Historical Returns of the Market Portfolio[ϕ]

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This second version contains an enhanced return series for real estate, an extended range of alternative portfolio allocations schemes in comparison to the Global Market Portfolio as well as textual additions and improvements.

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Abstract

Using a newly constructed unique dataset, we are the first to document returns of the market portfolio that contains basically all assets in which financial investors across the globe have invested. We analyze nominal, real, and excess return and risk characteristics of this global multi-asset market portfolio and the asset categories over the period 1960 to 2015. The GMP realizes a compounded real return of 4.36% with a standard deviation of 11.5% from 1960 until 2015. The compounded return of the GMP is 3.23% percentage points above the riskless rate. Our figures differ from those reported for aggregate wealth documented in recent literature. We also evaluate the performance of 51 alternative portfolio allocations with fixed weights and periodic rebalancing. These allocations range from a defensive to an offensive investment approach. We find support for their use as benchmarks for multi-asset portfolios, although they are not macro consistent.

Keywords: Asset Allocation, Benchmarking, Investing, Market Portfolio

JEL Classification: G11, G12

Introduction

This study aims to fill both a gap in the academic literature as well as a gap in return data availability for finance practitioners by providing returns of the global market portfolio (GMP). Our sample ranges from 1960 to 2015 and we take the perspective of an USD investor. Our GMP basically contains all assets in which financial investors have invested. A study on returns of the GMP has not been done before for such a long period and with such a level of detail. We document how we collected historical returns data on global asset classes, which is challenging for the period before 1985. Moreover, we make the resulting data publicly available so other researchers can use them in their own applications.

This paper contains unique features compared to the scarce academic literature on international asset returns. First, our sample period significantly extends the 1960-1980 period of Ibbotson and Siegel (1983), who are the first with a rigorous study on a global multi-asset market portfolio. They find a nominal compounded return of 8.36% for their so-called world market wealth portfolio over the period 1960-1980.[1] Compared to that study, we focus on assets in which financial investors have actually invested and which are publicly available. So, for example, we exclude farmland, family or state owned businesses, antiques, stamps, art and human capital as they usually belong to owners that do not hold it as a financial investment and hereby it is not widely publicly available. Ilmanen (2011, Appendix) also indicates that important parts of wealth are not investable.

Second, in comparison with Dimson, Marsh, and Staunton (2002)[2], a groundbreaking study that documents annual returns for equities, government bonds, and treasury bills in sixteen countries for the 101-year period 1900-2000, we include returns for more assets, for example corporate bonds and commercial real estate. Also, we use an all-maturity market capitalization weighted government bonds index instead of a GDP-weighted long term government bonds index. The latter is less useful for representing the performance of the asset class global government bonds.[3] Obviously, the length of their sample period remains unmatched.

This study on the returns of the GMP contains important information for both theoretical and practical applications. First, the mean-variance efficient frontier of Markowitz (1952) is the basis for the exploration that led to the CAPM. Tobin (1958) improves the efficient frontier by adding a risk-free asset. By combining the risk-free asset with the optimal portfolio on the efficient frontier we are able to construct the Capital Allocation Line (CAL). Every possible portfolio on the CAL has an ex-ante superior risk-adjusted expected return compared to other portfolios on the efficient frontier. However, neither Markowitz nor Tobin identified the asset mix of the portfolios on the efficient frontier. Sharpe's (1964) CAPM does so; he shows that the set of ex-ante optimal portfolios consists of the market portfolio, in which all risky assets are

[1] Ibbotson, Siegel and Love (1985) extend the results of the previous study from 1980 to 1984, while Ibbotson, Carr, and Robinson (1982) are seminal to document international equity and bond returns for a long historical sample.
[2] Updates are available at https://publications.credit-suisse.com/tasks/render/file/?fileID=B8FDD84D-A4CD-D983-12840F52F61BA0B.
[3] Using market cap weights causes lower-quality credits to be heavily represented due to the bums problem described in Siegel (2003).

weighed according to their market capitalization, plus long or short positions in the riskless asset. Roll (1977) argues that the CAPM cannot be tested as returns of the true market portfolio are unobservable, as they include all assets that economic agents hold, such as human capital, housing, and art. However, using a portfolio that closely resembles the market portfolio may have important implications for studies on asset prices. For example, Baltussen, Post, and Van Vliet (2012) indicate that the excess returns of equity value strategies are markedly smaller when evaluated against a CAPM-market portfolio consisting of both stocks and bonds, instead of the traditional use of only stocks. Although our study cannot resolve Roll's critique entirely, we aim to estimate the historical returns of the *invested* market portfolio as closely as possible. We do not guarantee that every asset in our *invested* market portfolio has also been fully *investable* at every point in historical time. But we expect that all of them will be in the future, as index providers typically require asset investability before they are included in their indexes.

Second, the GMP is also important for investors. It is an arithmetic fact that the average investor must hold the market portfolio. As Cochrane (2009) said, "*If any mass of investors follows new portfolio theory, then the return facts on which the advice is built will vanish. We can't all market-time, and we can't all buy value. The average investor can't even rebalance, despite common advice that we all should do so.*" One could add that the average investor can't even reinvest dividends or interest payments. Sharpe (2010) advocates that the market portfolio can be used as a starting point or benchmark for portfolio construction. The market portfolio reflects the average dollar invested in publicly available assets at any point in time. Moreover, passive investors in the GMP save costs of trading since, apart from reinvesting dividends and interest coupon payments, only marginal rebalancing is required due to differences in net issuance of asset classes. Sharpe (1991) argues that investors without a reason to deviate from the average should keep their costs as low as possible by being passive investors. As far as we know, there is no commercial index provider that has offered its clients access to a global market index, let alone with a history back to 1960. Our effort can be seen as an attempt to satisfy the need of practitioners that otherwise would be deprived of this return series.

Third, this new data set enables an extensive analysis of return and risk characteristics of the GMP and the asset categories over the period 1960 to 2015. We include conditional analyses on recessionary and inflationary periods. Also, this new data set provides an opportunity to gauge the difference in return and risk for the GMP and the riskless rate. Moreover, we evaluate the performance of 51 alternative portfolios allocations, ranging from defensive to offensive investment styles, with annual rebalancing. These 51 portfolios all take Graham's (1949) notion that the allocation to equities should be between 25% and 75%, and the allocation to bonds the inverse range of 75% to 25%, as a starting point. This analysis will also touch upon mean-reversion across asset classes. Moreover, this analysis reflects an approach which is common in the asset management industry to measure the performance of multi-asset portfolios. Such benchmarks are easy to construct and also match investor risk profile classifications.

Our main findings can be summarized as follows. The GMP realizes an average compounded real return of 4.40% with a standard deviation of 11.5% from 1960 until 2015, gross of trading costs, taxes and/or any management fees. The arithmetic average real return of the GMP of 5.05% is somewhat above the figures from Piketty (2014), but the numbers are not that easy to compare as, apart from other methodological differences, he defines capital as household wealth and uses national account data for calculating returns. We report lower returns than Jordà e.a. (2017), but again an easy comparison is hindered by the fact that our focus is on the investable GMP for financial investors instead of aggregate wealth. In recessions, the average annual real return of the GMP differs a statistically significant 9.37 percentage points from the return in expansions. In the inflationary period from 1960 to 1979 the average real return is 3.38 percentage points below the return in the disinflationary period from 1980 to 2015, but this gap is statistically insignificant. The reward for the GMP is a compounded return of 3.26 percentage points above the riskless rate. The real return of the GMP lies 0.82 percentage points below the mean-variance efficient frontier, but, ex-post the market portfolio is never mean-variance efficient. Finally, we show that all 51 alternative portfolio allocations that we consider have a higher Sharpe ratio than the GMP. This finding is robust for incorporating transactions costs in our analysis, changing the portfolio rebalancing frequency or splitting the sample into sub-periods.

In the next section, we discuss the returns of the GMP and the four asset categories Equities Broad, Real Estate, Nongovernment Bonds and Government Bonds Broad over the period 1960 until 2015. In the subsequent section, we examine the ex-post mean-variance efficient frontier. Afterwards we analyze the performance of alternative portfolio allocations relative to the GMP. The final section summarizes and contains our conclusions.

Returns of the Global Market Portfolio 1960-2015

We define the GMP as all assets held by financial investors. We distinguish four asset categories. The asset category Equities Broad contains the asset classes equities and private equity, the asset category Real Estate resembles the asset class real estate, the asset category Nongovernment Bonds contains the asset classes investment grade credits and high yield bonds, and the asset category Government Bonds contains the asset classes government bonds, inflation-linked bonds, and emerging market debt. All asset classes are nowadays easily available for both institutional and retail investors through active as well as passive mutual funds.

Private equity and real estate can be listed, i.e. listed companies whose primary business it is to invest in private equity respectively real estate, or non-listed. We assume the quality of return data of listed assets to be higher, as they are based on transaction prices. Therefore, in this study we use listed returns also as a proxy for unlisted assets. This approach is in line with Ibbotson (2006) who states "*Although all investors may not yet agree that direct commercial real estate investments and indirect commercial real estate investments (REITs) provide the same risk-reward exposure to commercial real estate, a growing body of research indicates that investment returns from the two markets are either the same or nearly so.*".[4]

As we outline in Appendix A, there are listed returns available for private equity since 1994. For 1990-1993 we estimate these returns. Before 1990, we do not take private equity returns into account in our Equities

[4] Pagliari, Scherer and Monopoli (2005) found that, controlling for difference in leverage, the returns on private real estate and listed real estate do not notably differ. Oikarinen, Hoesli and Serrano (2011) confirm this.

Broad Index, which implicitly means we use equity returns. This introduces just a minor bias as the weight of private equity in the asset category Equities Broad amounts to 1.7% at the end of 1990 while back then it represents 0.9% in the market portfolio. For real estate we use listed returns since 1972, before 1972 we partly base our data on listed returns and partly on intrinsic values.

Although Jordà e.a. (2017)[5] report housing to be around half of their documented wealth, we do not distinguish housing as a separate asset class. For financial investors, housing offers limited availability. To illustrate, homeownership in the US is about 65% according to data from US Census Bureau, while in Germany and France about 85% of the houses is owner occupied and in the UK the household share is even 95%, see Piketty and Zucman (2014). To underline, at the end of our sample period, the market value of commercial real estate in the GPR General World Index is seven times the value of residential real estate. In the US, the value of listed commercial REITs exceeds the value of residential REITs by factor five at year-end 2015 according to REITWatch (2016). Also, for a large part of our sample period, investability is further constrained by the required amount of money to compose a diversified residential real estate portfolio. Residential REITs or residential investment funds were not readily available. Even now, we are not aware of a single listed fund that offers exposure to the international residential real estate market, let alone a global fund. So, in this study, real estate returns primarily reflect the transaction prices based return on an investment in (leveraged) global commercial real estate, a reflection of the investable real estate universe.

We do not include hedge funds or commodities. Hedge funds are vehicles that primarily employ active strategies in (derivatives on) asset classes that we already cover. Including them would result in double counting. Investments in commodities are typically in derivatives contracts, which are in zero-net-supply.

For each asset category, we compose a total return series in US dollars. With these series, we basically cover the whole global invested market. We refer to Appendix A for details on the construction of our return series. We also perform robustness checks on our return series, for which we report the results in Appendix B. The robustness checks suggest that our data set of returns is reliable. Despite that we find indications that our data represent good estimates for historical returns, we are aware that our estimates are surrounded by uncertainty. Finally, appendix C describes the market capitalizations we use to arrive at the market capitalization weighted returns of the GMP.

Nominal returns

Table 1 shows the statistical properties based upon the annual nominal returns of the GMP and its four asset categories from 1960 until 2015. We also include the risk-free return and inflation in the table. As we report

[5] Jordà e.a. (2017) compose a new impressive data set that contains returns on housing next to equities, government bonds and bills. Their sample contains sixteen countries and their data series start as early as 1870. Our study differs in several ways from Jordà e.a. (2017). First and foremost, the focus of our study is on assets with investability for financial investors instead of aggregate wealth. Second, we compile a global market capitalization weighted return series, which is at the center of this study. Third, our study includes more assets, like commercial real estate and corporate bonds. Fourth, we use an all maturity government bonds index instead of long-term government bonds. Clearly, our sample period cannot touch upon the length of their sample period.

