NORGES BANK
INVESTMENT MANAGEMENT

02|2017

CORPORATE BONDS IN A MULTI-ASSET PORTFOLIO

DISCUSSION NOTE

In this note, we evaluate the risk and return characteristics of corporate bonds, and discuss the role of this asset class in a multi-asset portfolio consisting of equities and nominal Treasury bonds in addition to corporates. We pay particular attention to how the role of corporate bonds might vary with the size of the equity allocation.

Date 04/09/2017
ISSN 1893-966X

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MAIN FINDINGS

- Corporate bonds have historically enhanced the return on multi-asset portfolios, and long-history data going back to the 1930s suggest that corporate bonds have earned positive and statistically significant returns in excess of government bonds.

- The statistical significance and a good part of the excess returns disappear, however, once we use more recent and better quality data that offer precise information on bond duration. Adjusting for duration differences is important, as an allocation to corporate bonds comes with exposure to interest rate risk, which is already captured by a Treasury bond allocation.

- Realised corporate bond excess returns load significantly on both equity and Treasury excess returns, and do not deliver statistically significant excess returns beyond these exposures in recent samples.

- Corporate bond excess returns have historically been positively correlated to equity excess returns, while moving counter to excess returns on Treasuries. The multi-asset portfolio properties of corporate bonds therefore depend crucially on the initial equity-Treasury mix.

- Credit risk acts as a diversifier in a portfolio dominated by interest rate risk, while an allocation to corporate bonds has historically increased the overall volatility of multi-asset portfolios dominated by equity risk. The additional risk, however, comes with an insufficient amount of return to maintain the Sharpe ratios of simple equity-Treasury portfolios.

- While the key drivers behind excess credit spreads are still subject to discussion, some of the candidate explanations suggest overlapping return drivers with equities and Treasuries. These drivers are of particular relevance in this setting as they may influence any separate diversification benefits of corporate bonds in an equity-Treasury portfolio.

1. Introduction

In this note, we evaluate the risk and return characteristics of corporate bonds, and discuss their role in a multi-asset portfolio consisting of equities and Treasuries in addition to corporates. This note is a follow-up to DN 2-2016 "Risk and return of different asset allocations", where we focus on the interaction between equity and interest rate risk in portfolios with different combinations of the two risk factors.

Introducing credit risk into the analysis allows us to assess whether corporate bonds add any value over and beyond Treasuries in an equity-bond portfolio. Along the same lines as in DN 2-2016, the objective of this note is to shed light on the risk-return characteristics of corporate bonds as well as the asset class's co-movement properties against equities and government bonds. We pay particular attention to how the role of corporate bonds might vary with the size of the equity allocation.

We find that corporate bonds have historically enhanced multi-asset portfolio returns, although whether the enhancement is statistically and economically significant is highly sample-dependent. Of critical importance for the portfolio properties of corporate bonds, we find that corporate bond excess returns have historically been positively correlated to equity excess returns, while moving counter to excess returns on Treasuries. The multi-asset portfolio properties of corporate bonds therefore depend crucially on the initial equity-Treasury mix.

The upshot of this is that credit risk acts as a diversifier in a portfolio dominated by interest rate risk, while an allocation to corporate bonds has historically increased the overall volatility of multi-asset portfolios dominated by equity risk.

Drivers of credit returns

For an investor who has decided on a non-zero corporate bond allocation, the focus should be on the drivers of the yield difference, or spread, between corporate and government bonds. A large literature in academic finance, covering both theory and empirics, attempts to account for the variation in credit spreads. The literature points to a tight link between credit returns and drivers of returns in equity and Treasury markets.

A well-documented observation from this literature is that credit spreads have historically compensated for more than the expected loss from default using traditional credit models. The reason for this excess spread – termed the credit spread puzzle – must either be misspecification in the traditional models or that additional factors drive observed credit spreads.

The focus on credit spreads can be misleading, however. As Ilmanen (2012) points out, ex-post corporate bond excess returns are found to be meaningfully lower than implied by ex-ante credit spreads. Using Barclays data covering the period 1973–2009, Ilmanen finds average realised excess returns of roughly 30 basis points. Contrasting this number with the average option-adjusted credit spread of 120 basis points over the same period yields a significant residual.

Ilmanen (2012) attributes the difference to a host of factors, including the downgrading bias[1], the fallen-angel effect[2], differences in realised and expected defaults, and repricing effects that occur over multi-decade data samples. The upshot of this is that one should be careful to distinguish between *ex-ante* credit spreads and *ex-post* excess returns. Still, the key to understanding realised corporate bond returns arguably lies in the drivers of corporate bond prices and the yield spread over government bonds.

The literature dealing with the valuation of corporate debt starts with the seminal work of Merton (1974), who applies the option-pricing theory developed by Black and Scholes (1973) to the modelling of a firm's value and, crucially, to pricing corporate bonds. In a nutshell, Merton (1974) lays out a simple framework where a firm, with a total value V, issues a single zero-coupon bond with a face value F, and equity is the residual claim on the firm value. Default occurs at maturity T whenever the firm's liabilities exceed its assets (V < F).

The payoff to holders of equity and debt will naturally differ, depending on whether the firm defaults or not. Starting with the bond holder, the payoff can either be 1) face value F at maturity whenever V > F, or 2) firm value V whenever V < F and the firm defaults. On the flipside, this leaves the equity holder with zero whenever the firm defaults, and V – F otherwise. Merton (1974) recognises that the payoff to equity holders – max(0, V – F) – is equivalent to that of a call option on the assets of the firm.

The critical insight from Merton (1974) is perhaps better understood when applying the put-call parity of Stoll (1969). The put-call parity is a no-arbitrage condition, which simply states that the market value V of a given underlying asset must equate to the sum of a call option C with strike price K written on the asset, a put option P (also with strike K) on the same underlying asset, and the present value of a risk-free bond B with a face value equal to the strike price (V = C + P + B).

The risky corporate bond in the Merton framework is therefore equivalent to a combination of a risk-free bond and a short position in a put option written on the assets of the firm. This insight allows us to think of the credit spread – the spread between the risky corporate bond and a comparable risk-free bond – as a short put option on the firm. While still being a subject of great controversy in the financial literature, the Merton model clearly establishes a (positive) link between risk premiums in equity and corporate bond markets.

1 The downgrading bias refers to the observation that investment-grade bonds are more likely to be downgraded than upgraded, and, crucially, downgrades have a larger impact on credit spreads than improving ratings in the high-grade segment.

2 The fallen-angel effect refers to the fact that investment-grade indices typically have rules that force investors to sell bonds that are downgraded to non-investment grade. The rules for investment-grade bond indices mean that investors suffer price losses between the downgrade and the time when bonds exit the index, but do not benefit from a subsequent recovery. See Fridson and Wahl (1986), Ng and Phelps (2010) and Ng, Phelps and Lazanas (2013).

Attempts by academics to account for historical credit spreads have generated a substantial literature in finance covering both theory and empirics. Even though credit and recovery risk are considered the principal factors in accounting for credit spreads, several non-default-related factors, such as tax and illiquidity, have been suggested as possible components of the credit spread.

While the key drivers behind excess credit spreads are still subject to discussion, several of the candidate explanations suggest overlapping return drivers with equities and Treasuries, consistent with the original Merton model.

Common return drivers are of particular relevance in this setting, as they may influence any separate diversification benefits of corporate bonds in an equity-Treasury portfolio. We reviewed this literature in detail in DN 3-2011 "The Credit Premium" and therefore only present a brief update on more recent contributions to the literature in Appendix B of this note.

The remainder of this note is structured as follows. In Section 2, we outline the data and methodology used throughout the note, before we highlight the key historical risk-return characteristics of corporate bonds in Section 3. Section 4 then describes the portfolio properties of corporate bonds and assesses the portfolio implications of different allocations across the three asset classes. Finally, we conclude in Section 5.

2. Data and methodology

Throughout this note, we restrict our analysis to a US multi-asset portfolio, consisting of US corporate and Treasury bonds as well as equities. We focus on the investment-grade corporate bond segment, as this represents both the largest[3] non-government bond segment and the most direct exposure to credit risk. We obtain monthly time series for the total return on the S&P 500 index (EQ) and US 3-month Treasury bill rate (CASH) through Bloomberg (see Table 1 below for a full list of the data series used throughout the note).

There is a trade-off between sample size and data quality. Moody's offers credit spreads[4] back to 1919, and Ibbotson provides corporate bond returns[5] going back to 1926. However, neither of these data sets comes with additional information on bond duration, which is crucial in order to accurately calculate corporate bond excess returns over duration-matched Treasury bonds. Neutralising any duration differentials is essential, as the durations of corporate and Treasury bonds have historically differed

3 As of 28 February 2017, corporate bonds make up 99 percent of the non-government segment of the Bloomberg Barclays US Aggregate Index (excluding ABS, MBS and CMBS) and 87 percent of the global version of the same bond index.

