Factor Investing in the Corporate Bond Market*

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Abstract

We provide empirical evidence that Size, Low-Risk, Value and Momentum factor portfolios generate economically meaningful and statistically significant alphas in the corporate bond market. As the correlations between the single-factor portfolios are low, a combined multi-factor portfolio benefits from diversification between the factors: it has a lower tracking error and a higher information ratio than the individual factors. The results are robust to transaction costs, alternative factor definitions, alternative portfolio construction settings and the evaluation on a subsample of liquid bonds. Finally, allocating to corporate bond factors has added value beyond allocating to equity factors in a multi-asset context.

JEL Classification: G11, G12, G14, E44

Keywords: corporate bonds, factor premiums, strategic asset allocation, size, low-risk, value, momentum

1. Introduction

This paper examines the performance of Size, Low-Risk, Value and Momentum factor portfolios in the corporate bond market. A factor portfolio is constructed by sorting bonds on a specific characteristic: Size contains bonds of small companies, based on the market value of their outstanding bonds; Low-Risk contains short-maturity bonds with a high credit rating; Value selects bonds whose credit spread is high relative to a model-implied fair spread; Momentum consists of bonds with high past returns. In addition to these individual factors, we analyze a multi-factor portfolio that combines the four factors. We find that both single-factor and multi-factor portfolios generate economically meaningful and statistically significant alphas.

Our paper belongs to the empirical asset pricing literature[1] that documents that factor portfolios carry a premium beyond the traditional asset class premium, as postulated by the CAPM. Even though this literature has existed for decades, it has predominantly focused on equities. The best documented factors in the equity literature are Low-Risk (starting with Haugen and Heins, 1972), Value (Basu, 1977), Size (Banz, 1981), and Momentum (Jegadeesh and Titman, 1993). For corporate bonds, the evidence is more limited and more recent. Documented factors are Low-Risk (e.g. Ilmanen, Byrne, Gunasekera and Minikin, 2004, and more recently Frazzini and Pedersen, 2014) and Momentum (e.g. Pospisil and Zhang, 2010, and Jostova, Nikolova, Philipov and Stahel, 2013). Evidence on other factors is scarce. We are aware of only two papers on Value (L'Hoir and Boulhabel, 2010, and Correia, Richardson and Tuna, 2012) and

[1] Note that the fixed income return attribution literature, e.g. Kahn (1991), also uses the term 'factors'. This stream of literature is concerned with an ex post decomposition of a manager's outperformance in various drivers, or 'factors', such as currency, duration, yield curve, and credit. The remaining outperformance is often called 'issuer selection' or 'managerial skill'. It is exactly this managerial skill that 'our' factors Size, Low-Risk, Value, and Momentum try to replicate in a rules-based manner.

none on Size. The existing studies on factors in the corporate bond market each focus on one particular factor, while we jointly analyze the Size, Low-Risk, Value and Momentum factors using a consistent methodology on a single data set. Our data set consists of all bonds in the Barclays U.S. Corporate Investment Grade and High Yield indexes over the period from January 1994 to June 2015.

Our paper contributes to the existing literature in three ways. First, we confirm previous work on Low-Risk and Momentum, we confirm and extend the relatively new evidence on Value, and we are the first to provide evidence on Size. We show that all factors have significant alphas, both in the CAPM, correcting factor returns for their beta to the corporate bond market, and in the Fama-French-Carhart framework, additionally correcting for betas to equity and bond common risk factors. Our second contribution is that we go beyond previous work by combining factors in a multi-factor portfolio. We find that factors have relatively low pairwise correlations, so that the multi-factor portfolio substantially reduces the tracking error and improves the information ratio versus the corporate bond market index, compared to single-factor portfolios. The annualized Fama-French-Carhart alpha of a long-only multi-factor portfolio is 0.84% (3.65%) in Investment Grade (High Yield), which is sizable given the corporate bond market premium of 0.50% (2.33%). We find that break-even transaction costs are well above actual transaction costs of corporate bonds reported in various studies, so that after cost-alphas remain substantial. These findings are robust to a variety of sensitivity checks, including alternative factor definitions, alternative portfolio construction choices and the evaluation of factor portfolios on a subset of liquid bonds. Our final contribution is the joint application of factor investing in the equity and the corporate bond markets. We show that the corporate bond factors have added value beyond their counterparts in the equity market: by not only applying factor investing in the equity market, but also in the corporate bond market investors can increase the alpha of their multi-asset portfolio by more than 1% per year.

Our results have strong implications for strategic asset allocation decisions. Most investors focus on traditional asset classes when determining their strategic investment portfolio. For example, by including stocks, government bonds and corporate bonds, they aim to earn the Equity, Term and Default premiums. Implementation of the actual investment portfolio is typically delegated to external managers. However, the results of our study, in line with results of similar studies on equity markets, suggest that investors should strategically and explicitly allocate to factors instead of relying on external managers to implement factor exposures. A seminal study on this topic is that of Ang, Goetzmann and Schaefer (2009) who were asked by the Norwegian Government Pension Fund to analyze the fund's performance. This study finds that a large part of the fund's outperformance versus its strategic benchmark could be explained by factor exposures that were implicitly present in the investment portfolios. Therefore, the authors recommend making the fund's exposure to factors a "top-down decision rather than emerging as a byproduct of bottom-up active management" (Ang et al., 2009, p. 20). Blitz (2012) argues that investing in factors should be a strategic decision, because of the long-term investment horizon required to harvest the premiums. Bender, Briand, Nielsen and Stefek (2010) and Ilmanen and Kizer (2012) also make the case for strategic allocations to factors, stressing the diversification benefits. Ang (2014) devotes an entire book to factor investing.

Two papers that are related to ours are Israel, Palhares and Richardson (2016) and Bektic, Wenzler, Wegener, Schiereck and Spielmann (2016). Like our paper, these papers study single-factor and multi-factor portfolios in the corporate bond market. Our paper differs from Israel et al. (2016) in three important aspects. First, we use more realistic assumptions, such as a holding period of 12 months (instead of 1 month), we study long-only portfolios (instead of long-short) and we do not use leverage. Secondly, in our paper we conduct a variety of sensitivity analyses, including alternative factor definitions, to verify the robustness of our results. Finally, we conduct a multi-asset analysis to investigate the added value of corporate bond factor investing beyond equity factor investing. The key difference between Bektic et al. (2016) and our paper is that they use equity definitions for each factor, whereas we focus on bond-specific factor definitions. In one of our robustness checks we show that although factor portfolios constructed using the equity definitions do generate a premium in the corporate bond market, they do not work as well as the bond-specific definitions, with the exception of Momentum.

The setup of our paper is as follows. Section 2 describes the data and the methodology. Section 3 describes the definitions of the four factors in the corporate bond market. Section 4 presents the main empirical results on the single-factor and multi-factor portfolios. Section 5 examines the added value of factor investing in the corporate bond market in a multi-asset context. Section 6 verifies the robustness of our results using a variety of sensitivity analyses. Section 7 concludes.

2. Data and Methodology

Data

We use monthly constituent data of the Barclays U.S. Corporate Investment Grade index and the Barclays U.S. Corporate High Yield index from January 1994 to June 2015. For each bond in each month, Barclays provides various characteristics, including its market value, time-to-maturity, credit rating, credit spread and return. The data set is survivorship-bias free: whenever a firm defaults, the returns of its bonds are based on their final traded price, reflecting the market's expected recovery rate.

To calculate the monthly return of the factor portfolios, we use the excess return of each corporate bond versus duration-matched Treasuries. These excess returns are provided by Barclays as well and accurately remove the Term premium. The Term premium is driven by changes in risk-free interest rates and can be efficiently harvested by investing in government bonds. The main purpose of investing in corporate bonds is to additionally earn the Default premium, which is driven by changes in credit spreads. By using excess returns versus Treasuries we can focus on the credit spread component.

Since we evaluate factor portfolios using excess returns versus Treasuries, we also obtain excess returns for the Investment Grade and High Yield market indexes from Barclays. Barclays calculates the index return each month as the market value-weighted average excess return over all index constituents in that month. We use the index returns to calculate outperformances and alphas of the factor portfolios. Note that this index return is basically the standard benchmark return for active portfolio managers, but calculated using excess returns instead of total returns. In practice, portfolio managers are benchmarked using total returns. Portfolio managers could come close to replicating the excess return-outperformance by using Treasury bond futures to hedge the interest rate exposure of the portfolio to that of the benchmark.

Our data set contains over 1.3 million bond-month observations, of which about 900,000 are in Investment Grade and about 400,000 in High Yield. The average number of observations per month is 3,520 in Investment Grade and 1,473 in High Yield. Table 1 provides further summary statistics of our data set by showing the mean and various percentiles of the bond characteristics.

All statistics are first calculated cross-sectionally per month, and then averaged over time. We observe that Investment Grade bonds tend to have lower excess returns over Treasuries, longer time-to-maturities, and are issued by larger companies, as compared to High Yield.