Table 1

Statistical properties for nominal returns (1960-2015)

	GMP	EB	RE	NGB	GBB	TB	CPI*
Compounded average return (%)	8.37	9.46	10.48	7.44	6.98	4.95	3.80
Arithmetic average return (%)	8.99	11.03	12.41	7.71	7.21	5.00	3.84
Standard deviation (%)**	11.46	17.76	20.44	7.89	7.12	3.31	2.93
Minimum annual return (%)	-24.40	-43.52	-41.84	-3.33	-5.28	0.03	-0.02
Maximum annual return (%)	35.61	42.80	58.17	33.50	27.19	15.27	13.25
Maximum cumulative drawdown (%)	-24.40	-43.52	-43.47	-3.33	-8.24	0.00	-0.02
# years with return < 0%	14	15	15	8	6	0	1
# years with return < -10%	2	7	5	0	0	0	0
Longest period cumulative R < 0%	3	5	6	1	3	0	1
Avg. return when R(GMP) < 0% (%)	-6.38	-13.50	-5.97	3.03	4.75	5.00	4.35
Avg. return when R(GMP) > 0% (%)	14.11	19.20	18.54	9.27	8.03	5.00	3.68
Avg. return in recessions (%)	3.41	2.67	3.11	6.79	7.06	6.43	5.28
Avg. return in expansions (%)	11.22	14.37	16.14	8.08	7.27	4.43	3.27
Avg. return inflationary period (%)	7.80	9.48	12.70	6.56	6.11	5.37	4.98
Avg. return disinflationary period (%)	9.65	11.88	12.26	8.35	7.82	4.80	3.21
Sharpe ratio	0.34	0.34	0.36	0.34	0.31	-	-
Sortino ratio	1.97	1.28	1.46	8.45	6.09	-	-
Skewness	-0.37	-0.67	-0.06	1.18	0.74	0.64	1.63
Kurtosis	0.71	0.52	0.17	2.02	0.42	0.75	2.62
P-value JB	[0.296]	[0.092]	[0.948]	[0.000]	[0.064]	[0.078]	[0.000]

* Global Market Portfolio (GMP), Equities Broad (EB), Real Estate (RE), Nongovernment Bonds (NGB), Government Bonds Broad (GBB), 3-month Treasury-bills (TB) and inflation (CPI).

**Here and in following tables we likely slightly underestimate the standard deviation of Real Estate as in our return calculation we partly use intrinsic values instead of returns based on market prices from 1960 to 1971.

all returns in US dollars, we use US Treasury bills for the risk-free rate and US inflation to convert nominal returns to real returns in our analyses. This mirrors the methodology of Dimson, Marsh and Staunton (2002).[6] During our 56-year sample period, the GMP delivers a compounded annual return of 8.37%, gross of trading costs, taxes and/or any management fees. Real Estate realizes the highest compounded annual

[6] We use three-month secondary market Treasury bills. For inflation, we use the seasonally adjusted consumer price index for all urban consumers from the Bureau of Labor Statistics.

return with 10.48%, followed by Equities Broad (9.46%), Nongovernment Bonds (7.44%) and Government Bonds (6.98%). An investment in three-month Treasury bills would have returned 4.95%, while inflation has averaged 3.80% during our sample period. This implies that the equity (real estate) return has been 4.51 (5.53) percentage points above cash, the multiplicative premium is 4.30 (5.27) percentage points. The, statistically insignificant, global return premium of Real Estate versus Equities Broad is 1.00 percentage points, or a geometric 0.92 percentage points. This looks like figure for the US. The, also statistically insignificant, geometric return difference between the FTSE/NAREIT Equity REIT Index and the S&P500 is 1.59 percentage points from its inception at year-end 1971 to 2015. For this period, the global figure is 0.50 percentage points. The excess return of real estate might be partially attributable to the premium for small cap value stocks, see Anderson e.a. (2005). Standard deviations for the asset categories vary from 7.1% for Government Bonds Broad to 20.4% for Real Estate.[7] The GMP has a standard deviation of 11.5%.

Besides the more usual statistics in Table 1, we also report data for which we split the sample into recessions and expansions based on NBER data. Here, we assign a recession label to years with at least one quarter in an official NBER recession. Also, we distinguish an inflationary environment, being the period 1960-1979 as inflation was in an uptrend, and a disinflationary environment from 1980 onwards. In periods of recession, not surprisingly, Equities Broad and Real estate return less than the GMP. But, in both inflationary and disinflationary environments they return more than the GMP. Nongovernment bonds and Governments Bonds Broad only return more than the GMP in a recession.

If we adjust the returns for risk by the Sharpe and Sortino ratios[8], it appears that the Sharpe ratio of the GMP lags the one for Real Estate. The asset category Government Bonds Broad has the lowest Sharpe ratio of all. The Sortino ratio shows a different picture. Then, the GMP lags Nongovernment Bonds and Government Bonds Broad, whereas it is ahead of Equities Broad and Real Estate. The skewness of the GMP is -0.37, which indicates that returns have an asymmetric probability distribution with extreme observations or more observations on the left side of the return distribution. The excess kurtosis has a value of 0.71, which means that the distribution of nominal returns has fatter tails than the normal distribution. However, we do not reject the null hypothesis that the returns of the GMP are normally distributed at a significance level of 5%, using the Jarque and Bera (1987) test.[9]

Real returns

Real returns are useful as these provide insight in the development of purchasing power through time, so we adjust the returns for inflation[10]. Figure 1 shows the cumulative real return of the GMP and the four asset categories. The real value of the GMP grows from 100 at the end of 1959 to 1,113 at year end 2015, which

[7] Pagliari (2017) notes that the measured volatility of private (unleveraged) real estate as measured by NCREIF Property is only 2/3 of that of public real estate equity as measured by NAREIT Equity over the period 1978-2013. However, Sharpe ratios for annual investment horizons are similar with 0.51 and 0.47.

[8] For more on the Sharpe and Sortino ratios, see Sharpe (1994) and Sortino and Price (1994) respectively. The minimum required rate of return is 0% in our calculation of the Sortino ratio.

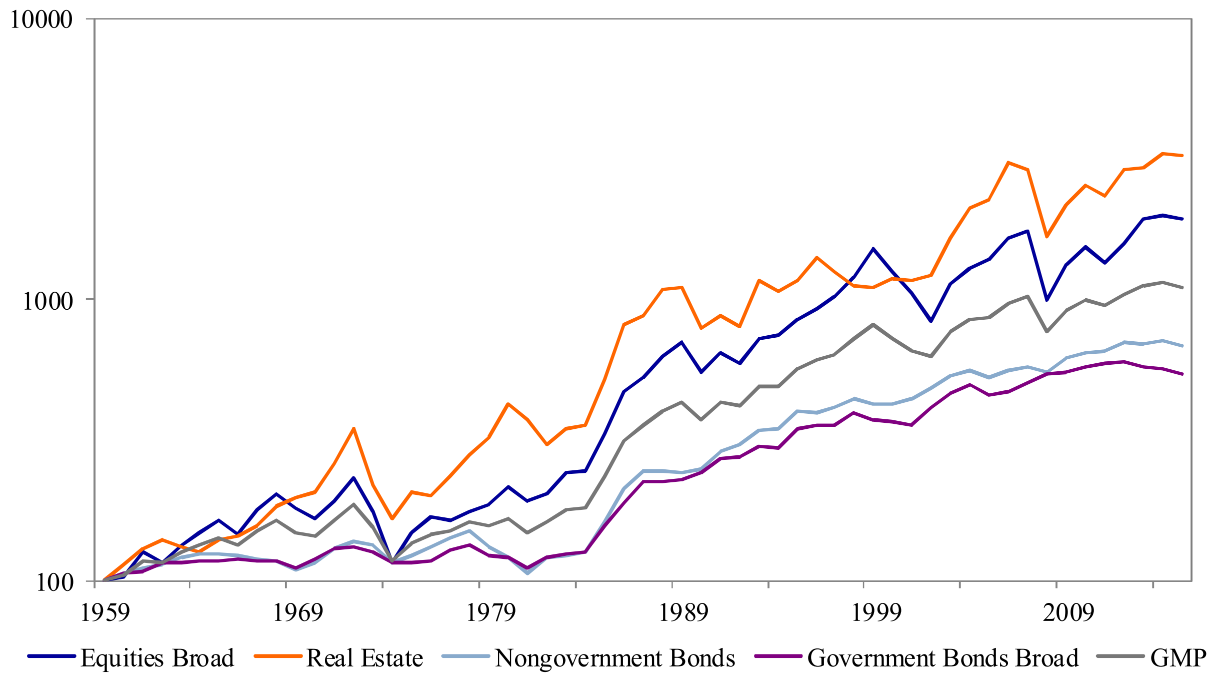
[9] Throughout this article, we maintain a significance level of 5% for all significance tests.

[10] We use geometric return calculations for real and excess returns.

implies a compounded annual return of 4.40%. Real Estate reaches a value of 3,284 (6.43%), followed by Equities Broad with 1,954 (5.45%), Nongovernment Bonds with 687 (3.50%) and Government Bonds Broad with 541 (3.06%). The risk-free asset grows to 185 and delivers a compounded annual return of 1.10%.

Figure 1

Cumulative Real Return of the GMP and the Four Asset Categories (1959-2015)



The arithmetic average real return of the GMP of 5.05% is somewhat above the figures from Piketty (2014). He estimates a return on capital of 4.9% for the period 1960-2015 for France and 3.9% for the UK for the period 1960-2010[11,12], and labels the combination of these series global. Our compounded return of 4.40%, which might be a better measure for a comparison as returns from Piketty are rather stable, falls in the middle of France and the UK. But, apart from the fact that Piketty's returns are not truly global, are in local currency and likely have lower standard deviations (unreported), the figures are not easy to compare for several reasons. First, Piketty (2014) defines capital as household wealth and derives his return figures from macro-economic data by dividing the total of various kinds of capital income by the aggregate stock of capital. Second, the equities part of the GMP is not fully entitled to economic growth, as a significant part of economic growth results from what Bernstein and Arnott (2002) label 'entrepreneurial capitalism'. New enterprises create a dilution effect that causes earnings and dividends from existing companies to grow slower than the economy. Finally, Bonnet e.a. (2014) argue that Piketty's return is mainly driven by rising housing prices, while housing has just a marginal weight in the GMP.

[11] The GMP realizes an average arithmetic real return of 5.31% in the period 1960-2010.

[12] We derive these figures from the Technical Appendix to Piketty (2014) which is available on his website http://piketty.pse.ens.fr/en/capital21c2. We used the data files belonging to chapter six (sheet TS6.1 and TS6.2) and ten (sheet TS10.3).

Jordà e.a. (2017) report a GDP weighted cross sample arithmetic average real return on capital for their sixteen countries of 6.58% in local currencies for the 1950-2015 sub period. The separate figure for equities is 8.22%, for housing 7.44%, for bonds 2.60% and for bills 1.17%. An estimate for the arithmetic average real return on our GMP for 1950-2015 would be roughly 5.6% in US dollars.[13] Although they do not compose a global wealth portfolio, they do provide equally weighted (across countries) US-dollar geometric real returns for the period 1950-2015 with 3.10% for bonds, 6.36% for equities and 8.67% for housing. An estimate for the compounded average return for our GMP over that period would be roughly 5.0%. Given the fact that housing constitutes approximately half of their wealth portfolio and the high return figures they report for housing, it is rather likely that the (unreported) market capitalization weighted return on capital of global wealth would have been above the return of our GMP for financial investors. Although Jordà e.a. (2017) provide valuable insights into the return on aggregate wealth, it should be obvious that their results may not be confused with return and risk characteristics of the investable GMP for financial investors.

Table 2 shows additional statistical properties for real returns. Sharpe ratios are close to each other. However, taking downward risk into account as measured by the Sortino ratio, Nongovernment Bonds and Government Bonds perform the best. In the inflationary period from 1960 to 1979, the average annual real return of the GMP is 2.88% (compounded this is 2.28%, not reported in table), while in the disinflationary period from 1980 to 2015 the GMP has an average return of 6.25% (compounded 5.59%). So, the gap between both periods is 3.38 percentage points. However, this difference is not statistically different, contrary to returns in recessions and expansions which differ 9.37 percentage points, i.e. a return of -1.64% in recessions and 7.73% in expansions (significance tests unreported).

As can be seen from Figure 1, the real return for the GMP is relatively low, although positive, in the first and last parts of the period studied. Table 3 shows the compounded real returns over several periods. The returns shown on the diagonal are decade-by-decade returns. There, it is also obvious that the eighties and nineties produced higher returns than other decades, for both the GMP and the asset categories, with Real Estate being the only exception in the nineties. To illustrate, the GMP yields a real return in the eighties and nineties of 10.61% and 6.63% respectively, while the other four decades delivered, in chronological order, 3.99%, 0.60% and 1.12%. For the last six years of our sample, the GMP returned on average 3.32% per year. As also can be seen in Table 3, there has not been a single calendar decade in our sample period with a negative compounded real return for the GMP or the asset categories, Equities Broad being the exception for the 2000-2009 period.

Table 4 panel A shows the correlation matrix for real returns. The returns of Government Bonds Broad have the lowest correlation with those of the GMP, as well as with Equities Broad and Real Estate. Equities Broad's returns have the highest correlation with returns of the GMP since Equities Broad has the highest average weight of all asset categories in the GMP during the period of 56 years.

[13] Here, to get an indication, we use an annualy rebalanced 50/50 equities and government bonds portfolio for the period 1950-1959 with returns from Dimson, Marsh and Staunton (2015b).

Table 4 panel B shows separate correlations for up markets (upper right part of the matrix), and down markets (lower left matrix) of the GMP. For return correlations between the GMP and for Equities Broad or Real Estate, it appears that correlations are higher in down markets. This is in line with results reported by Chow, Jacquier, Kritzman, and Lowry (1999). This also applies to the correlations of returns for Equities and Real Estate themselves. The reverse applies to Nongovernment Bonds and Government Bonds Broad. The negative correlation between Equities Broad and Government Bonds Broad in down markets illustrates the benefits of diversification.

