gross profits due to alpha decay, all

TABLE 11

Turnover and Transaction Costs

Table 11 shows monthly one-way turnover, transaction costs, as well as gross and net performance of the long-short investment strategy based on bond book-to-market for monthly rebalanced (Panel A) and 12-month buy-and-hold strategies (Panel B). Results are reported separately for the returns of the portfolios of the lowest bond book-to-market bonds (Q1), the highest bond book-to-market bonds (Q5), and the spread portfolio (Q5–Q1). Separately for the BBW factor model and the augmented BBW factor model, column 1 reproduces the factor alphas from Tables 4 and 11, respectively. Regressors for the Bai et al. (2019) factor model are the excess return on the bond market portfolio, return spreads based on value-at-risk (the second worst returns in the previous 3 years), rating (credit rating), illiquidity (the Bao et al.'s (2011) measure), and reversal (past 1-month return). The augmented BBW factor model further adds a term structure factor. Column 2 reports one-way turnover (in percent per month). Columns 3–8 report the average transaction costs based on 2-way turnover and transaction cost adjusted (net) performance as the intercept of a regression of quintile portfolio returns (in excess of 1-month USD LIBOR) minus monthly transaction costs on the risk factors. Standard errors are estimated using the Newey and West (1987) procedure. Daily average bid and ask prices are computed by taking the average of all dealer buy and dealer sell transactions for all bonds in a quintile. We then take the average of daily bids and asks in a month separately for bids and asks and compute monthly bid–ask spreads. We assign these quintile-level half spreads to bonds that join the quintile and calculate transaction costs as in equation (4) in the Supplementary Material. As shown in the column headings, the bid–ask spreads are calculated alternatively for all traditional bond transactions in TRACE ("All") and transactions with volume of at least 100,000 U.S. dollars ("Institutions"). The return sample period is Feb. 2003 to Sept. 2020.

			All			Institutions		
Portfolio	Alpha	One-Way Turnover	Transaction Costs	Net Performance	*t*-Statistic	Transaction Costs	Net Performance	*t*-Statistic
Panel A. Monthly Rebalancing								
BBW Factor Model								
Q1	0.207	12%	0.085	0.282	[3.75]***	0.045	0.250	[3.35]***
Q5	0.400	19%	0.410	0.032	[0.34]	0.147	0.270	[3.13]***
Q5–Q1	0.193	31%	0.495	−0.250	[−2.46]**	0.192	0.020	[0.22]
Augmented BBW Factor Model								
Q1	0.128	12%	0.085	0.198	[3.65]***	0.045	0.165	[3.08]***
Q5	0.358	19%	0.410	−0.004	[−0.05]	0.147	0.234	[2.76]***
Q5-Q1	0.230	31%	0.495	−0.202	[−2.03]**	0.192	0.069	[0.75]
Panel B. Buy-and-Hold								
BBW Factor Model								
Q1	0.208	2%	0.018	0.226	[3.30]***	0.009	0.219	[3.20]***
Q5	0.332	4%	0.090	0.255	[3.60]***	0.033	0.307	[4.36]***
Q5–Q1	0.124	7%	0.108	0.029	[0.46]	0.043	0.088	[1.44]
Augmented BBW Factor Model								
Q1	0.141	2%	0.018	0.157	[2.89]***	0.009	0.150	[2.77]***
Q5	0.298	4%	0.090	0.221	[3.36]***	0.033	0.273	[4.25]***
Q5–Q1	0.157	7%	0.108	0.064	[1.04]	0.043	0.123	[2.06]**

buy-and-hold alphas net of transaction costs are positive. BBW 5-factor net profit for all customer trades remains insignificant, but the augmented BBW model shows net profits of 12 bp (t = 2.06). Thus, the buy-and-hold strategy survives the costs incurred by larger trades, typically initiated by institutions, enhancing overall net performance. While institutions may also face additional short sales costs and constraints, these can be avoided when merely tilting long-only portfolios toward underpriced and away from overpriced bonds.