[Insert Table 1 around here]

Methodology

For each factor in each month, we construct an equally-weighted top (bottom) portfolio of the 10% corporate bonds with the highest (lowest) exposure to that factor. Our key results are presented in two ways. First, we analyze long-short portfolios on a one-month investment horizon. This analysis serves to identify the potential of the factors to generate alpha in the corporate bond market by overweighting or underweighting bonds. However, shorting corporate bonds is hard and costly in practice, so including the short-side inflates potential benefits beyond those achievable in practice; see also Huij, Lansdorp, Blitz and van Vliet (2014) for a discussion on long-short factor portfolios in the equity market. In our second set of results, we therefore analyze long-only portfolios on a twelve-month horizon using the overlapping portfolio methodology of Jegadeesh and Titman (1993). This is a realistic holding period and prevents extreme turnover. Next to the single-factor portfolios, we also analyze a multi-factor portfolio, which invests 25% in each of the four single-factor portfolios. In Section 6 we check the robustness of our results when the factor portfolios contain 20% of the bonds (instead of 10%) or when the bonds in the portfolio are market value-weighted (instead of equally weighted).

We create the factor portfolios separately for Investment Grade and High Yield, because these market segments are basically treated as two separate asset classes by financial market participants, such as asset owners (making separate allocations to Investment Grade and High Yield), both passive and active asset managers (offering separate investment products for Investment Grade and High Yield), index providers (offering separate indices for Investment Grade and High Yield) and regulators (often prohibiting certain groups of institutional investors to hold High Yield-rated bonds). Evidence on the segmentation of the corporate bond market into Investment Grade and High Yield segments is provided by Ambastha, Ben Dor, Dynkin, Hyman and Konstantinovsky (2010) and Chen, Lookman, Schürhoff and Seppi (2014). Chen et al. (2014) mention that a large stream of theoretical literature exists that shows that labels (in this case: ratings of corporate bonds) can lead to market segmentation and asset class effects by affecting investors' willingness to hold the security and thus can affect security prices. Chen et al. (2014) provide empirical evidence that credit ratings indeed segment the market in two parts: Investment Grade and High Yield. Therefore, it is crucial to create and evaluate the factor portfolios separately in the Investment Grade and High Yield market segments.

We calculate outperformances and alphas of factor portfolios versus their own market segment. To calculate the CAPM-alpha we run the following regression:

$$R_t = \alpha + \beta \mathrm{DEF}_t + \varepsilon_t \tag{1}$$

where R_t is the return on a factor portfolio and DEF_t the corporate bond market premium, which is the Investment Grade index excess return for Investment Grade factor portfolios and the High Yield index excess return for High Yield factor portfolios. The intercept of regression (1) is the CAPM-alpha. We also evaluate the factor portfolios against the Fama and French (1993) five-factor model supplemented with the Carhart (1997) equity momentum factor:

$$R_t = \alpha + \beta_1 \mathrm{RMRF}_t + \beta_2 \mathrm{SMB}_t + \beta_3 \mathrm{HML}_t + \beta_4 \mathrm{MOM}_t + \beta_5 \mathrm{TERM}_t + \beta_6 \mathrm{DEF}_t + \varepsilon_t \tag{2}$$

where $RMRF_t$ is the equity market premium, SMB_t the equity Size premium, HML_t the equity Value premium, MOM_t the equity Momentum premium, and $TERM_t$ the default-free interest rate Term premium. We refer to the intercept of regression (2) as the Fama-French-Carhart alpha. The four equity factors are downloaded from the website of Kenneth French.[2] The Term factor is constructed as the total return of the Barclays US Treasury 7-10 year index minus the 1-month T-bill rate from Kenneth French.[3]

3. Defining factors in the corporate bond market

Next, we describe the definitions of the Size, Low-Risk, Value and Momentum factors. For each factor definition, we purposely use only bond characteristics, such as rating, maturity and credit spread, and we do not use accounting data, e.g. leverage or profitability, or equity market information, e.g. equity returns or equity volatility. This choice makes sure that we can include all bonds in our analyses, and not only bonds issued by companies with publicly listed equity. Our definitions also facilitate the actual implementation of factors in investment portfolios. We acknowledge that accounting and equity market information, or the use of more sophisticated methods, could improve the results. However, by using bond-only definitions we demonstrate that factor investing already works using readily available data and methods. In Section 6 we investigate the sensitivity of our results to the specific choice for the factor definitions.

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[2] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[3] We use the 7-10 year Treasury index, because it best matches the average maturity of the corporate bonds. For Investment Grade (High Yield), the average maturity in our sample is about 10.9 (7.7) years. We could have used a Barclays index containing all maturities, such as the US Treasury index. However, our results do not materially change, as the return correlation of the US Treasury 7-10 year index with the US Treasury index is 98.6%.

Size

To define the Size factor in the corporate bond market, we use the total index weight of each company, calculated as the sum of the market value weights of all its bonds in the index in that month. We thus look at a company's total public debt instead of the size of individual bonds, because most explanations for the Size effect in equity markets relate to the company size, e.g. incomplete information about small firms, or size being a proxy for (default) risk; see van Dijk (2011) for a literature overview. Moreover, since smaller companies tend to issue smaller bonds,[4] and smaller bonds are less liquid than larger bonds (Sarig and Warga, 1989), our Size definition picks up a potential illiquidity premium as well. To the best of our knowledge we are the first to document a Size effect at the company level in the corporate bond market.

To construct Size decile portfolios, we rank each month all bonds on their issuer's size. The top (bottom) portfolio contains the bonds of the 10% smallest (largest) companies.

Low-Risk

Previous studies show that bonds with lower risk earn higher risk-adjusted returns. Most papers use maturity and/or rating as risk measures. The short-maturity effect has been documented by Ilmanen et al. (2004) and Derwall, Huij and de Zwart (2009); the high-rating effect has been documented by amongst others Kozhemiakin (2007) and Frazzini and Pedersen (2014). Blitz,

[4] For Investment Grade (High Yield), the average size of bonds issued by the 10% largest companies is about 3.4 (4.5) times larger than bonds issued by the 10% smallest companies.

Falkenstein and van Vliet (2014) provide an overview of possible explanations for the existence of a low-volatility effect in equity markets. Most explanations in their overview are related to human behavior, incentive structures or constraints, and are therefore equally applicable to corporate bond markets as they are to equity markets.

We follow Ilmanen (2011) by using both maturity and rating to construct our Low-Risk factor portfolios. For the Low-Risk top portfolio, we select high-rated, short-dated bonds, while the bottom portfolio consists of low-rated, long-dated bonds. For the Investment Grade top portfolio, we first select all bonds rated AAA to A-, hence excluding the most risky bonds rated BBB+, BBB or BBB-. From these bonds, we select each month all bonds shorter than M years such that the portfolio makes up 10% of the total number of bonds. This maturity threshold M thus fluctuates through time. We use this approach to allow a fair comparison with the other factor portfolios that also contain 10% of the bonds by definition. For High Yield, we follow the same procedure, selecting bonds rated BB+ to B- in the first step. On average, the maturity threshold equals 3.1 (3.6) years for Investment Grade (High Yield).

For the bottom portfolio, we select for Investment Grade (High Yield) the longest 10% of all bonds rated below AA- (BB-). On average, the maturity threshold for the bottom portfolio equals 26.4 (11.6) years for Investment Grade (High Yield).

Value

The Value effect in equity markets is well-documented since the 1970s, starting with Basu (1977). It can be summarized as mean-reversion in valuations: cheap stocks outperform, while expensive stocks underperform. To determine whether a stock is cheap or expensive, the market value of a company is compared to a fundamental measure, such as earnings or the equity book value. As far as we know, L'Hoir and Boulhabel (2010) and Correia et al. (2012) are the only papers that study Value investing in the corporate bond market. They translate the Value concept from equities to credits by comparing the market's required compensation for the bond's riskiness (i.e. the credit spread) to fundamental risk measures. In other words, a bond is cheap if it offers an ample reward for the risk investors bear by buying the bond. Both studies consider a variety of risk measures, including leverage, profitability, equity volatility and the distance-to-default measure of Merton (1974). Our methodology is in the spirit of L'Hoir and Boulhabel (2010) and Correia et al. (2012), but we restrict ourselves to risk measures that can be derived from the bond market only. We choose maturity, rating, and the 3-month change in the bond's credit spread. The latter is motivated by Norden and Weber (2004) and Norden (2015), who show that, on average, credit spreads already increase three months prior to a rating downgrade. Therefore, the spread change is a useful risk indicator beyond rating or maturity.

Specifically, to construct Value factor portfolios each month, we first run a cross-sectional regression of credit spreads on rating dummies (AAA, AA+, AA, … , C), time-to-maturity and 3-month spread change

$$S_i = \alpha + \sum_{r=1}^{21} \beta_r I_{ir} + \gamma M_i + \delta \Delta S_i + \varepsilon_i \tag{3}$$

where S_i is the credit spread of bond i, I_{ir} is equal to 1 if bond i has rating r, and 0 otherwise, M_i is the maturity and ΔS_i is the 3-month change in the credit spread. Then, following Correia et al. (2012), we calculate the percentage difference between the actual credit spread and the fitted ('fair') credit spread for each bond. Finally, we rank all bonds on this percentage difference from high to low and select the first (last) 10% bonds for the top (bottom) Value portfolio.

