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RISK AND RETURN OF DIFFERENT ASSET ALLOCATIONS

DISCUSSION NOTE

In this note, we evaluate the risk and return characteristics of equities and government bonds, and discuss how the risk and return profile of a portfolio of these asset classes varies with the size of the equity allocation and the duration of the bond allocation.

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SUMMARY

- The return on a portfolio of equities and bonds is driven by the equity risk premium and the bond term premium.

- The *risk* of a portfolio of equities and bonds depends on the asset class volatilities and the correlation of equity and bond returns.

- The ratio of bond to equity volatility has historically been fairly stable.

- The correlation between equity and bond returns changed from being robustly positive to being robustly negative in the late 1990s, significantly altering the risk characteristics of a portfolio of equities and bonds.

- For a sufficiently negative correlation between equities and bonds, total portfolio risk can go *down* as the bond volatility goes *up*.

- The duration of the bond portfolio plays an important role in determining total portfolio risk, especially at intermediate allocations to equities.

- Even though the diversifying properties of bonds have varied significantly over time, we observe few instances where a portfolio completely concentrated in equities has had higher risk-adjusted returns than a mixed one.

1 – Introduction

In this note, we evaluate the risk and return characteristics of equities and bonds, and discuss how the risk and return profile of a portfolio of these asset classes varies with the size of the equity allocation and the duration of the bond allocation.

A natural starting point is to analyse the return characteristics of the two asset classes. Modern Portfolio Theory (MPT), the seminal work of Harry Markowitz (1952, 1959), brought attention to the second moment of the return distribution and importantly the co-movement of assets when constructing a portfolio. Using this mean-variance framework, we highlight the relative importance of the key components that define the risk-return characteristics of a portfolio of equities and bonds.

The return component of the portfolio is simply the weighted combination of the asset class returns. The volatility of the portfolio returns, however, depends on both asset class volatilities and their correlation. All three determinants of total portfolio volatility have varied over time and thereby changed the extent to which bonds have diversified equity risk.

The magnitude of bond to equity volatility has varied over time, but remained fairly stable around an average of 40 percent in our sample going back to 1961. The portfolio volatility reduction offered by bonds, being a less volatile component than equities, has therefore been quite a stable feature.

The reduction in portfolio volatility due to bonds' low or negative return correlations with equities has been a less stable feature. The correlation between equity and bond returns changed from being robustly positive to robustly negative in the late 1990s, strengthening the portfolio volatility-reducing characteristics of bonds. Understanding this asset class correlation is therefore key when assessing the portfolio properties of bond risk, as the *variation* in the equity-bond correlation is an important driver of changes in portfolio properties.

For a given allocation to bonds, duration determines the portfolio's exposure to bond risk. The impact of the volatility of the bond component on overall portfolio volatility is contingent on the asset class correlation. The ability of bonds to reduce overall portfolio volatility simply by exhibiting lower volatility than equities diminishes as the asset class correlation becomes increasingly negative.

For a sufficiently negative correlation between equities and bonds, total portfolio risk can go *down* when the bond volatility goes *up*. How negative the correlation needs to be before this relationship flips depends on the initial volatility of bonds relative to equities as well as the asset allocation.[1] The duration of the bond component plays a more important role in determining total portfolio risk at intermediate allocations to equities.

1 The overall portfolio volatility becomes decreasing in bond volatility whenever the asset class correlation is lower than the negative of the ratio of asset class weights times the ratio of volatilities, see section 4 for more details.

A key question going forward is whether the post-2000 negative equity-bond correlation will persist or revert towards positive territory. Given the current low levels of inflation expectations, a negative rather than positive correlation seems like a more likely assumption going forward. In addition to the equity-bond correlation, asset class risk and return properties will be important drivers of the variation in future performance across portfolios with different asset allocations.

As pointed out in NBIM (2016), the global expected equity risk premium has declined meaningfully since the end of the Global Financial Crisis, and is probably currently near its long-term repricing-adjusted average level at around 3–4 percent. Using the term premium estimates made available by Adrian, Crump and Moench (2013), the expected term premium on US 10-year bonds is currently near its all-time low at roughly -50 bps.[2] These levels have not been observed in the data since the early 1960s, which were followed by a 20-year period of negative realised excess returns on long-term bonds relative to short-term bills.

Our main data sample covers the period 1961–2016. We split the sample into two subsamples, 1961–1986 and 1987–2016, and this split should allow us to separate two very distinct regimes in terms of inflation, monetary policy and bond yields. The steady decline in global yields will heavily influence the risk and return characteristics of government bonds during the 1987–2016 period. Extending the sample period back further to include the 1960s and 1970s allows us to gauge the portfolio properties of bonds during a period with yield levels more similar to levels observed today, and may as such potentially serve as a better guide for the medium- to long-term future.

The remainder of this note is structured as follows. In Section 2, we highlight the key historical risk-return characteristics of equities and bonds, before we turn to the portfolio implications of different allocations to the two asset classes in Section 3. Section 4 thereafter describes the portfolio properties of bond volatility in a dual asset class portfolio. Finally, we conclude in Section 5.

2 – Risk and return characteristics of different asset classes

We are ultimately interested in how risk-return characteristics vary across portfolios with different equity allocations and levels of bond risk. The time variation in the asset class risk, return and co-movement properties will drive portfolio characteristics. This time variation is the subject of this section.

Throughout this note we restrict our analysis to a US multi-asset portfolio, consisting of US Treasuries and equities. We obtain monthly time series for the total return on the S&P 500 index ('SPX') and US 3-month Treasury bill

2 Data available at: https://www.newyorkfed.org/research/data_indicators/term_premia.html – estimate as at 13 September 2016.

rate ('CASH') through Bloomberg (see Table A3 in Appendix A for a full list of the data series used throughout the note).

Bond indices, such as the Barclays Aggregate, typically only extend back to the mid or late 1980s. The steady secular decline in global yield levels from their peak in the late 1970s until the present day will heavily influence the risk and return characteristics of the indices. To get a longer-term sample, extending further back towards the beginning of the post-war era when yields were considerably lower, we source bond data from Gürkaynak, Sack and Wright (2006). This data set gives us the entire US yield curve all the way back to 1961.[3]

We use the total returns on the following constant-maturity yields as proxies for bond maturity buckets: '2 year', '4 year', '6 year', '8 year' and '17 year'.[4] In addition, we define our aggregate bond proxy ('UST_AGG') as the simple arithmetic average of the five maturity buckets. The advantage of this approach is twofold for the purpose of our analysis. First, by equally weighting the five constant-maturity bond proxies, we get an aggregate bond proxy with a constant maturity profile. Second, since we know the maturity of the five bond proxies, we are able to vary the maturity profile of the aggregate proxy and assess the portfolio implications of different variations. All in all, this gives us a complete data set consisting of nominal total returns for equities and bonds of different maturities covering the period 1961–2016 (see Appendix A for more details on data and methodology).

Following Adrian, Crump, Diamond and Yu (2016), who use the same bond data as in this note, we split our data sample into two subsamples, 1961–1986 and 1987–2016, and this split should allow us to separate two very distinct regimes in terms of inflation, monetary policy and bond yields. Adrian et al. motivate their choice as follows: "The earlier period was characterized by high and variable inflation and Treasury yields. But the year 1987, when Alan Greenspan became the chairman of the Federal Reserve, marked the start of the so-called 'Great Moderation', a period defined by lower, more stable inflation and a steady fall in Treasury yields. These two periods reflect an economically meaningful partition of the data."

Table 1 displays the historical return-risk statistics for the proxies used for the empirical analysis. Panel A shows statistics for the full sample period, while Panels B and C show the same numbers for two subsamples, 1961–1986 and 1987–2016 respectively. 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.

3 See Appendix A for more details on how we move from so-called Nelson-Siegel-Svensson parameters to bond yields, then finally to bond returns.

4 We set the maturity cut-offs for the par yields by matching the duration of those yields with the average duration of each Barclays maturity bucket. We do this to be consistent with commonly used bond benchmarks such as Barclays US Treasuries (which only goes back to 1987), and to facilitate comparison for the period when our data set overlaps with the Barclays index. See Appendix A for more details.

The first row in each panel displays the risk-return characteristics of cash. While Panel A shows that cash has earned on average almost 5 percent over the full sample period, Panels B and C illustrate that the risk and return characteristics of cash have been nearly the opposite across the two subsamples. Cash returned on average 6.5 percent annually during the 1961–1986 period, double the return on cash during the subsequent period from 1987 onwards. The two distinct regimes for return on cash have meaningfully impacted the excess returns on both equities and bonds.

Table 1: Annualised risk and return statistics for equities and bonds
Panel A: 1961–2016

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio
CASH	4.85	0.92	0.00	NaN
UST_2y	6.02	2.86	1.17	0.42
UST_4y	6.59	4.53	1.74	0.38
UST_6y	6.94	5.84	2.10	0.36
UST_8y	7.17	6.93	2.32	0.33
UST_17y	7.56	10.78	2.72	0.25
UST_AGG	6.86	5.88	2.01	0.34
SPX	10.52	14.85	5.67	0.38

Panel B: 1961–1986

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio
CASH	6.54	0.85	0.00	NaN
UST_2y	7.36	3.61	0.82	0.23
UST_4y	7.29	5.33	0.75	0.14
UST_6y	7.12	6.55	0.58	0.09
UST_8y	6.96	7.59	0.41	0.05
UST_17y	6.53	12.04	-0.01	0.00
UST_AGG	7.05	6.66	0.51	0.08
SPX	10.23	14.52	3.69	0.25

Panel C: 1987–2016

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio
CASH	3.37	0.75	0.00	NaN
UST_2y	4.85	1.93	1.48	0.82
UST_4y	5.97	3.70	2.60	0.71
UST_6y	6.79	5.16	3.42	0.66
UST_8y	7.35	6.32	3.98	0.63
UST_17y	8.47	9.56	5.10	0.53
UST_AGG	6.69	5.10	3.31	0.65
SPX	10.77	15.15	7.40	0.49

Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

Risk and return characteristics of equities

Panel A reflects the well-known observation that equities have historically earned a substantial premium over both Treasury bonds and bills. This large and positive excess return – termed the *equity risk premium* (ERP) – has been documented both across a wide selection of countries and over several decades, even centuries. Still, the realised ERP has also exhibited substantial variability over time and has been low or even negative for several multi-year periods; see NBIM (2016) for a detailed review of the theoretical and empirical evidence on the ERP.

In our sample, equities have on average returned a total of 10.5 percent, just shy of 6 percent in excess of cash, which together with a volatility of almost 15 percent translates into a Sharpe ratio of 0.38. Even though the total return of equities will naturally vary over time, the risk-adjusted performance is very much in line with some of the most well-known data sets in the literature. For example, the long-history data made available by Robert Shiller[5] (1871–2012) and Aswath Damodaran[6] (1928–2015) yield similar Sharpe ratios of 0.4 and 0.39 respectively (NBIM, 2016).

Panels B and C of Table 1, which display statistics for the two subsamples, show that the equity volatility has been stable around 15 percent across both subsamples. The total return of equities has also been more or less the same on average during the two sample periods. However, cash (and bonds) exhibits nearly the opposite risk and return statistics across the two sample periods. Thus, the excess returns of equities end up being considerably lower during the 1961–1986 period when cash earned high average returns.