4 Moody's Seasoned Corporate Bond Yields of different rating classes are available via the St. Louis Fed's data service Federal Reserve Economic Data (FRED) at https://fred.stlouisfed.org/series/BAA. Note that these series were discontinued on 11 October 2016.

5 Long-term corporate bond returns are available in Ibbotson's latest yearbook (Ibbotson, 2016), and Morningstar offers a paid subscription giving access to the full dataset. More information is available at: http://corporate.morningstar.com/us/asp/subject.aspx?page=6&xmlfile=283.xml.

significantly, and this may lead to term premiums partly offsetting, or even completely dwarfing, any pure credit risk factor.

To avoid such biases in our data, we choose not to use these long-term data samples as our main sample, and rather attempt to find the longest-history data of sufficient quality. To our knowledge, corporate bond returns from Bloomberg Barclays provide the longest history of accurately duration-matched corporate bond excess returns.[6] This dataset gives us duration-matched excess returns (CRED ER) back to August 1988, and total returns for both corporate bonds (CRED) and Treasury bonds (TSY) back to January 1973. In addition, this data set allows us to break down corporate bond returns along sector, rating and maturity dimensions, facilitating sensitivity analysis on our main empirical results.

Table 1: Data description

Asset class	Short name	Sample	Proxy index	Source
Equity	EQ	1973–2017	S&P 500 ('SPX Index') total return (inc. div.)	Bloomberg
Cash	CASH	1973–2017	3-month T-bill ('USGG3M Index')	Bloomberg
Treasury	TSY	1973–2017	US Treasury Index total return	Bloomberg Barclays
Corporate	CRED	1973–2017	US Corporate Index total return (not duration-matched)	Bloomberg Barclays
Corporate	CRED ER	1988–2017	US Corporate Index excess return (duration-matched)	Bloomberg Barclays
Corporate	CORP XS	1926–2014	US Long-Term Corporate excess return (duration-matched)	Asvanunt and Richardson (2017)
Treasury	GOVT XS	1926–2014	US Long-Term Government excess return	Asvanunt and Richardson (2017)
Equity	SP500 XS	1926–2014	S&P 500 excess return	Asvanunt and Richardson (2017)

Source: Bloomberg, Bloomberg Barclays, Asvanunt and Richardson (2017), NBIM

This dataset, together with the equity and T-bill returns from Bloomberg, serves as our main data sample throughout the note. However, as argued in Luu and Yu (2011), 20-something years of return data are not necessarily sufficient when studying the long-term risk-return characteristics of a given

6 Bloomberg Barclays calculates corporate bond excess returns based on the so-called Key Rate Duration method. This approach summarises the yield curve exposure of each corporate bond using six key duration points. The excess return on a given corporate bond is then calculated by subtracting from its return the return of a hypothetical Treasury that is constructed to match the duration profile of the corporate bond. Note that this method is based on the analytical duration of corporate bonds, as opposed to the empirical duration used in Asvanunt and Richardson (2017). While the empirical duration is a purely backward-looking estimate based on historical data, the analytical duration estimate has the advantage of being based on a bond pricing model. By using analytical duration when calculating duration-matched excess returns, we are likely over-hedging the duration exposure, as (realised) empirical durations tend to be lower than analytical durations. As such, when we use the term "duration-matched excess returns" in this note, we are not referring to corporate bond returns that are necessarily ex-post insensitive to Treasury returns, but rather designed to be ex-ante neutral in terms of their analytical duration exposure.

asset class. Their solution is to use the Moody's data and, by assuming a corporate bond maturity of ten years, calculate corporate bond excess returns all the way back to 1926.

Another, also imperfect, solution to the problem of missing duration information is to estimate the duration empirically, by regressing both realised corporate and government bond returns on contemporaneous yield changes. Excess credit returns are then obtained by subtracting empirical-duration-adjusted government bond returns from the return on corporate bonds.

Asvanunt and Richardson (2017) follow this methodology using the long-term return series from Ibbotson. Their corporate bond excess return dataset thus goes back to 1926, and is available through the AQR data library.[7] Even though this methodology is inherently backward-looking and less accurate than the return data from Bloomberg Barclays, we use this as an alternative dataset in order to shed some light on the risk-return properties of corporate bonds going back further than our 1988–2017 sample.

Following Asvanunt and Richardson (2017), we splice the long-history credit returns with the Bloomberg Barclays series once it becomes available in 1988. This allows us to extend the entire Asvanunt-Richardson dataset, which ends in December 2014, to the end date of our main sample (January 2017). All in all, this gives us two different duration-matched corporate bond excess return series: CRED ER and CORP XS. In addition, we use the *non*-duration-matched Bloomberg Barclays total corporate return series and refer to this simply as CRED.

Table 2 displays the historical return-risk statistics for the main return series used for the empirical analysis. We report total returns for all asset classes, but we are predominantly interested in the returns each asset has earned in excess of the so-called risk-free rate, proxied by the US 3-month Treasury bill rate (CASH) in this note. The first row displays the risk-return characteristics of cash, which has earned on average almost 5 percent over the full sample period.

Table 2: Annualised asset class risk and return statistics, 1973–2017

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio	t-stat
CASH	4.88	1.02	0.00	NaN	NaN
TSY	7.12	5.22	2.24	0.43	2.85
CRED	7.78	7.07	2.90	0.41	2.69
EQ	10.92	15.28	6.04	0.39	2.62

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

Equities, Treasuries and corporate bonds, however, have returned on average roughly 11, 7 and 8 percent respectively, all outperforming T-bills by a good margin. Note that the corporate and Treasury proxies here are not

7 *Asvanunt-Richardson data available at:*
www.aqr.com/library/data-sets/credit-risk-premium-preliminary-paper-data.

constructed to have matching duration profiles, so they cannot be compared on a like-for-like basis. The two asset class proxies do, however, represent commonly used off-the-shelf benchmarks that provide broad exposures to the two asset classes. For an investor considering allocating to a market-weighted corporate bond index, it is worth noting that such an allocation resulted in a similar return profile to that of Treasuries over the 1973–2017 sample, only with higher volatility and more meaningful drawdowns.

As highlighted in DN 2–2016, the positive excess returns on equities and Treasuries reflects two well-documented patterns in empirical finance: the *equity risk premium* (ERP) and the *term premium* (TP). Both risk premiums have been documented both across a wide selection of countries and over several decades, even centuries – see DN 4–2011, DN 1–2016 and DN 2–2016 for detailed reviews of the theoretical and empirical evidence on both the ERP and the TP.

3. Risk and return characteristics of corporate bonds

We are ultimately interested in the portfolio properties of corporate bonds in a portfolio already containing equity and government bond risk. Asset class risk, return and co-movement properties drive portfolio characteristics. In this section, we highlight the key historical risk-return characteristics of corporate bonds, before we describe the portfolio properties of corporate bonds and assess the portfolio implications of different allocations across the three asset classes.

The *credit premium* (CP) is a well-documented pattern in empirical finance. The CP refers to the excess return that an investor obtains for holding bonds issued by entities other than governments. Rather than the returns in excess of cash displayed in Table 2, we are therefore predominantly interested in the risk-return characteristics of corporate bond returns in excess of (duration-matched) Treasuries, and, in particular, whether this return spread adds any separate diversification benefit to an equity-Treasury portfolio.[8]

We therefore show the historical return-risk statistics of realised corporate bond returns in excess of Treasuries in Table 3. The first two panels show return statistics for the empirical duration-matched credit premium (CORP XS) of Asvanunt-Richardson – both for the full 1936–2017 period (Panel A) and for the post-World War 2 period (Panel B). The last panel shows the same

8 As in Asvanunt and Richardson (2017), we define the (realised) CP as (realised) corporate bond returns in excess of Treasuries. However, both the theoretical and empirical literatures point to a tight link between the realised CP and equity returns. We should therefore expect the realised CP to come with equity exposure, and so attempt to assess whether the realised excess returns are sufficient to compensate for the added equity exposure. An alternative, and perhaps more elegant, method would be to follow the structural credit model approach and define the CP as corporate bond returns in excess of both Treasuries and equities. In this setting, a positive CP would be an indication that corporate bonds have enhanced the return on multi-asset portfolios. Since we focus exclusively on investment-grade corporate bonds in this note, we use the simple CP definition rather than the alternative structural-model-implied CP. We also report corporate bond returns in excess of both Treasuries and equities in Table 4 and find that the value added (alpha) is not significantly different from zero in more recent periods (see the intercepts in columns 3, 6 and 9 of Table 4).

statistics for the duration-matched excess return series (CRED ER) from our main data sample (Panel C).