Momentum

Research on Momentum started with the seminal study by Jegadeesh and Titman (1993) on equity markets. Results of studies on corporate bond Momentum are mixed. Investment Grade bond returns exhibit either reversal (Khang and King, 2004; Gebhardt, Hvidkjaer and Swaminathan, 2005) or insignificant Momentum effects (Jostova et al., 2013). In the High Yield market, on the other hand, Momentum strategies have been shown to generate profits; see Pospisil and Zhang (2010) and Jostova et al. (2013).

We follow Jostova et al. (2013) by defining Momentum as the past 6-month return using a one-month implementation lag. We use the excess return versus duration-matched Treasuries, for consistency with our return measure for evaluating factor portfolios. The 10% bonds with the highest (lowest) past returns are selected for the Momentum top (bottom) portfolio.

4. The benefits of allocating to factors

In this section we present our main result that factor portfolios in the corporate bond market earn alpha beyond the corporate bond market premium and beyond common equity and bond risk premiums. We also highlight the tension between evaluating factors in an absolute or relative risk context and the importance of a long investment horizon. Further, we show the diversification benefits of combining the factors in a multi-factor portfolio, which substantially reduces the tracking error and improves the information ratio versus the corporate bond market, compared to single-factor portfolios. Finally, by calculating break-even transaction costs and comparing them to actual transaction costs, we show that single-factor and multi-factor portfolios deliver positive after-cost alphas.

Long-short factor portfolios

We start our empirical analysis by showing performance statistics for long-short factor portfolios, which go long in the top decile portfolio and short in the bottom decile portfolio; see Table 2. Panels A and B show the annualized CAPM-alphas and Fama-French-Carhart alphas. A comparison of these panels shows that both alphas are actually very similar. For Investment Grade, alphas range from around 1.2% for Size and Low-Risk to 2.5 to 3% for Value. For Low-Risk and Value the alphas are statistically significant, with *t*-values well above 2 for Low-Risk and above 3 for Value. For Size the *t*-values are around 1.6. The absence of a Momentum effect in Investment Grade is consistent with previous literature; see e.g. Jostova et al. (2013).

For High Yield, the CAPM-alphas and Fama-French-Carhart-alphas of Value and Momentum are highly significant with *t*-values between 2 and 3. Alphas are around 5% for Value and around 8% for Momentum. For Low-Risk, the CAPM-alpha of 2.0% is statistically significant, while the Fama-French-Carhart-alpha of 1.2% is not. Just like for Investment Grade, the alphas for Size are strongly positive, but insignificant.

To investigate diversification opportunities between the factors, Panel C shows pairwise correlations between the CAPM-alphas. Most correlations tend to be below 20%, except between Value and Size. Correlations are lowest between Value and Momentum. The results imply that there are diversification benefits to be gained by combining multiple factors in one portfolio. We will investigate this below in a long-only context.

[Insert Table 2 around here]

Long-only single-factor portfolios

Having discussed the more theoretical long-short portfolios evaluated on a 1-month investment horizon, we now turn our attention to the more realistic long-only portfolios on a 12-month horizon. Table 3 contains the performance statistics for the long-only factor portfolios as well as for the corporate bond market. Panel A shows that for our sample period from January 1994 to June 2015 the Investment Grade (High Yield) corporate bond market generated 0.50% (2.33%) per annum in excess of duration-matched Treasury bonds. For both Investment Grade and High Yield we find substantial outperformances for Size (1.12% and 5.50%, respectively), Low-Risk (0.41% and 1.45%), Value (1.30% and 4.26%) and Momentum (0.30% and 2.04%) versus the corporate bond market; see Panel B. The magnitude of these factor premiums is substantial: investors could have tripled their long-term average excess returns by investing in factors as compared to passively investing in the corporate bond market index.

We calculate risk-adjusted returns in three ways. First, in Panel A we measure returns relative to total volatility using the Sharpe ratio measure. For Investment Grade (High Yield) the Sharpe ratios of the factor portfolios are all higher than the Sharpe ratio of 0.12 (0.23) of the market. Except for Investment Grade Momentum, these differences are statistically significant. Second, in Panel C, we calculate annualized CAPM-alphas, risk-adjusting factor returns for their systematic exposure to the corporate bond market. We find that all CAPM-alphas are positive, large and statistically significant, except for Momentum and Value in Investment Grade. For Investment Grade, alphas range from 0.35% to 1.24% and for High Yield from 2.15% to 5.68%.

These alphas are sizeable compared to the average corporate bond market returns of 0.50% and 2.33% for Investment Grade and High Yield, respectively. Third, we calculate annualized Fama-French-Carhart alphas. These are actually very similar in magnitude to the CAPM-alphas. Again, most alphas are statistically significant, except for Size and Momentum in Investment Grade. We conclude that factor portfolios generate superior risk-adjusted returns, measuring risk either as volatility, beta to the corporate bond market, or betas to equity and bond common risk factors.

Nonetheless, investing in factor portfolios could be considered risky in a *relative* sense, as evidenced by the substantial tracking errors (volatility of the outperformance) in Panel B.[5] For Investment Grade, the tracking errors range from 1.84% to 3.07%, which are fairly large compared to the market's excess return volatility of 4.32%. For High Yield, tracking errors range from 3.86% to 7.95%, which are again substantial compared to the High Yield market's excess return volatility of 10.04%. As a result, the information ratios of single-factor portfolios are not high. This is especially true for Low-Risk, with information ratios of only 0.14 and 0.29 in Investment Grade and High Yield, respectively. On the other hand, the Low-Risk portfolio does have high Sharpe ratios of 0.41 and 0.56, respectively. This highlights the importance of a long-term investment horizon for factor investing, because on shorter horizons factor portfolios may underperform the market index due to their large tracking errors. The relatively low information ratios also make clear that single-factor portfolios are unattractive from the point of view of portfolio managers of delegated investment portfolios that are benchmarked to the market index.

[Insert Table 3 around here]

[5] Recall from Section 2 that in practice portfolio managers could come close to this excess return-tracking error by using Treasury futures to hedge duration differences between their portfolio and the corporate bond market index.

Long-only multi-factor portfolio

The correlations in Table 2 indicate that combining multiple factors in a single portfolio can generate substantial diversification benefits. We construct a multi-factor long-only portfolio that has equal allocations to each of the single-factor portfolios.[6] Table 3 shows that both for Investment Grade and for High Yield, the multi-factor portfolio has a lower tracking error than each of the single-factor portfolios. Nonetheless, the alphas and Sharpe ratios are among the highest. Because of the lower tracking error, and the still substantial outperformance, the information ratio of the multi-factor portfolio is higher than of all single-factor portfolios. The Investment Grade (High Yield) multi-factor portfolio has a Sharpe ratio of 0.32 (0.56), which is more than twice as high as the Sharpe ratio of the corporate bond market of 0.12 (0.23), and an information ratio of 0.66 (0.85). The CAPM (Fama-French-Carhart) alphas are 0.84% (0.84%) and 3.49% (3.65%) per annum.

Note that one can easily improve the multi-factor portfolio, e.g. by allocating more to Size and Low-Risk, which have the highest stand-alone Sharpe ratios, or by allocating more to Size and Value, which have the highest returns and alphas, or by omitting Momentum from the Investment Grade multi-factor portfolio. However, one should be careful in cherry-picking the results. A multi-factor approach, which balances the individual factors, is a robust method to harvest the various premiums offered in the corporate bond market.

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[6] Alternatively, one could conduct a portfolio optimization aimed at maximizing the Sharpe ratio. Blitz (2012) demonstrates that a portfolio with equal allocations to each factor already captures most of the improvements of a multi-factor portfolio compared to single-factor portfolios.

Break-even transaction costs

The results above show that allocating to factors leads to higher risk-adjusted returns. However, the analyses do not take transaction costs into account. Therefore, we calculate break-even transaction costs, both for single-factor and multi-factor portfolios. We define the break-even transaction costs of a portfolio as the costs that would lower its CAPM-alpha to 0.