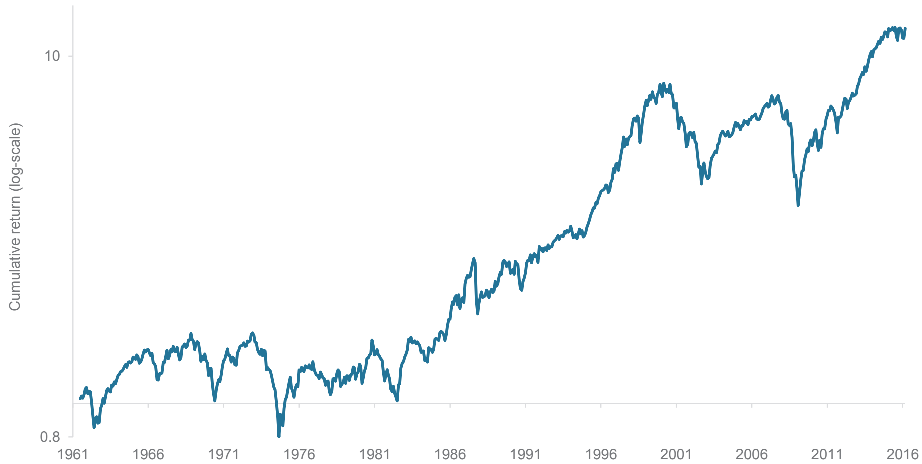
Figure 1, which shows the cumulative *excess* returns for equities, reveals substantial variability in the realised premium, even over long multi-year periods. Most notably, the realised ERP was flat or negative during the 1970s, when the US economy experienced double-digit inflation rates and high nominal interest rates. More recently, from 2007 to the present, a period with very low policy rates and expansionary monetary policy, the realised ERP has been high.

Despite having been highly time-varying, most long-term averages would result in a positive realised ERP. The expected ERP is typically estimated from quantitative models that assume investors' required rates of return equal the expected premium. As pointed out in NBIM (2016), the global expected ERP has declined meaningfully since the end of the Global Financial Crisis and is probably currently near its long-term repricing-adjusted average level at around 3–4 percent.

5 *Robert Shiller data available at:* www.econ.yale.edu/~shiller/data/ie_data.xls

6 *Aswath Damodaran data available at:* http://www.stern.nyu.edu/~adamodar/pc/datasets/histretSP.xls

Figure 1: Cumulative realised equity risk premium, 1961–2016



Source: Bloomberg, NBIM calculations

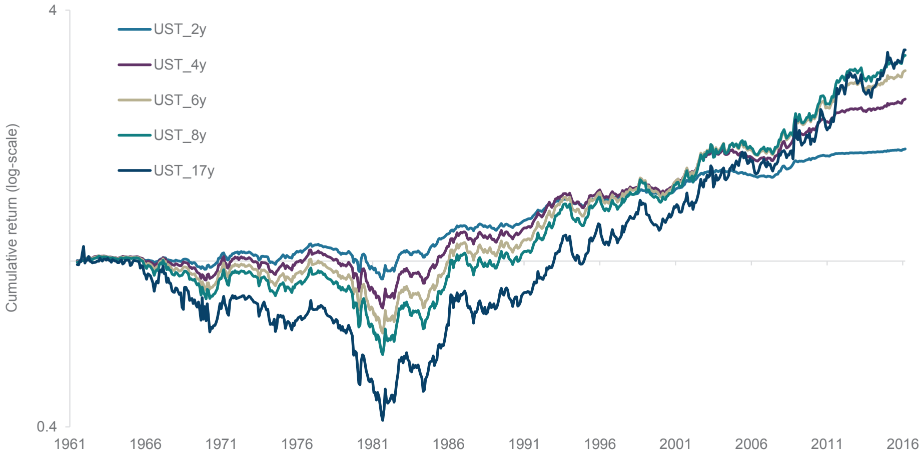
Risk and return characteristics of bonds

Panel A of Table 1 further reveals another well-documented pattern in empirical finance: the *term premium* (TP). The TP refers to the excess return that an investor obtains from holding a long-term bond instead of rolling a series of short-term bonds. Like the ERP, the realised TP has varied greatly over time, but has on average been documented to be positive for long sample periods. The data used in Panel A reveal a consistent pattern: the total and relative returns on the five Treasury indices are monotonically increasing with maturity.

The risk-adjusted excess returns, however, exhibit a very different term structure. Consistent with previous studies, we observe a so-called "hockey stick pattern" when looking at the Sharpe ratios of bond returns across maturities. Empirical research by Ilmanen, Byrne, Gunasekera and Minikin (2004) and Ilmanen (2011) among others shows that an investor is rewarded for moving out along the curve, but only up to a certain point. Historical numbers put this point somewhere along relatively short durations of roughly 2–3 or 4–5 years, depending on the sample period chosen. Panel A of Table 1 shows that the peak in risk-adjusted returns appears already at the 2-year maturity point for the full sample period.

Bonds of maturities longer than that of cash have experienced two distinct, and indeed nearly opposite, risk-return profiles across the two subsamples in Panels B and C of Table 1. The two different regimes have significantly impacted realised term premiums across bonds of various maturities. Figure 2 plots these numbers back to 1961, and the time series profile of these returns reveals a clear pattern.

Figure 2: Cumulative realised term premiums for all maturity buckets, 1961–2016



Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

Before 1980, the excess return series are largely flat and even negative for a period in the late 1970s. An investor would have been better off being invested in short-maturity bonds, or even cash, during this rising nominal rate environment – contrary to the long-history evidence of a positive TP. Panels B and C of Table 1 show that, similar to the full sample results, the 2-year maturity bucket has exhibited the highest Sharpe ratio. The decay in Sharpe ratios, however, is much steeper for the early sample period, where it even goes into negative territory.

While the highest risk-adjusted return remains at the 2-year maturity point for the 1987–2016 period, the decay in Sharpe ratios is much smaller, and bonds of all maturities have on average returned Sharpe ratios of 0.5 or higher. As Figure 2 shows, not only did long-maturity bonds perform better than both cash and short-term Treasuries, but they also more than recovered their underperformance from the preceding period.

As Panel C of Table 1 shows, both realised total and risk-adjusted returns on bonds were particularly high during the 1987–2016 period, and as such this period is probably more of an oddity than a representative sample for expected future bond returns. We will return to this issue later in the note when we complement our main data sample with a longer data sample, going back to 1900.

The upshot of these historical patterns is that cash and bonds have experienced two dramatically different regimes in terms of risk and return characteristics. Adding a bit more colour on the two yield regimes, Figure 3 plots the 10-year bond yield together with the US 3-month Treasury bill. The chart shows that both the level and the volatility of yields have experienced two distinct regimes over the sample period. As Table 1 shows, the volatility of the aggregate bond index was 1.5 percentage points lower in the 1987–2016 subsample compared to the pre-1987 period. This change, which translates into a 25 percent reduction in volatility, may of course make bonds more attractive for taking down the overall portfolio volatility.

An allocation to government bonds comes with exposure to so-called interest rate risk. The duration of the bond component tells us how sensitive the allocation is to interest rate risk. Allocating to long-term bonds, rather than short-term bills or cash, hence exposes an investor to interest rate risk to a greater extent. As Figure 3 shows, the volatility of both the short-term bill and the long-term bond yield was higher during the first half of the data sample. Even a small change in the underlying interest rate volatility can have a meaningful impact on the volatility of bonds with a longer maturity. Crucially, changes in interest rate volatility will change the portfolio properties of bonds, and particularly bond duration.

Figure 3 also shows that the 1960s saw yield levels more similar to levels observed today and may as such serve as a better guide for the medium- to long-term future. Using the term premium estimates made available by Adrian, Crump and Moench (2013), the expected term premium on US 10-year bonds is currently near its all-time low at roughly -50 bps.[7] These levels have not been observed in the data since the early 1960s, which were followed by a 20-year period of negative realised excess returns on long-term bonds relative to short-term bills (Figure 2).

Figure 3: 10-year government bond and 3-month Treasury bill yields (percent), 1961–2016

Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

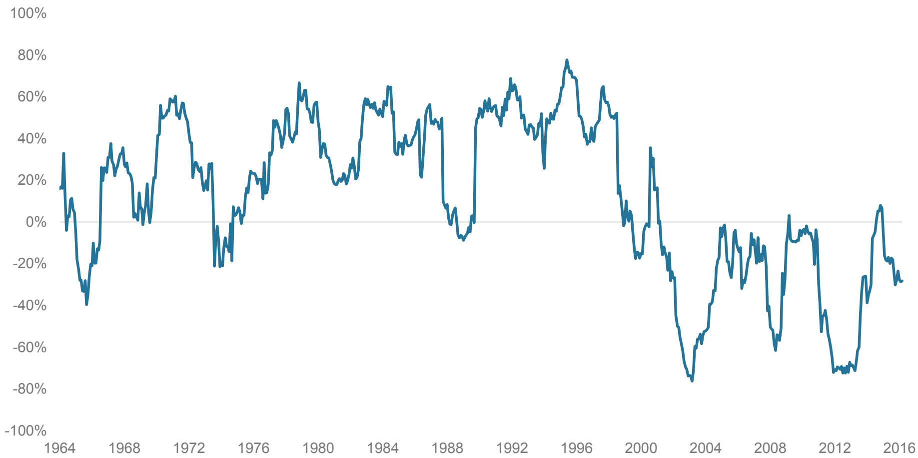
Asset class correlation

Figure 4 shows an estimate of the US equity-bond correlation, measured over 24-month rolling windows. While long-term historical estimates put the equity-bond correlation near zero (Ilmanen, 2003; Rankin and Idil, 2014), both the magnitude *and sign* of the asset class correlation have been documented to vary over time (Campbell, Sunderam and Viceira, 2013). As Figure 4 shows, the variation in the equity-bond correlation is striking, with a maximum and minimum of roughly +0.7 and -0.7 respectively. More interestingly, the correlation was mostly positive up until the early 2000s, after which it turned strongly negative.

7 Data available at: https://www.newyorkfed.org/research/data_indicators/term_premia.html – estimate as at 13 September 2016.

The regime shift in the co-movement of equities and bonds materially impacts the portfolio properties of bonds in a dual asset class portfolio. Campbell, Sunderam and Viceira (2013) find that the term premium is partly determined by the covariance between bond and equity returns. In particular, investors will require a positive (negative) term premium for holding bonds whenever this covariance is positive (negative). They argue that bond risk is low whenever returns on bonds and equities move in opposite directions, as in the early 2000s. Investors treat bonds as a hedge against equity risk in these scenarios, while the opposite will be the case when bond and equity returns tend to co-move, as in the early 1980s.

Figure 4: 24-month rolling US equity-bond correlation



Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

A key question going forward is whether the post-2000 negative equity-bond correlation will persist or revert towards positive territory. This in turn raises the question of what the main drivers of the equity-bond correlation are. Researchers have put forward a number of modelling frameworks that attempt to account for the time variation in the equity-bond correlation.

Ilmanen (2003) identifies inflation and equity market volatility as key drivers of the correlation. Similarly, Yang, Zhou and Wang (2009) propose that short rates and inflation can both account for parts of the co-movement, while Connolly, Stivers and Sun (2005) argue that the equity-bond correlation becomes more muted (and negative) during periods of elevated equity market turmoil. On the other hand, both Pastor and Stambaugh (2003) and Baele, Bekaert and Inghelbrecht (2010) conclude that the co-movement of stocks and bonds is driven by liquidity rather than macro variables.

More recently, Campbell, Pflueger, and Viceira (2015) attempt to explain why the covariance between equities and bonds changes over time. The authors argue that the different macro shocks that have hit the economy over time – shocks to supply vs shocks to demand – combined with a changing monetary policy response to these shocks, can account for the time-varying risk properties of bonds. Their model implies that shocks to supply lead to countercyclical inflation, while shocks to demand result in inflation and output moving in the same direction. Pro- and countercyclical inflation regimes imply negative and positive equity-bond correlations respectively.[8]

The authors further argue that Central Banks pursuing anti-inflationary monetary policies amplify the forces at play during supply shock regimes. This happens as Central Banks aggressively raise interest rates in response to inflationary supply shocks. The resulting increase in real rates prompt or further strengthen any ongoing recession.