Table 2

Statistical properties for real returns (1960-2015)

	GMP	EB	RE	NGB	GBB	TB*
Compounded average return (%)	4.40	5.45	6.43	3.50	3.06	1.10
Arithmetic average return (%)	5.05	7.02	8.29	3.82	3.30	1.13
Standard deviation (%)	11.55	17.51	19.64	8.34	7.24	2.30
Minimum annual return (%)	-24.90	-43.51	-41.82	-13.43	-8.34	-3.42
Maximum annual return (%)	33.53	41.12	56.31	30.73	22.55	7.24
Maximum cumulative drawdown (%)	-37.79	-50.05	-52.25	-29.10	-17.19	-10.69
# years with return < 0%	16	16	18	16	18	18
# years with return < -10%	6	11	8	3	0	0
Longest period cumulative R < 0%	12	10	7	6	6	9
Avg. return when R(GMP) < 0% (%)	-9.23	-15.06	-7.17	-1.44	0.44	0.49
Avg. return when R(GMP) > 0% (%)	10.76	15.86	14.48	5.93	4.45	1.38
Avg. return in recessions (%)	-1.64	-2.36	-2.03	1.63	1.82	1.12
Avg. return in expansions (%)	7.73	10.78	12.42	4.70	3.90	1.13
Avg. return inflationary period (%)	2.88	4.53	7.48	1.63	1.17	0.42
Avg. return disinflationary period (%)	6.25	8.41	8.75	5.04	4.49	1.52
Sharpe ratio	0.35	0.34	0.36	0.32	0.30	-
Sortino ratio	0.81	0.69	0.84	1.09	1.21	1.19
Skewness	-0.36	-0.64	-0.09	0.77	0.72	0.37
Kurtosis	0.78	0.43	0.43	2.11	0.46	0.11
P-value JB	[0.265]	[0.119]	[0.772]	[0.000]	[0.068]	[0.526]

* Global Market Portfolio (GMP), Equities Broad (EB), Real Estate (RE), Nongovernment Bonds (NGB), Government Bonds Broad (GBB) and 3-month Treasury-bills (TB).

Table 3

Average compounded real returns by decade (%)

From →: To ↓:	1960	1970	1980	1990	2000	2010
Global Market Portfolio						
1969	3.99					
1979	2.28	0.60				
1989	4.99	5.49	10.61			
1999	5.40	5.87	8.60	6.63		
2009	4.53	4.66	6.05	3.84	1.12	
2015	4.40	4.48	5.59	3.72	1.94	3.32
Equities Broad						
1969	6.07					
1979	3.16	0.33				
1989	6.72	7.05	14.22			
1999	7.02	7.34	11.03	7.93		
2009	5.33	5.14	6.80	3.27	-1.19	
2015	5.45	5.32	6.75	4.00	1.62	6.48
Real Estate						
1969	7.01					
1979	6.05	5.10				
1989	8.32	8.98	13.00			
1999	6.21	5.94	6.36	0.11		
2009	6.36	6.19	6.56	3.47	6.95	
2015	6.43	6.31	6.64	4.30	7.00	7.08
Nongovernment Bonds						
1969	0.92					
1979	1.40	1.89				
1989	2.98	4.03	6.20			
1999	3.68	4.62	6.00	5.81		
2009	3.72	4.43	5.30	4.85	3.89	
2015	3.50	4.07	4.69	4.11	3.06	1.70
Government Bonds Broad						
1969	1.02					
1979	1.05	1.07				
1989	2.80	3.70	6.40			
1999	3.35	4.13	5.70	5.00		
2009	3.48	4.10	5.14	4.51	4.02	
2015	3.06	3.51	4.20	3.36	2.35	-0.38

Table 4

Correlations of annual real returns (1960-2015)

	GMP	EB	RE	NB	GBB
Panel A.					
GMP	1.00				
Equities Broad (EB)	0.96	1.00			
Real Estate (RE)	0.76	0.74	1.00		
Nongovernment Bonds (NB)	0.70	0.50	0.48	1.00	
Government Bonds Broad (GBB)	0.52	0.28	0.34	0.87	1.00
Panel B. Correlations in up markets in the upper right part, down markets in the lower left part.					
GMP	1.00	0.89	0.65	0.76	0.68
Equities Broad (EB)	0.91	1.00	0.59	0.45	0.29
Real Estate (RE)	0.80	0.80	1.00	0.41	0.36
Nongovernment Bonds (NB)	0.42	0.04	0.15	1.00	0.88
Government Bonds Broad (GBB)	0.19	-0.22	-0.02	0.82	1.00

Excess returns

We close this section by documenting excess returns. The data offer the opportunity to compare the return of the average investment portfolio to a risk-free investment held by savers. The compounded return for the GMP is 3.26 percentage points above the riskless rate, as shown in Table 5. The standard deviation is 11.2%. In 18 of the 56 years the GMP ends with a lower return than the riskless rate, the remaining 38 years the return of the GMP ends above the riskless rate. The GMP realizes a maximum annual loss of wealth of 25.44% and a maximum cumulative loss of 34.67%, compared to the results for the riskless rate. The longest period that the cumulative return of the GMP lagged the risk-free investment is 12 years, from 1973 through 1984. In years with a down market the GMP loses on average 8.88 percentage points relative to the risk-free investment, in years of a recession 2.70 percentage points. In both inflationary and disinflationary environments, the GMP is on average better off than the risk-free investment.

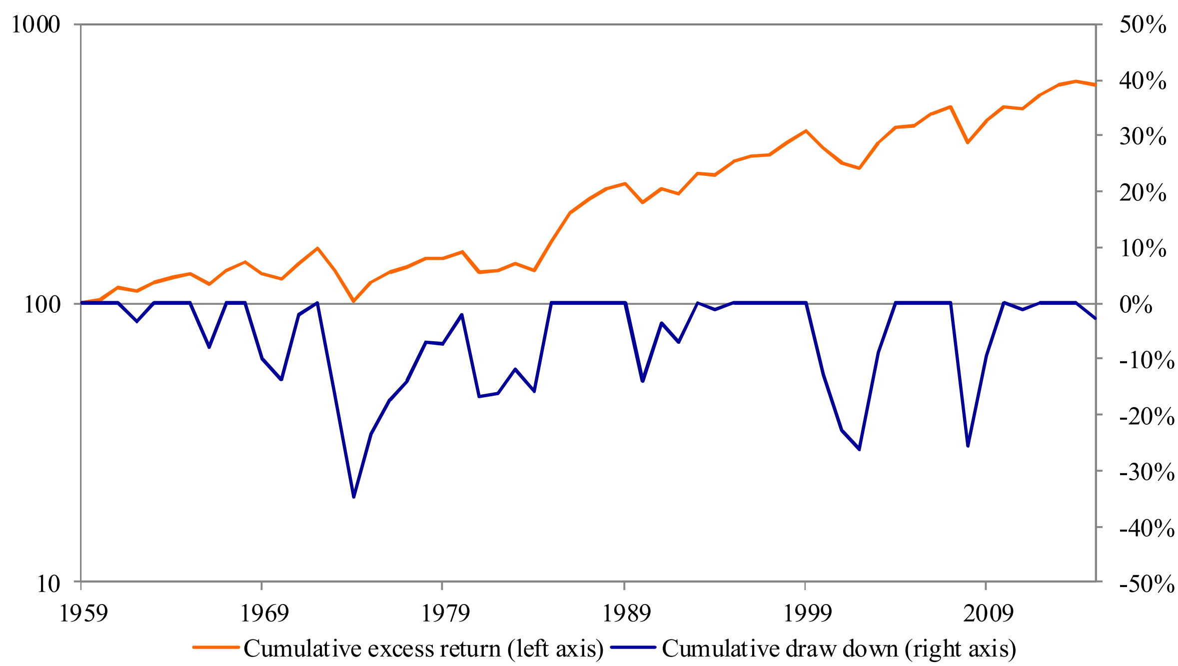
Figure 2 shows that a cumulative index of excess returns has risen considerably over time, compounding to a 519% gain over the 56-year study period (see the log scale on the left axis). The figure also shows that the investor experienced three drawdowns in excess of 20% relative to the saver: 35% in 1974, 26% in 2002, and 25% in 2008 (right axis).

Table 5
Statistical properties for excess returns (1960-2015)

	GMP	EB	RE	NGB	GBB*
Compounded average return (%)	3.26	4.30	5.27	2.37	1.94
Arithmetic average return (%)	3.87	5.83	7.16	2.67	2.16
Standard deviation (%)	11.17	17.24	19.66	7.90	6.88
Minimum annual return (%)	-25.44	-44.31	-42.64	-15.98	-13.13
Maximum annual return (%)	27.18	37.78	48.88	24.51	17.91
Maximum cumulative drawdown (%)	-34.67	-47.54	-49.85	-32.33	-22.97
# years with return < 0%	18	18	19	21	25
# years with return < -10%	8	10	8	3	1
Longest period cumulative R < 0%	12	7	7	7	14
Avg. return when R(GMP) < 0% (%)	-8.88	-13.96	-7.44	-1.90	-0.42
Avg. return when R(GMP) > 0% (%)	9.91	15.20	14.07	4.83	3.38
Avg. return in recessions (%)	-2.70	-3.37	-2.96	0.53	0.71
Avg. return in expansions (%)	6.51	9.51	11.21	3.52	2.74
Avg. return inflationary period (%)	2.40	4.02	6.99	1.18	0.74
Avg. return disinflationary period (%)	4.70	6.84	7.25	3.49	2.95
Sharpe ratio	0.35	0.34	0.36	0.34	0.31
Sortino ratio	0.60	0.57	0.69	0.70	0.69
Skewness	-0.42	-0.58	-0.15	0.42	0.48
Kurtosis	0.33	0.32	0.03	0.72	-0.12
P-value JB	[0.382]	[0.181]	[0.905]	[0.241]	[0.340]

* Global Market Portfolio (GMP), Equities Broad (EB), Real Estate (RE), Nongovernment Bonds (NGB) and Government Bonds Broad (GBB).

Figure 2
Excess returns and drawdowns for excess returns of the GMP (1959-2015)



We conclude our discussion of returns with Table 6, which is an overview of the market capitalization and the composition of the GMP, as well as the nominal, real and excess returns of the GMP for each year in our sample period 1959-2015. The market capitalization of the GMP amounted to USD 101 trillion year-end 2015. Again, we refer to Appendix C for market capitalizations as we focus on returns in this study. Now that we have investigated the historical returns of the GMP and its underlying four asset categories, we show the mean-variance efficient frontier and the capital asset line in the next section.

The Mean-Variance Frontier of the Four Asset Categories

Figure 3 depicts the mean-variance efficient frontier of the four asset categories based upon the annual real returns from 1960 until 2015.[14] On the vertical axis, we have the average real return from 1960 until 2015. On the horizontal axis, we have the standard deviations of the portfolios. All individual asset categories lie below the efficient frontier since a portfolio of different asset categories provides diversification advantages. The average real risk-free rate is 1.13% for this period. Thus, on the efficient frontier we find portfolios with higher realized Sharpe ratios than the GMP. The point at the efficient frontier which has the same standard deviation lies 0.82 percentage points above the arithmetic average real return of 5.05% from the GMP. But, ex-post, the market portfolio is never mean-variance efficient.

The Capital Allocation Line (CAL) combines the risk-free asset with the tangency portfolio on the efficient frontier. The tangency portfolio contains the highest Sharpe ratio of all portfolios on the efficient frontier. Its composition is 17% Equities Broad, 23% Real Estate, 0% Nongovernment Bonds and 60% Government Bonds Broad. The CAL contains portfolios with the highest realized Sharpe ratios.

Figure 4 draws the composition of each of the portfolios on the efficient frontier.[15] The portfolio weight of Government Bonds Broad decreases monotonically, whereas the portfolio weight of Real Estate increases monotonically if we require portfolios with higher average returns. Until an average arithmetic return of 7.91% the weight of equities broad increases, since beyond that return solely real estate can keep track with the required return of the portfolio. Based upon the mean-variance optimization nongovernment bonds do not appear in any portfolio.

In the following section, we evaluate the performance of alternative allocations that rebalance portfolios with fixed asset allocation weights.

[14] The mean-variance frontier is constructed with arithmetic annual returns.

[15] All portfolios on the efficient frontier are fully invested and short selling is not allowed. These restrictions are often realistic and binding in practice.