In order to calculate the break-even transaction costs, we first calculate the turnover of each portfolio. Recall from Section 2 that we use the overlapping portfolio approach of Jegadeesh and Titman (1993) with a 12-month holding period. This implies that the weight of each bond in a factor portfolio is equal to the average weight across the 12 portfolios constructed from month t-11 to t. The single-counted turnover from month t to month t+1 is subsequently determined as the sum over all weight increments across the portfolio constituents. Likewise, we calculate the turnover for the Investment Grade and High Yield market indexes. Panel D of Table 3 reports the results. Note that the 31% (55%) annualized turnover of the Investment Grade (High Yield) index indicates that tracking the market comes at a cost. The index turnover comes from new bonds entering the index (due to bond issuance or rating migrations from Investment Grade to High Yield or vice versa) and from bonds leaving the index (due to redemptions, calls, and migrations, or from no longer satisfying the index inclusion rules, e.g. a maturity shorter than one year). The four single-factor portfolios have higher turnover than the market, with Size being on the lower end (small companies tend to remain small), and Momentum on the high end, with more than 100% turnover. One may expect that the Low-Risk portfolio also has low turnover (because ratings tend be fairly sticky). However, as it contains only short-dated bonds, it has to regularly reinvest redemptions from maturing bonds. The turnover of the multi-factor portfolio is equal to the average turnover of the single-factor portfolios.

Next, we calculate the break-even transaction costs of each portfolio as its gross alpha divided by its turnover; see Panel D. For Investment Grade, we find that Low-Risk, Value and the multi-factor portfolio can sustain transaction costs of around 1% to generate positive after-cost alphas. For Size, the break-even transaction costs are the highest (around 2%), because it has the highest gross alpha and the lowest turnover. The opposite holds for Momentum, which has the lowest before-cost alpha and the highest turnover, resulting in break-even transaction costs of only 0.34%. We see similar patterns for High Yield, with Size having the highest break-even transaction costs of 6.60% and Momentum the lowest of 1.82%. The break-even transaction costs for Low-Risk, Value and the multi-factor portfolio are in between.

To put these figures into perspective, we compare them to actual bid-ask spreads and transaction costs of corporate bonds. Chen, Lesmond and Wei (2007, Table I) report that the average bid-ask spread over the period from 1995 to 2003 are 41 (81) bps for Investment Grade (High Yield). Feldhütter (2012, Table 1), using data from 2004 to 2009, estimates average transaction costs at 42 (25) [18] bps for trade sizes of at least USD 100.000 (500.000) [1.000.000], without distinguishing between Investment Grade and High Yield. Harris (2015, Table 1) analyzes a 2014-2015 data set and estimates bid-ask spreads at 30 (51) bps for Investment Grade (High Yield). Finally, Mizrach (2015, Figure 13) analyses data from 2003 to 2015 and estimates a 30 bps average bid-ask spread across all ratings.

All these transaction cost and bid-ask spreads are well below the break-even transaction costs reported in Panel D, except for Momentum in Investment Grade. We thus conclude that also after transaction costs single-factor and multi-factor portfolios generate positive CAPM-alphas.

5. Strategic allocation to factors in a multi-asset context

Asset owners do not only hold corporate bonds in their portfolios, but also other assets such as government bonds and equities. Below we show that allocating to corporate bond factors leads to better performance, also if investors already apply factor investing for their equity investments.

Data

For the equity factors Size, Value and Momentum we use the top decile portfolio returns from Kenneth French' website.[2] For Size, we take the equally-weighted portfolio consisting of the 10% stocks with lowest equity market value ("Lo 10"). For Value, we take the equally weighted portfolio containing the 10% stocks with the highest equity book-to-market ratio ("Hi 10"). For Momentum, we take the equally weighted portfolio containing the 10% stocks with the highest past 12-1 month returns ("High"). The construction of these portfolios is most similar to the methodology used in this paper. Unfortunately, Kenneth French does not provide a series for the equity Low-Risk factor. Therefore, we use the returns of the MSCI Minimum Volatility Index, obtained via Bloomberg[7]. For all four equity factor series, we subtract the 1-month T-bill rate ("RF") of Kenneth French. The RMRF factor is used to reflect the equity market premium. We

[7] Bloomberg code: M00IMV$T index

construct the government bond market premium (Term) as the total return of the Barclays US Treasury 7-10 year index minus the 1-month T-bill rate; see also Section 4.

So far, we have used excess returns over Treasuries to analyze the corporate bond market and factor premiums. To compare them with equity and government bond premiums, which are measured in excess of the risk-free rate, we add the Term premium to our corporate bond series. This implies that the corporate bond total returns thus constructed have the same interest rate return as the Term factor, so that interest duration differences do not affect our results.

Correlations of individual factors across markets

Table 4 shows the correlations between the corporate bond market and factor portfolios and their respective counterparts in the equity market. For example, we calculate the correlation between the Size portfolio in the equity market and the Size portfolio in the Investment Grade corporate bond market. The first line shows the correlations of the excess returns over the risk-free rate. As the Investment Grade market return is dominated by the Term premium, the correlation between the Investment Grade market premium and the equity market premium is only 17%. For High Yield, the correlation is 57%, reflecting the higher credit risk. We observe a similar difference for the factor portfolios. In Investment Grade, the correlations range from 2% to 34%, whereas for High Yield the correlations are between 30% and 72%. The correlations are lower for the factor outperformances versus their own market, which are shown in the second line in Table 4. The multi-factor portfolios have correlations of 17% and 35% with equities for Investment Grade and High Yield respectively. The third line shows the correlations between the CAPM-alphas, thus adjusting the outperformances for market exposures. Low-Risk is the only factor for which the beta-adjustment has a large impact on the correlations: they drop from 49% (55%) to 16% (21%) for Investment Grade (High Yield). As the betas of the multi-factor portfolios are close to one, the correlations between the credit and equity multi-factor alphas are similar: 18% and 41%. This shows that the alphas of the corporate bond multi-factor portfolios diversify with the alpha of the equity multi-factor portfolio. Hence, factor investing in the corporate bond market captures different, though partially similar, effects as factor investing in the equity market.

[Insert Table 4 around here]

Multi-asset portfolios

Table 5, Panel A, shows the performance statistics of the market portfolios for equities, government bonds, and Investment Grade and High Yield corporate bonds. As Treasury yields have declined substantially over this sample period, government bonds have generated a large 3.50% annualized excess return over the risk-free rate with a Sharpe ratio of 0.55. This also leads to high Sharpe ratios for the Investment Grade and High Yield market portfolios of 0.61 and 0.64. Note that these Sharpe ratios are higher than the 0.12 and 0.23 mentioned in Table 3, because the return series in Table 5 additionally benefit from the Term premium. The equity market Sharpe ratio of 0.49 is the lowest across the four asset classes.

Panel B shows the same statistics for the multi-factor portfolios in equities and Investment Grade and High Yield corporate bonds. All three multi-factor portfolios have higher returns and Sharpe ratios than their own market portfolios. The Sharpe ratios range from 0.72 (equities) to 1.00 (High Yield). Panel C shows that the multi-factor portfolios also did well in a relative sense, significantly outperforming their market indexes with information ratios between 0.58 and 0.85.

[Insert Table 5 around here]

To analyze the added value of factor investing in a multi-asset context, we construct four portfolios. The first portfolio, “Traditional”, consists of an equal allocation of 25% to each asset class.[8] The second portfolio, “Equity Factor Investing”, allocates the 25% equities to the equity multi-factor portfolio instead of to the equity market. The third portfolio, “Corporate Bond Factor Investing”, replaces the Investment Grade and High Yield allocations of the Traditional portfolio with their respective multi-factor portfolios. The fourth portfolio, “Equity + Corporate Bond Factor Investing”, allocates both to the equity and corporate bond multi-factor portfolios. Panel A of Table 6 summarizes the portfolio weights of these four portfolios.

Panel B shows the return statistics of the four portfolios. Clearly, both equity and corporate bond factor investing lead to higher Sharpe ratios: 0.91 and 0.96 versus 0.78 for the Traditional portfolio. However, investing in factors in both the equity and the corporate bond market leads to an even higher Sharpe ratio of 1.07. Panel C shows that not only investing in the equity multi-factor portfolio, but also in the corporate bond multi-factor portfolios improves the outperformance from 1.33% to 2.35% and the information ratio from 0.58 to 0.81. Panel D shows the 4-factor alpha relative to the four market portfolios. The alphas of the three portfolios that include at least one multi-factor portfolio are large and highly significant. The “Equity + Corporate Bond Factor Investing” portfolio has an alpha of 2.53%, versus 1.26% for “Equity Factor Investing”. This shows that the corporate bond factors add over 1% alpha per annum for investors beyond their equity counterparts.

[8] The allocation chosen is arbitrary, and only serves as an example.

[Insert Table 6 around here]

6. Robustness checks

In this section we check whether our findings are robust to the specific definition of the factors, the portfolio weighting, and the portfolio size. We also verify whether the performance is robust across subperiods, ratings, maturity segments and sectors. Finally, we check whether our results our robust to liquidity effects by creating factor portfolios on a liquid subset of our data sample.

Alternative factor definitions using corporate bond data

Although we believe that the definitions presented in Section 3 are suitable representations of the factors, they are by no means the only way to define them. This is similar to the choices investors face when applying factor investing in the equity market, where multiple definitions could be used to capture a factor. For instance, the equity Value factor can be defined as the book-to-market ratio, the price-earnings ratio or the dividend yield. Likewise, Momentum can be calculated over various formation periods. In Appendix A we describe our alternative factor definitions for corporate bonds.