Indeed, as pointed out by David and Veronesi (2016), the central bank adopted a strong anti-inflationary stance after the US economy experienced double-digit inflation in the 1970s. In their model (David and Veronesi, 2013), investors may have interpreted any sign of inflation as bad news during this period, as stagflation fears loomed large. Thus, both equity and bond prices moved with the perceived inflation threat, resulting in a positive co-movement during this period.

The opposite inflation regime has arguably prevailed since the turn of the millennium, when two recessions were associated with deflation fears rather than investors worrying about excessive inflation. Investors will then potentially interpret higher inflation readings as good news, pushing equities up and bond prices down – causing the two assets to exhibit negative covariance.

The upshot of this is that bonds will be regarded as a hedge asset, exhibiting very favourable portfolio properties, whenever inflation is low – or fear of *too high* inflation is low. Within this kind of framework, the type of inflation regime that will prevail in the medium-term future will naturally have a bearing on the appropriate allocation to nominal bonds. Given the current low levels of inflation expectations, a negative rather than positive bond-equity correlation seems like a more likely scenario going forward. This may again be associated with low future bond term premiums.

3 – Risk and return characteristics of different asset allocations

In this section, we highlight the portfolio characteristics of different equity allocations. We discuss how bonds diversify equity risk and assess the portfolio implications of the asset class risk and return dynamics we have documented.

8 Campbell, Pflueger, and Viceira (2015) find that the period characterised by a negative equity-bond correlation in our data sample has seen negative persistent shocks to long-term inflation. This would imply positive bond returns as inflation expectations are lowered. The negative equity-bond correlation arises as equity prices fall in response to the negative or slower growth, which stems from temporary recessionary pressures caused by the permanent, albeit delayed, impact of the deflationary shocks.

The return on an equity-bond portfolio r_p with weights w_{EQ} and w_{FI} is simply the weighted average of the asset class returns:

$$r_p = w_{EQ}r_{EQ} + w_{FI}r_{FI}$$

The portfolio volatility depends on the asset class correlation in addition to the asset class volatilities. In particular, the variance of an equity-bond portfolio σ_p^2 with weights w_{EQ} and w_{FI}, asset class variances σ_{EQ}^2 , σ_{FI}^2 and correlation $\rho_{EQ,FI}$ is given by:

$$\sigma_p^2 = w_{EQ}^2\sigma_{EQ}^2 + w_{FI}^2\sigma_{FI}^2 + 2w_{EQ}w_{FI}\rho_{EQ,FI}\sigma_{EQ}\sigma_{FI}$$

A common strategic role of government bonds in a multi-asset portfolio is to diversify equity risk and hence lower overall portfolio volatility. The portfolio volatility formula above makes it clear that the extent to which bonds work as an efficient portfolio diversifier depends on two factors: the level of bond volatility relative to the volatility of equities, and the equity-bond correlation. Leibowitz and Bova (2012) divide the diversifying function of bonds in a multi-asset portfolio into two main effects: a buffering and a hedging effect.

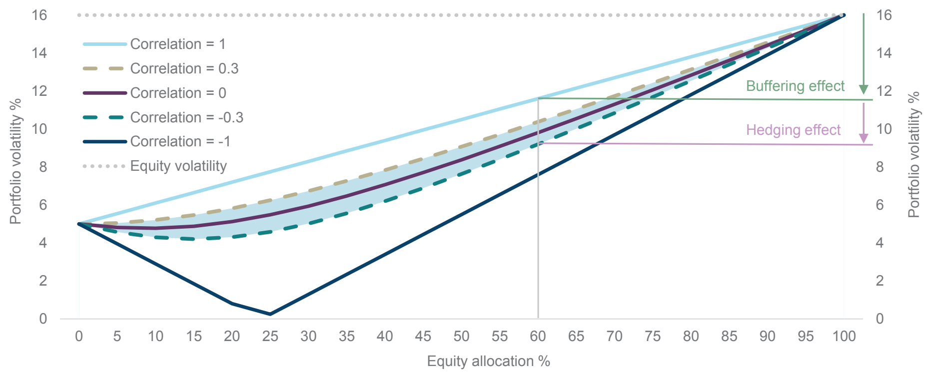
The buffering effect accounts for the downscaled portfolio volatility observed when introducing a perfectly correlated asset with lower volatility into the portfolio. In the context of a traditional multi-asset portfolio consisting of equities and bonds, this effect comes into play as bond returns typically are less volatile than equity returns. Hence, introducing bonds into the portfolio lowers overall portfolio volatility.

The hedging effect accounts for the further reduction in overall portfolio volatility as bonds are less than perfectly correlated, and ideally negatively correlated, with equities.[9] Figure 5 illustrates this volatility breakdown across various equity allocations and correlation regimes. In line with Leibowitz and Bova (2012), we assume that equities have a volatility of 16 percent, while the duration and volatility of the bond portfolio are 5 and 5 percent respectively.[10] Note that the bond volatility is proxied by assuming 1 percent interest rate volatility and a volatility of D x 1 percent for a bond portfolio with duration D.

9 Leibowitz and Bova (2012) refer to this second effect as the de-correlation and hedging effect, but we collapse the two into the hedging effect.

10 These simplifying assumptions are broadly in line with empirical observations, see Table 1.

Figure 5: Volatility of an equity-bond portfolio with an X percent equity allocation (x-axis) across correlations



Source: Leibowitz and Bova (2012), NBIM

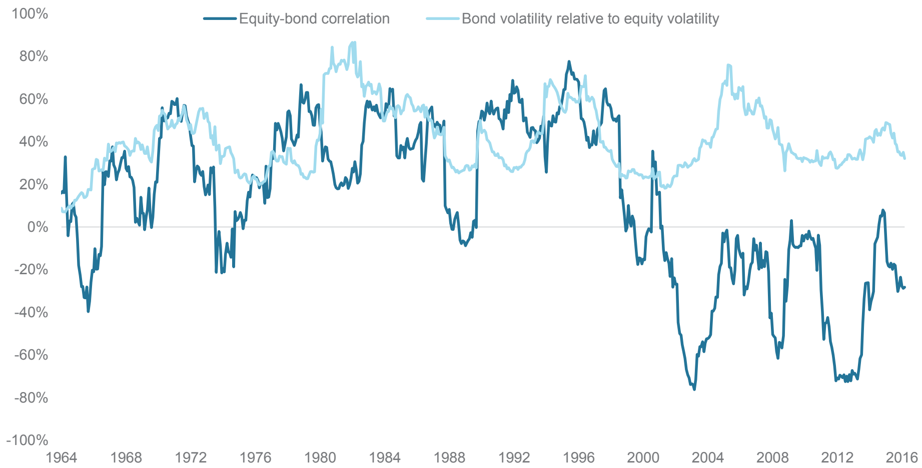
Based on these risk levels, we calculate the overall portfolio volatility under varying correlation assumptions. If we focus on the 60/40 equity-bond portfolio, Figure 5 shows that the 40 percent allocation to bonds would reduce portfolio volatility from 16 percent (100 percent equities) to 11.6 percent if equities and bonds were perfectly correlated, i.e. a pure buffering effect. Portfolio volatility would be reduced by another 2.4 percentage points to 9.2 percent with an equity-bond correlation of -0.3, i.e. the hedging effect. Thus, the buffering effect would be the main driver behind the lowered volatility of allocating 40 percent of a multi-asset portfolio to a bond index with a duration of 5 and a moderately negative equity-bond correlation.

Time-varying portfolio characteristics: main sample (1961–2016)

Turning to our empirical analysis using our main data set, we find that this relationship, and the role of bonds in a dual asset portfolio, is *not* static. The relative importance of the buffering and hedging effects vary over time. Figure 6 shows the same estimate of the equity-bond correlation (the hedging effect) as in Figure 4, as well as an estimate of the ratio of bond to equity volatility (the buffering effect).

The magnitude of bond to equity volatility has varied over time, but has mainly remained within the interval of 20 to 60 percent. The ratio has been 40 percent on average since 1961, and this has contributed to lowering the overall volatility of an equity-bond portfolio. The volatility reduction offered by bonds in a portfolio context simply by being less volatile than equities has been a much more stable feature than the hedging properties due to low or negative return correlations with equities. The correlation between equity and bond returns changed from being robustly positive to robustly negative in the late 1990s, altering the characteristics of a portfolio of equities and bonds.

Figure 6: 24-month rolling equity-bond correlation and ratio of 24-month standard deviations (bonds to equities)



Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

Table 2 shows the historical return-risk statistics across different equity allocations. As in the previous section, the bond component (UST_AGG) is the equally weighted combination of the five constant-maturity bond proxies, and the equity proxy (SPX) is the S&P 500 index. We keep the same sample split from Section 2: 1961–1986 and 1987–2016. Panel A shows statistics for the full sample period, while Panels B and C show the same numbers for two subsamples, 1961–1986 and 1987–2016 respectively. From top to bottom in each panel, we start with a portfolio that is fully invested in bonds, incrementally increasing the equity allocation until the last row, which shows statistics for a portfolio consisting of only equities.

Unsurprisingly, the portfolio that is fully invested in equities has delivered the highest return (10.5 percent), but also the highest annualised return volatility (14.8 percent), over the full sample period, shown in Panel A. The power of diversification becomes obvious when reducing the allocation to equities and introducing an asset with a different source of risk. Specifically, reducing the equity weight from 100 to 50 percent allows the investor to cut the total portfolio volatility almost in half.

The benefits of diversification are maximised at intermediate allocations to equities of 20 to 40 percent, where we observe the most attractive risk-return properties over the full sample period. On the margin, an equity-bond split of 30–70 performed the best in Sharpe ratio terms – with an annualised excess return and volatility of 3.11 and 6.4 percent respectively, resulting in a Sharpe ratio of 0.48.

These are of course uncertain estimates that come with standard errors. The standard errors[11] 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 50 years of monthly data, the Sharpe ratio estimates are uncertain. The standard errors are, however, tight enough to exclude the extreme all-equity and all-bond portfolios, and conclude that diversified dual-asset portfolios with intermediate equity allocations have delivered a better risk-return trade-off.

11 Sharpe ratio standard errors are calculated following Lo (2002).

Panels B and C reveal significant variation around the full-sample portfolio properties observed in Panel A. Briefly, while equities have delivered very similar total returns over the two subsamples (10.2 and 10.7 percent), the bond segment has exhibited dramatically different return statistics over the two sample periods. Whereas equities earned lower, yet positive, excess returns over the first half of the sample, the excess return on bonds was negative during the first subsample, 1961–1986.

This does not necessarily mean that the portfolio should be concentrated in equities. Even a low-return asset with non-equity-like volatility may improve the risk-return properties in a dual asset class portfolio with equities. Still, the (marginally) highest attainable Sharpe ratio would have been achieved with a portfolio fully invested in equities over this period. Portfolios with a modest allocation to bonds (10–20 percent) would have delivered very similar Sharpe ratios. Again, the standard errors highlight that we cannot really tell these very similar Sharpe ratios apart.

The picture is more or less the opposite for the second subsample, 1987–2016, shown in Panel C. Both equities and bonds delivered high excess returns over this period, and even though the Sharpe ratio of equities is twice as high compared to the first subsample, bonds did even better with a Sharpe ratio of 0.65.

Still, the benefits of diversification ensure that an even higher Sharpe ratio can be achieved by moving to somewhere between the two extremes – in this subsample, intermediate equity allocations of 20 to 50 percent have delivered the highest portfolio return for the risk taken. This conclusion is still valid when taking into account the standard errors of the Sharpe ratio estimates.