Table 6

End of year market capitalization, index weights and return of the global market portfolio (%)

Year	Market value (USD tn)	Composition				Returns		
		Equities Broad	Real Estate	Nongovern-ment Bonds	Government Bonds Broad	Nominal return	Real return	Excess return
1959	0.6	51.6	1.4	17.6	29.4			
1960	0.7	49.9	1.3	17.7	31.1	6.0	4.6	2.9
1961	0.8	54.1	1.2	15.5	29.1	13.6	12.8	10.9
1962	0.8	50.9	1.4	16.8	30.9	-0.6	-1.8	-3.4
1963	0.8	54.2	1.4	16.2	28.2	10.4	8.7	7.0
1964	0.9	56.7	1.4	15.3	26.6	8.1	6.8	4.2
1965	0.9	58.9	1.5	14.4	25.3	8.0	6.0	3.8
1966	0.9	57.3	1.7	14.8	26.3	-3.2	-6.3	-7.8
1967	1.0	62.0	1.6	13.0	23.3	16.0	12.3	11.1
1968	1.1	64.4	1.6	12.5	21.5	13.8	8.7	7.8
1969	1.1	63.9	2.0	12.6	21.6	-3.9	-9.3	-10.2
1970	1.1	61.4	2.1	13.4	23.1	2.7	-2.8	-3.8
1971	1.3	60.4	2.0	14.4	23.2	18.5	14.7	13.4
1972	1.5	63.3	1.8	13.8	21.1	17.8	13.9	13.1
1973	1.5	59.8	2.1	14.9	23.1	-9.8	-17.2	-16.0
1974	1.3	49.2	3.0	18.0	29.7	-15.8	-24.9	-22.2
1975	1.6	50.8	2.6	18.0	28.7	24.1	15.8	17.0
1976	1.9	50.0	2.2	17.8	30.0	13.5	8.1	7.9
1977	2.1	44.7	2.3	18.8	34.2	9.9	3.0	4.2
1978	2.5	42.7	2.2	18.6	36.4	16.5	6.8	8.3
1979	2.8	45.8	2.3	16.3	35.5	10.4	-2.5	-0.4
1980	3.4	48.8	2.2	14.8	34.3	18.5	5.4	5.5
1981	3.4	47.0	2.5	14.8	35.8	-2.0	-10.1	-15.0
1982	3.7	45.7	2.4	14.9	37.0	12.2	8.1	0.8
1983	4.4	48.7	2.1	13.3	35.9	14.9	10.7	5.3
1984	4.5	48.4	2.2	13.1	36.3	5.3	1.2	-4.5
1985	6.0	49.6	2.8	12.7	35.0	35.6	30.7	25.7
1986	8.0	52.9	3.4	11.6	32.1	35.1	33.5	27.2
1987	8.8	55.3	4.1	10.8	29.8	19.1	14.1	12.3
1988	10.4	58.4	5.1	9.7	26.7	16.4	11.5	8.8
1989	11.6	60.4	4.9	9.3	25.4	12.6	7.6	3.7
1990	10.9	52.5	4.1	11.6	31.8	-7.1	-12.6	-13.9
1991	13.1	52.6	3.7	11.8	31.8	18.2	14.7	11.9
1992	13.5	50.3	3.6	12.5	33.6	0.0	-2.9	-3.5
1993	16.4	53.0	4.4	8.8	33.9	20.6	17.3	17.0
1994	17.5	55.6	4.5	7.5	32.4	3.2	0.6	-1.1
1995	20.5	56.5	4.0	7.6	31.9	18.4	15.5	12.0
1996	23.1	57.1	5.3	7.3	30.3	10.0	6.4	4.6
1997	25.5	59.7	4.8	8.1	27.4	7.1	5.3	1.7
1998	32.6	57.1	3.8	14.3	24.8	15.3	13.5	9.9
1999	39.0	63.6	3.3	11.8	21.3	15.6	12.6	10.3
2000	38.4	60.5	3.3	15.1	21.1	-7.5	-10.6	-12.8
2001	35.9	54.9	3.8	18.3	23.0	-8.4	-9.9	-11.6
2002	35.5	45.1	3.9	22.3	28.7	-2.9	-5.3	-4.5
2003	45.7	48.6	4.4	20.2	26.9	25.1	22.6	23.9
2004	53.2	49.3	4.7	18.6	27.4	14.2	10.6	12.7
2005	56.3	52.6	5.0	17.0	25.4	4.8	1.4	1.6
2006	65.8	53.9	6.0	16.1	24.0	16.3	13.4	10.9
2007	71.8	53.4	5.6	16.7	24.3	9.4	5.0	4.6
2008	56.3	40.5	3.5	21.6	34.4	-24.4	-24.4	-25.4
2009	72.1	42.3	4.0	21.1	32.5	21.5	18.2	21.3
2010	81.3	42.9	4.3	19.6	33.2	10.7	9.1	10.5
2011	81.2	39.4	4.5	20.4	35.7	-1.0	-3.9	-1.0
2012	90.6	40.0	5.1	20.2	34.8	11.5	9.6	11.4
2013	99.1	44.5	5.3	19.0	31.1	9.1	7.5	9.1
2014	102.9	44.1	5.9	18.9	31.2	2.6	1.9	2.6
2015	101.0	43.7	6.1	19.1	31.1	-2.7	-3.3	-2.7
Average	-	52.3	3.3	15.1	29.3	9.0	5.0	3.9

Figure 3

Mean-variance efficient frontier for the four asset categories, 1960-2015

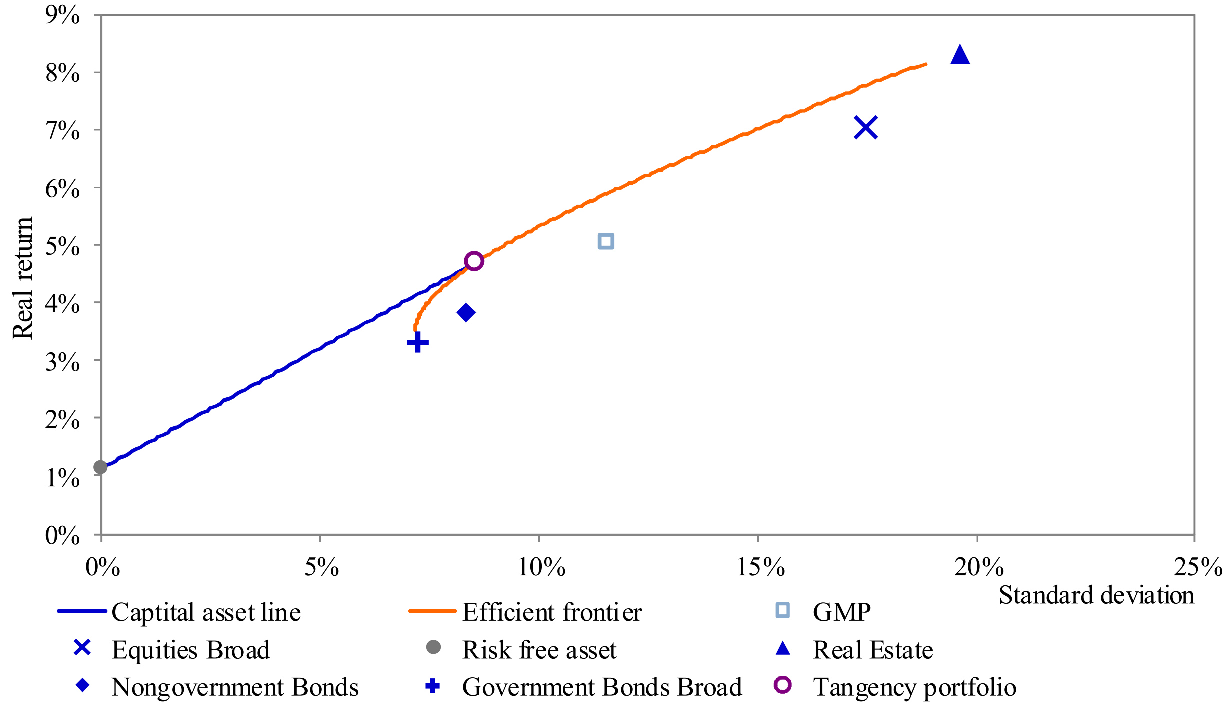
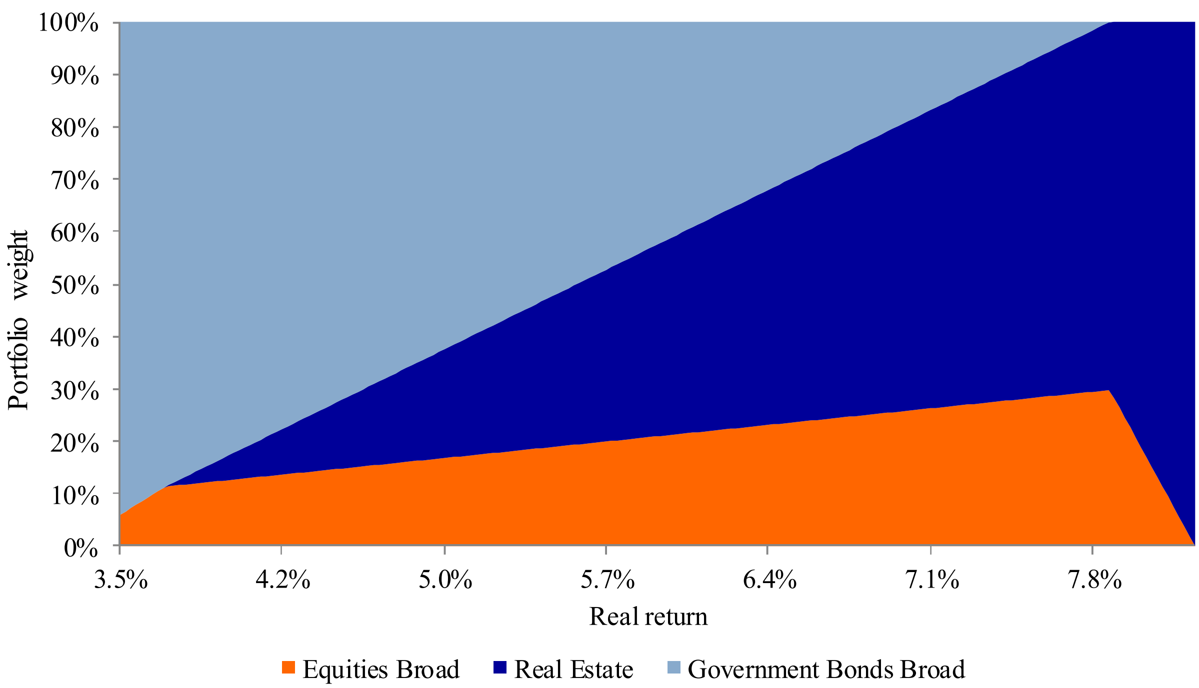


Figure 4

Weights and average arithmetic real returns of the portfolios on the mean-variance efficient frontier



Alternative portfolio allocations versus the GMP

There is only one macro-consistent benchmark for investors, that is, only one portfolio that everyone could hold without any securities left over. This is the portfolio in which all investable assets are weighed according to their market capitalization weights. As such, the GMP reflects the average dollar invested.

There are various reasons to believe that the GMP might not be the most attractive combination of risk and return. From the asset demand side, investors might not be able to incorporate news efficiently into asset prices, leading from time to time to over- and undervaluation at the asset class level. A practical investment strategy that does not require sophisticated fair value models uses valuation signals based on long-term mean-reversion. For example, Asness, Moskowitz, and Pedersen (2013) use the current asset price relative to its five-year historical price to determine deviations from fair value within asset classes that lack a clear fundamental value. From the asset supply side, corporate managers may time the market by issuing shares that are overvalued and repurchasing those that are undervalued. Graham and Harvey (2001) survey CFOs for important factors when issuing new shares, and stock price turns out to be most important. Empirical evidence that confirms the underperformance of new equity issuance can be found in Loughran and Ritter (1995), Baker and Wurgler (2000), and Gompers and Lerner (2003). When calculating the time-series return at the asset class level, these timing effects are hidden. Dichev's (2007) empirical results suggest that by dollar-weighting equity returns the average return for investors can be more than one percentage point lower over long sample periods. The returns of the GMP that we document, account for the time-varying relative market capitalization of each asset class. For example, when equities represent a higher share of the GMP, its returns have more impact relative to periods in which its share is lower. Hence, in this sense, it is a dollar-weighted return series.

One could argue that any alternative portfolio allocation benefits from hindsight bias and that ex-post it is always possible to find a trading rule that has done better than the GMP. To partly counter such critique, we take the notion of Graham (1949) that the allocation to equities should not be less than 25% and no more than 75%, and the allocation to bonds should be in the inverse range of 75% to 25%, as a starting point for a further analysis. Using one percentage point steps and starting at a 25% allocation to stocks and ending at the portfolio with 75% in stocks, we compare the performance of no less than 51 portfolios to the GMP. So, the first portfolio allocates 25% to equities and 75% to bonds, the second portfolio uses weights of 26% for equities and 74% for bonds respectively, while the last portfolio is a 75% equities/25% bonds portfolio. By resorting to Graham's notion that dates back before our sample period and by taking a huge number of portfolio allocations into account, which range from a defensive to an offensive investment approach, we minimize the risk that we document results that benefit from an ex-post optimized comparison. This analysis also reflects an approach which is common in the asset management industry to measure the performance of multi-asset portfolios.[16]

[16] We use a predetermined rebalancing frequency and the same asset mix for each alternative portfolio over the entire sample period. We realize that in practice rebalancing may be more sophisticated, as it may be based on deviations from strategic weights at any point in time, or the composition of the strategic allocation may change.

We proceed by composing a market capitalization weighted ‘All Equities Index’ which includes the asset category Real Estate next to Equites Broad, and an ‘All Bonds Index’ that combines the asset categories Nongovernment Bonds and Government Bonds Broad. Hereby, we analyze portfolios that invest in the same asset categories as the GMP. Next, we rebalance all 51 alternative portfolio allocations to their initial weights each year. In other words, these portfolios correspond to time-weighted returns, as their allocation does not change over time. Therefore, these are implicitly mean-reversion strategies as in Bernstein (2010). As these portfolios differ from market capitalization weights, they cannot be followed by all investors at the same time.