Table 7 shows key statistics for these alternative definitions as well as for the base case definitions to facilitate the comparison. For the Size factor (Panel A), we consider bond size as alternative to company size. The bond size measure yields a significant Sharpe ratio for High Yield of 0.54, but not for Investment Grade (0.22). There are two possible explanations. Firstly, the alternative definition measures *bond* size rather than *company* size, so that it proxies bond illiquidity; see Sarig and Warga (1989). Since Investment Grade bonds are generally more liquid than High Yield bonds (see Chen et al., 2007, Table I), the illiquidity premium is likely to be lower in Investment Grade. Secondly, a large part of the companies in the High Yield market has only one bond in the index (on average 65% versus 30% for Investment Grade), so that the difference between selecting small bonds or small companies is smaller.

For the Low-Risk factor there is a strong consistency in the results in Panel B, because all three alternative definitions generate significantly positive alphas, varying between 0.42% (1.80%) and 0.65% (2.20%) for Investment Grade (High Yield).

For the Value factor, the results in Panel C show that for Investment Grade, both alphas (1.21% and 1.64%) pass the significance tests, while for High Yield one alpha (3.70%) is significant and the other alpha (1.53%) is positive but insignificant.

Finally, in Panel D, we find that for both Investment Grade and High Yield the shorter formation period of 3 months generates significantly positive alphas of 0.50% and 2.35%, respectively. Alphas decrease as the formation period increases. For High Yield 9- and 12-month Momentum still deliver positive alphas of 1.52% and 0.78%, while for Investment Grade both alphas are around 0. As noted before, the absence of a Momentum effect in Investment Grade is a common finding in the literature.

It is evident from Table 7 that the results are robust to alternative definitions of the factors.

[Insert Table 7 around here]

Alternative factor definitions using equity data

Above we analyzed alternative definitions using bond market information. In this section we test whether equity factor definitions also generate premiums in the corporate bond market. For this analysis we link all corporate bonds in our sample to the parent company. This reduces the sample size from 1.3 million to 1.1 million bond-month observations, since not all companies have publicly listed equity . For Size, we construct decile portfolios of corporate bonds by ranking on the company's equity market capitalization; for Low-Risk we use the 1-year volatility of daily equity returns; for Value we use the book-to-market ratio; for Momentum we use 12-1 month equity returns. We might call these definitions 'stock-bond factor spillovers', in the spirit of 'stock-bond momentum spillover'; see Gebhardt et al. (2005) and Bektic et al. (2016).

Panel E in Table 7 shows the results. All equity spillover definitions generate positive alphas and Sharpe ratios that are higher than the Sharpe ratio of the corporate bond market. However, only for Momentum spillover in Investment Grade the alpha is statistically significant. In fact, the alpha is even higher than of corporate bond Momentum itself, a result which is consistent with Gebhardt et al. (2005) and Haesen, Houweling and van Zundert (2015).

This analysis shows that although the equity spillover definitions generate a premium in the corporate bond market, they do not work as well as the bond-based definitions with the exception of Momentum spillover. So, factor investing in corporate bonds requires the explicitly use of bond market information, and investors cannot just copy the equity definitions.

Controlling for rating, maturity or sector effects

Factor portfolios could, either structurally or temporarily, exhibit preferences to particular market segments, such as credit ratings, maturity buckets or sectors. To determine to which extent our results are impacted by such preferences, we construct rating-neutral, maturity-neutral and sector-neutral factor portfolios. First, we divide the sample in groups, e.g. using credit rating. Then, we select the top 10% based on a particular factor in each group. Finally, we merge the decile portfolios of all groups to construct the group-neutral factor portfolio. We conduct this analysis for all factors for credit ratings (AAA/AA, A, BBB, BB, B and CCC/CC/C), maturities (five equal-sized groups) and sectors (Consumer Cyclical, Consumer Non-Cyclical, Energy + Utilities, Industrials, Financials, Others). The exception is the Low-Risk factor, for which we do not control for rating and maturity, because they are an integral part of the Low-Risk definition.

The results are shown in Table 8. In general we find that the performance of the factor portfolios is robust to controlling for rating, maturity or sector effects. For both Investment Grade and High Yield all Sharpe ratios remain statistically significant and most are very similar to the base case. The same is true for the alphas, with a few exceptions. An interesting improvement can be observed for Momentum in Investment Grade, where the maturity-neutral portfolio construction results in a significantly higher Sharper ratio than the corporate bond market and in a significant alpha as well; see Panel D.

[Insert Table 8 around here]

Portfolios constructed on a liquid subsample

A concern when investing in corporate bonds is that they are less liquid than stocks. To examine the effect of liquidity on the performance of factor portfolios, we restrict our bond sample to a liquid subset by choosing the most liquid bond of each company. We use the age (time since issuance) and size (amount outstanding) of each bond as liquidity criteria, because previous studies show that these are effective liquidity proxies; see e.g. Sarig and Warga (1989) and Crabbe and Turner (1995). In each month and for each company we use the following procedure:

1. Limit the set of bonds of the company to bonds with an age of at most 2 years. If no bonds are younger than 2 years, limit to bonds with an age of at most 4 years instead. If still no bonds were found, select all bonds of the company.
2. Within the age-restricted set of bonds, select the largest bond.

Table 9 shows performance statistics of the factor portfolios on the liquid subset and, for comparison, on the full data set too. For Investment Grade almost all and for High Yield all Sharpe ratios and alphas remain statistically significant and are very similar to the base case. We therefore conclude that the performance of the factor portfolios is robust to liquidity effects.

[Insert Table 9 around here]

Other robustness checks

Besides the analyses described above, we conduct three additional robustness checks (tables are available on request). First, we evaluate market value-weighted portfolios instead of equally weighted portfolios. This means that the portfolios do not benefit from the Size premium, leading to lower returns. The return of the multi-factor portfolio decreases from 1.28% (5.64%) to 1.09% (5.03%) for Investment Grade (High Yield). The Sharpe ratios also drop to 0.27 and 0.49 from 0.32 and 0.56 respectively, but are still highly significant with *t*-statistics larger than 3.0. A similar picture emerges for the CAPM-alphas. The alpha drops from 0.84% (3.49%) to 0.64% (2.78%) for Investment Grade (High Yield). The *t*-statistics remains high at 2.49 (3.21).

Second, we evaluate the factors using quintile portfolios instead of decile portfolios. In general, the results become a bit weaker, as the portfolios are less tilted to the factors. The return of the multi-factor portfolio decreases from 1.28% (5.64%) to 1.18% (4.63%) for Investment Grade (High Yield). The Sharpe ratios drop to 0.31 and 0.48 respectively. However, the *t*-statistics remain large, 3.49 and 3.52, indicating that the multi-factor portfolios still perform significantly better than the corporate bond market. Also, the alphas remain large and highly significant at 0.75% and 2.50% for Investment Grade and High Yield.

Third, we check the robustness of our results in subsamples. It could be, for example, that our results are driven by the higher market volatility since 2007. We split our sample period in two subsamples: the first 10 years (from January 1994 to December 2003) and the remaining period (from January 2004 to June 2015). The Sharpe ratio of the Investment Grade long-only multi-factor portfolio over the period 1994-2003 (2004-2015) is 0.56 (0.27), versus 0.32 full sample. The alpha is 0.90% (0.80%) with a *t*-statistic of 3.05 (1.56). In High Yield, the Sharpe ratio of the multi-factor portfolio is 0.44 and 0.65 for 1994-2003 and 2004-2015 respectively. The alphas are 3.41% (with a *t*-statistic of 2.21) and 3.37% (*t*-statistic of 2.28) respectively.

7. Conclusions and implications

We provide empirical evidence that explicitly allocating to the four well-known factors Size, Low-Risk, Value and Momentum, delivers economically meaningful and statistically significant risk-adjusted returns in the corporate bond market. We use monthly constituent data of the Barclays U.S. Corporate Investment Grade index and the Barclays U.S. Corporate High Yield index from January 1994 to June 2015 and measure corporate bond returns in excess of duration-matched Treasury bonds. Both single-factor and multi-factor portfolios show higher Sharpe ratios than the corporate bond market and significant alphas. The Investment Grade long-only multi-factor portfolio has a Sharpe ratio of 0.32, versus 0.12 for the market. In High Yield, the Sharpe ratio also more than doubles, from 0.23 to 0.56. The Fama-French-Carhart-alphas are 0.84% and 3.65% per annum, for Investment Grade and High Yield respectively. These alphas are statistically significant and are large compared to the Investment Grade (High Yield) market returns over this period of 0.50% (2.33%). We find that break-even transaction costs are well above actual transaction costs of corporate bonds reported in various studies, so that after cost-alphas remain substantial. Finally, we find that the corporate bond factors have added value above equity factors. Investors that already apply factor investing in the equity market can add more than 1% alpha and 0.1 Sharpe ratio by allocating to factors in the corporate bond market too.