The difference between the two subsamples is down to the diversification benefit offered by bonds. The ineffectiveness of bonds as a diversifier of equity risk during the 1961–1986 period was due to two factors: bonds were relatively more volatile during this period, and the equity-bond correlation was strongly positive during the entire subsample.

Table 2: Annualised risk and return statistics for portfolios with different equity allocations
Panel A: 1961–2016

Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
0%_EQ	6.86	5.88	2.01	0.34	0.040
10%_EQ	7.22	5.68	2.37	0.42	0.041
20%_EQ	7.59	5.88	2.74	0.46	0.041
30%_EQ	7.96	6.44	3.11	0.48	0.041
40%_EQ	8.32	7.29	3.47	0.47	0.041
50%_EQ	8.69	8.33	3.84	0.46	0.041
60%_EQ	9.05	9.51	4.21	0.44	0.041
70%_EQ	9.42	10.77	4.57	0.42	0.041
80%_EQ	9.79	12.09	4.94	0.41	0.041
90%_EQ	10.15	13.46	5.30	0.39	0.040
100%_EQ	10.52	14.85	5.67	0.38	0.040

Panel B: 1961–1986

Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
0%_EQ	7.05	6.66	0.51	0.08	0.057
10%_EQ	7.37	6.60	0.83	0.12	0.057
20%_EQ	7.69	6.84	1.15	0.17	0.058
30%_EQ	8.01	7.33	1.46	0.20	0.058
40%_EQ	8.32	8.03	1.78	0.22	0.058
50%_EQ	8.64	8.90	2.10	0.23	0.058
60%_EQ	8.96	9.89	2.42	0.24	0.058
70%_EQ	9.28	10.97	2.74	0.25	0.058
80%_EQ	9.60	12.11	3.05	0.25	0.058
90%_EQ	9.91	13.3	3.37	0.25	0.058
100%_EQ	10.23	14.52	3.69	0.25	0.058

Panel C: 1987–2016

Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
0%_EQ	6.69	5.10	3.31	0.65	0.059
10%_EQ	7.09	4.73	3.72	0.79	0.061
20%_EQ	7.50	4.90	4.13	0.85	0.062
30%_EQ	7.91	5.57	4.54	0.82	0.062
40%_EQ	8.32	6.59	4.95	0.75	0.060
50%_EQ	8.73	7.82	5.36	0.69	0.059
60%_EQ	9.14	9.17	5.76	0.63	0.058
70%_EQ	9.54	10.61	6.17	0.58	0.058
80%_EQ	9.95	12.09	6.58	0.55	0.057
90%_EQ	10.36	13.61	6.99	0.51	0.057
100%_EQ	10.77	15.15	7.40	0.49	0.056

Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

We have so far focussed exclusively on standard deviation as a measure of risk. It is, however, not obvious that portfolio volatility is the most appropriate risk measure for a long-term investor with no defined liabilities. This important question goes beyond the scope of this note, but in order to provide some insight into the implications of using other, perhaps more appropriate, risk measures, we summarise the results from using a few alternative measures in Table 3. While equities appear more risky than bonds on most measures of risk, the choice of risk metric can have meaningful implications for the risk-return trade-off for portfolios with different equity allocations.

Table 3: Alternative risk measures for portfolios with different equity allocations, 1961–2016

Portfolio	Standard deviation	Downside Deviation	Skewness	Kurtosis	Max Drawdown
0%_EQ	5.88	3.03	0.49	3.54	-12
10%_EQ	5.68	2.87	0.47	3.36	-9
20%_EQ	5.88	2.96	0.38	2.51	-9
30%_EQ	6.44	3.34	0.24	1.64	-13
40%_EQ	7.29	3.95	0.08	1.20	-18
50%_EQ	8.33	4.72	-0.07	1.13	-24
60%_EQ	9.51	5.59	-0.18	1.24	-30
70%_EQ	10.77	6.52	-0.26	1.40	-36
80%_EQ	12.09	7.48	-0.33	1.55	-41
90%_EQ	13.46	8.48	-0.38	1.69	-46
100%_EQ	14.85	9.50	-0.41	1.81	-51

Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

Time-varying portfolio characteristics: longer sample (1900–2014)

Given the presence of the regime shifts and trends that we have highlighted in the return data, any asset allocation implications may be dependent on the data and sample period chosen. We try to mitigate this by complementing our main data sample with a longer data sample, effectively downplaying any characteristics specific to the 1961–2016 sample. For this exercise, we use the extensive data set on equities and bonds of Dimson, Marsh and Staunton (2015), henceforth referred to as DMS. Even though not offering the same number of dimensions as our main sample, the DMS data allow us to meaningfully increase the length of the sample all the way back to 1900.

The frequency of the DMS data is annual and there is no information on bond duration or further maturity breakdown beyond two categories: bills and bonds. The disadvantage of not having detailed maturity information is that we do not know the maturity profile of the bond proxy or how this may have changed over time. As a result, this data set will not allow us to extend the analysis on the portfolio properties of bond duration further back. However, ignoring the bottleneck requirement that our sample includes information on multiple maturity points, we are able to significantly extend the length of our sample period for the analysis on the risk and return profiles of portfolios with different equity allocations.

Table 4 repeats the same analysis as in Table 2, only using the longer time series on US equities and bonds from the DMS data set. The table shows the historical return-risk statistics across all variations of the equity-bond portfolio for the full sample period (1900–2014). From top to bottom in each table, we start with a portfolio that is fully invested in bonds, incrementally increasing the equity allocation until the last row, which shows statistics for a portfolio consisting of only equities.

Just like in our main data sample, equities have outperformed bills and bonds by a wide margin. The table shows that an investment in US equities has on average returned slightly more than twice that of an investment in US Treasuries, and beaten bills by roughly 7.5 percent per annum. Still, due to the benefits of diversification, the highest risk-adjusted returns can be observed for portfolios with intermediate equity allocations of 30 percent or more. We are not able to tell the portfolios in this broad interval apart in terms of risk-adjusted performance as the estimates are based on annual data and come with meaningful standard errors.

The diversifying properties of bonds in this sample are due to both the lower volatility of bonds and the less than perfect asset class correlation. Table 4 shows that bonds have on average been half as volatile as equities over the full sample period. In addition, the equity-bond correlation has been 5 percent over the period 1900–2014, almost identical to the average correlation over the 1961–2016 period in Figure 4.

Table 4: Annual risk and return statistics for portfolios with different equity allocations, 1900–2014

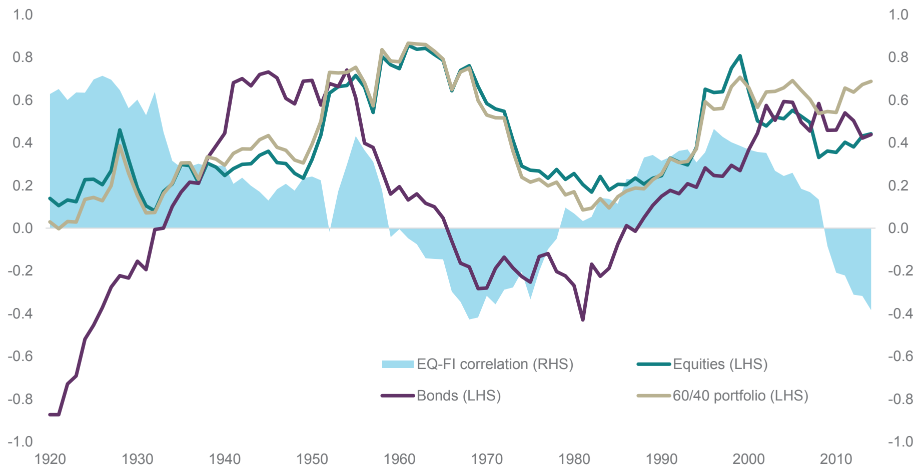
Portfolio	Mean return	Standard deviation	Mean excess return	Sharpe ratio	Sharpe SE
0%_EQ	5.38	9.06	1.53	0.17	0.094
10%_EQ	6.00	8.48	2.15	0.25	0.095
20%_EQ	6.61	8.42	2.76	0.32	0.096
30%_EQ	7.22	8.89	3.38	0.37	0.096
40%_EQ	7.84	9.82	3.99	0.39	0.097
50%_EQ	8.45	11.08	4.60	0.40	0.097
60%_EQ	9.06	12.59	5.22	0.40	0.097
70%_EQ	9.68	14.26	5.83	0.40	0.097
80%_EQ	10.29	16.04	6.44	0.39	0.097
90%_EQ	10.90	17.90	7.06	0.39	0.097
100%_EQ	11.52	19.81	7.67	0.38	0.097

Source: Dimson, Marsh and Staunton (2015), NBIM calculations

The 50–70 percent range for the equity allocations with the highest risk-adjusted returns is higher than the 20–50 percent range we arrived at using our main sample period (Table 2, Panel A). The larger allocation to equities in this longer sample period is mostly due to the poor performance of bonds, and not because equities have performed particularly well. Indeed, the risk-adjusted performance of equities has been 0.38 for both full sample periods, 1961–2016 and 1900–2014. Bonds on the other hand have delivered very different Sharpe ratios over the two samples: 0.34 for 1961–2016 and 0.17 over the full 1900–2014 sample.

This highly time-varying performance of bonds is similar to what we observed previously across the two subsamples in Panels B and C in Table 2. In order to shed further light on the changing performance and portfolio properties of bonds – and contrast this with equities – we plot 20-year rolling Sharpe ratios for both asset classes, a 60/40 equity-bond portfolio and 20-year rolling equity-bond correlations in Figure 7. Equities certainly have exhibited strongly time-varying risk-adjusted performance – with min and max Sharpe ratios of 0.1 and 0.9 respectively – but the 20-year figure has remained positive for the entire 1900–2014 period.

Figure 7: 20-year rolling Sharpe ratios for US equities and bonds and 20-year rolling asset class correlation, 1900–2014



Source: Dimson, Marsh and Staunton (2015), NBIM calculations

The variation in the risk-adjusted performance of equities pales in comparison with that of bonds, which have seen long periods of both positive and negative Sharpe ratios – spanning all the way from -0.9 to +0.8 since 1900. Bonds have experienced two prolonged periods of poor risk-adjusted returns over this sample period: the 1920s/1930s and the period from the early 1970s to the early 1980s. The chart shows how the combination of poor total returns for long-term bonds and elevated cash rates led to the all-bond portfolio having a negative Sharpe ratio all the way until the late 1980s. The ensuing 30-year period has been characterised by declining bond yields, driving up the bond Sharpe ratio towards current levels.

As we highlighted in Figure 4, the equity-bond correlation has experienced two distinct regimes over the 1961–2016 sample. The longer history available in Figure 7 illustrates that the post-2000 negative equity-bond correlation has not been a unique occurrence. After a long period of mostly positive correlation from 1900 to late 1950s, this long-term measure of the asset class correlation turned negative in the early 1960s and stayed negative until the late 1970s. However, in contrast to the post-2000 period, this period coincided with low and even negative bond returns, subduing any meaningful hedging properties of nominal government bonds.

As we noted earlier, even though bonds have earned positive excess returns throughout the post-1980 period, introducing bonds into the portfolio only started making a meaningful impact on the overall portfolio risk-adjusted returns when the asset class correlation turned significantly negative in the post-2000 period. The negative asset class correlation combined with the attractive risk-return characteristics of bonds turned the bond component into a very useful hedge asset for the two equity drawdowns that occurred in the 2000s, and the dual asset portfolio significantly outperforms the portfolio completely concentrated in equities in risk-adjusted terms.