Table 3: Annualised risk and return statistics, realised corporate bond returns in excess of Treasuries (duration-matched)

Asset class	Mean excess return	Standard deviation	Sharpe ratio	t-stat
Panel A: January 1936 – January 2017				
CORP XS	1.37	3.65	0.38	3.39
Panel B: January 1946 – January 2017				
CORP XS	1.17	3.82	0.31	2.58
Panel C: August 1988 – January 2017				
CRED ER	0.58	3.87	0.15	0.80

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

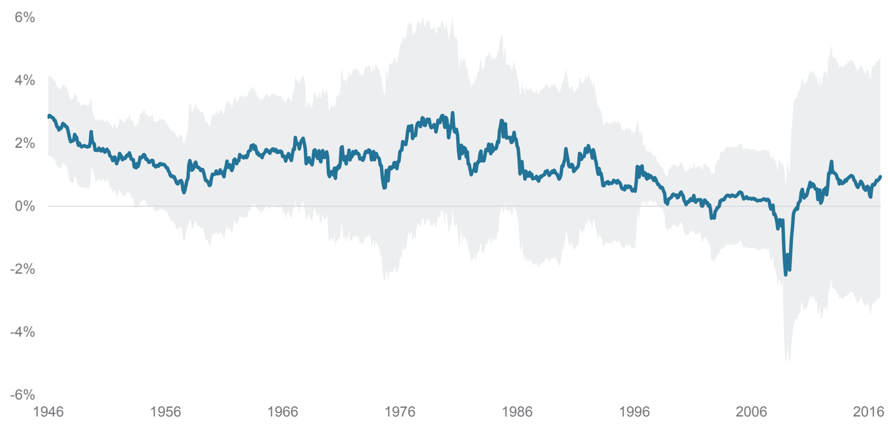
All three panels show that corporate bonds have historically delivered positive excess returns over the respective sample periods. The average excess returns realised over our main sample period (Panel C) are, however, less than half the long-history averages in Panels A and B. Even though not reported here, this difference remains even when restricting the long-history data to the overlapping 1988–2017 period.[9] As noted by Asvanunt and Richardson (2017), this difference is likely attributable to the fact that the two indices differ both in constituent bonds and in index rules and construction, rather than the methodology for matching bond durations.

The realised credit premium has varied greatly over time. Our main credit proxy comes with annualised return volatility of around 4 percent and thus is not found to be statistically significant[10] over the full main sample period. In line with Asvanunt and Richardson (2017), Panel A shows that the empirical-duration-matched corporate bond index has delivered statistically significant excess returns over Treasuries for the 1936–2017 period. The premium and the statistical significance, however, decrease in Panel B, which leaves out the first ten years of data and shows the same statistics for the post-World War 2 period. Figure 1, which plots the 10-year rolling excess returns (using the same long-history data as in Panel A of Table 3), reveals that a great deal of the statistical significance is confined to the early part of the sample period, when the volatility of corporate bond excess returns was particularly low.

9 Asvanunt and Richardson (2017) report the same result (Exhibit 3, Panel B, page 12) when comparing the average excess return using the Ibbotson data (161 basis points) with the excess returns using the Barclays data (50 basis points) over the same sample period of August 1988 to December 2014.

10 The table reports raw (unadjusted) standard errors, but the conclusions remain unchanged when using heteroskedasticity- and autocorrelation-robust standard errors.

Figure 1: 10-year rolling corporate bond returns in excess of Treasuries with 95% confidence bands



Source: Bloomberg Barclays, Bloomberg, NBIM calculations

The conflicting results across the various panels in Table 3 echo the inconclusive evidence of an ex-post credit premium in the empirical finance literature. Luu and Yu (2011) and Asvanunt and Richardson (2017) find economically and statistically significant realised credit premiums when using the long-history credit data from Moody's and Ibbotson respectively.[11] On the other hand, Ilmanen, Byrne, Gunasekera and Minikin (2004) and Ilmanen (2012) document low realised credit premiums in more recent, and arguably more precise, data samples, with information ratios around 0.1 depending on rating class.

Corporate bonds have delivered very different excess returns across maturity buckets as well, as highlighted by Ilmanen, Byrne, Gunasekera and Minikin (2004). They find that most of the poor performance is concentrated in long-maturity corporate bonds, while moving from short-maturity Treasuries to short-maturity corporate bonds has earned meaningful returns, with information ratios of close to 1. The choice of sample period and data source is therefore of great importance when evaluating corporate bond excess returns.

We report the same return-risk statistics as in Table 3 in Table A1 in Appendix A, where we break down the corporate bond returns along sector, rating and maturity dimensions. Consistent with previous findings, we find that short-term corporate bonds have delivered significantly higher risk-adjusted returns than their longer-term counterparts. However, none of these sub-indices has delivered statistically significant excess returns over the 1988–2017 period. Thus, using the broadest, and arguably most relevant, high-quality indices, we cannot reject the null hypothesis that corporate bonds have on average earned zero returns in excess of Treasuries.

11 As pointed out by Ilmanen (2012) and Hallerbach and Houweling (2013), the Ibbotson data suffer from both quality and maturity biases and thus cannot be used in their raw form. Asvanunt and Richardson (2017) correct for the maturity bias by estimating empirical durations, and Luu and Yu (2011) resolve the missing-duration issue in the Moody's data by using the returns on a hypothetical 10-year constant-maturity corporate bond.

The credit premium versus term and equity risk premiums

In order to gauge whether corporate bonds provide any separate diversification benefits in an equity-Treasury portfolio, we now regress realised corporate excess returns on Treasury and equity excess returns. Table 4 shows the results from this exercise. The first three columns show the results from regressing CRED ER on Treasuries alone, then on equities, and finally on both Treasuries and equities. The next two sets of columns show the results from running the same regressions using Asvanunt-Richardson's long-history CORP XS for the full 1936–2017 period as well as the post-World War 2 period.

Table 4: Regression statistics, realised credit excess returns on realised TSY and EQ excess returns

	CRED ER: 1988–2017			CORP XS: 1936–2017			CORP XS: 1946–2017		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept %	1.38	-0.43	0.31	1.43	0.84	0.92	1.23	0.56	0.63
(annualised)	(1.96)	(-0.68)	(0.51)	(3.53)	(2.16)	(2.36)	(2.70)	(1.28)	(1.44)
TSY	-0.27		-0.24	-0.03		-0.04	-0.03		-0.04
	(-6.03)		(-6.11)	(-1.89)		(-3.01)	(-1.86)		(-3.07)
EQ		0.13	0.13		0.07	0.07		0.08	0.09
		(10.45)	(10.49)		(9.55)	(9.85)		(9.67)	(10.00)
R^2	0.10	0.24	0.32	0.00	0.09	0.09	0.00	0.10	0.11

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

The positive, and marginally significant[12], intercept in the first column in Table 4 indicates that corporate bonds have added *some* value over and above Treasuries in a pure fixed income portfolio. However, as the next two columns show, the excess returns and the statistical significance disappear once equities are introduced into the portfolio. Realised corporate bond excess returns load significantly on both equity and bond excess returns and do not deliver statistically significant excess returns beyond these exposures. In the next section we evaluate directly the effect on risk-adjusted returns of introducing corporate bonds into a 60-40 Equity-Treasury portfolio, finding that corporate bonds have *reduced* the risk-adjusted returns of a portfolio that already has 60% in equities.[13]

These results depend on the sample period used for the regression analysis. The next set of columns shows the result from running the same regressions, only this time using the long-history Asvanunt-Richardson data. The sign of the Treasury and equity loadings remains the same, but the intercept is larger

12 The table reports raw (unadjusted) standard errors, but the conclusions remain unchanged when using heteroskedasticity- and autocorrelation-robust standard errors. The exception is the intercept in column (1), which becomes insignificant at the 5 percent level with robust standard errors.

13 Note that the positive alphas in Table 4 suggest that corporate bonds have enhanced in-sample risk-adjusted returns on an unconstrained mean-variance-efficient multi-asset portfolio, although not significantly so in more recent data. This implied positive allocation to corporate bonds is, however, entirely dependent on the very modest allocation to equities implied by the in-sample mean-variance-efficient weights. As the equity allocation increases (for any equity allocation above 30 percent), the mean-variance solution allocates nothing to corporate bonds and instead favours Treasuries. As the results in the next section show, when we consider asset allocations with equity shares of 60 percent or higher, introducing corporate bonds would historically have lowered risk-adjusted portfolio returns. The reason for these seemingly contradicting results is that the equity shares considered in Tables 5 and 6 are higher than the low in-sample mean-variance-efficient allocation to equities (as highlighted in DN 2-2016) implied by the alphas in Table 4.