Figure 5 summarizes our findings. The compounded real return of 4.40% for the GMP falls in the lower half of all 51 portfolios, while its standard deviation of 11.5% falls in the higher half. The return of the alternative portfolio with a similar standard deviation is 4.87%, which implies a return gap of 47 basis points. All 51 alternative portfolios have a higher Sharpe ratio than the GMP as the GMP has a relatively low return and a relatively high standard deviation. Also, all alternative portfolio allocations yield a higher Sortino ratio.

The GMP has an average turnover from the annual rebalancing of 3.2%[17], while this varies from 5.4% to 7.2% for the alternative portfolio allocations. The turnover is double counted, so it includes buying and selling. In case historical trading costs would have amounted to 50 basis points for a single trip[18], they would at worst have resulted in an additional 2 basis points transaction costs above the rebalancing costs of the GMP, i.e. 7.2% -/-3.2% multiplied by 0.5%. So, the additional transaction costs are marginal. The Sharpe and Sortino ratios, based on returns corrected for the transaction costs of rebalancing, are higher than the GMP for all alternative portfolios.

When we split the sample period into the inflationary period 1960-1979 and the disinflationary period 1980-2015, results are similar. The Sharpe ratios of all portfolios are higher than for the GMP in both subsamples. This also applies to the Sortino ratio for the first sample period, while for the second sample period 44 from the 51 portfolios have a higher Sortino ratio than the GMP.

When we rebalance each two years instead of every year, the real return for the GMP rises from 4.40% to 4.41%. The standard deviation rises from 11.5% to 11.6%. For the 51 portfolios, the average return drops from 4.68% to 4.55% while the average standard deviation drops from 10.8% to 10.6%. The return of the alternative portfolio with a similar standard deviation as the GMP is 4.76%, still 36 basis points above the GMP. The Sharpe ratios of all alternative portfolios remain higher than for the GMP. There are four

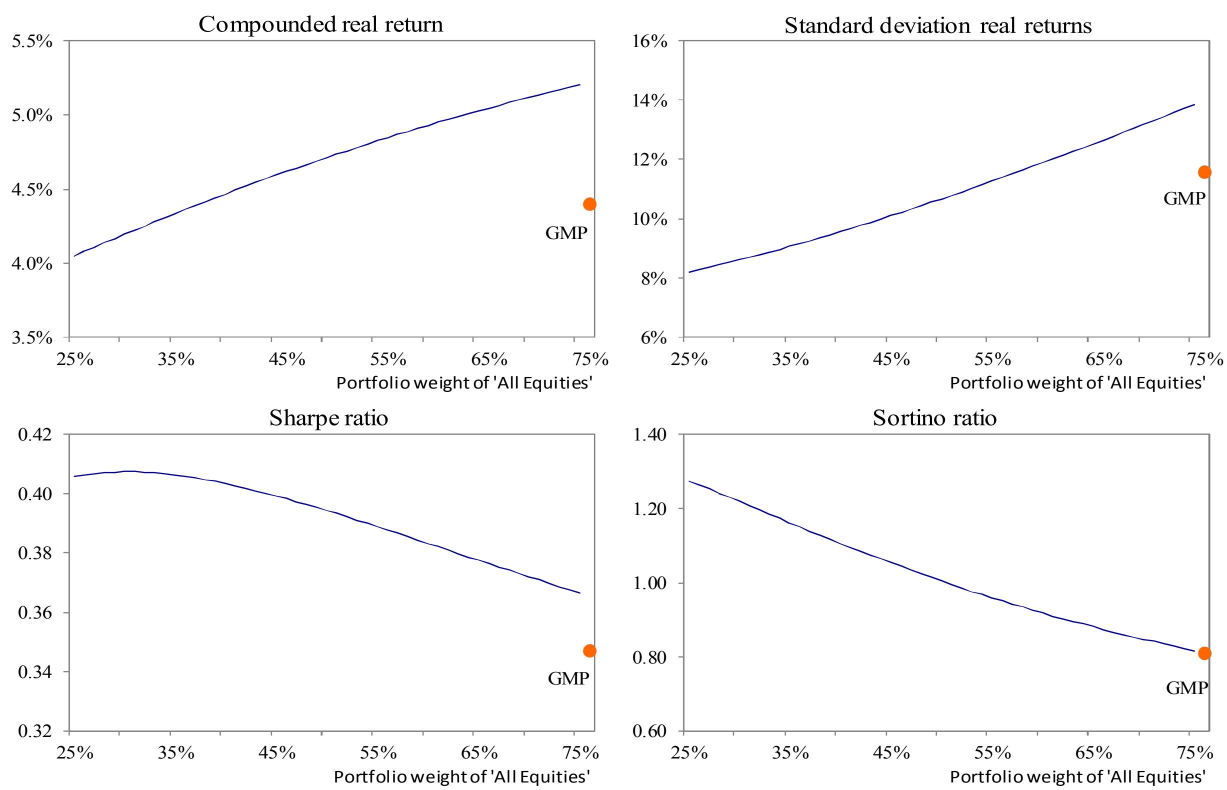
[17] Marginal rebalancing for the GMP is required due to differences in net issuance of asset classes. Therefore, the GMP has to be reset at actual portfolio weightings for each asset category. Turnover concerns switching transactions between the ‘All Equites Index’ and the ‘All Bonds Index’. Turnover within both indices, also due to differences in issues and redemptions, are excluded as we lack data to calculate it. Turnover within the indices are less relevant for this analysis as it affects both the GMP and the alternative allocations.

[18] Obviously, compared to recent transaction costs, this estimate is too conservative. But, for the past it is harder to determine true transaction costs as direct and indirect transaction costs (bid-ask spreads) were higher than nowadays. Our transaction costs match the transaction costs which Anderson, Bianchi and Goldberg (2012) use for the period 1956-1970. For 1971-2010 they use 10 basis points. Note that actual trading costs might differ across asset classes.

portfolios that have a lower Sortino ratio than for the GMP. When we rebalance each three years, results remain similar.[19]

Figure 5

Statistics for 51 alternative portfolio allocations with 'All Equities' and 'All Bonds' weightings ranging from 25%-75% to 75%-25%, and the GMP. The X-axis shows the percentage invested in 'All Equities', the rest is invested in 'All Bonds'. X-axis does not apply to the GMP which has varying instead of fixed portfolio weights. The GMP is shown after the 51 portfolios with a dot.



As said, one could argue that any alternative portfolio allocation benefits from a hindsight bias. But, on the other hand, as a starting point for this analysis we use a rather simple rule of thumb that has been formulated before the start of our sample period. Moreover, we show that, without any exception, all alternative portfolios of no less than the 51 that we consider realize a Sharpe ratio that is higher than for the GMP. Whether we take transaction costs into account, split our sample period into two subsamples or change the rebalancing frequency, there is not a single alternative portfolio with a lower Sharpe ratio than for the GMP. At best, we find four portfolios with a lower Sortino ratio than for the GMP when we use subsamples or another rebalancing frequency. So, the reported risk-return characteristics of the alternative portfolios have been better than for the GMP. Therefore, this analysis seems to support multi-asset allocators using fixed-

[19] Then, the average return for the GMP is 4.39% with a standard deviation of 11.5%. The average return for all alternative portfolios becomes 4.57% with an average stand deviation of 10.7%. The Sharpe ratios of all portfolios are higher than for the GMP, while 48 of the 51 alternative portfolios have a higher Sortino ratio than the GMP.

weight benchmarks with periodic rebalancing. These benchmarks are easy to construct and also match investor risk profile classifications. Moreover, their risk adjusted performances have been better than for the GMP, which raises the portfolio performance when the benchmark is the starting point of the portfolio construction. However, we have to realize that such fixed-weight benchmarks are not macro consistent, in the sense that not all financial investors in aggregate can invest like this. The only macro consistent benchmark is the GMP, reflecting the return of the average dollar invested.

Conclusion

We construct a new data set that offers the opportunity to analyze nominal, real, and excess return and risk characteristics of the global multi-asset market portfolio and the asset categories over the period 1960 to 2015. The Global Market Portfolio is the only macro-consistent benchmark for financial investors, and reflects the average dollar invested. A study on returns of the GMP has not been done before for such a long period and with this level of detail. Moreover, we make the resulting data publicly available so other researchers and investors can use them in their specific applications. With the detailed description of our data and methodology we empower replication of our return series and enable data updates going forward. Despite that we find indications that our data represent good estimates for historical returns, we are aware that our estimates are surrounded by uncertainty.

Our study contributes to the historical understanding of the financial markets and to the recent public debate on financial inequality by documenting the return on capital that financial investors have earned. Over the period 1960 to 2015, we estimate the market portfolio to realize an average compounded real return of 4.40% with a standard deviation of 11.5%. The average arithmetic real return of the GMP of 5.05% is somewhat above the figures from Piketty (2014), while our compounded average return is in line with his figures. But, the figures are not easy to compare as, apart from other methodological differences, he defines capital as household wealth and uses national account data for calculating returns. Compared to the long-term figures of Jordà e.a. (2017) we report lower returns as our focus is on the investable GMP for financial investors instead of the return on aggregate wealth in which housing has a very large weight. In our GMP, housing has a marginal weight.

In recessions, the average annual real return of the GMP is -1.64% and in expansions it is 7.73%, a statistically significant difference of 9.37 percentage points. In the inflationary period from 1960 to 1979, the real return averages 2.88% while that is 6.25% in the disinflationary period from 1980 to 2015. But, this gap of 3.38 percentage points is statistically insignificant. The GMP has a compounded return of 3.26 percentage points above the riskless rate. This may serve as guidance for the long-term expected return of multi-asset investors compared to people who decide not to invest their capital.

We include an analysis that evaluates the performance of portfolios with fixed asset allocation weights relative to the GMP. We examine 51 alternative portfolio allocations which take Graham's (1949) notion that the allocation to equities should be between 25% and 75%, and the allocation to bonds should be in the inverse range of 75% to 25% as a starting point. We show that both the Sharpe and Sortino ratio for all 51 alternative portfolio allocations are above those for GMP. Results are similar when we adjust for transactions costs, look into subsample periods or when we change the portfolio rebalancing frequency. These empirical results seem to support multi-asset allocators using fixed-weight benchmarks with periodic rebalancing. These benchmarks are simple and raise the portfolio performance when the benchmark is the starting point of the portfolio construction. However, we have to realize that such fixed-weight benchmarks are not macro consistent, in the sense that not all financial investors in aggregate can invest like this. The only macro consistent benchmark is the GMP, reflecting the return of the average dollar invested.

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Appendix A. Data details of returns

For each of the four main asset categories in this study, Equities Broad, Real Estate, Nongovernment Bonds and Government Bonds Broad, we composed market capitalization weighted total return series in US dollars which we expect to be representative for the performance for an asset category. The return series for a main asset category are based on the asset classes that belong to it. In selecting the return data sources, we stay close to the selected data sources for market capitalization data as referred in Appendix C. Below, we discuss these four main asset categories and the eight asset classes involved.

Equities Broad

Equities

Period 1995-2015

For the period 1995 to 2015, we use a market capitalization weighted total return of the MSCI All Countries World Index and the MSCI All Countries World Small Cap Index.

Period 1988-1994

From its inception at the end of 1987 through 1994, we use the total return MSCI All Countries World Index. Before 1995 we do not take small caps into account in our return calculations as there is no global small cap index available. The median weight of small caps is 13% from year end 1994 through 2015. Excluding the return of small caps hardly matters for that period as the monthly returns of the all cap portfolio show a correlation of (a rounded) 1.00 with those of the standard MSCI All Countries Index, while the average compounded annual performance of 7.0% and 7.1% respectively are very close to each other. We do not expect the lack of global small cap returns before 1995 to have a significant impact on our return estimate for equities.

Period 1985-1987

For the period 1985 to 1987, we use the return of the MSCI World Index. Hereby, we exclude emerging markets for this period. This introduces just a minor bias as emerging markets represent 0.8% of the MSCI All Countries World Index at the start of 1988.

Period 1960-1984

From 1960 until 1984, we use the global equity returns from Ibottson, Siegel and Love (1985). Their universe is larger than for the MSCI World Index with a market capitalization at the end of 1984 of USD 3,214 billion versus USD 1,765 billion, respectively. Nevertheless, the returns of the MSCI World Index are representative for the global stock market, especially after 1984. We further discuss this in Appendix B.

Private equity

Period 2002-2015

We use the LPX Composite from 2002 until 2015 as a measure for the performance of private equity. The LPX Composite is a diversified global equity index that covers listed private equity companies. We refer to the website of the index provider for more detailed information.[20]

Period 1994-2001

For the period 1994 until 2001 we use the LPX50. The LPX50 is a global equity index that covers the 50 largest listed private equity companies, which fulfill certain liquidity constraints. With 50 constituents, its breadth is less than the LPX Composite, but it has a longer history. To our knowledge, LPX is the only provider that has global private equity indices with such a long history available.

Period 1990-1993

We estimate the performance of private equity for the period 1990 through 1993 using the three-factor model of Fama and French (1993). First, we estimate the factor loadings on size, value and the excess market return using the global developed market factors from the data library of Kenneth French over the period 1994-2015.[21] This regression results in a R^2 of 0.79. Subsequently, using the 1990-1993 global factor return series, we derived estimates for private equity returns. For the first six months in 1990, we only use the global equity market factor, which we proxy with the MSCI World Index. The risk-free rate comes from the Kenneth French database and we use the estimation period 1994-2015 again. R^2 is now 0.70, which is only slightly below the 0.79 for the three-factor model. This suggests that the global equity market factor is the dominant factor in explaining private equity returns.