We have so far exclusively used data from the US. Many observers attribute the large realised ERP in the US to the success of the US economy and the US equity market (Ilmanen, 2012). This could potentially bias our results towards a higher allocation to equities being the optimal allocation in Sharpe terms. In order to check whether our findings are the result of events specific to the US or can be applied more generally, we repeat the main analysis from the previous sections using the full cross-section of the 21 countries covered in the DMS data set. The results from this exercise are reported in Appendix B. The global evidence suggests that the optimal equity allocation of 50–70 percent that we have observed is not unique to the US, and as such cannot be attributed solely to survivorship bias.

4 – The role of bond risk in portfolios with different asset allocations

In Sections 2 and 3, we highlighted the time variation in the asset class risk, return and co-movement properties, and showed how this has impacted the risk and return profile of portfolios with different equity allocations. We now turn to the question of how changing levels of bond volatility will affect the portfolio characteristics of a *given* asset allocation.

The equity-bond correlation defines how the equity risk in the portfolio interacts with the inherent interest rate risk that comes with a given allocation to bonds. The duration of the bond allocation tells us how sensitive the allocation is to interest rate movements. All else equal, bonds with a longer time to maturity, or duration D_{FI}, will be more exposed to interest rate volatility σ_i, and we can proxy bond volatility σ_{FI} as $\sigma_i D_{FI}$ Thus, for a given *allocation* to bonds, duration determines the portfolio's *exposure* to interest rate risk.

The portfolio implications of bond volatility are more ambiguous than the portfolio properties of the asset class correlation.[12] In particular, the impact of the volatility of the bond component on overall portfolio volatility is

12 Changes in the equity-bond correlation will always be positively related to the total portfolio volatility. In other words, a lower asset class correlation will always lower total portfolio risk.

contingent on the asset class correlation. To illustrate this, consider the partial derivative of the portfolio variance with respect to bond volatility, which is given by:

$$\frac{\partial \sigma_p^2}{\partial \sigma_{FI}} = 2w_{FI}^2\sigma_{FI} + 2w_{EQ}w_{FI}\rho_{EQ,FI}\sigma_{EQ}$$

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

$$0 < 2w_{FI}^2\sigma_{FI} + 2w_{EQ}w_{FI}\rho_{EQ,FI}\sigma_{EQ}$$

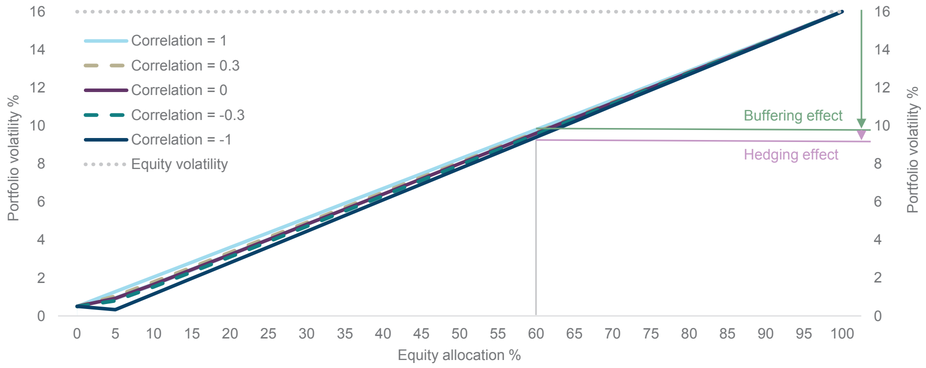
which will happen whenever

$$-\frac{w_{FI}}{w_{EQ}}\frac{\sigma_{FI}}{\sigma_{EQ}} < \rho_{EQ,FI}$$

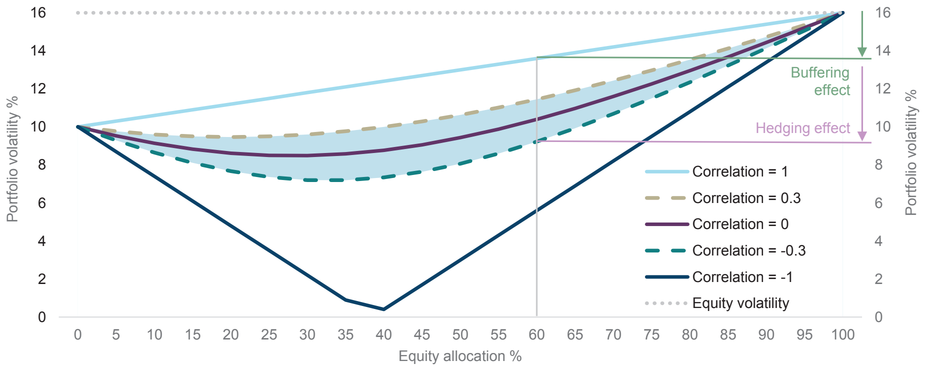
That is, total portfolio volatility will be increasing in the volatility of the bond component whenever the equity-bond correlation is greater than the negative of the ratio of weighted asset class volatilities. However, when the asset class correlation is sufficiently negative, more so than the negative of the ratio of weights times volatilities, the volatility of the portfolio will become *decreasing* in bond volatility. Naturally, the larger the allocation to bonds and the riskier these bonds initially are relative to equities, the more negative the asset class correlation has to be before the overall portfolio volatility becomes decreasing in the volatility of the bond component.

Using the framework of Leibowitz and Bova (2012), we can illustrate the interaction between the equity-bond correlation and the volatility of the bond allocation, proxied by the bond duration. Figure 8 shows the same breakdown as in Figure 5 and illustrates the effect of bond duration on overall portfolio volatility. Rather than the duration of 5 assumed in Figure 5, Panels A and B of Figure 8 use bond durations of 0.5 and 10 respectively.

Figure 8: Volatility of equity/bond portfolio with X percent (x-axis) bond weight
Panel A: Bond portfolio with duration of 0.5 across correlation regimes



Panel B: Bond portfolio with duration of 10 across correlation regimes



Source: Leibowitz and Bova (2012), NBIM

Note that by changing the duration of a given *allocation* to bonds, we are changing the *exposure* to interest rate risk, and thus scaling up or down the *volatility* of the bond allocation. While interest rate volatility is assumed to be constant at 1 percent, using the same approximation as above where bond volatility is proxied by , the volatility of the bond allocations with durations of 0.5 and 10 becomes 0.5 and 10 percent respectively. As shown in Panel A, virtually the entire volatility reduction comes from the buffering effect when the bond allocation has a very short duration (i.e. practically a cash rather than a bond allocation).

If we extend the duration of the bond allocation, this buffering effect decreases, because total return volatilities are higher for longer durations. However, as can be seen from Panel B, the decreasing buffering effect is to a large extent offset by an increasing hedging effect as bond duration is extended. A significant portion of the diversification benefit of the bond allocation comes from the fact that long-maturity bonds will counter moves in the equity portfolio to a greater extent than bonds of shorter maturity. At longer durations, this increasing de-correlation and hedging effect is largely offset against a diminishing buffering effect.

The upshot of this interplay is that, for a given bond weight and equity-bond correlation of close to zero, the duration of the bond portfolio does not have a meaningful impact on overall portfolio volatility.

However, with a non-zero and positive equity-bond correlation, the total volatility increases significantly with the duration of the bond component. The relationship between bond duration and portfolio volatility eventually switches from positive to negative as the asset class correlation becomes sufficiently negative. In particular, the overall portfolio volatility becomes *decreasing* in bond duration, or bond volatility, whenever the asset class correlation is lower than the negative of the ratio of asset class weights times the ratio of volatilities. Having observed two distinct correlation regimes in Figure 4, it becomes clear that the choice of bond duration will impact the risk and return profile of portfolios with different equity allocations.

Table 5 maps out the above logic for a 60/40 equity-bond portfolio at different combinations of bond duration (from 1 to 16) and equity-bond correlation (from -1 to 1), using the same asset class volatility assumptions as above. The first row shows portfolio volatility when the bond allocation has a duration of 1, effectively cash. Across this row, the overall volatility will be almost invariant to the different correlation regimes. As we increase the duration of the bond portfolio, i.e. move down along the rows, the portfolio volatility strictly increases for zero and positive correlations.

With a meaningfully negative equity-bond correlation, the volatility strictly decreases with the duration of the bond portfolio. Less obviously, with a slightly negative equity-bond correlation of -0.3, the total portfolio volatility initially decreases with duration, then flips and starts increasing as we move down beyond the 10-year duration point. In other words, at positive or zero asset class correlations, bonds with lower volatility will be a strictly better diversifier of equity risk. As the correlation turns increasingly negative, high volatility bonds will be more effective at lowering the total volatility of the portfolio. The location of this inflection point will depend on the relative volatility of bonds to equities as well as the asset allocation.

Using the above condition for the portfolio impact of bond volatility, the volatility of a 60/40 portfolio with a bond-equity volatility ratio of 40 percent will become decreasing in bond volatility whenever the equity-bond correlation is lower than -0.27 (-[0.4/0.6] * 0.4 = -0.27). Therefore, when the equity-bond correlation is meaningfully negative – as it has been since the early 2000s (see Figure 4) – an investor will be able to add to the hedging properties of bonds by *extending* the duration of the bond allocation.

Table 5: Volatility (percent) of 60/40 equity-bond portfolio across duration and correlation regimes

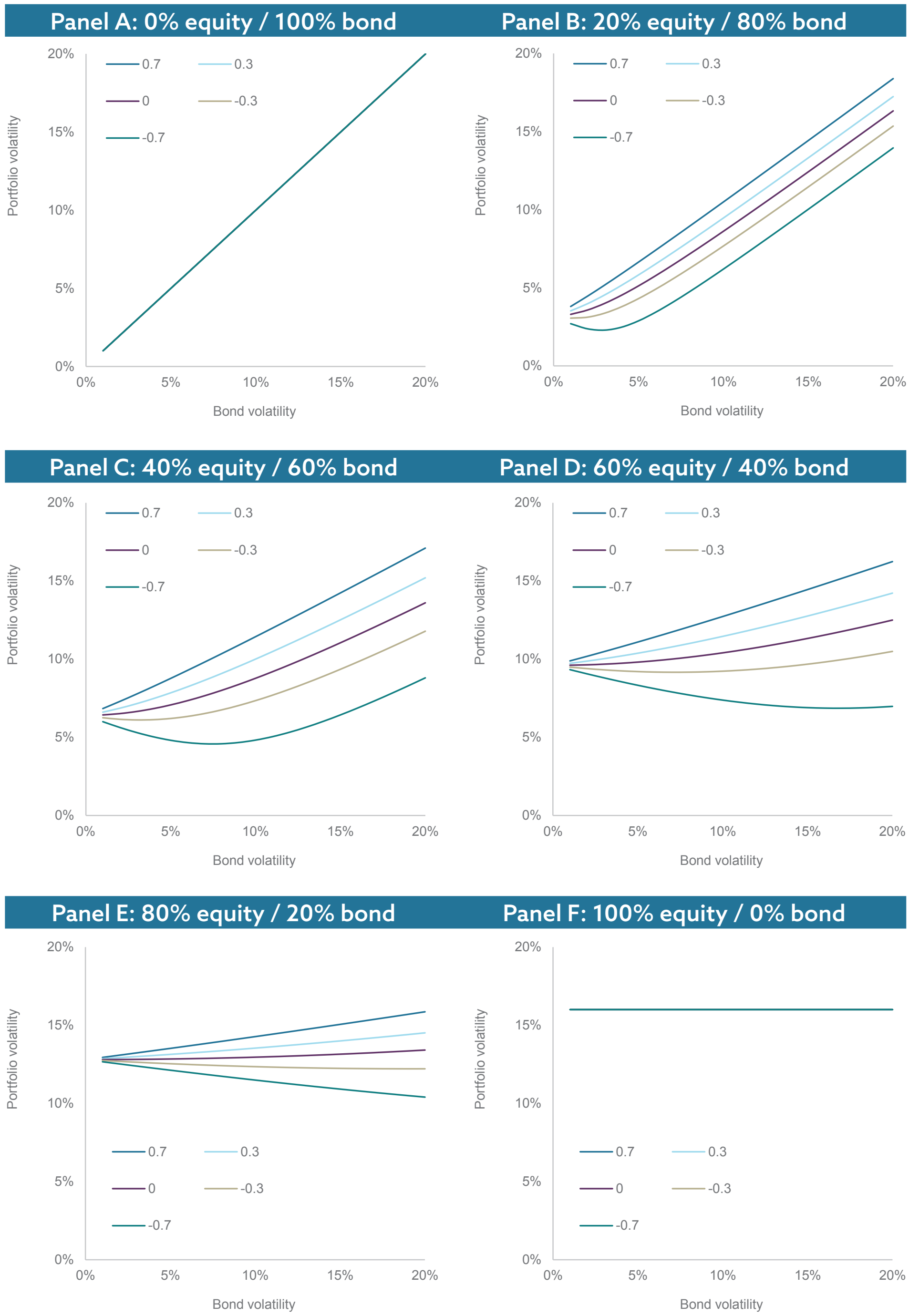
	EQ-FI correlation						
Duration	1.0	0.7	0.3	0.0	-0.3	-0.7	-1.0
1	10.0	9.9	9.7	9.6	9.5	9.3	9.2
2	10.4	10.2	9.9	9.6	9.4	9.1	8.8
3	10.8	10.5	10.0	9.7	9.3	8.8	8.4
4	11.2	10.8	10.2	9.7	9.2	8.6	8.0
5	11.6	11.1	10.4	9.8	9.2	8.3	7.6
6	12.0	11.4	10.6	9.9	9.2	8.1	7.2
7	12.4	11.7	10.8	10.0	9.2	7.9	6.8
8	12.8	12.1	11.0	10.1	9.2	7.7	6.4
9	13.2	12.4	11.2	10.3	9.2	7.5	6.0
10	13.6	12.7	11.5	10.4	9.2	7.4	5.6
11	14.0	13.1	11.7	10.6	9.3	7.2	5.2
12	14.4	13.4	12.0	10.7	9.4	7.1	4.8
13	14.8	13.8	12.2	10.9	9.4	7.0	4.4
14	15.2	14.1	12.5	11.1	9.6	6.9	4.0
15	15.6	14.4	12.8	11.3	9.7	6.9	3.6
16	16.0	14.8	13.0	11.5	9.8	6.9	3.2