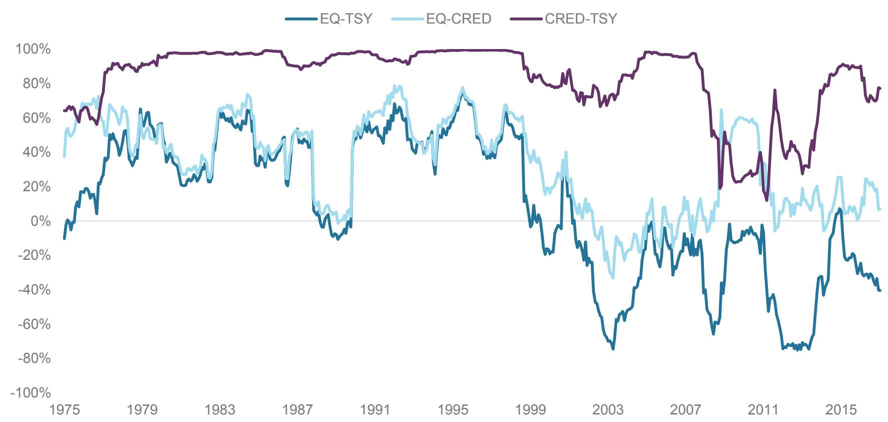
in value and now statistically significant. This is consistent with the results in Asvanunt and Richardson (2017), which indicate that corporate bonds have delivered statistically significant excess returns beyond Treasury and equity market risk factors, albeit with a t-statistic of just above 2.

The statistical significance of the intercept, however, seems to rely on the first ten years of the sample period (1936-1945). The last set of columns shows the results from re-running the regressions for the post-World War 2 period, leaving out the first ten years of data. The results indicate that corporate bonds have not delivered statistically significant excess returns beyond Treasuries and equities over the full post-World War 2 period, consistent with the main result in the first three columns.

Asset class correlations

We highlight in DN 2–2016 that changes in the equity-Treasury correlation materially impact the portfolio properties of Treasury bonds in a dual asset class portfolio. Similarly, the co-movement of corporate bonds with equities and Treasuries may affect the role of corporate bonds in a multi-asset portfolio. Figure 2 shows estimates of the three asset class correlations (EQ-TSY, EQ-CRED and CRED-TSY), measured over 24-month rolling windows. As pointed out in DN 2–2016, while the EQ-TSY correlation has historically on average been close to zero[14], both the magnitude *and sign* of the asset class correlation have been documented to vary over time (Campbell, Sunderam and Viceira, 2016).[15]

Figure 2: 24-month rolling asset class correlations, returns in excess of cash



Source: Bloomberg Barclays, Bloomberg, NBIM calculations

The credit-Treasury correlation, on the other hand, has historically been positive and much more stable. It is perhaps not surprising that corporate and Treasury returns in excess of cash are positively related, as the yield component has historically dominated the spread component, particularly

14 See Ilmanen (2003) and Rankin and Idil (2014).

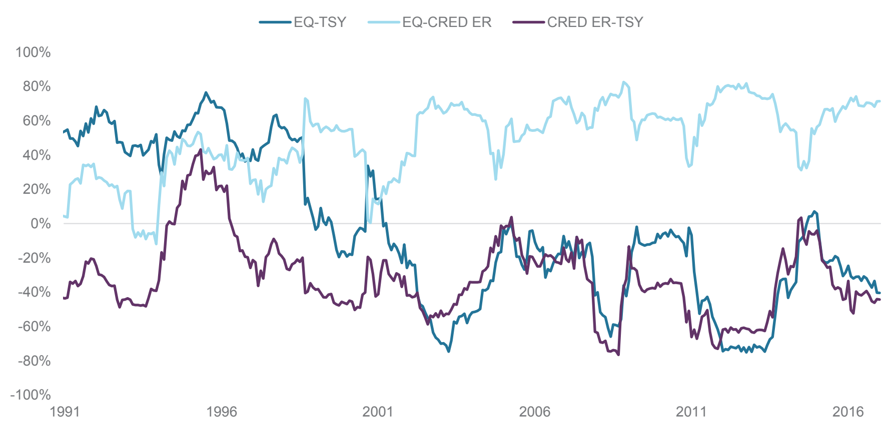
15 Researchers have put forward a number of modelling frameworks that attempt to account for the time variation in the equity-Treasury correlation. The list includes, but is not limited to, inflation and equity market volatility (Ilmanen, 2003), short rates and inflation (Yang, Zhou and Wang, 2009), equity market turmoil (Connolly, Stivers and Sun, 2005), liquidity (Pastor and Stambaugh, 2003; Baele, Bekaert and Inghelbrecht, 2010) and different macro shocks (supply vs demand shocks) combined with a changing monetary policy response to these shocks (Campbell, Pflueger and Viceira, 2015; David and Veronesi, 2013, 2016).

for investment-grade corporate bonds. Reilly and Wright (2001) similarly find that the correlation between BBB-rated corporate bonds and Treasury bonds has fluctuated around 60-100 percent. The authors observe that this correlation typically falls during recessions or states of market turmoil, just as we observe in Figure 2, and find that both the magnitude and sign of the correlation vary across rating categories.[16]

The equity-credit correlation displayed in Figure 2 behaves much like the equity-Treasury correlation up until the early 2000s, after which the two correlations diverge. As highlighted in DN 2–2016, the equity-Treasury correlation has remained in negative territory since this divergence occurred. The equity-credit correlation, however, has generally been positive throughout the sample period, even after the equity-Treasury correlation turned negative in the early 2000s.

The portfolio impact of these time-varying correlations[17] is clearer when we distinguish between corporate bond returns in excess of cash or Treasury bonds. Figure 3 allows us to do this: while Figure 2 shows correlations using returns in excess of *cash* for all assets, Figure 3 shows the same set of correlations using corporate bond returns in excess of duration-matched *Treasuries*. Whereas the first plot tells us how credit returns have moved together with equities and Treasuries, the second plot allows us to gauge the portfolio implications of introducing duration-matched corporate bonds into a pure equity-Treasury portfolio.

Figure 3: 24-month rolling asset class correlations, returns in excess of cash for equities and Treasuries and in excess of duration-matched Treasuries for credit



Source: Bloomberg Barclays, Bloomberg, NBIM calculations

Figure 3 reveals a different picture for the equity-credit correlation: the EQ-CRED correlation was about 20 percent during the first five years of the period and has since drifted upwards towards 70-80 percent.

16 *However, negative credit-Treasury correlations seem to be confined to the high-yield segment rather than investment-grade bonds.*

17 *The time variation in asset class correlations suggests that there may potentially be important asset allocation considerations that could be made in order to enhance risk-adjusted portfolio returns over the medium term. As this note is primarily focussed on the strategic allocation to corporate bonds, such questions are better suited for future research.*

The upward trend in the equity-credit correlation is consistent with Warren (2009), who finds that equity betas of investment-grade corporate bond excess returns roughly doubled in the ten years following 1999 compared to the preceding ten-year period. The positive relationship between equity and corporate bond returns is also consistent with the Merton model and is by now a well-documented observation in the empirical literature (Cornell and Green, 1991; Shane, 1994; Reilly and Wright, 2001; Avramov, Jostova and Philipov, 2007).

The credit-Treasury correlation naturally switches sign in Figure 3 when we strip out Treasury returns from the corporate bond returns. The relationship between credit spreads and interest rates has, however, been a more controversial topic in the literature. According to the Merton model, the two variables should be negatively related, as increasing interest rates lead to higher expected returns and future asset values, and thus a lower probability of default and narrower credit spreads. The predicted negative correlation has subsequently been both validated[18] and challenged[19]. In our data sample, the correlation has been consistently negative with the exception of a brief spike in the mid-1990s.

4. Portfolio properties of corporate bonds

In this section, we highlight the portfolio properties of different corporate bond allocations. We discuss how the diversification benefit of corporate bonds crucially depends on the presence of equity risk in the portfolio, and assess the portfolio implications of the asset class risk and return dynamics we have documented.