Before 1990 we do not take the performance of the asset class private equity into account due to a lack of historical return data. So, implicitly it means that before 1990 we suppose the performance of private equity to equal the performance of equities. This introduces just a minor bias as the weight of private equity in the asset category Equities Broad amounts to 1.7% at the end of 1990 while back then it represents 0.9% in the market portfolio.

Real estate

Period 1999-2015

From 1999, we use listed returns from the GPR General World Index from Global Property Research, which has an inception date of 31 December 1983. This index has the broadest market coverage that we were able to find. To illustrate, at the end of 1983 the market capitalization of the GPR General World Index amounted USD 26.1 billion, while the MSCI Real Estate Index reached USD 17.2 billion.[22] The market capitalization of the GPR General World Index was USD 1,751 billion at the end of 2015. This means that the market coverage of the GPR index is also larger than of the FTSE EPRA/NAREIT Global Index with a market capitalization of USD 1,428 billion and the S&P Global Real Estate Investment Trusts Index with a market capitalization of USD 1,117 billion at the end of 2015.

[20] http://www.lpx-group.com/lpx/home.html

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

[22] Market capitalization data for the MSCI Real Estate industry index start in 1986. This number is an estimate derived from discounting the January 1986 market capitalization by the price return of the MSCI Real Estate industry back to year end 1983.

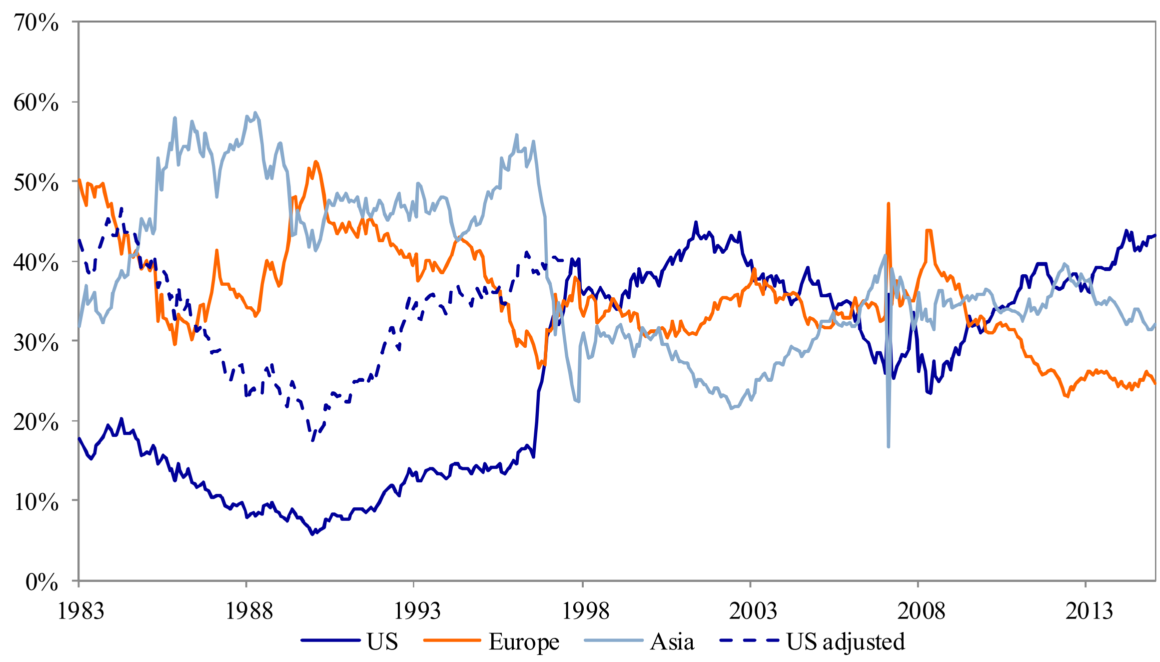
Period 1984-1998

We use an adjusted GPR General World Index for the period 1984-1988 to raise the US-weight in the index for that period. As Figure A1 shows, from 1983 through 1996, the US-weight in the index is far below the weight of Europe and Asia. Although that may be a fair reflection for the investment opportunities in listed real estate for that period, we use the returns as an estimate for both listed and unlisted real estate. It is rather unlikely that such a big market would represent a minor fraction of the investment opportunities for financial investors in real estate. Especially because the US index weight jumps in 1997 from 15.5% to 40.3% in just 14 months due to additions to the index.

We bring this 24.8 percentage points jump in index weight forward to year-end 1983 and subsequently we let this index addition develop like the original index weight. We phase out our index addition in 1997 and 1998 by correcting for each index addition in the 14 month period that the jump in US index weight takes place. The adjusted weight for the US is also shown in Figure A1. The additional index weight for the US in the period 1983-1998 comes at the expense of both Europe and Asia, proportional to their index weight. We use the adjusted regional weights and the regional total returns in US dollars to calculate the total adjusted returns. The compounded average total return for the adjusted index is 11.64% for the period 1983-1998, while this is 11.01% for the actual GPR General World Index. The annualized standard deviations of monthly returns are 15.6% and 17.6% respectively.

Figure A1

Initial regional weights in the GPR General World Index, and the adjusted US weight for the 1983-1998 period



Period 1972-1983

For the period 1972-1983, we combine two data series. First, we derive total returns for the MSCI Real Estate Price Index, following Doeswijk and van Vliet (2011). This is a discontinued industry index of the MSCI World Index which originates from Capital International Indices. Originally, they focused on composing indices for non-North American markets. From December 1974 on, they also include North-American companies in their industry indices, but the US-weight in their real estate index remained marginal with just one small cap since 1980.[23] The Capital International Real Estate Index is a stock-market based index, like the FTSE/NAREIT Equity REIT Index.

We compose a global total return real estate index by combining the MSCI Real Estate Index with the FTSE/NAREIT Equity REIT Index for the US which starts in 1972. We derive the index weights for both series by discounting the market capitalizations at year end 1983 by the change in their price indices. Hereby, we arrive at starting weights at year-end 1971 of 56.7% for the MSCI Real Estate Index and 43.3% for the FTSE/NAREIT Equity REIT index.

Period 1970-1971

Before 1972, there is no data series available with real estate returns for the US market. Therefore, we construct a synthetic US residential REIT index as house prices are available for the period before 1972. To the best of our knowledge, data on prices for commercial real estate are not available back then. Therefore, we use residential data as an estimator for the commercial real estate market.[24] The correlation of monthly returns of the FTSE/NAREIT Equity Residential Index and of the FTSE NAREIT Equity REIT Index is 0.90 for the period from 1994, the inception date of FTSE NAREIT sub-indices, to 2015. The compounded annual nominal returns in that period are 12.3% and 10.7% respectively, with a corresponding standard deviation of 19.2% for both. Hence, the residential market seems to provide a reasonable estimate for the whole real estate market.

We use the following figures to construct the synthetic US residential REIT index: we use a fixed leverage of 46% – corresponding to the average in the 1990-2012 US-sample of Giacomini, Ling and Naranjo (2016) – and for each year we take the rental income returns net of depreciation from Sprinkel and Genetski (1977). For the costs of leveraging we use the annual return on mid-term corporate bonds from ISL (1985). Every year, we determine the intrinsic value of the synthetic residential REIT with these same figures. We reinvest the rental income and we value the mid-term loan at market prices. For house prices data we use Shiller (2015).

Obviously, our synthetic residential REIT index does not reflect deviations of market prices from the intrinsic value. Therefore, we underestimate the standard deviation of the returns. To illustrate, the S&P 500 returned 8.7% in the period 1960-1972 with a standard deviation of 12.9%, while the synthetic REIT returned 8.2% but with a standard deviation of 4.2%. But, any remaining estimation error in our return data

[23] For more details on the history of Capital International Indices, see Sikorsky (1982).

[24] Ibbotson and Siegel (1983) use a building costs index, an estimated depreciation rate and residential rental income to arrive at their estimate for the return on business real estate.

for real estate is mitigated as we combine our US synthetic REIT with listed non-US real estate. Moreover, US real estate has a small weight in the GMP in 1970 and 1971.

For the years 1970 and 1971 we combine return of the synthetic US REIT index with the return of the MSCI Real Estate Index. Before 1971, we cannot calculate reliable market capitalizations due to a lack of data on market capitalization as well as price indices. Therefore, we continue by using the year end weights from 1971, i.e. 43.3% for the US and 56.7% for the rest of the world as mentioned above, for both regions. From 1971 backwards to 1960, we use buy-and-hold total returns without any rebalancing based on actual market capitalizations.

Period 1960-1969

For the US we use the synthetic residential REIT index that we composed as described before. For the rest of the world we resort to five real estate companies in the MSCI Real Estate Index which are also are listed in 1960, as the MSCI Real Estate Index itself starts in 1970. These five companies are Land Securities from the UK, Foncière Lyonnaise from France, Generale Immobiliare from Italy, Mitsubishi Estate from Japan and Mitsui Real Estate which also is from Japan. With five stocks, we overestimate the standard deviation relative to a broadly diversified global non-US index. Hereby, we counterbalance the underestimation of the standard deviation for the synthetic US residential REIT index.

We create a non-US real estate total return index for four countries with these five companies, supposing that the companies' returns are indicative for the corresponding countries. Although that will not be completely true, biases are likely to be uncorrelated. We put the year end 1969 country weights for the non-US index at the average country weight in the three asset classes equities, government bonds and investment grade credits. This results in 40% for the UK, 15% for France, 21% for Italy and 24% for Japan. The 24% for Japan we split into 16% for Mitsubishi Estate and 8% for Mitsui Real Estate, to reflect their difference in market capitalization. We derive price returns from Capital International S.A. (1975)[25], dividend yields from The Capital Group (1971)[26] and we use the exchange rates from Dimson, Marsh and Staunton (2015b) to

[25] For all five stocks we carefully derive annual returns from an enlarged semi-logarithmic bar chart that contains the low, high and closing price of each year. We made sure that the annual returns add up to the cumulative ten year return. Another option would be to retrieve financial newspapers from the sixties and look for the five stock's prices from all year end editions. However, this would introduce the risk that we miss a corporate event like a stock split, stock dividends, distributions or right offerings which could lead to huge errors in the returns we calculate. For Land Securities from the UK, we use data from Datastream for the period 1965-1969.

[26] This edition provides dividends from 1967. For price returns we used the 1975 edition as the 1971 edition contains line graphs instead of the more useful bar graphs with year-end prices from the 1975 edition. Since we have different years for the books, we are required to adjust the dividends for corporate actions. This adjustment enables us to use the dividends from the 1971 edition in comparison with the prices from the 1975 edition. Consequently, we scale them with the ratio of the dividend in 1970 (1971 for the companies from Japan) that we take from both editions. To calculate the dividend yield in year t, we divide the dividend from year t-1 by the average of the year-end stock prices at year t and t-1. We suppose dividend yields in 1960-1967 to equal the average of the dividend yields in 1968 and 1969 as we have no dividend data before 1967.

For Land Securities from the UK we have the dividend yield since 1965 from Datastream. We backfill this dividend yield from 1964 to 1960 using the dividend yields from Barclays' (2011) UK equity index, supposing they move proportional to each other.

Although the dividend yields for earlier years are surrounded by some uncertainty, any estimation errors will only have a limited impact as price returns dominate misestimates of a part of the dividend yield for the period 1960-1965/67.

convert local currencies to US-dollars. We do not rebalance the index. We backfill the MSCI Real Estate Index, as described for the period 1970-1971, with the returns of the non-US real estate index that we composed.

As we use intrinsic values of our synthetic residential REIT for the US instead of transaction prices before 1973, and just five stocks for the non-US part of our global real estate index before 1970, we make an additional analysis to check the resulting global index. We compare the thirteen years from 1960 to 1972 to the other thirteen year periods. Figure A2 shows statistical characteristics relative to Equities Broad, the closest related asset category. The thirteen year cumulative (multiplicative) return premium of our global real estate index over Equities Broad amounts to 33% at the end of 1972, which is not unusual as the figure shows. The correlation of 0.42 over the period 1960-1972 is at the low end of all observations in our sample period, although we have seen lower correlations for the thirteen year periods ending in 2005, 2006 and 2007. Obviously, it seems likely that we underestimate the standard deviation in the period 1960-1972 as it is on the low side over the first thirteen years with 0.84 times the standard deviation of Equities Broad. The average standard deviation for real estate over thirteen year periods from 1985 on (so we do not include any year from the 1960-1972 period) is 1.2 times the standard deviation of Equities Broad. However, as we partly use intrinsic values instead of market prices until 1972, that does not come as a surprise. Keeping that in mind, we conclude that this check suggests that our global real estate index for the period until 1972 seems a credible reflection of the global real estate market back then.

We finalize this section with Figure A3 which illustrates that the relative total return index of Real Estate versus Equities Broad shows a similar picture as the FTSE NAREIT Equity REIT Index versus the S&P500.