Our results are robust to various checks regarding the construction of the factor portfolios. Importantly, we find a strong consistency between the results using a variety of alternative factor definitions. In addition to factor definitions that only use bond characteristics, we also investigate factor portfolios that are constructed using equity characteristics. We find that these ‘stock-bond factor spillovers’ also generate positive alphas and higher Sharpe ratios, although the results are generally weaker than for the bond-specific definitions, with the exception of Momentum spillover. This shows that investors that seek to apply factor investing to corporate bonds should use a bond-specific approach and should not simply copy the equity definitions.

We see several advantages of investing in a multi-factor portfolio over selecting a single factor. Firstly, diversifying across factors protects against the possible underperformance of one or more factors for prolonged periods of time; see also Bender et al. (2010) and Ilmanen and Kizer (2012) for a more detailed exposition on the diversification benefits of allocating to factors. Secondly, the tracking errors of individual factors to the market are relatively large, but given the modest correlations between the factors' outperformances, the tracking error of the multi-factor portfolio is well below the average of the tracking errors of the individual factors. Thirdly, the magnitude of the premiums realized in the past may not be representative for the future. So, the best-performing factor in the past might not be the winning factor in the future.

What about the implementation of factors in actual investment portfolios? Traditionally, investors delegate the implementation of their investment portfolios to contracted external managers. However, these investment managers, being benchmarked to the market index, might not be willing to implement certain factors, because of the factors' large tracking errors or limited information ratios. The Low-Risk factor, for example, does not yield a high information ratio. Therefore, the traditional paradigm of delegated and benchmarked asset management, at best leads to implicit and time-varying exposures to factors, and at worst to no exposures at all.

In an absolute-risk framework, evaluated by the Sharpe ratio instead of the information ratio, allocating to factors does offer clear benefits. Factor investing is thus a strategic choice: in the short run, the tracking error versus the market may be large, but in the longer run higher risk-adjusted returns lure on the horizon. Investors should therefore seek managers that explicitly and consistently implement factor exposures in their investment strategy.

At the moment investors do not have many investment vehicles available to harvest factor premiums in the corporate bond market.[9] In equity markets, value, small cap and low-vol funds are numerously available. Therefore, with the increasing popularity of the factor investing concept, we expect this to change in the near future in the corporate bond market too.

[9] The exceptions are various funds exclusively investing in short-dated corporate bonds, hence partially offering exposure to the Low-Risk factor.

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Appendix A: Alternative definitions

Our base case definition for Size**,** to which we will now refer as S0, is the total market capitalization of all bonds of a company in the index. Our alternative definition, S1, does not look at *company* size, but at *bond* size, by selecting the 10% of the bonds with the smallest market capitalization in the index.

For Low-Risk the base case definition LR0 selects the 10% shortest-maturity bonds within the highest ratings: AAA/AA/A for Investment Grade and BB/B for High Yield. Our first alternative definition, LR1, is more restrictive in the rating dimension by choosing from AAA- and AA-rated bonds in Investment Grade and from BB-rated bonds in High Yield. Otherwise, LR1 uses the same construction method. Our second alternative definition for Low-Risk, LR2, uses spread and maturity as risk measures, instead of rating and maturity as in the base case. LR2 selects the 1/3 of the bonds with the shortest maturities within the 1/3 of the bonds with the lowest credit spreads. It thus contains 11% of the bonds, which is very close to the 10% used in the previous definitions. The final alternative definition, LR3, selects the 10% of the bonds with the lowest Duration Times Spread (DTS). Ben Dor et al. (2007) provide strong evidence that DTS is a predictor of the volatility of a corporate bond. De Carvalho et al. (2014) demonstrate the existence of a low-risk effect across various fixed income markets using DTS as risk measure.

The Value base case definition V0 conducts a regression of spread on minor rating (AAA, AA+, AA, … C) dummies, maturity and three-month spread change and selects the 10% bonds for which the percentage deviation between the market spread and the fitted spread is the largest. The first alternative definition, V1, also uses rating and maturity just like the base case, but instead of a regression, it first creates three equally populated maturity buckets within each major rating group (AAA/AA, A, BBB, BB, B, CCC/CC/C) and then selects the 10% highest spreads within each rating x maturity peer group. The second alternative Value definition, V2, is a direct translation of the book-to-market measure in the equity market by selecting the 10% of the bonds with the highest ratio of its notional amount to its market value (i.e. the reciprocal of the bond price).

For Momentum we use a formation period of 6 months in the base case definition M0. For the alternative definitions M1, M2 and M3 we change the formation period to 3 months, 9 months and 12 months, respectively.

Table 1: Summary statistics data set

This table shows summary statistics for U.S. Investment Grade and U.S. High Yield corporate bonds over the period January 1994 – June 2015. The *annualized excess return* is the monthly return of the bond over duration-matched Treasuries, multiplied by 12, and reported in percentages. The *time-to-maturity* is the number of years until the bond expires. *Credit rating* is the middle credit rating of the three rating agencies S&P, Moody's and Fitch (worst rating in case of two ratings), where the credit ratings have been converted to a numeric scale as follows: AAA=1, AA+=2, AA=3, etc. The *credit spread* is the option-adjusted yield of the bond in excess of the yield of the duration-matched government bond, in basis points. The *market value of the company* is the sum of the market value of all bonds of the company in the corporate bond index, in billion USD. The *number of observations* is the average number of bonds per month. For every characteristic the mean and five percentiles (5%, 25%, 50%, 75%, 95%) are reported. Each statistic is first calculated cross-sectionally per month, and subsequently averaged over time.

	Investment Grade						*High Yield*					
	mean	5%	25%	50%	75%	95%	mean	5%	25%	50%	75%	95%
annualized excess return	0.58	-1.75	-0.40	0.08	0.56	1.86	2.46	-5.78	-1.02	0.33	1.68	5.92
time-to-maturity	10.89	1.63	3.92	7.21	16.13	28.93	7.74	2.45	4.98	6.76	8.44	18.61
credit rating	6.69	3.45	5.56	7.04	8.80	10.00	14.30	11.00	12.93	14.67	16.09	18.22
credit spread	148.16	58.95	93.55	127.15	172.65	293.77	481.11	213.76	322.48	440.70	677.44	1540.58
market value company	13.83	0.44	1.70	4.43	9.49	19.32	3.27	0.14	0.30	0.77	2.10	8.48
number of observations	3520						1473					

Table 2: Performance statistics and correlations of long-short factor portfolios

This table shows performance statistics of the Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield corporate bonds over the period January 1994 – June 2015. Each month, a factor portfolio takes equally-weighted long positions in the top 10% of the bonds and short positions in the bottom 10% of the bonds: for Size, the issuers with the smallest (largest) market value of debt in the index; for Value, the bonds with the highest (lowest) percentage deviation between their market spread and the fitted spread from a regression on rating dummies, maturity and 3-month spread change; for Momentum, the bonds with the highest (lowest) past 6-month return, implemented with a 1-month lag; for Low-Risk, the short-maturity bonds within AAA/AA/A (BB/B) in Investment Grade (High Yield) (long maturity bonds in A/BBB resp. B/C). Panel A shows the CAPM-alpha and -beta with respect to the corporate bond market (DEF). Panel C shows the Fama-French-Carhart-alpha (RMRF, SMB, HML, MOM, TERM and DEF). Panel D shows pairwise correlations between the CAPM-alphas of the factors. Alphas are annualized. Corporate bond returns are measured as excess returns versus duration-matched Treasuries. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the mean returns and alphas are different from 0 (*t*-tests with Newey-West standard errors).

	Investment Grade				*High Yield*			
	Size	Low-Risk	Value	Momentum	Size	Low-Risk	Value	Momentum
Panel A: CAPM statistics								
alpha	1.15%	1.27%*	2.56%**	-1.38%	3.28%	2.02%*	5.14%**	8.49%**
t-value	(1.63)	(2.49)	(3.14)	(-0.77)	(1.21)	(2.04)	(2.70)	(2.80)
beta	-0.27	-1.28	0.98	-1.04	0.19	-0.76	0.60	-1.07
adjusted R^2	0.17	0.81	0.65	0.29	0.03	0.66	0.40	0.38
Panel B: Fama-French-Carhart statistics								
alpha	1.22%	1.18%*	3.01%**	-3.46%	4.84%	1.19%	5.33%**	7.84%*
t-value	(1.56)	(2.39)	(3.24)	(-1.68)	(1.77)	(1.18)	(2.82)	(2.28)
adjusted R^2	0.23	0.82	0.67	0.38	0.09	0.70	0.43	0.40
Panel C: CAPM-alpha correlations								
Size		-17%	41%	18%		-19%	51%	-19%
Low-Risk			10%	-17%			-18%	10%
Value				-14%				-36%
Momentum								

Table 3: Performance statistics of long-only factor portfolios

This table shows performance statistics of the corporate bond market and the Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield corporate bonds over the period January 1994 – June 2015. The return in month *t* is calculated as the average of the portfolios constructed from month *t-11* to *t*. Each month, a factor portfolio takes equally-weighted long positions in 10% of the bonds: for Size, the issuers with the smallest market value of debt in the index; for Value, the bonds with the highest percentage deviation between their market spread and the fitted spread from a regression on rating dummies, maturity and 3-month spread change; for Momentum, the bonds with the highest past 6-month return, implemented with a 1-month lag; for Low-Risk, the short-maturity bonds within AAA/AA/A (BB/B) in Investment Grade (High Yield). The multi-factor portfolio is an equally weighted combination of Size, Low-Risk, Value and Momentum. Panel A shows the return statistics. Panel B shows the outperformance statistics. Panel C shows the CAPM-alpha (DEF) and the Fama-French-Carhart alpha (RMRF, SMB, HML, MOM, TERM and DEF). Panel D shows the turnover and break-even transaction costs implied by the CAPM-alpha and turnover. Mean, volatility, outperformance, tracking error and alphas are annualized. Corporate bond returns are measured as excess returns vs. duration-matched Treasuries. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is different from the Sharpe ratio of the corporate bond market (Panel A, Jobson and Korkie (1981)-test), whether the outperformance is different from 0 (Panel B, *t*-test), and whether the alphas are different from 0 (Panel C, *t*-test). The *t*-tests are calculated with Newey-West standard errors.