The return on a multi-asset portfolio r_p, containing equities, Treasuries and corporate bonds with weights w_{EQ}, w_{TSY} and w_{CRED}, is simply the weighted average of the asset class returns:

$$r_p = w_{EQ} r_{EQ} + w_{TSY} r_{TSY} + w_{CRED} r_{CRED}$$

The portfolio volatility depends on the asset class correlations in addition to the asset class volatilities. In particular, the variance of a multi-asset portfolio σ_p^2 with weights w_{EQ}, w_{TSY} and w_{CRED}, asset class variances σ_{EQ}^2, σ_{TSY}^2 and σ_{CRED}^2 and correlations $\rho_{EQ,TSY}$, $\rho_{EQ,CRED}$ and $\rho_{CRED,TSY}$ is given by:

$$\begin{aligned}\sigma_p^2 = {} & w_{EQ}^2 \sigma_{EQ}^2 + w_{TSY}^2 \sigma_{TSY}^2 + w_{CRED}^2 \sigma_{CRED}^2 \\ & + 2 w_{EQ} w_{TSY} \rho_{EQ,TSY} \sigma_{EQ} \sigma_{TSY} \\ & + 2 w_{EQ} w_{CRED} \rho_{EQ,CRED} \sigma_{EQ} \sigma_{CRED} \\ & + 2 w_{CRED} w_{TSY} \rho_{CRED,TSY} \sigma_{CRED} \sigma_{TSY}\end{aligned}$$

18 See, for example, Kim, Ramaswamy and Sundaresan (1993) and Longstaff and Schwartz (1995).

19 See, for example, Duffee (1998), Bevan and Garzarelli (2000) and Davies (2008).

The portfolio volatility formula makes it clear that the impact of corporate bonds on total portfolio volatility depends both on corporate bond volatility and the asset class correlations. The impact of the latter is straightforward: a lower asset class correlation will always lower total portfolio risk. The impact of corporate bond volatility on overall portfolio volatility is, however, contingent on the asset class correlations.

In order to isolate the portfolio impact of the corporate bond return spread over Treasuries, it is easier to work with credit returns in excess of duration-matched Treasuries. This allows us to assess any separate portfolio properties of credit risk, leaving the interest rate risk, which is common across Treasuries and corporates, aside. To do this, we express credit total returns r_{CRED} as a combination of duration-matched Treasuries r_{TSY} and credit excess returns $r_{CRED\ ER}$, so that:

$$\begin{aligned} r_p &= w_{EQ}r_{EQ} + w_{TSY}r_{TSY} + w_{CRED}r_{CRED} \\ &= w_{EQ}r_{EQ} + w_{TSY}r_{TSY} + w_{CRED}(r_{TSY} + r_{CRED\ ER}) \\ &= w_{EQ}r_{EQ} + (w_{TSY} + w_{CRED})r_{TSY} + w_{CRED}r_{CRED\ ER} \\ &= w_{EQ}r_{EQ} + w^*_{TSY}r_{TSY} + w_{CRED}r_{CRED\ ER} \end{aligned}$$

Then, consider the partial derivative of the portfolio variance with respect to the volatility of corporate bond excess returns, which is given by:

$$\begin{aligned} \frac{\partial \sigma_p^2}{\partial \sigma_{CRED\ ER}} = \ & 2w^2_{CRED}\sigma_{CRED\ ER} \\ & +2w_{EQ}w_{CRED}\rho_{EQ,CRED\ ER}\sigma_{EQ} \\ & +2w^*_{TSY}w_{CRED}\rho_{CRED\ ER,TSY}\sigma_{TSY} \end{aligned}$$

which can be either positive or negative, depending on $\rho_{EQ,CRED\ ER}$ and $\rho_{CRED\ ER,TSY}$. The portfolio variance will be positively related to corporate bond volatility if

$$0 < \frac{w_{CRED}\sigma_{CRED\ ER}}{w_{EQ}\sigma_{EQ}} + \frac{w^*_{TSY}\sigma_{TSY}}{w_{EQ}\sigma_{EQ}}\rho_{CRED\ ER,TSY} + \rho_{EQ,CRED\ ER}$$

The first two terms $\frac{w_{CRED}\sigma_{CRED\ ER}}{w_{EQ}\sigma_{EQ}}$ and $\frac{w^*_{TSY}\sigma_{TSY}}{w_{EQ}\sigma_{EQ}}$ will always be positive for a long-only portfolio, and the two correlations $\rho_{CRED\ ER,TSY}$ and $\rho_{EQ,CRED\ ER}$ have on average been -32 and 49 percent respectively over the full sample period covered in Figure 3. The impact of corporate bond volatility therefore depends on the relative asset class weights and volatilities in addition to the correlations.

For a 60/40 multi-asset portfolio with a market-weighted Treasury-corporate mix, the equity component will be the largest allocation, while the allocation to corporate bonds will be the smallest – i.e. $w_{EQ} > w^*_{TSY} > w_{CRED}$, which has typically been the case in most market-weighted indices.[20] Whenever this is the case, the first ratio will be smaller than the second one, and the two ratios will roughly cancel out once the second is multiplied with the negative credit-Treasury correlation.[21] The only element left is then the correlation

20 See Doeswijk, Lam and Swinkels (2014).

21 Assuming asset class volatilities are roughly in line with historical numbers, which in our 1988 – 2017 sample implies annual volatilities of 14% (σ_{EQ}), 4% ($\sigma_{CRED\ ER}$) and 5% (σ_{TSY}).

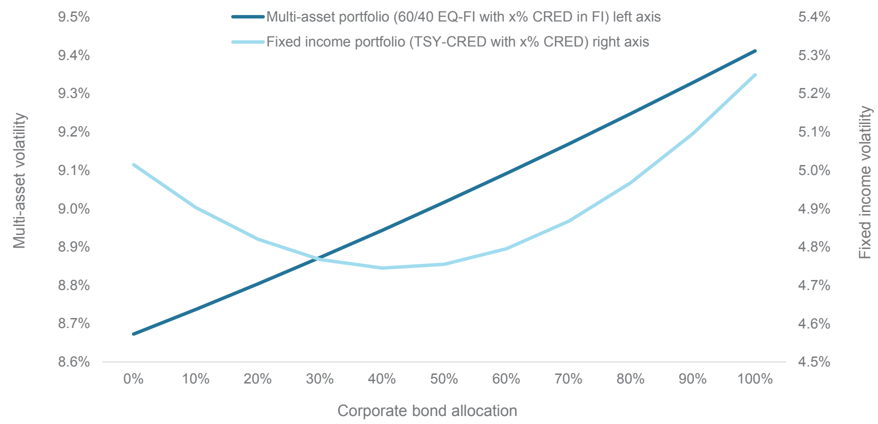
between equities and corporate bond excess returns, which has historically been positive.

On the other hand, the volatility impact of corporate bonds can be negative whenever the Treasury component is sufficiently large compared to the other asset classes.[22] This is, of course, obvious in the case of a pure fixed income portfolio, where a modest allocation to corporate bonds will diversify the Treasury bond volatility, given that the two assets are not perfectly correlated. We illustrate the different impact corporate bonds will have on the total volatility of a pure fixed income portfolio and a multi-asset portfolio in Figure 4.

The plot shows how total portfolio volatility changes as we increase the allocation to corporate bonds (moving from left to right in the chart) in both portfolios. For the fixed income portfolio, the allocation transforms from a pure Treasury portfolio to the far left into a pure corporate bond portfolio to the far right. The multi-asset portfolio has a constant 60 percent equity allocation, while the remaining 40 percent is allocated to the fixed income portfolio, thus transforming from a 60/40 EQ-TSY portfolio to a 60/40 EQ-CRED allocation in 10 percent increments.

The contrast between the two volatility profiles is stark: while the multi-asset portfolio volatility is linearly increasing in the size of the corporate bond allocation, the volatility of the fixed income portfolio takes on a U-shaped profile. The volatility initially falls as corporate bonds are introduced into the portfolio until it reaches a minimum point around the 40-50 percent allocation, and then starts increasing with the credit share.

Figure 4: Annualised portfolio standard deviations for different corporate bond allocations, 1988–2017



Source: Warren (2009), Bloomberg Barclays, Bloomberg, NBIM calculations

Warren (2009) reports a similar result using both investment-grade and high-yield corporate bonds. The author puts the different portfolio properties

22 That is, whenever $\frac{w^*_{TSY}\sigma_{TSY}}{w_{EQ}\sigma_{EQ}}$ *is sufficiently large to make* $\frac{w^*_{TSY}\sigma_{TSY}}{w_{EQ}\sigma_{EQ}}\rho_{CRED,TSY}$ *more negative than the sum* $\frac{w_{CRED}\sigma_{CRED}}{w_{EQ}\sigma_{EQ}} + \rho_{EQ,CRED}$.

of credit risk into the context of the changing role of interest rate risk we highlighted in DN 2–2016: "while interest rate exposure typically adds to the risk of a fixed-income portfolio, it can play a diversifying role within a broader portfolio context. Conversely, credit exposure augments risk at the total portfolio level, but can act as a diversifier within the fixed-income portfolio" (Warren, 2009, p. 58).