E. Trading Costs and Arbitrage Barriers

Panel B of Table 5 showed that the gamma measure of illiquidity, which is linked to trading costs, significantly predicts returns when interacted with BBM. This finding is consistent with trading cost heterogeneity deterring arbitrage for some bonds but not others. Bao et al. (2011) find that gamma illiquidity correlates with yields, but the article does not study gamma's effect on returns. Moreover,

TABLE 12

Bond Return and Alpha Spreads from Quintile Sorts of Gamma and BBM

Table 12 reports the average return and alpha spreads between the extreme quintile bond book-to-market (BBM) portfolios, when sorted into bond gamma quintiles (rows). To form the spread portfolios, each month, we independently sort bonds into 25 categories based on gamma illiquidity and BBM. For each gamma quintile, we compute the spread in the month $t+1$ equal- and value-weighted bond returns (based on bond value outstanding) between the top and bottom BBM quintiles. To estimate alphas, we regress the return spreads on the bond market factor constructed using the WRDS bond returns and report the intercept. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Equal-Weighted Portfolios				Value-Weighted Portfolios			
	Raw Returns		Bond Market Index (WRDS)		Raw Returns		Bond Market Index (WRDS)	
Gamma Quintile	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Q1 (liquid)	0.271	[1.36]	0.038	[0.20]	0.280	[1.51]	0.077	[0.42]
Q2	0.269	[1.95]*	0.160	[0.93]	0.264	[1.75]*	0.137	[0.78]
Q3	0.404	[3.27]***	0.260	[2.41]**	0.447	[3.36]***	0.316	[2.92]***
Q4	0.421	[3.14]***	0.281	[2.30]**	0.451	[3.53]***	0.309	[2.83]***
Q5 (illiquid)	0.505	[2.63]***	0.245	[1.41]	0.541	[3.40]***	0.352	[2.75]***
Q5–Q1	0.234	[2.38]**	0.207	[1.75]*	0.260	[2.63]***	0.275	[2.25]**

Table 5 Panel B's Fama–MacBeth regressions control for YTM in specifications with bond controls.

Independent quintile sorts of gamma and BBM further assess whether trading costs allow large deviations from fair value to emerge. The deviations entice arbitrageurs to exploit the profit opportunity and, in so doing, drive the BBM anomaly. Table 12 reports raw return spreads along with alpha spreads from the 1-factor CAPM. Table 12 shows evidence that arbitrage barriers, tied to transaction costs, account for our findings. BBM spreads are fairly monotonic across liquidity quintiles, irrespective of whether the portfolios are equal- or value-weighted. While unreported, the largest spread changes are driven by illiquidity's enhancement of BBM Q5's return. There is little power to assess liquidity's impact on low-BBM bond alphas, as highly illiquid bonds with very low BBM are rare. So, it is possible that BBM Q1's relatively low return for illiquid bonds is statistical noise or stems from other arbitrage deterrents, like short sales frictions.

VI. Conclusion

Alpha spreads between BBM's extreme quintile portfolios – 32 bp per month with the most extensive controls – are sizable considering the volatility of corporate bonds compared to stocks. The raw return spread's Sharpe ratio, 0.92, exceeds those of both the S&P 500 and the Fama and French's (1993) HML factor. These findings likely stem from mispricing, particularly for small-issue bonds. Alternative explanations, like omitted risk, microstructure, or liquidity controls, are inconsistent with the pattern of profits from BBM signal delay, calibrations from yield spreads, and BBM signal efficacy for bonds with more default risk, with less liquidity, or hedged with equity.

Bond trading faces greater trading and liquidity frictions than several other asset classes, which allows deviations from fair value to exist initially. Indeed, average transaction costs, estimated for different trade sizes, are large enough to deter arbitrageurs who would otherwise profit from the anomaly's monthly rebalancing signal. However, institutional strategies with lower turnover, like 1-year buy-and-hold strategies, do earn significant risk-adjusted profits even net of transaction costs. Moreover, long-term investors, who incur transaction costs anyway, benefit from knowing which bonds have the highest and lowest risk- and liquidity-adjusted returns.

BBM spreads tend to be larger for higher gamma (i.e., lower liquidity) bonds. This is likely due to arbitrageurs devoting their talents to their most profitable opportunities and is not a liquidity premium per se. For bonds with large gamma, convergence needs to wait until hedge funds find the mispricing large enough to offset its costs. For others, convergence to fair value is left to the supply and demand of less sophisticated agents who trade bonds with less haste and different motivations.

Mispricing may explain book-to-market's effects in other asset classes. If bonds, which have adequate risk controls, favor a mispricing explanation for BBM's effect, mispricing becomes a more likely explanation for the related anomalies of other assets, like equity, where controls are harder to come by. Consistent with the equity mispricing explanation is equity HML's missing premium in the last 25 years, as trading frictions declined and the anomaly became a popular topic.

Supplementary Material

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