Nongovernment bonds

Investment grade credits

2010-2015

We use a market capitalization weighted average total return of the Bloomberg Barclays Global Aggregate Corporate Float Adjusted Index and the Bloomberg Barclays Global Aggregate Securitized Float Adjusted Index for the most recent period. Prior to 2010, there are no annual free float adjusted returns available.

2001-2009

We use a market capitalization weighted average total return of the Bloomberg Barclays Global Aggregate Corporate Index and the Bloomberg Barclays Global Aggregate Securitized Index for the period 2001-2009. We derive annual total returns from its inception in 2001.

1997-2000

For the period 1997 to 2000, we use a market capitalization weighted average total return of the Bank of America Merrill Lynch Global Broad Market Corporate Index and the Bank of America Merrill Lynch Global Collateralized Index.

Figure A2

Cumulative relative real return of Real Estate relative to Equities Broad, the ratio of their standard deviations, and their correlation (data for thirteen year periods; since year-end 1972).

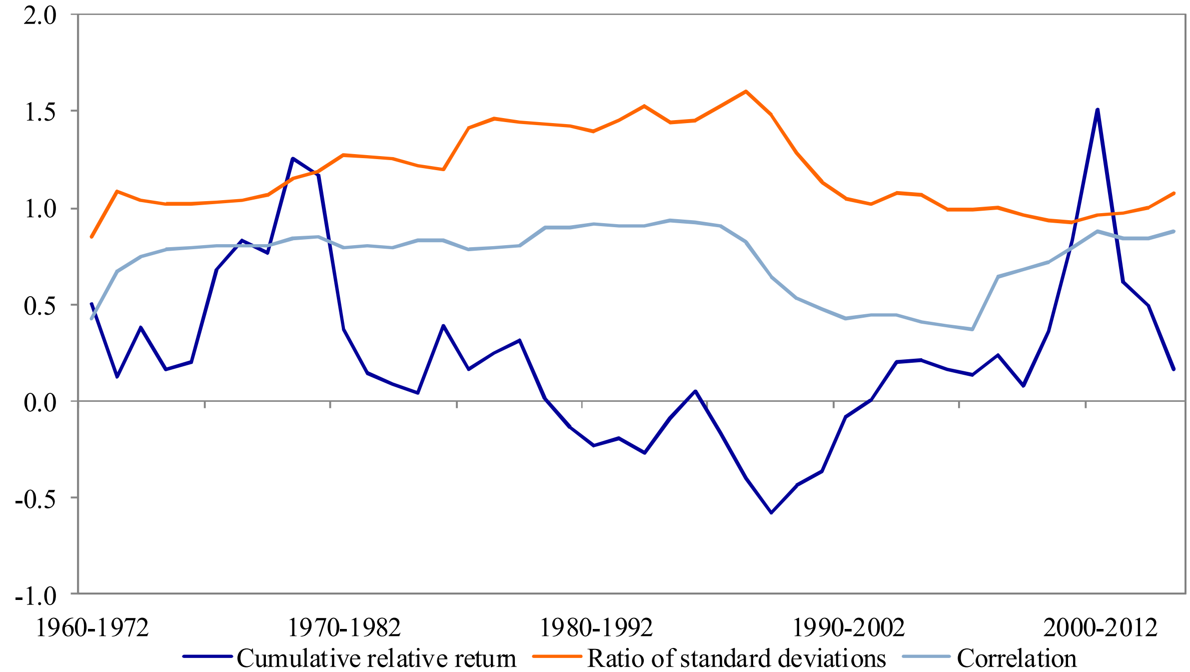
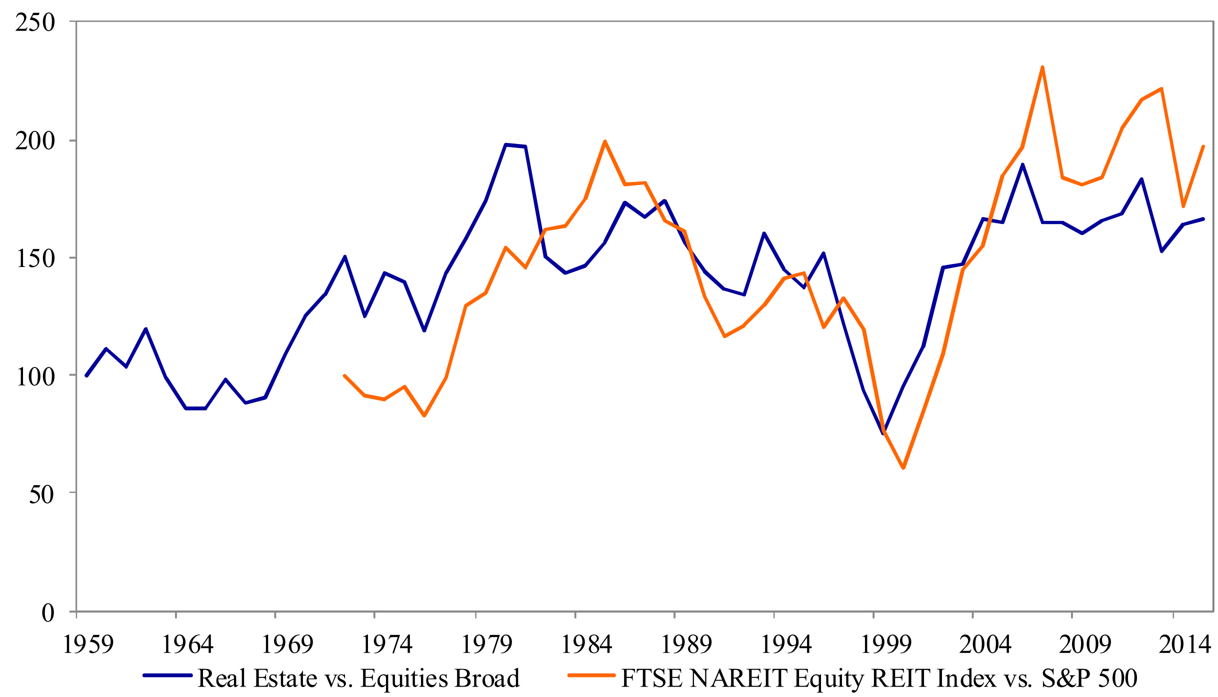


Figure A3

Relative return index for real estate versus equities, global as well as US only



1960-1996

We are not aware of the existence of a corporate or collateralized global index that starts before 1997. However, we are able to compose our own global corporate bond index for the period 1960 to 1996, which we use to represent the returns of investment grade credits before 1997. We expect the returns of corporate bonds to be a good estimate for the returns on investment grade credits for two reasons.

First, there is a strong correlation between returns on investment grade corporate bonds and collateralized bonds. The correlation of monthly returns in the index that we composed for the period 1997-2015, as we describe above, is 0.86. The correlation of annual returns is 0.72. Without the exceptional financial crises years 2008 and 2009, these figures are 0.88 and 0.84. The compounded average return for corporate bonds is 5.80%, while collateralized bonds return 5.13% from 1997 through 2015.

Second, although at the start of 1997 the market capitalization of the Bank of America Merrill Lynch Global Collateralized Index accounts for 60% of the combined market value of the Bank of America Merrill Lynch Global Broad Market Corporate Index and the Bank of America Merrill Lynch Global Collateralized Index, it is unlikely that collateralized debt securities have been a been a heavy weight for the entire 1960-1996 period. Although Frehen, Goetzmann and Rouwenhorst (2014) trace back early examples of mortgage backed securities date to the eighteenth century, Midanek and Midanek (1995) note that the secondary market remained small and fragmented until the seventies. The asset backed security market started in 1986 when securities backed by computer leases are created, see Cowan (2003).

In constructing a global corporate global bond index before 1997, we use total return estimates for eleven countries over this period. These countries are Austria, Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Spain, the United Kingdom and the United States. Below, we explain in detail how we estimate the market capitalization weights of these countries from year end 1959 to year end 1995, as well as our method to calculate the annual total returns per country from 1960 through 1996.

Country weights

Unfortunately, to our knowledge, there are no time series of annual market capitalization weights of nongovernment bonds before 1997. However, the OECD has annual data on net corporate bond issuance over this period, as well as a couple of years with market capitalization data.[27]

In general, the higher the market capitalization of a country's nongovernment bonds market is, the higher its net issuance is likely to be. In other words, whether we determine the weight of a country in the nongovernment bond index on its market capitalization compared to other countries' market capitalizations or on its relative net issuance should lead to comparable results. We use the net issuance data throughout the period 1960 to 1995 to determine the year-end country weights. As an accuracy check, we compare these weights with the few observation points that we have on market capitalization weights.

For 10 out of 11 countries, the net issuance data start in 1960, with Austria starting in 1967. Columns two to four in Table A1, summarize the availability of net issuance data for each country. Belgium and Canada have

[27] We used the yearly volumes of the OECD Financial Statistics books from 1974 until 1996.

missing data for the year 1969. We deal with these few missing data points for these three countries by using the median growth rate of net issuance of the other countries to derive an estimate. Here, we backfill Austria by discounting growth rates from the 1967 data point, while we fill 1969 for Belgium and Canada by using the median growth rate for 1969 and their issuance data for 1968.

Table A1

Overview of data availability for net issuance and market capitalization

Country	Issuance data			Market capitalization data	
	Start	Missing	End	1967	1978
Austria	1967	-	1991	1967	1977
Belgium	1960	1969	1987	1967	-
Canada	1960	1969	1990	1964 & 1968	1978
France	1960	-	1996	1967	1978
Germany	1960	-	1996	1971	1978
Italy	1960	-	1996	1964 & 1968	-
Japan	1960	-	1996	1964 & 1969	1978
Netherlands	1960	-	1995	1966	-
Spain	1960	-	1996	1967	1978
UK	1960	-	1996	1964	1977
US	1960	-	1993	1964 & 1968	1978

Unfortunately, some net issuance data series end before 1995. We proceed by freezing market weights from 1993 for 1994 and 1995 for all countries. As market weights tend to change gradually, the freeze of market weights is likely to have a limited effect on the global nongovernment bonds return that we calculate with these weights. For three countries, net issuance data end before 1993: Austria (1991), Belgium (1987) and Canada (1990). For these countries, we freeze country weights also before 1993. As these three countries represent a combined 3-4% of our corporate bond index, this will neither significantly impact the return of the global nongovernment bond portfolio.

We estimate market capitalizations by taking a ten-year equally weighted moving average of net issuance data for eleven countries, and relate the net issuance for each country to its ten-year moving average relative to the total net issuance of all countries. By using a ten-year moving average, we arrive at a gradually changing estimate, contrary to using yearly issuance data that can be volatile and sometimes negative. From 1965 to 1969, we use an expanding window estimate, as we have no ten-year history available. For the five years before that, we freeze the weights at the 1965 levels. As market weights tend to change gradually, the freeze of market weights for 1960 to 1964 is likely to have a limited impact on the return of the global nongovernment bonds portfolio that we calculate with these weights, let alone the impact on the return of the global multi-asset market portfolio.

To examine the strength of the link between estimated market capitalization series based on net issuance data and reported market capitalization, we compare both for 1967 and 1978. For these two years, most countries have market capitalization data for exactly these years, or a few years earlier or later. To arrive at data for 1967 for all countries, we used one of the two following methodologies if 1967 itself is not available. If there is an additional year available with market capitalization data within four years before and after 1967, we estimate 1967 by adding respectively subtracting net issuance data.[28] Subsequently, we average these two 1967 outcomes for the most robust estimate.[29] This first method applies to Canada, Italy, Japan and the United States. If there is only one year with market capitalization data within four years available, we estimate the 1967 market capitalization by adding (subtracting) a country's net issuance to (from) the closest observation. This applies to Germany, the Netherlands and the United Kingdom. The fifth column in Table A1 shows which year(s) we use as a base year. We use exchange rates of the Dimson, Marsh, and Staunton (2015b) database to convert all local currencies into US dollars.

For the 1978 data comparison, we have market capitalization data for 1978 for six countries (Canada, France, Germany, Japan, Spain and the United States). For two countries, we have observations for 1977 (Austria and the United Kingdom). Here, we add the issuance in 1978 to market capitalization of 1977 to arrive at the market capitalization figure for 1978. We do not take Belgium, Italy and the Netherlands into account for the 1978 comparison, as these countries have no market observations within five years of 1978, and we want to exclude the possibility that imperfect reporting of historical net issuance data affects the comparison between issuance and market capitalization too much. The last column in Table A1 summarizes the base years for the comparison in 1978.

Figure A4 shows the country weights for 1967 based on market capitalization and based on net issuance, relative to the total of all countries involved in this comparison. The largest difference arises for the United States, where issuance data underestimate the market capitalization by 12 percentage points. The total of all absolute differences sums up to 27 percentage points in 1967. Stated differently, our weights overlap for 73%. Although not perfect, the net issuance data seems to fit relatively well for 1967.

Figure A5 shows the country weights for 1978. Now, France shows the largest difference with a 4 percentage points overestimate of the market capitalization. The total of all absolute differences is 13 percentage points for 1978, or an index overlap of 87%. Therefore, this validity check suggests that our methodology to arrive at a time series of estimated relative market capitalizations seems to mirror reported market capitalizations weights well. Given the (lack of) availability of historical market capitalization data this seems us to be the best way to estimate market capitalizations weights. Figure A6 provides an overview of the country weights we use in our Nongovernment Bonds index for the period 1959-1995.