Source: Leibowitz and Bova (2012), Bloomberg, NBIM calculations

The combined portfolio impact of bond volatility and the equity-bond correlation will to a great extent be contingent on the asset allocation, the mix of equities and bonds. While Table 5 assumed a 60/40 equity-bond portfolio, Figure 9 maps out the same volatility numbers across various specifications of the US multi-asset portfolio.

The subplot shows six distinct asset allocations (equity weights of 0, 20, 40, 60, 80 and 100 percent in Panels A to F), and the lines in each plot represent the different correlation regimes. Finally, moving along the lines is akin to changing the volatility of the bond component, starting with a bond volatility of 1 percent to the far left of each plot (marked on the horizontal axis). Naturally, all five lines overlap at the 0 percent equity portfolio, then diverge as we move along the panels, until they re-converge as we approach the 100 percent equity portfolio.

Figure 9: Total volatility of equity-bond portfolios with various equity shares across bond volatility and correlation regimes



Source: Bloomberg, NBIM calculations

Aside from the obvious fact that the lowest portfolio volatility is always achieved with the most negative asset class correlation, the charts highlight that the lowest total volatility is not always ensured by keeping the volatility of the bond portfolio as low as possible. On the flipside, for an investor who wants to take on more risk in an equity-bond portfolio, the answer will not necessarily be to increase the volatility of the bond portfolio. As the plots show, overall portfolio volatility will be increasing in bond volatility when the equity-bond correlation is positive, and particularly so with modest equity allocations. As the allocation to equities grows, the impact of bond volatility on portfolio volatility diminishes.

However, with negative asset class correlations, the volatility impact of bond volatility can be either positive or negative, depending on the initial ratio of bond-equity volatility as well as the equity-bond mix. In negative correlation regimes, with modest allocations to equities (10–30 percent), duration risk plays a dominant role in the portfolio, and thus total volatility remains strictly increasing in bond volatility. For slightly larger equity allocations (40–60 percent), the volatility lines start taking on a shallow U-shape, where total volatility first decreases up to some point, then starts increasing. Finally, with meaningful equity allocations (above 60 percent), the relationship inverts and the volatility of the equity-bond portfolio becomes strictly decreasing for negative equity-bond correlations.

Time-varying portfolio impact of bond volatility

Turning to our data set used in Sections 2 and 3, we assess the impact that different levels of bond volatility have had on the risk-adjusted portfolio returns. This will obviously depend on the *return* that has been associated with changing the risk properties of the bond allocation. As we saw in Section 2, the term structure of bond returns has varied substantially over our sample period.

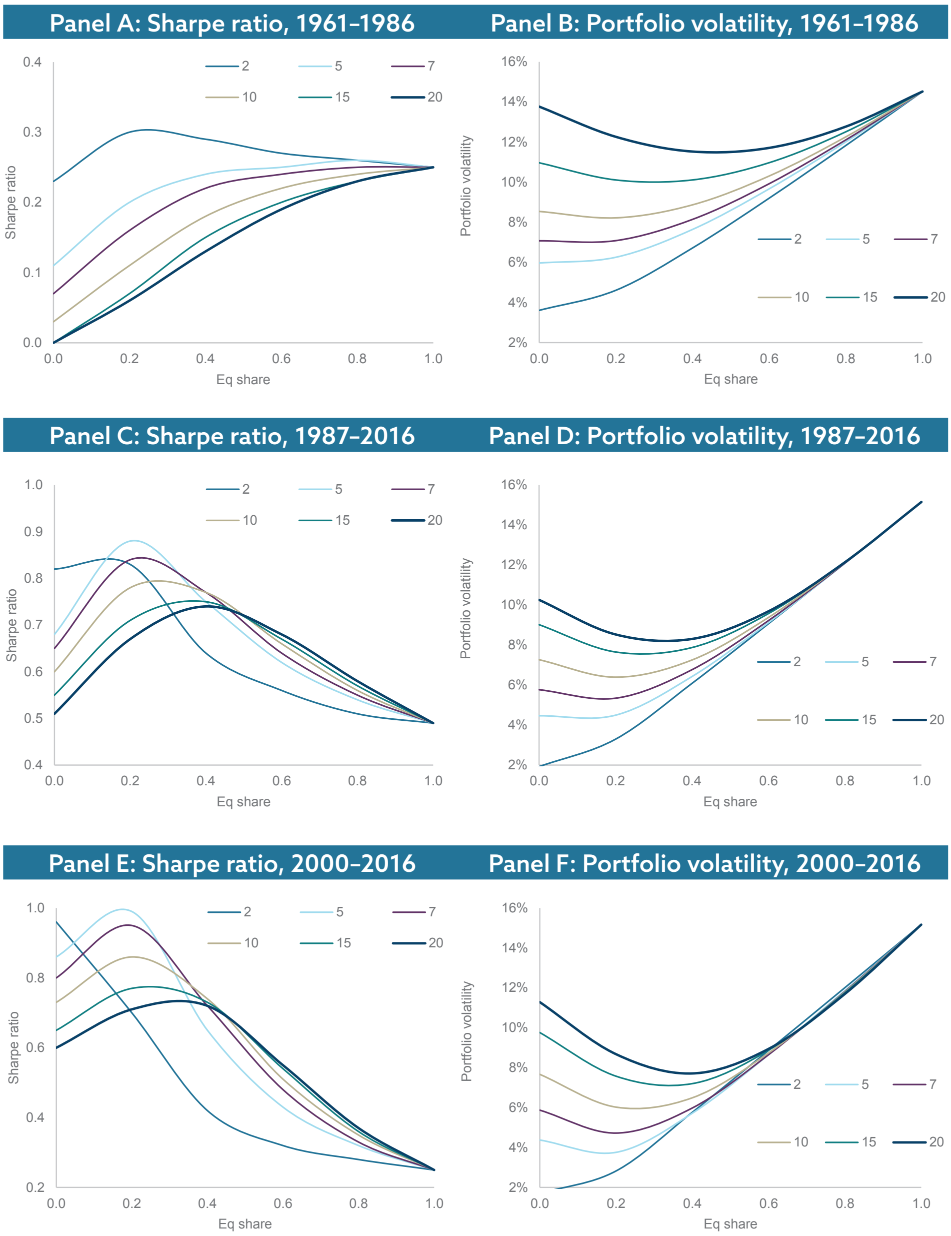
Figure 10 summarises the main empirical findings. The three panels to the left – A, C and E – display the Sharpe ratio profiles across different equity shares for different bond durations, while the Panels to the right – B, D and F – show the corresponding total portfolio volatility profiles. The different lines reflect various duration targets (from 2 to 20) at different equity allocations.

All numbers are shown for the same two sample periods used throughout the note: 1961–1986 and 1987–2016. In addition, we carve out the post-2000 period as a separate subsample in order to highlight the portfolio properties during this particular period, which is characterised by a negative equity-bond correlation (-27 percent on average). The different correlations lead to stark contrasts in the portfolio properties of duration across our data sample. The combined impact of the changing bond return characteristics and asset class correlation is clearly visible when comparing the Sharpe ratio profiles in Panels A and C.

Looking at the first subsample, 1961–1986, in Panel A, investors would have been generally better off – regardless of asset allocation – with relatively short duration profiles, with the highest Sharpe ratios occurring with modest equity allocations (≤ 40 percent) and short duration profiles (< 5 years). This is mainly due to two key observations from Section 2. First, bond returns were positively correlated with equity returns and were therefore a poor hedge for equity risk during this period. Second, the additional risk incurred when holding longer-duration securities was not rewarded, as the bond term premium was negative during the 1961–1986 period.

With the benefit of hindsight, taking almost any of the equity allocations along the lines in Panel A as a starting point, an investor could have increased her Sharpe ratio by either increasing the equity share or lowering the volatility of the bond component. What these numbers are telling us is that an investor could certainly increase the risk of, say, a 60/40 portfolio by extending the duration of the bond component (Panel B), but the additional risk would come with an insufficient amount of return to maintain the Sharpe ratio of the original portfolio.

Figure 10: Sharpe ratios and portfolio volatility of equity-bond portfolios across various equity shares and duration targets



Source: Gürkaynak, Sack and Wright (2006), Bloomberg, NBIM calculations

The duration of the bond allocation became a much more potent tool for affecting the overall portfolio characteristics in the second subsample, as shown in Panels C and D. During this period, a cross-asset investor could have benefited from both the upward-sloping term structure of bond returns and the negative asset class correlation, allowing her to decrease the risk of the overall portfolio by increasing the volatility of the bond component. As noted earlier, the risk-adjusted returns on bonds were particularly high during this sub-sample, and as such this period is probably more of an oddity than a representative sample for expected future bond returns.

The Sharpe ratio profiles in Panels C and E take on a hump-shaped profile: at modest equity allocations, the risk-return characteristics of bonds dominate the portfolio properties, and a shorter bond duration would have increased the Sharpe ratio. However, some of the Sharpe reduction that would have been incurred by increasing the equity allocation could have been offset by choosing a longer bond duration (shifting the Sharpe profiles upwards in Panels C and E). In the second subsample with on average zero equity-bond correlation, this becomes like effectively leveraging up the dual asset portfolio, as the increased bond risk does increase the overall portfolio volatility, see Panel D.[13]

However, as expected, in the subsample with a negative asset class correlation, increasing the bond volatility does not necessarily increase portfolio volatility (Panel F). While portfolio volatility is strictly increasing in the duration of the bond component during the subsample with a positive equity-bond correlation, the volatility profiles in Panel F eventually switch order for meaningful equity allocations during the post-2000 subsample with negative asset class correlation.