	Investment Grade						*High Yield*					
	Market	Size	Low-Risk	Value	Momentum	Multi-factor	Market	Size	Low-Risk	Value	Momentum	Multi-factor
Panel A: Return statistics												
mean	0.50%	1.61%	0.91%	1.79%	0.80%	1.28%	2.33%	7.83%	3.78%	6.58%	4.37%	5.64%
volatility	4.32%	3.82%	2.24%	6.76%	4.32%	3.98%	10.04%	12.20%	6.69%	13.37%	10.29%	10.04%
Sharpe ratio	0.12	0.42*	0.41*	0.27*	0.19	0.32**	0.23	0.64**	0.56**	0.49**	0.42*	0.56**
t-value JK test		(2.57)	(2.14)	(2.02)	(0.76)	(3.44)		(2.72)	(3.32)	(3.02)	(2.33)	(3.88)
Panel B: Outperformance statistics												
outperformance		1.12%*	0.41%	1.30%	0.30%	0.78%**		5.50%*	1.45%	4.26%*	2.04%*	3.31%**
tracking error		2.29%	2.85%	3.07%	1.84%	1.18%		7.95%	5.02%	5.66%	3.86%	3.88%
information ratio		0.49	0.14	0.42	0.16	0.66		0.69	0.29	0.75	0.53	0.85
t-value		(2.15)	(0.60)	(1.35)	(0.72)	(2.79)		(2.24)	(1.16)	(2.28)	(2.20)	(3.04)
Panel C: Alpha statistics												
CAPM		1.24%*	0.70%**	1.06%	0.35%	0.84%**		5.68%*	2.39%**	3.72%*	2.15%*	3.49%**
t-value		(2.08)	(3.12)	(1.87)	(0.81)	(2.71)		(2.36)	(3.43)	(2.49)	(2.24)	(3.12)
Fama-French-Carhart		1.13%	0.78%**	1.32%*	0.15%	0.84%**		6.36%**	2.28%**	3.62%**	2.36%**	3.65%**
t-value		(1.76)	(3.68)	(2.01)	(0.35)	(2.64)		(2.78)	(3.61)	(2.64)	(2.88)	(3.61)
Panel D: Turnover and break-even transaction costs												
turnover	31%	63%	78%	80%	103%	81%	55%	86%	92%	96%	118%	98%
break-even costs		1.97%	0.90%	1.33%	0.34%	1.04%		6.60%	2.60%	3.88%	1.82%	3.56%

Table 4: Correlations between long-only corporate bond and equity factor portfolios

This table shows the correlations of the Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield corporate bonds over the period from January 1994 to June 2015 with their U.S. equity counterparts. For the corporate bond single-factor and multi-factor portfolios we use the series as described in Table 3 where we add the Term premium to each series to obtain total returns. For the equity factors we download data from Kenneth French's website: "RMRF" for the market factor, "Lo 10" for Size, "Hi 10" for Value and "High" for Momentum; for the equity Low-Risk factor we download the "M00IMV$T" series from Bloomberg, which contains the MSCI Minimum Volatility Index. The left-hand side of the table shows correlations for Investment Grade, the right-hand side shows the same for High Yield. We calculate correlations between the equity and corporate bond series using (A) the excess return of each series over the 1-month T-bill rate ("RF" from Kenneth French' website), (B) the outperformance of each factor portfolio versus its own market and (C) the CAPM-alpha of each factor portfolio, calculated as the intercept of a regression of the portfolio on its own market.

	Investment Grade						*High Yield*					
	Market	Size	Low-Risk	Value	Momentum	Multi-factor	Market	Size	Low-Risk	Value	Momentum	Multi-factor
A: return	0.17	0.07	0.02	0.34	0.14	0.13	0.57	0.48	0.30	0.72	0.50	0.58
B: outperformance		0.03	0.49	0.47	0.13	0.17		0.24	0.55	0.59	0.21	0.35
C:CAPM- alpha		0.04	0.16	0.45	0.10	0.18		0.28	0.21	0.52	0.24	0.41

Table 5: Performance statistics government bond, corporate bond and equity market and factor portfolios

This table shows the performance statistics for equities, government bonds and U.S. Investment Grade and U.S. High Yield corporate bonds over the period from January 1994 to June 2015. The government bond index is the Barclays US Treasury 7-10 year index. See Table 4 for details on the corporate bond and equity series. Panel A shows the mean, volatility and Sharpe ratio of the excess return over the 1-month T-bill rate for the market portfolios. Panel B shows the same statistics for the multi-factor portfolios for equities and Investment Grade and High Yield corporate bonds. Panel C shows the outperformance statistics. Mean, volatility, outperformance and tracking error are annualized. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is different from the Sharpe ratio of the market (Panel B, Jobson and Korkie (1981)-test), and whether the outperformance is different from 0 (Panel C, *t*-test with Newey-West standard errors).

		corporate bonds		
	government bonds	Investment Grade	High Yield	equities
Panel A: Market				
mean	3.50%	3.99%	5.82%	7.54%
volatility	6.34%	6.51%	9.10%	15.30%
Sharpe ratio	0.55	0.61	0.64	0.49
Panel B: Multi-factor portfolio				
mean		4.78%	9.14%	12.85%
volatility		6.21%	9.14%	17.87%
Sharpe ratio		0.77**	1.00**	0.72
t-value JK test		(3.84)	(3.77)	(1.93)
Panel C: Outperformance statistics				
outperformance		0.78%**	3.31%**	5.31%*
tracking error		1.18%	3.88%	9.21%
information ratio		0.66	0.85	0.58
t-value		(2.79)	(3.04)	(2.22)

Table 6: Performance statistics multi-asset portfolios

This table shows performance statistics of four multi-asset portfolios consisting of government bonds, corporate bonds and equities over the period from January 1994 to June 2015. All portfolios are constructed using the portfolios displayed in Table 5. The "Traditional" portfolio invests 25% in equities, 25% in government bonds, 25% in Investment Grade corporate bonds and 25% in High Yield corporate bonds. The "Equity Factor Investing" portfolio only applies factor investing in the equity market. The "Corporate Bond Factor Investing" only applies factor investing in the corporate bond market. The "Equity + Corporate Bond Investing" portfolio applies factor investing in both the equity and corporate bond markets. Panel A shows the portfolio weights. Panel B shows the statistics of the excess return over the 1-month T-bill rate. Panel C shows the outperformance statistics. Panel D shows the alpha of a regression of the portfolio return on the four market returns (Table 5, Panel A). Mean, volatility, outperformance, tracking error and alpha are annualized. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is larger than the Sharpe ratio of the traditional portfolio (Panel B, Jobson and Korkie (1981)-test), whether the outperformance is different from 0 (Panel C, *t*-test), and whether the alpha is different from 0 (Panel D, *t*-test). The *t*-tests are calculated with Newey-West standard errors.

	Traditional	Equity Factor Investing	Corporate Bond Factor Investing	Equity + Corporate Bond Factor Investing
Panel A: Weights				
Government bond market	25%	25%	25%	25%
Investment Grade corporate bond market	25%	25%		
High Yield corporate bond market	25%	25%		
Equity market	25%		25%	
Investment Grade corporate bond multi-factor			25%	25%
High Yield corporate bond multi-factor			25%	25%
Equity multi-factor		25%		25%
Panel B: Return statistics				
mean	5.21%	6.54%	6.24%	7.57%
volatility	6.69%	7.16%	6.48%	7.09%
Sharpe ratio	0.78	0.91	0.96**	1.07**
t-value JK test		(1.86)	(4.65)	(3.07)
Panel C: Outperformance statistics				
outperformance	0.00%	1.33%*	1.02%**	2.35%**
tracking error	0.00%	2.30%	1.17%	2.91%
information ratio		0.58	0.88	0.81
t-value		(2.22)	(3.13)	(2.91)
Panel D: Alpha statistics				
alpha		1.26%*	1.27%**	2.53%**
t-value		(2.09)	(4.10)	(3.18)

Table 7: Performance statistics of long-only factor portfolios for various factor definitions

This table shows performance statistics of the base case and alternative definitions of the Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield corporate bonds over the period from January 1994 to June 2015. See Table 3 for details on the construction of the factor portfolios and Appendix A for the definition of the factors. The left-hand side of the table shows the mean, volatility, Sharpe ratio and CAPM-alpha for Investment Grade, the right-hand side shows the same for High Yield. Mean, volatility and alpha are annualized. Corporate bond returns are measured as excess returns vs. duration-matched Treasuries. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is different from the Sharpe ratio of the corporate bond market (Jobson and Korkie (1981)-test) and whether the CAPM-alpha is different from 0 (*t*-test with Newey-West standard errors).