Summarising the net portfolio impact of the asset class risk and return dynamics we have documented above, Tables 5 and 6 show the historical risk and return statistics across different asset allocations, varying all three components – equities, Treasuries and corporates. Both tables show the same statistics, except the numbers in Table 5 are based on the 1973–2017 sample where the corporate and Treasury bond indices are not constructed to have matching duration profiles, while Table 6 uses the duration-matched indices that only go back to 1988.

In both tables, Panel A shows statistics for a pure fixed income portfolio, while Panels B and C report the same numbers for equity-bond portfolios with equity allocations of 60 and 70 percent respectively. From top to bottom in each panel, the size of the credit allocation increases from zero to 100 percent along the rows.

The effect of neutralising the duration difference between the corporate and Treasury indices is naturally most visible in the results for the pure fixed income portfolio. Contrary to the results in Figure 4, the volatility of the fixed income portfolio is increasing in the size of the credit allocation in the first panel of Table 5. This happens because the credit allocation comes with both additional interest rate risk,[23] which the portfolio already contains, and credit risk. The additional risk only comes with a slight return increase, so even though a modest credit allocation of 10 percent marginally improves on the risk-adjusted returns of the Treasury-only portfolio, the Sharpe ratio profile flattens out beyond this point.

23 The duration of the Bloomberg Barclays US corporate bond index has on average been 6 over the period 1988–2017, while the duration of the Bloomberg Barclays US Treasury index has on average been 5.3 over the same period.

Table 5: Annualised risk and return statistics for portfolios with different asset allocations, 1973–2017

Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
Panel A: TSY-CRED fixed income portfolio with x% CRED:					
0% CRED	7.12	5.22	2.24	0.43	0.05
10% CRED	7.18	5.29	2.30	0.43	0.05
30% CRED	7.32	5.53	2.44	0.44	0.05
50% CRED	7.45	5.87	2.57	0.43	0.05
70% CRED	7.58	6.30	2.70	0.42	0.05
100% CRED	7.78	7.07	2.90	0.41	0.05
Panel B: 60/40 EQ-FI portfolio where FI is a TSY-CRED portfolio with x% CRED:					
0% CRED	9.40	9.57	4.52	0.47	0.05
10% CRED	9.42	9.65	4.54	0.47	0.05
30% CRED	9.48	9.82	4.60	0.47	0.05
50% CRED	9.53	9.99	4.65	0.46	0.05
70% CRED	9.58	10.17	4.70	0.46	0.05
100% CRED	9.66	10.46	4.78	0.46	0.05
Panel C: 70/30 EQ-FI portfolio where FI is a TSY-CRED portfolio with x% CRED:					
0% CRED	9.78	10.94	4.90	0.45	0.05
10% CRED	9.80	11.00	4.92	0.45	0.05
30% CRED	9.84	11.12	4.96	0.44	0.05
50% CRED	9.88	11.24	5.00	0.44	0.05
70% CRED	9.91	11.37	5.04	0.44	0.05
100% CRED	9.97	11.58	5.09	0.44	0.05

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

The power of fixed income diversification becomes apparent when increasing the allocation to the duration-matched corporate bond index in the first panel of Table 6. In line with the results in Figure 4, the overall volatility of the fixed income portfolio initially decreases as we add credit bonds and hence introduce an asset with a different source of risk. The increasing allocation also comes with additional return, and thus Sharpe ratios increase up until a balanced 50/50 credit-Treasury portfolio, after which the volatility starts increasing, reversing the gain in risk-adjusted returns.[24]

This diversification benefit, however, disappears when we move over to the multi-asset portfolios in Panels B and C in both tables. The total volatility of all equity-bond portfolios increases as we introduce corporate bonds, as we are essentially increasing the allocation to risk factors already captured by the pure equity-Treasury portfolio. As realised credit excess returns have been positive over both sample periods, the increased allocation to corporate bonds does lead to higher total portfolio returns. The additional risk, however, comes with an insufficient amount of return to maintain the Sharpe ratio of the original portfolio. Thus, with the benefit of hindsight, the most

24 These are, of course, uncertain estimates that come with standard errors. The standard errors for the Sharpe ratio estimates, which can be found in the far right column in each panel, are included to remind us that even with more than 40 years of monthly data, the Sharpe ratio estimates are uncertain. Sharpe ratio standard errors are calculated following Lo (2002).

efficient asset allocation would have been the pure equity-Treasury portfolios for all different equity allocations across Tables 5 and 6.

Table 6: Annualised risk and return statistics for portfolios with different asset allocations, 1988–2017

Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
Panel A: TSY-CRED fixed income portfolio with x% CRED:					
0% CRED	6.47	5.01	3.34	0.67	0.06
10% CRED	6.53	4.90	3.39	0.70	0.06
30% CRED	6.64	4.77	3.51	0.74	0.06
50% CRED	6.76	4.75	3.63	0.77	0.06
70% CRED	6.88	4.87	3.74	0.77	0.06
100% CRED	7.05	5.25	3.91	0.74	0.06
Panel B: 60/40 EQ-FI portfolio where FI is a TSY-CRED portfolio with x% CRED:					
0% CRED	9.02	8.67	5.88	0.68	0.06
10% CRED	9.04	8.74	5.90	0.68	0.06
30% CRED	9.09	8.87	5.95	0.67	0.06
50% CRED	9.13	9.02	6.00	0.67	0.06
70% CRED	9.18	9.17	6.04	0.66	0.06
100% CRED	9.25	9.41	6.11	0.65	0.06
Panel C: 70/30 EQ-FI portfolio where FI is a TSY-CRED portfolio with x% CRED:					
0% CRED	9.44	10.02	6.31	0.63	0.06
10% CRED	9.46	10.07	6.32	0.63	0.06
30% CRED	9.49	10.18	6.36	0.63	0.06
50% CRED	9.53	10.29	6.39	0.62	0.06
70% CRED	9.56	10.40	6.43	0.62	0.06
100% CRED	9.61	10.58	6.48	0.61	0.06

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

5. Summary

In this note, we evaluate the risk and return characteristics of corporate bonds and discuss the role of this asset class in a multi-asset portfolio consisting of equities and nominal Treasury bonds in addition to corporates. We find that corporate bonds have historically enhanced multi-asset portfolio returns, although whether the enhancement is statistically and economically significant is highly sample-dependent.

Of critical importance for the portfolio properties of corporate bonds, we find that corporate bond excess returns have historically been positively correlated to equity excess returns, while moving counter to excess returns on Treasuries. The multi-asset portfolio properties of corporate bonds therefore depend crucially on the initial equity-Treasury mix.

The upshot of this is that credit risk acts as a diversifier in a portfolio dominated by interest rate risk, while an allocation to corporate bonds has historically increased the overall volatility of multi-asset portfolios dominated by equity risk. The additional risk, however, comes with an insufficient amount of return to maintain the Sharpe ratios of simple equity-Treasury portfolios.

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Appendix A:
Additional empirical results

Table A1: Annualised risk and return statistics, realised corporate bond returns in excess of Treasuries, 1988–2017

Asset class	Mean excess return	Standard deviation	Sharpe ratio	t-stat
CRED ER	0.58	3.87	0.15	0.80
CRED ER (1-10 year maturity)	0.68	3.09	0.22	1.18
CRED ER (10+ year maturity)	0.37	6.27	0.06	0.32
CRED ER (Financial Institutions)	0.82	4.53	0.18	0.96
CRED ER (Industrial)	0.51	3.86	0.13	0.71
CRED ER (Utility)	0.42	4.39	0.10	0.52
CRED ER (AAA)	0.02	2.60	0.01	0.04
CRED ER (AA)	0.40	2.83	0.14	0.76
CRED ER (A)	0.39	3.95	0.10	0.53
CRED ER (BBB)	0.78	4.77	0.16	0.87

Source: Bloomberg Barclays, Bloomberg, NBIM calculations

Appendix B: Drivers of corporate bond spreads

Even though not statistically significant, we saw in the main body of this note that corporate bonds have outperformed duration-matched Treasury bonds on the margin. Another key observation from our empirical analysis is that corporate bond returns in excess of Treasuries seem to be related to both equity and Treasury bond returns. This raises the question of what the main drivers of corporate bond excess returns are.

The academic literature has tended to focus on credit spreads rather than returns. As Ilmanen (2102) points out, ex-post corporate bond excess returns are found to be meaningfully lower than implied by ex-ante credit spreads. Using Barclays data covering the period 1973–2009, Ilmanen finds average realised excess returns of roughly 30 basis points. Contrasting this number with the average option-adjusted credit spread of 120 basis points over the same period gives us a significant residual. The author attributes the difference to a host of factors, such as the downgrading bias[25], the fallen-angel effect[26] and repricing effects that occur over multi-decade data samples.