Portfolio volatility is more or less unchanged when varying the duration of the bond component for an equity allocation of 60 percent, and even becomes mildly decreasing for bigger equity shares. Finally, all panels illustrate that the duration of the bond component plays a more important role in determining the total portfolio properties at intermediate allocations to equities.

5 – Conclusion

In this note, we evaluate the risk and return characteristics of equities and government bonds, and discuss how the risk and return profile of a portfolio of these asset classes varies with the size of the equity allocation and the duration of the bond allocation. We highlight the relative importance of the three key components that make up the overall portfolio risk-return profile: equity and bond risk-return characteristics and the equity-bond correlation. We show that all three factors have historically had an impact on the risk and return profile of portfolios with different equity allocations.

The asset class risk-return characteristics of both equities and bonds have changed over time, and while the excess return on equities has varied significantly over time, short-term bills and long-term bonds have experienced two very distinct regimes in terms of risk-return characteristics

13 A rational mean-variance optimising investor who wants to combine several risky assets, such as equities and bonds, in a portfolio should set the asset class weights in order to maximise expected return per unit of risk. However, this decision in itself does not dictate the level of risk in the portfolio – it simply sets out the mix of risks in the portfolio. For a leverage-constrained investor with an equity-bond portfolio, the level of risk taken can potentially be altered by varying the duration of the bond portfolio, rather than mixing the optimal risky portfolio with risk-free cash. This is related to the work by Asness et al. (2012) and Asness (2014). This general point is made by Asness (1996), who shows that not only does a levered 60/40 portfolio beat a portfolio fully invested in equities, but "even if investors can't lever, they should still choose a portfolio with the least risk given an expected return". Small-cap equities are used as an example, and the author goes on to show how, without leverage, simply replacing the equity component of the 60/40 portfolio with small-caps would have beaten the all-equity portfolio, in terms of both total and risk-adjusted returns.

since the early 1960s. The two regimes have affected the portfolio properties of bonds and thus influenced which equity-bond mix historically has offered the best return per unit of risk.

During the period 1961–1986, which is characterised by rising bond yields and low excess returns on bonds, portfolios with equity allocations of 80–100 percent offered the highest Sharpe ratios. In contrast, portfolios with intermediate equity allocations of 20–30 percent delivered the highest portfolio return for the risk taken over the subsequent period 1987–2016, when both bonds and equities delivered high excess returns on average.

A meaningful part of the variation in the portfolio risk-return profiles is due to the changing asset class risk-return characteristics. However, the striking difference between the two subsamples is the diversification benefit offered by bonds. The ineffectiveness of bonds as a diversifier of equity risk during the 1961–1986 period was due to two factors: bonds were relatively more volatile during this period, and the equity-bond correlation was strongly positive during the entire subsample.

The correlation between equities and bonds has changed from being robustly positive until the late 1990s to robustly negative ever since. The *changing* equity-bond correlation is an important driver of the *changing* portfolio properties of bonds. We highlight that the ability of bonds to reduce overall portfolio volatility simply by exhibiting lower volatility than equities diminishes as the asset class correlation becomes increasingly negative. For a sufficiently negative correlation between equities and bonds, total portfolio risk can go *down* when the bond volatility goes *up*.

A key question going forward is whether the post-2000 negative equity-bond correlation will persist or revert towards positive territory. Given the current low levels of inflation expectations, a negative rather than positive correlation seems a more likely assumption going forward. In addition to the equity-bond correlation, the asset class risk and return properties will be important drivers of the variation in future performance across portfolios with different asset allocations.

As pointed out in NBIM (2016), the global expected equity risk premium has declined meaningfully since the end of the Global Financial Crisis and is probably currently near its long-term repricing-adjusted average level at around 3–4 percent. Using the term premium estimates made available by Adrian, Crump and Moench (2013), the expected term premium on US 10-year bonds is currently near its all-time low at roughly -50 bps.[14] These levels have not been observed in the data since the early 1960s, which were followed by a 20-year period of negative realised excess returns on long-term bonds relative to short-term bills.

14 Data available at: https://www.newyorkfed.org/research/data_indicators/term_premia.html *– estimate as at 13 September 2016.*

References

Adrian, T., R. Crump and E. Moench (2013): "Pricing the Term Structure with Linear Regressions", *Journal of Financial Economics* 110(1), 110–138.

Adrian, T., R. Crump, P. Diamond and R. Yu (2016): "Forecasting Interest Rates over the Long Run," Federal Reserve Bank of New York Liberty Street Economics (blog), 18 July 2016, http://libertystreeteconomics.newyorkfed.org/2016/07/forecasting-interest-rates-over-the-long-run.html.

Asness, C. (1996): "Why Not 100% Equities," *Journal of Portfolio Management*, 22(2), 29–34.

Asness, C. (2014): "Risk Parity: Why We Lever," AQR Cliff's Perspective, available online: https://www.aqr.com/cliffs-perspective/risk-parity-why-we-fight-lever.

Asness, C., A. Frazzini and L. Pedersen (2012): "Leverage Aversion and Risk Parity", *Financial Analysts Journal*, 68(1), 47–59.

Baele, L., G. Bekaert and K. Inghelbrecht (2010): "The Determinants of Stock and Bond Return Comovements", *Review of Financial Studies* 23(6), 2374–2428.

Campbell, J., C. Pflueger and L. Viceira (2015): "Monetary Policy Drivers of Bond and Equity Risks", National Bureau of Economic Research, Working Paper 20070.

Campbell, J., A. Sunderam and L. Viceira (2013): "Inflation Bets or Deflation Hedges? The Changing Risks of Nominal Bonds", Harvard University, working paper.

Connolly, R., C. Stivers and L. Sun (2005): "Stock Market Uncertainty and the Stock-Bond Return Relation", *Journal of Financial and Quantitative Analysis*, 40(1), 161–194.

David, A. and P. Veronesi (2013): "What Ties Return Volatilities to Price Valuations and Fundamentals", *Journal of Political Economy*, 121(4), 682–746.

David, A. and P. Veronesi (2016): "The Economics of the Comovement of Stocks and Bonds", in *Handbook of Fixed-Income Securities* (ed. P. Veronesi), Hoboken, NJ: John Wiley & Sons.

Dimson, E., P. Marsh and M. Staunton (2015): *Global Investment Returns Sourcebook 2015*, Zurich: Credit Suisse Research Institute.

Gürkaynak, R. and B. Sack (2006): "The U.S. Treasury Yield Curve: 1962 to 2004", unpublished, Federal Reserve Board.

Ilmanen, A. (2003): "Stock-Bond Correlations", *Journal of Fixed Income*, 13(2), 55–66.

Ilmanen, A. (2011): "Expected Returns: An Investor's Guide to Harvesting Market Rewards", Chichester: John Wiley & Sons.

Ilmanen, A. (2012): "Expected Returns on Major Asset Classes", Charlottesville, VA: Research Foundation of CFA Institute.

Ilmanen, A., R. Byrne, H. Gunasekera and R. Minikin (2004): "Which Risks Have Been Best Rewarded?", *Journal of Portfolio Management*, 30, 53–57.

Leibowitz, M. and A. Bova (2012): "The Duration Decision in Diversified Portfolios", Morgan Stanley Research, February.

Litterman, R. and J. Scheinkman (1991): "Common Factors Affecting Bond Returns", *Journal of Fixed Income*, 54–61.

Lo, A.W. (2002): "The Statistics of Sharpe Ratios", *Financial Analysts Journal*, 58, 36–50.

Markowitz, H. (1952): "Portfolio Selection", *Journal of Finance*, 7(1), 77–91.

Markowitz, H. (1959): "Portfolio Selection: Efficient Diversification of Investments", New York: John Wiley & Sons.

Nelson, C. and A. Siegel (1987): "Parsimonious Modelling of Yield Curves", *Journal of Business*, 60(4), 473–489.

Norges Bank Investment Management (2016): "The Equity Risk Premium", NBIM Discussion Note 1-2016.

Pastor, L. and R. Stambaugh (2003): "Liquidity Risk and Expected Stock Returns", *Journal of Political Economy*, 111(3), 642–685.

Rankin, E. and M. Idil (2014): "A Century of Stock-Bond Correlations", *RBA Bulletin*, 67–74.

Svensson, L. (1994): "Estimating and Interpreting Forward Interest Rates: Sweden 1992–1994", Center for Economic Policy Research, CEPR Discussion Papers No. 1051.

Yang, J., Y. Zhou and Z. Wang (2009): "The Stock-Bond Correlation and Macroeconomic Conditions: One and a Half Centuries of Evidence", *Journal of Banking and Finance*, 33(4), 670–680.

Appendix A – Data and methodology

In this section, we outline the data and methodology used in the empirical analysis. For simplicity, we restrict our analysis to a US multi-asset portfolio, consisting of US Treasuries and equities. There is a trade-off between sample length and breadth. The former is arguably more important for a study such as this, where we are interested in understanding the risk and return characteristics of different asset classes over time. However, we need bond data that cover the entire term structure – or at least a few maturity points – in order to assess the portfolio properties of bond duration. This will act as a bottleneck in terms of how far back in history we will be able to go.

US indices for both equities and bonds generally extend back significantly further than their global or regional counterparts do. For US equities, the S&P 500 index is available all the way back to 1871 through Robert Shiller's online data library[15], or back to the 1920s through Bloomberg. The important exception is the extensive study of global equities and bonds by Dimson, Marsh and Staunton (2015). Their data set currently covers 21 countries over the period 1900–2014. However, the frequency of this data is annual and there is no information on bond duration or further maturity breakdown beyond two categories: bills and bonds. We use the DMS data set in Section 3 to abstract from the sample period chosen here and assess to what degree our empirical results are influenced by the choice of data and sample period.

Bond indices, such as the Barclays Aggregate, typically only extend back to the mid or late 1980s. This particular sample period is characterised by a steady decline in global yield levels from their peak in the late 1970s. The secular decline in yields will heavily influence the risk and return characteristics of bond indices limited to this particular sample period. It is therefore desirable to extend further back beyond the early 1980s towards the beginning of the post-war era when yields were considerably lower.

To get a long-term sample with maturity information, we source bond data from Gürkaynak, Sack and Wright (2006), henceforth referred to as GSW. The GSW data, which are updated regularly, go back to 1961 and are available through the Federal Reserve Board's website[16]. As in Adrian, Crump and Moench (2013), we take the Nelson-Siegel-Svensson parameters estimated by GSW and use these to infer the entire yield curve all the way back to 1961. Briefly, GSW fit the US Treasury yield curve using quotes on Treasury securities from the Center for Research in Security Prices (CRSP) for the period 1961 to 1987 and from the Federal Reserve Bank of New York (FRBNY) for 1987 onwards.

GSW employ the Svensson (1994) extension of the original model by Nelson and Siegel (1987), which is a commonly used method to parsimoniously model the term structure of interest rates. Nelson and Siegel (1987) introduce three factors that explain 96 percent of the variation in yields for their (short) sample period of 1981–1983. Litterman and Scheinkman (1991)

15 Robert Shiller data available at: www.econ.yale.edu/~shiller/data/ie_data.xls

16 GSW data available at: http://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html find that the first factor explains roughly 89 percent of the variability in the term structure, the second factor 8 percent, and the third factor another 2 percent, for their sample of 1984–1987. The main innovations of Litterman and Scheinkman (1991) are the labels they put on the three factors: *level*, *steepness* and *curvature*.