	Investment Grade				*High Yield*			
	Mean	Volatility	Sharpe ratio	CAPM-alpha	Mean	Volatility	Sharpe ratio	CAPM-alpha
Panel A: Size								
S0: Company size	1.61%	3.82%	0.42*	1.12%*	7.83%	12.20%	0.64**	5.68%*
S1: Bond size	1.17%	5.43%	0.22	0.65%	8.31%	15.47%	0.54*	5.34%*
Panel B: Low-Risk								
LR0: AAA/AA/A, BB/B; short maturity	0.91%	2.24%	0.41*	0.70%**	3.78%	6.69%	0.56**	2.39%**
LR1: AAA/AA, BB; short maturity	0.71%	2.71%	0.26	0.42%*	3.52%	6.11%	0.58**	2.20%**
LR2: Spread x Maturity	0.96%	2.76%	0.35**	0.65%**	3.60%	8.09%	0.45**	1.81%**
LR3: DTS	0.71%	1.04%	0.68**	0.60%**	2.59%	3.89%	0.67**	1.80%**
Panel C: Value								
V0: Spread regression maturity + rating + delta spread	1.79%	6.76%	0.27*	1.06%	6.58%	13.37%	0.49**	3.72%*
V1: Rating x maturity x spread	2.49%	7.88%	0.32*	1.64%**	5.13%	17.01%	0.30	1.53%
V2: Bond book-to-market	2.09%	8.13%	0.26	1.21%*	7.99%	21.45%	0.37	3.70%*
Panel D: Momentum								
M0: 6-month	0.80%	4.32%	0.19	0.35%	4.37%	10.29%	0.42*	2.15%*
M1: 3-month	1.04%	4.99%	0.21	0.50%*	4.78%	11.16%	0.43**	2.35%*
M2: 9-month	0.53%	3.92%	0.13	0.14%	3.54%	9.60%	0.37	1.52%
M3: 12-month	0.34%	3.84%	0.09	-0.04%	2.75%	9.40%	0.29	0.78%
Panel E: Equity definitions								
Size: equity market cap	1.33%	4.73%	0.28	0.85%	5.11%	14.24%	0.36	2.42%
Low-Risk: equity volatility	0.66%	3.64%	0.18	0.28%	2.79%	7.74%	0.36	1.18%
Value: equity book-to-market	0.97%	7.18%	0.13	0.22%	3.66%	15.98%	0.23	0.58%
Momentum: 12-month equity return	1.03%	3.94%	0.26	0.60%*	2.98%	8.59%	0.35	1.13%

Table 8: Performance statistics of long-only factor portfolios controlled for rating, maturity or sector effects
This table shows performance statistics of the base case and rating-, maturity- and sector-neutral alternatives of the Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield corporate bonds over the period from January 1994 to June 2015. See Table 3 for details on the construction of the factor portfolios. The rating-, maturity- and sector-neutral portfolios are created by first creating factor portfolios per rating group (AAA/AA, A, BBB, BB, B, CCC/CC/C), maturity group (five equal-sized groups) or sector (Consumer Cyclical, Consumer Non-Cyclical, Energy+Utilities, Industrials, Financials, Others) and then combining all groups to form the final factor portfolio. The left-hand side of the table shows the mean, volatility, Sharpe ratio and CAPM-alpha for Investment Grade, the right-hand side shows the same for High Yield. Mean, volatility and alpha are annualized. Corporate bond returns are measured as excess returns vs. duration-matched Treasuries. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is different from the Sharpe ratio of the corporate bond market (Jobson and Korkie (1981)-test) and whether the CAPM-alpha is different from 0 (*t*-test with Newey-West standard errors).

	Investment Grade				*High Yield*			
	Mean	Volatility	Sharpe ratio	CAPM-alpha	Mean	Volatility	Sharpe ratio	CAPM-alpha
Panel A: Size								
base case	1.61%	3.82%	0.42*	1.12%*	7.83%	12.20%	0.64**	5.68%*
rating-neutral	1.43%	3.68%	0.39*	1.07%	5.52%	9.72%	0.57**	3.64%*
maturity-neutral	1.59%	4.06%	0.39*	1.20%	7.44%	12.55%	0.59*	5.18%*
sector-neutral	1.53%	3.66%	0.42*	1.17%*	7.02%	12.23%	0.57*	4.85%*
Panel B: Low-Risk								
base case	0.91%	2.24%	0.41*	0.70%**	3.78%	6.69%	0.56**	2.39%**
sector-neutral	0.89%	1.59%	0.56**	0.73%**	3.22%	6.42%	0.50**	1.86%**
Panel C: Value								
base case	1.79%	6.76%	0.27*	1.06%	6.58%	13.37%	0.49**	3.72%*
rating-neutral	1.87%	6.65%	0.28*	1.14%*	6.36%	13.36%	0.48**	3.49%*
maturity-neutral	1.85%	6.70%	0.28*	1.12%*	6.27%	13.75%	0.46**	3.33%*
sector-neutral	1.79%	5.97%	0.30**	1.14%*	5.15%	12.75%	0.40*	2.43%
Panel D: Momentum								
base case	0.80%	4.32%	0.19	0.35%	4.37%	10.29%	0.42*	2.15%*
rating-neutral	0.73%	4.32%	0.17	0.27%	3.64%	9.40%	0.39	1.59%
maturity-neutral	1.09%	4.25%	0.26	0.63%*	4.32%	10.53%	0.41*	2.05%*
sector-neutral	0.73%	4.28%	0.17	0.28%	3.87%	10.25%	0.38	1.65%

Table 9: Performance statistics of long-only factor portfolios on liquid subsample

This table shows performance statistics of Size, Low-Risk, Value and Momentum factors for U.S. Investment Grade and U.S. High Yield, limited to the most liquid bond of each company. The most liquid bond is determined in two steps. Step 1: limit to bonds with an age of at most 2 years. If no bonds were found, restrict to an age of at most 4 years instead; if still no bonds were found, select all bonds. Step 2: within the age-restricted set of bonds, select the bond with the largest amount outstanding. See Table 3 for the details on the construction of the factor portfolios. Sample period from January 1994 to June 2015. The left-hand side of the table shows the mean, volatility, Sharpe ratio and CAPM-alpha for Investment Grade, the right-hand side shows the same for High Yield. Mean, volatility and alpha are annualized. Corporate bond returns are measured as excess returns vs. duration-matched Treasuries. * and ** indicate statistical significance at the 95% and 99% confidence levels, respectively, of two-sided tests whether the Sharpe ratio is different from the Sharpe ratio of the corporate bond market (Jobson and Korkie (1981)-test) and whether the CAPM-alpha is different from 0 (*t*-test with Newey-West standard errors).

	Investment Grade				*High Yield*			
	Mean	Volatility	Sharpe ratio	CAPM-alpha	Mean	Volatility	Sharpe ratio	CAPM-alpha
Panel A: Size								
all bonds	1.25%	4.02%	0.31*	1.25%*	7.89%	12.40%	0.64**	5.71%*
liquid subsample	1.49%	3.85%	0.39*	1.11%	8.04%	12.42%	0.65**	5.85%*
Panel B: Low-Risk								
all bonds	0.91%	2.24%	0.41*	0.70%**	3.78%	6.69%	0.56**	2.39%**
liquid subsample	0.95%	2.23%	0.43**	0.72%**	3.60%	6.95%	0.52**	2.14%**
Panel C: Value								
all bonds	1.79%	6.76%	0.27*	1.06%	6.58%	13.37%	0.49**	3.72%*
liquid subsample	2.11%	6.92%	0.31	1.43%	7.15%	13.09%	0.55**	4.47%*
Panel D: Momentum								
all bonds	0.80%	4.32%	0.19	0.35%	4.37%	10.29%	0.42*	2.15%*
liquid subsample	1.17%	4.06%	0.29	0.75%	4.55%	9.95%	0.46**	2.44%*
Panel E: Multi-factor								
all bonds	1.28%	3.98%	0.32**	0.84%**	5.64%	10.04%	0.56**	3.49%**
liquid subsample	1.43%	4.11%	0.35**	1.00%*	5.83%	10.18%	0.57**	3.72%**