The upshot of this is that one should be careful to distinguish between *ex-ante* credit spreads and *ex-post* excess returns. Still, the key to understanding realised corporate bond returns arguably lies in the drivers of corporate bond prices and the yield spread over government bonds. In this appendix, we therefore review the theory and empirical evidence of the drivers of corporate bond spreads.

The Merton model and the credit spread puzzle

The literature dealing with the valuation of corporate debt starts with the seminal work of Merton (1974), who applies the option-pricing theory developed by Black and Scholes (1973) to the modelling of a firm's value and, crucially, to pricing corporate bonds. In a nutshell, Merton (1974) lays out a simple framework where a firm, with a total value V, issues a single zero-coupon bond with a face value F, and equity is the residual claim on the firm value. Default occurs at maturity T whenever the firm's liabilities exceed its assets ($V < F$).

The payoff to holders of equity and debt will naturally differ, depending on whether the firm defaults or not. Starting with the bond holder, the payoff can either be 1) face value F at maturity whenever $V > F$, or 2) firm value V whenever $V < F$ and the firm defaults. On the flipside, this leaves the equity holder with zero whenever the firm defaults, and $V - F$ otherwise. Merton

25 The downgrading bias refers to the observation that investment-grade bonds are more likely to be downgraded than upgraded, and crucially, downgrades have a larger impact on credit spreads than improving ratings in the high-grade segment.

26 The fallen angel effect refers to the fact that investment-grade indices typically have rules that force investors to sell bonds that are downgraded to non-investment grade. The rules for investment grade bond indices mean that investors suffer price losses between the downgrade and the time when bonds exit the index, but do not benefit from a subsequent recovery. See Fridson and Wahl (1986), Ng and Phelps (2010) and Ng, Phelps and Lazanas (2013).

(1974) recognises that the payoff to equity holders – max(0, V – F) – is equivalent to that of a call option on the assets of the firm.

The critical insight from Merton (1974) is perhaps better understood when applying the put-call parity of Stoll (1969). The put-call parity is a no-arbitrage condition, which simply states that the market value V of a given underlying asset must equate to the sum of a call option C with strike price K written on the asset, a put option P (also with strike K) on the same underlying asset and the present value of a risk-free bond B with a face value equal to the strike price (V = C + P + B).

The risky corporate bond in the Merton framework is therefore equivalent to a combination of a risk-free bond and a short position in a put option written on the assets of the firm.[27] This insight allows us to think of the credit spread – the spread between the risky corporate bond and a comparable risk-free bond – as a short put option on the firm. While still being a subject of great controversy in the financial literature, the Merton model clearly establishes a (positive) link between risk premiums in equity and corporate bond markets.

The Merton model thus prices debt and equity as contingent claims on firm value and uses the evolution of these structural variables to determine the point of default. These types of models are referred to as structural models, and the Merton model is considered the first such model. However, standard structural models have since been found to produce significantly smaller credit spreads than historical spreads on traded bonds (Jones, Mason and Rosenfeld, 1984; Huang and Huang, 2012).

Huang and Huang (2012) estimate credit spreads using a range of different traditional structural models and historical company data on leverage, default and recovery. The authors compare the results with historical spreads and find consistent evidence of underestimation in the models. The term "credit spread puzzle" was thus coined. The reason for this puzzle must either be misspecification in the traditional structural models or that additional factors drive the empirically observed credit spreads.

Default, liquidity and tax factors

Attempts by academics to account for historical credit spreads have generated a substantial literature in finance covering both theory and empirics. We reviewed this literature in detail in DN 3-2011 "The Credit Premium" and therefore emphasise more recent contributions here, paying particular attention to potential overlapping return drivers with equities and Treasuries.

Credit spreads are typically seen as compensation for two main types of risk: default risk and recovery risk. The former refers to the risk of an issuer defaulting, while the latter is the risk of receiving less than the promised payment if the issuer defaults. While credit and recovery risk are considered the principal factors in accounting for credit spreads, several non-default-related factors have been suggested as possible components of the credit spread.

27 See, for instance, Chapter 8 in Hull (2009) for a graphical illustration of these payoff profiles.

In DN 3-2011, we highlight, among others, a liquidity factor, reflecting the fact that corporate bonds are less actively traded than Treasuries (Houweling, Mentink and Vorst, 2005; Longstaff, Mithal and Neis 2006). In addition, interest earned on corporate bonds is subject to state tax in the US, while interest payments on government bonds are exempt from this tax. It has been argued that this tax effect can account for parts of observed credit spreads (Elton, Gruber, Agrawal and Mann, 2001; Grinblatt, 2001; Driessen, 2005).

Driessen (2005) argues that, on top of tax and liquidity effects, a premium compensating investors for exposure to credit event risk can explain a significant portion of credit spreads – up to 30 basis points for 10-year BBB-rated bonds. More recently, however, Bai, Collin-Dufresne, Goldstein and Helwege (2015) claim that the estimated magnitude of such a credit event risk premium is significantly overstated.

The authors argue that *if* default events are diversifiable, corporate bonds exposed to such events should not be compensated with an event risk premium. On the other hand, if default events are not diversifiable, investors holding bonds exposed to what the authors refer to as a contagion risk should require a premium. Credit event risk premiums are therefore negligible (< 1 basis point) in their model, while contagion risk commands a premium several orders of magnitude larger – up to 20 basis points.

Equity risk factors

Several papers still find a meaningful residual spread after subtracting tax and illiquidity factors in addition to expected defaults from corporate bond spreads. This residual is often interpreted as a risk premium and, interestingly, is frequently found to be positively related to equity market risk – as predicted in Merton (1974).

Elton, Gruber, Agrawal and Mann (2001) find, for example, that almost 50 percent of spreads on 10-year corporate bonds remain unexplained after accounting for expected defaults and tax effects. They regress this residual on the three-factor model of Fama and French (1993) and find that exposure to equity market risk as well as value and size factors can account for most of the residual. The authors thus conclude that a meaningful portion of credit spreads is driven by a systematic risk premium closely related to equity markets.

Similarly, Campello, Chen and Zhang (2008) find that expected returns obtained from credit spreads (adjusted for expected defaults and tax effects) load positively on the same three factors, namely the market, size and value factors. In addition, the authors employ an extension of the three-factor model (Carhart, 1997) which includes the momentum factor of Jegadeesh and Titman (1993), but find that momentum is not a priced factor in their data set.

More recently, the theory of common risk factors, affecting returns of both corporate bonds and equities, has been explored further. Chordia, Goyal, Nozawa, Subrahmanyam and Tong (2016) examine the relationship between cross-sectional corporate bond returns and an extensive list of equity factors. Their list of equity factors extends beyond the four-factor model (market, size, value and momentum) previously studied and includes, among others, the two additional profitability[28] and investment[29] factors in the five-factor model of Fama and French (2015) as well as accruals[30] and earnings surprises.[31] Controlling for lagged returns, distance-to-default (Merton, 1974) and the liquidity factor of Amihud (2002), the authors find that corporate bond returns load on size, momentum, profitability and investment factors.

In a similar study, Franke, Müller and Müller (2016) document a strong positive relationship between equity and credit risk premiums. However, rather than using realised corporate bond returns for their analysis, the authors estimate a measure of expected excess returns on corporate bonds. Their expected return measure is net of expected defaults and tax effects, and thus aims to isolate the risk premium component. The authors study the implied risk premium using pooled panel regressions and find that the credit premium loads positively on equity factors such as market, size, value and investment in addition to the illiquidity factors of Bao, Pan and Wang (2011) and Pastor and Stambaugh (2003). On the other hand, they also find that the credit premium loads negatively on equity profitability and momentum as well as the bond term premium.

Other studies also find that corporate bonds share return drivers with not only equities, but also government bonds. Koijen, Lustig and van Nieuwerburgh (2016) develop an asset-pricing model using three factors previously found to explain both equity and government bond returns: 1) a broad equity market risk factor, 2) the yield curve level factor and 3) the yield curve factor of Cochrane and Piazzesi (2005). The authors argue that their three-factor model not only works for equity and government bond portfolios, but also does a good job pricing corporate bond portfolios.

Most of the above papers try to assess to what extent priced equity risk factors drive credit excess returns. However, the link between equity and credit risk premiums can, of course, be studied the other way around as well, i.e. are default probabilities and credit risk reflected in equity prices? Friewald, Wagner and Zechner (2014) attempt to answer this question. They estimate credit risk premiums using CDS data and find a strong positive relationship between credit risk and equity returns.