Svensson (1994) adds a second hump to the original model. The motivation for the second hump is to capture yield curve dynamics that characterise the very long end of the yield curve. This was not necessary when the original version of the model was estimated, as Treasury securities were typically issued with maturities ranging between 0 and 10–15 years. As bonds are now issued with maturities all the way out to 20–30 years, the Svensson extension of the Nelson-Siegel model has become the benchmark yield curve model.

GSW estimate the Nelson-Siegel-Svensson parameters by minimising pricing errors versus real-life bonds for the theoretical prices estimated using the following function:

$$Y_t^{(n)} = \beta_{0,t} + \beta_{1,t}\frac{1-exp\left\{-\frac{n}{\tau_{1,t}}\right\}}{\frac{n}{\tau_{1,t}}} + \beta_{2,t}\left[\frac{1-exp\left\{-\frac{n}{\tau_{1,t}}\right\}}{\frac{n}{\tau_{1,t}}} - exp\left\{-\frac{n}{\tau_{1,t}}\right\}\right]$$
$$+\beta_{3,t}\left[\frac{1-exp\left\{-\frac{n}{\tau_{2,t}}\right\}}{\frac{n}{\tau_{2,t}}} - exp\left\{-\frac{n}{\tau_{2,t}}\right\}\right]$$

The intuition of the above equation is that a yield of any maturity n, $Y_t^{(n)}$, can be expressed as a combination of four yield curve factors $\beta_{0,t}$, $\beta_{1,t}$, $\beta_{2,t}$ and $\beta_{3,t}$ – level, slope and two curvature factors. The level factor, which is a constant, affects yields of all maturities, while the slope factor decreases with maturity. Both the decay of the slope factor and the peak of the two curvature factors will be determined by $\tau_{1,t}$ and $\tau_{2,t}$.

Since there are few bonds with a maturity longer than 10 years prior the 1980s, GSW use the Nelson-Siegel version from 1961 to 1980 and then the full Nelson-Siegel-Svensson model from 1980 onwards. The above function is reduced to the original Nelson-Siegel model by setting $\beta_{3,t}$ equal to zero. For more details on data, methodology and estimation issues, see GSW.

We use the time series of these six yield curve parameters and infer the entire yield curve by evaluating the Nelson-Siegel-Svensson function. This gives us a cross-section of zero-coupon yields covering maturities from 6 months to 10 years, and all the way out to 30 years for the post-1980 period. However, the US Barclays Treasury index, which is part of the Government Pension Fund Global's bond benchmark, comprises coupon-bearing securities. Thus, expressing the zero-coupon yields as coupon-equivalent par yields will serve as a better proxy. We therefore first compute discount factors over the same maturities using:

$$d_t^{(n)} = exp\left(-Y_t^{(n)}n\right)$$

From the discount factors, we back out coupon-equivalent par yields using:

$$Y_{p,t}^{(n)} = \frac{2\left(1 - d_t^{(n)}\right)}{\sum_{i=1}^{2n} d_t^{(i/2)}}$$

This gives us par yield curves (covering the same maturities as the zero yields) going back to 1961. Next, we compute monthly total returns using the coupon-equivalent yields. For each maturity the total return is calculated as the sum of the price and yield return, where we take into account the roll-down effect due to the fact that for example a 10-year bond becomes a 9-year and 11 months bond after the one month holding period.

In addition, we obtain monthly US Treasury total returns made available through Barclays Live. As previously mentioned, these data only go back to 1987, but will serve as a comparison for the period where the two bond data sets overlap. This is useful as we want to make sure that using the par yields derived from the GSW parameters results in similar risk and return profiles to commonly used bond benchmarks.

Tables A1 and A2 display annualised risk and return statistics for equities and bonds over the period 1987–2016 where the two bond data sets overlap, using both GSW and Barclays data. The two tables confirm that we get very similar, and indeed virtually identical, results for the post-1986 period when using bond returns from Barclays rather than the GSW data used throughout the note.

Table A1: Annualised risk and return statistics for equities and bonds, 1987–2016 (GSW)

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio
CASH	3.37	0.75	0.00	NaN
UST_2y	4.85	1.93	1.48	0.82
UST_4y	5.97	3.70	2.60	0.71
UST_6y	6.79	5.16	3.42	0.66
UST_8y	7.35	6.32	3.98	0.63
UST_17y	8.47	9.56	5.10	0.53
UST_AGG	6.69	5.10	3.31	0.65
SPX	10.77	15.15	7.40	0.49

Table A2: Annualised risk and return statistics for equities and bonds, 1987–2016 (Barclays)

Asset class	Mean return	Standard deviation	Mean excess return	Sharpe ratio
CASH	3.37	0.75	0.00	NaN
UST_1_3	4.67	1.74	1.30	0.81
UST_3_5	5.87	3.62	2.49	0.69
UST_5_7	6.51	4.86	3.14	0.65
UST_7_10	6.99	6.30	3.62	0.57
UST_10	8.47	9.77	5.10	0.52
UST_AGG	6.16	4.53	2.79	0.62
SPX	10.77	15.15	7.40	0.49

Source: Gürkaynak, Sack and Wright (2006), Bloomberg, Barclays, NBIM

Following Adrian, Crump, Diamond and Yu (2016), who use the same bond data as in this note, we choose to split our full 1961–2016 sample into two subsamples: 1961–1986 and 1987–2016. Not only does this split facilitate a straightforward comparison of the two bond data sets, but splitting the sample into pre- and post-1987 will allow us to separate two very distinct regimes in terms of inflation, monetary policy and bond yields.

The Barclays US Treasury index is divided into five subindices based on the bonds' time to maturity. The five subindices are '1–3 year', '3–5 year', '5–7 year', '7–10 year' and '10+ year'. We therefore create similar maturity buckets, or rather duration-targeting portfolios, using the par yields derived from the GSW parameters. We set the maturity cut-offs for the par yields by matching the duration of those yields with the average duration of each Barclays maturity bucket. The corresponding maturity buckets for par yields are then '2 year', '4 year', '6 year', '8 year' and '17 year'. In addition, we define our bond index as the simple arithmetic average of the five maturity buckets. The advantage of this approach is twofold for the purpose of our analysis. First, by equally weighting the five constant-maturity bond proxies, we get an aggregate bond proxy with a constant maturity profile. Second, since we know the maturity of the five bond proxies, we are able to vary the maturity profile of the aggregate proxy and assess the portfolio implications of different variations.

Finally, we obtain monthly time series for the total return on the S&P 500 index and US 3-month Treasury bill rate through Bloomberg. All in all, this gives us a complete data set consisting of total returns for equities and bonds of different maturities covering the period 1961–2016. Throughout the analysis, we use a monthly rebalancing frequency for all multi-asset portfolios. We also assume zero trading costs throughout the note. Table A3 summarises the data items and sources used throughout the note.

Table A3: Data description (note: all return series are total returns)

Asset class	Sample start	Proxy index	Source
Equity	1961–2016	S&P 500 ('SPX Index') total return (inc. div.)	Bloomberg
Cash	1961–2016	3-month T-bill ('USGG3M Index')	Bloomberg
Treasury	1961–2016	Treasury constant-maturity 2-yr par yields	Gürkaynak, Sack and Wright (2006)
Treasury	1961–2016	Treasury constant-maturity 4-yr par yields	Gürkaynak, Sack and Wright (2006)
Treasury	1961–2016	Treasury constant-maturity 6-yr par yields	Gürkaynak, Sack and Wright (2006)
Treasury	1961–2016	Treasury constant-maturity 8-yr par yields	Gürkaynak, Sack and Wright (2006)
Treasury	1961–2016	Treasury constant-maturity 17-yr par yields	Gürkaynak, Sack and Wright (2006)
Treasury	1987–2016	Treasury maturity bucket 1–3 years	Barclays
Treasury	1987–2016	Treasury maturity bucket 3–5 years	Barclays
Treasury	1987–2016	Treasury maturity bucket 5–7 years	Barclays
Treasury	1987–2016	Treasury maturity bucket 7–10 years	Barclays
Treasury	1987–2016	Treasury maturity bucket 10+ years	Barclays
Equity	1900–2014	Global equities (21 countries)	Dimson, Marsh and Staunton (2015)
Cash	1900–2014	Global T-bills (21 countries)	Dimson, Marsh and Staunton (2015)
Treasury	1900–2014	Global bonds (21 countries)	Dimson, Marsh and Staunton (2015)

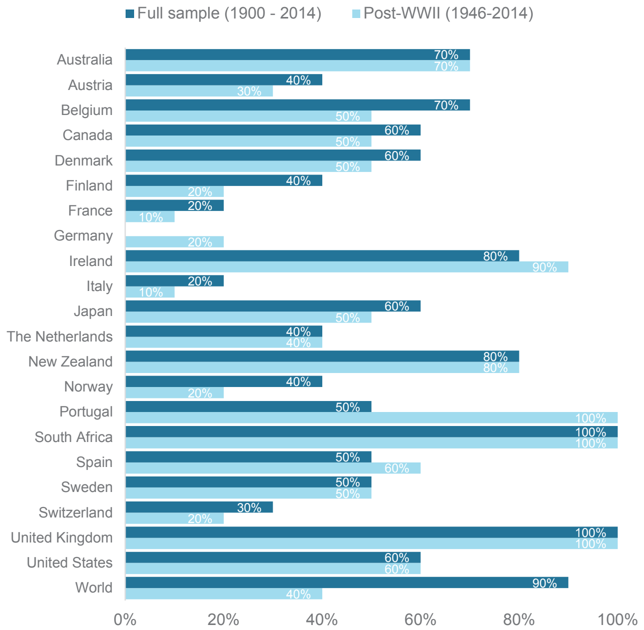
Source: Gürkaynak, Sack and Wright (2006), Dimson, Marsh and Staunton (2015), Bloomberg, Barclays, NBIM

Appendix B – Global Sharpe-optimal equity allocations, 1900–2014

We use the extensive DMS data set on global equities and bonds which currently covers 21 countries over the period 1900–2015. Throughout this note we have exclusively used data from the US. Indeed, many observers attribute the large realized ERP in the US to the success of the US economy and the US equity market (Ilmanen, 2012). This could potentially bias our results towards favouring a higher allocation to equities.

In order to check whether our findings are the result of events specific to the US or indeed can be applied more generally, we repeat the main analysis from Section 3 using the full cross-section of countries covered in the DMS data set. For each country, we compute Sharpe ratios across all variations of the equity-bond portfolio. Figure B1 shows the optimal equity allocation in country-by-country dual asset class portfolios. The chart includes numbers for the full DMS sample period, 1900–2014, and in addition we report the same numbers for the post-World War II period.

Figure B1: Global Sharpe-optimal equity allocations, 1900–2014



Source: Dimson, Marsh and Staunton (2015), NBIM calculations

The optimal equity share certainly has varied across the global sample, with a few instances of zero or close to zero percent having been the best equity allocation (e.g. Germany, France and Switzerland). At the other end of the scale, where equity shares of 100 or close to 100 have delivered the best risk-adjusted returns, we find countries such as UK, Ireland, New Zealand and South Africa. Taken together, most of the portfolios would have fared best with intermediate equity allocations in the range of 40–80 percent – with both mean and median roughly at 50 percent.

Note that the global Sharpe-optimal equity allocation drops from 90 to 40 percent when focusing on the post-WWII period. The big drop appears to be mainly due to relatively poor risk-adjusted performance of the global bond portfolio during the 1900–1945 period. In fact, the Sharpe ratio of this portfolio is twice as high at 0.3 during the 1946–2014 period compared to 0.14 over the first five decades of the sample. The global evidence suggests that the optimal equity allocation of 50–70 percent that we have observed is not unique to the US and as such cannot be attributed solely to survivorship bias.