Extensions of the Merton model

The traditional Merton model has generated a substantial family of credit risk models. While explicitly founded in the framework laid out by Merton (1974), this growing group of models aim to produce more realistic credit spreads by either relaxing some of the original assumptions or introducing richer model dynamics and frictions such as macroeconomic conditions or bankruptcy codes. Briefly, the most important extensions include, but are not limited to,

28 See Haugen and Baker (1996), Cohen, Gompers and Vuolteenaho (2002), Novy-Marx (2013), Fama and French (2006, 2008) and Hou, Xue and Zhang (2015).

29 See Fairfield, Whisenant and Yohn (2003), Titman, Wei and Xie (2004), Cooper, Gulen and Schill (2008), Aharoni, Grundy and Zeng (2013), Fama and French (2006, 2008) and Hou, Xue and Zhang (2015).

30 See Sloan (1996) and Lev and Nissim (2006).

31 See Ball and Brown (1968), Bernard and Thomas (1989, 1990) and Livnat and Mendenhall (2006).

flexible default time (Black and Cox, 1976), more complex capital structures (Geske, 1977, 1979), dynamic capital structures (Fischer, Heinkel and Zechner, 1989), taxes and bankruptcy costs (Leland, 1994), contagion effects (Giesecke, 2004) and macroeconomic dynamics (Tang and Yan, 2006). Again, see DN 3-2011 for a more detailed review of these models.

Chen, Collin-Dufresne and Goldstein (2009) further break down the credit spread puzzle into two puzzles: the credit spread level puzzle and the credit spread time-variation puzzle. This refers to the observation that structural models not only fail to generate the average level, but also the volatility, in particular the high degree of default clustering that occurs during recessions. Chen, Collin-Dufresne and Goldstein (2009) argue that credit spreads can be accounted for by extending the standard models, such as the Merton model, along the same dimensions that have previously been used to account for the equity premium puzzle.[32]

This is a particularly interesting and relevant question, since it might shed some light on the issue of whether credit risk and equity risk are two distinctly different risk factors or whether they are rather two different manifestations of the same fundamental risk factor.

One critical assumption in the Merton framework is that of constant reward-to-volatility ratios. As noted by Mehra and Prescott (1985), the equity premium puzzle refers to the difficulty of reconciling the smooth, low-growth consumption series with the more volatile, high-growth equity series, and not the equity premium as such. Thus, the equity premium puzzle results from the fact that the standard model gives, via the consumption series, a constant and (too) low reward-to-volatility ratio (Hansen and Jagannathan, 1991)[33]. Two widely cited papers on resolving the equity premium puzzle are Campbell and Cochrane (1999) and Bansal and Yaron (2004). Both methods are based on raising the reward-to-volatility ratio of market prices of risks, satisfying the Hansen-Jagannathan bound.

Employing the same extensions, Chen, Collin-Dufresne and Goldstein (2009) explore to what extent these structural models can also account for the credit spread premium. Their paper is motivated by the fact that at the core of both the equity premium puzzle and the credit spread puzzle are the stochastic properties of the reward-to-volatility ratio. Their logic states that if structural models incorporate strongly time-varying reward-to-volatility ratios (risk premium per unit of risk), and take into account the greater likelihood of

32 The equity premium puzzle is another well-known puzzle in financial economics which has received much attention during the last couple of decades. Since the puzzle was first stated by Mehra and Prescott (1985), a lot of progress has been made in exploring the puzzle and identifying the dimensions along which structural models must be extended in order to resolve it. See DN 1-2016 "The equity risk premium" for a detailed review of the theoretical and empirical evidence on the equity risk premium.

33 Hansen and Jagannathan developed a measure to evaluate whether an asset-pricing model can account for observed financial time series. A necessary requirement for passing this measure is that a model-generated reward-to-volatility ratio is greater than a certain lower bound defined by movements of observed time series. The Hansen and Jagannathan bound gives an alternative representation of the equity premium puzzle. It highlights the fact that the standard model from which the equity premium puzzle was defined gives an almost constant and (too) low reward-to-volatility ratio. Hence, in order to account for observed asset price movements, including the equity premium puzzle, the model's market prices of risks (discount factor) must be highly volatile. The Hansen and Jagannathan bound evaluates whether a model meets this requirement, or, more specifically, whether the reward-to-volatility ratios generated by the model are large and volatile enough.

default during recessions, they can capture both the level and time-variation of historical spreads.

This promising class of structural credit models can account for the default component of observed credit spreads, but has also been criticised for ignoring the drivers behind the residual spread that is not due to defaults. As argued by Chen, Cui, He and Milbradt (2016), a sound credit model should be able to account for the *entire* credit spread – i.e. both the default component and the residual spread. Combining the time-varying macro risk feature of Chen, Collin-Dufresne and Goldstein (2009) and Chen (2010) with the liquidity dynamics of He and Milbradt (2014), the authors attempt to match historical credit spreads.

Richer liquidity dynamics are ensured by introducing the search frictions in the over-the-counter (OTC) markets of Duffie, Gârleanu and Pedersen (2005) into the modelling of secondary corporate bond markets. The authors argue that, by jointly modelling time-varying default and liquidity risks, they are able to capture crucial interaction effects between the two risk factors. In a nutshell, countercyclical market risk together with cash flows and market liquidity that moves with the business cycle generate model-based credit spreads that match not only the level and variation of observed credit spreads and defaults, but also liquidity measures such as bid-ask spreads and bond-CDS spreads.

A different, but related, line of criticism of the structural credit models following Chen, Collin-Dufresne and Goldstein (2009) argues that these models put too much emphasis on modelling a firm's financing decisions as opposed to the much more important, and potentially complex, macroeconomic dynamics. As pointed out by Swanson (2016), a modelling framework aiming to account for several key asset-pricing facts[34] should probably focus more on the latter modelling issue. Swanson (2016) proposes a structural macroeconomic model which includes a simple reduced-form representation of the corporate financing decision and is able to account for level and variation in both the equity premium and credit spreads.

The default dynamics of Chen, Collin-Dufresne and Goldstein (2009) have been extended to take into account time-varying inflation risk.[35] Kang and Pflueger (2015) and Gomes, Jermann and Schmid (2016) develop models that capture the interaction between a firm's debt burden and inflation shocks, thus allowing investors' fear of debt deflation (Fisher, 1933) to be priced in credit spreads. Within this framework, a negative shock to inflation worsens a firm's debt burden and increases the probability of default.

As Kang and Pflueger (2015) argue, both the volatility and cyclicality of inflation should be reflected in corporate bond spreads. First, inflation volatility should affect default probabilities, just as asset volatility impacts defaults and credit spreads in the original Merton model. Even when assuming that inflation shocks and asset values are completely uncorrelated,

34 See Cochrane (2008)

35 See Engle (1982), Baele, Bekaert and Inghelbrecht (2010), Viceira (2012), David and Veronesi (2013) and Campbell, Sunderam and Viceira (2016).

less than perfectly certain inflation will widen the spectrum of real payoff outcomes for bondholders.

Second, taking into account the potential for co-movement of inflation and real cash flows adds another, separate, dimension of inflation risk. Procyclical inflation introduces worst-case scenarios in which recession and deflation occur simultaneously, and leaves investors with both low real cash flows and elevated real liabilities, arguably at a time when their marginal utility is particularly high. The existence of such a scenario may account for wider credit spreads, as risk averse investors require compensation for bearing this risk.

The authors confirm their theoretical model using historical credit spreads and proxies for inflation volatility and cyclicality. Their empirical results show that credit spreads load positively on both inflation risk factors. Controlling for inflation risk presumably priced in government bonds, the authors argue that the inflation risk driving corporate bond spreads comes in addition to the inflation risk already priced in nominal government bonds.

In a recent study, Feldhutter and Schaefer (2016) return to the traditional models of Merton (1974) and Black and Cox (1976) and reassess their ability to match observed credit spreads when applying them on better, and only recently made available, default rate data. The new default data from Moody's go back to 1920, rather than the 1970-present sample commonly used, and thus produce more accurate default estimates. The authors stress that these long-run default rates were not available when Huang and Huang (2012) conducted their study of a broad set of structural models and documented the credit spread puzzle.

First, contrary to previous studies, Feldhutter and Schaefer (2016) find that the original Merton model is, in fact, able to account for the *level* of observed credit spreads once calibrated to their long-term default rates. Second, they calibrate the Black and Cox model to the same set of default rates and find that the model does well in accounting for the *variation* in observed credit spreads. The authors thus argue that the original credit spread puzzle was not due to misspecification in the models per se, but rather a result of small-sample biases, and thus conclude that credit spreads are well explained by the default risk in the Merton model.