[28] We choose a range of up to four years as this enables us to check the accuracy of our market capitalization estimates in 1967 for all eleven countries in our sample.

[29] We use this two-way calculation as simply adding or subtracting net issuance data to/from available market capitalization data does not end up with earlier, respectively later, market capitalization observations. We do not know exactly where these differences arise from. It might have to do with changes in the market value of nominal net issuance during a year through year-end or imperfect reporting of historical data.

Figure A4

Comparison of Nongovernment Bonds' country weights for 1967 based on market capitalization and net issuance (eleven countries)

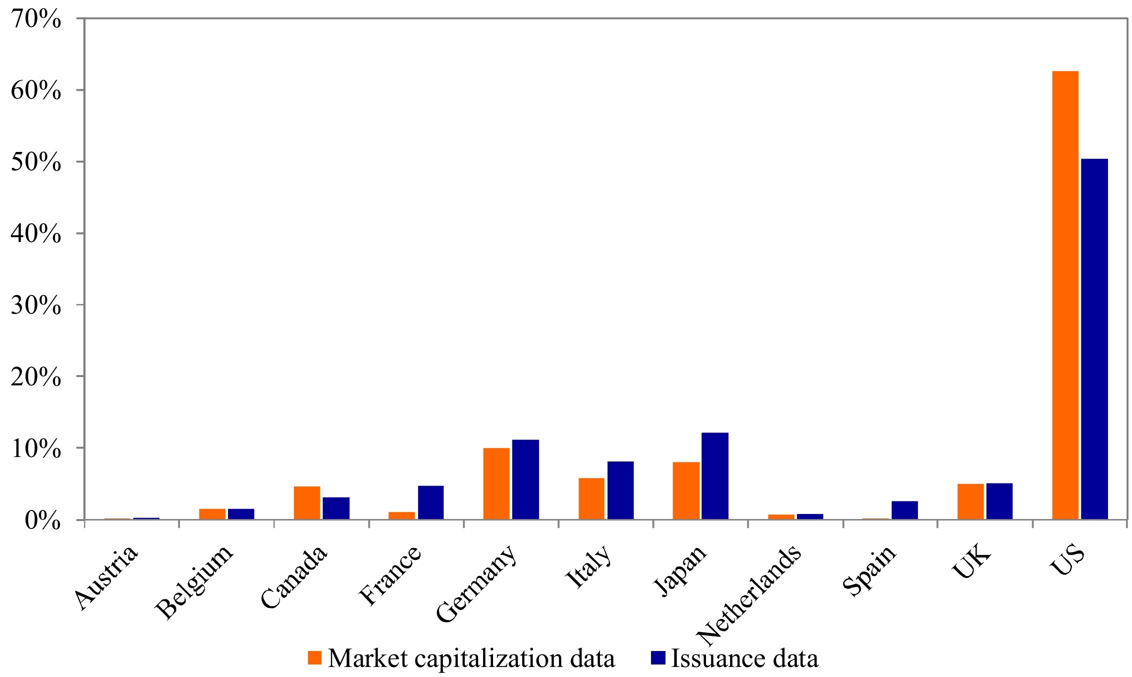


Figure A5

Comparison of Nongovernment Bonds' country weights for 1978 based on market capitalization and net issuance (eight countries)

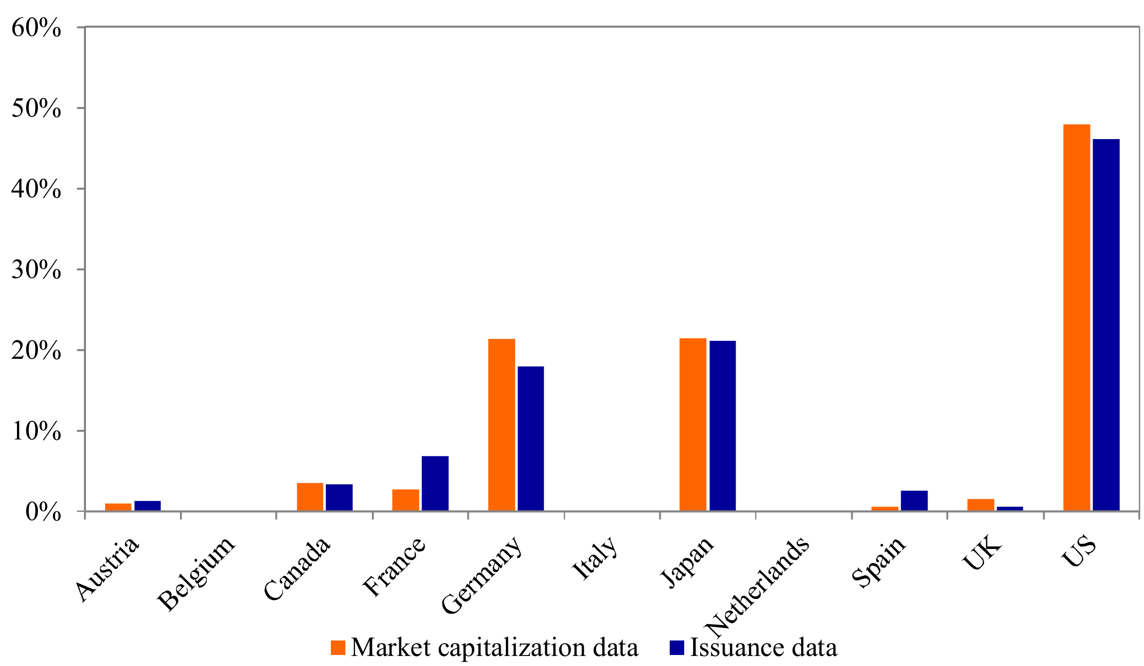
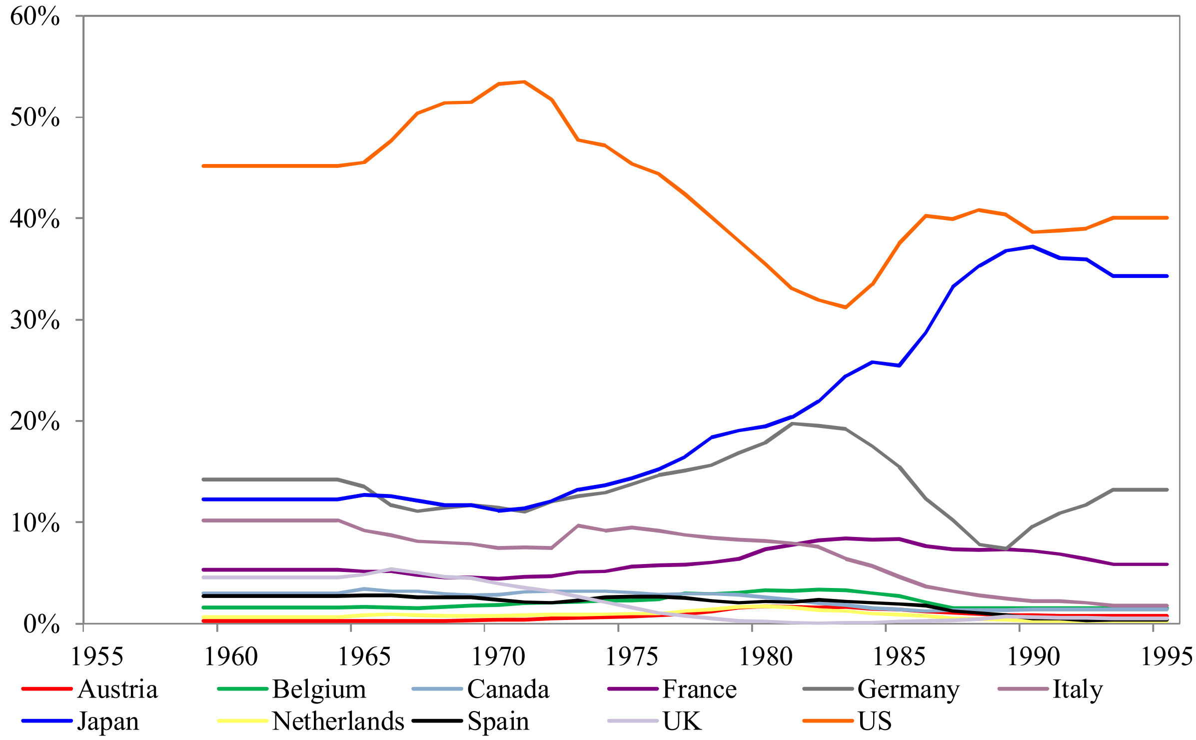


Figure A6

Country weights in our global Nongovernment Bonds index (1959-1995)



Yields

For the US, we use total return data for the period 1985 to 1996 from the Bloomberg Barclays US Aggregate Corporate Index.[30] For 1960 to 1984 we use total return data from Ibbotson, Siegel and Love (1985, p. 37, 2nd and 3rd column). Like Ibbotson, Carr, and Robinson (1982), we use yields from 1959 to 1969 of the OECD for other countries. As there are no data available for 31 December 1959, we used the yields of 31 January 1960 as an estimate, assuming that the yields did not change during the first month of our sample.[31]

For some countries, there are missing observations in the OECD data: Austria (1960-1964), Belgium (1980-1996), Italy (1990-1994), the Netherlands (1985-1986), Spain (1980, 1984-1987) and the United Kingdom (1995-1996). For the United Kingdom, we used corporate bonds total return data from Bloomberg Barclays (2010, p. 63, fig. 77) for these two years to circumvent the problem of missing yield data that we used to calculate returns.

When there is no yield data available for a year, we excluded a country for that year and the year that follows the missing observation (as the change in yield is needed to calculate a return). Due to missing observations, in 23 years we do not include one or more countries, while in 14 years we cover all eleven countries. Despite missing yield data for one or more countries in 23 years, it appears that the market capitalization that we take

[30] This index equals the Bloomberg Barclays US Credit Index until 1999.

[31] This seems a reasonable assumption. The 10-year interest rate on US Treasuries only was 4.69% in December 1959 and 4.72% in January 1960. Moody's BAA corporate bond yield in the US increased from 5.28% to 5.34% over the first month in 1960. Source: FRED Database (St Louis FED).

into account varies from 93.9% to 99.7% in those 23 years. Therefore, despite some missing yield observations, the data cover almost the whole market capitalization of the eleven countries that we use to compose a global nongovernment total return bond index.

Returns

We calculated returns using Equation A1:

$$r_t = -D_t(y_t - y_{t-1}) + \frac{(y_t - y_{t-1})^2}{2} C_t + y_{t-1} \tag{A1}$$

Where:

r_t = *total return*

D_t = *modified duration* = $\left[1 - \frac{1}{(1+0.5y)^{2M}}\right] / y$

y_t = *yield*

M = assumed maturity of the bonds

C_t = *convexity* ≈ D^2.

We used the maturity estimates of Ibbotson, Carr and Robinson (1982) and extend them to 1996. For the equations of the modified duration and convexity we follow Serrat and Tuckman (2011).[32] With Equation A2, we calculate the convexity:

$$C = \frac{1}{B} \frac{d^2(B(r))}{dr^2} \tag{A2}$$

where:

C = *convexity*

r = floating interest rate of the bond

B = price of the bond.

Another way of expressing *C* in terms of the modified duration *D* is:

$$\frac{d}{dr} B(r) = -D * B \tag{A3}$$

Therefore:

$$C * B = \frac{d(-D*B)}{dr} = (-D)(-D * B) + (-\frac{dD}{dr})(B) \tag{A4}$$

which is equal to:

$$C = D^2 - \frac{dD}{dr} \tag{A5}$$

As the last component is negligible we approximate the convexity by:

$$C \approx D^2$$

[32] See Equation 4.14 on page 132 and Equation 4.45 on page 146.

Final return series with correction for defaults

Obviously, for each year we sum the multiplications of all percent market capitalization weights and corresponding returns to arrive at our total return series for 1960 to 1996. Finally, we still make a correction for defaults for the non-US weight in our index, as we use total return series of external suppliers for the US, as described above. Moody's (2012, exhibit 23, p. 27) contains annual credit loss rates on global investment grade from 1982 on. As Moody's (2012, exhibit 16, p. 20) global corporate issuer default counts for the period 1920-2011 shows, we only have credit losses in 1970, 1973 and 1977 for the period 1960-1981. During the 30-year period 1982-2011 there were 15 years with a credit loss. We proceed by assuming that the credit loss in those three years equals the median credit loss on investment grade for the fifteen years with a credit loss. This median is 0.11 percentage points (average equals 0.12 percentage points). We correct the return of the non-US weight in our index 0.11 percentage points. Hereby, we implicitly assume that global credit losses are evenly distributed across the countries in our sample, relative to a country's weight in the index. We remark that this credit loss correction only has a minor effect on the return series.

High yield bonds

Period 2002-2015

For the period 2002 until 2015, we use the Bloomberg Barclays Global Corporate High Yield Index. This index represents the industrial, utility and financial institutions issuers from the union of the US High Yield, the Pan-European High Yield, and Emerging Markets Hard Currency High Yield Indices.

Period 1998-2001

For the period 1998 to 2001, we use the Bank of America Merrill Lynch Global High Yield Index. This index contains below investment grade corporate debt.

Period 1985-1997

From 1985 through 1997, we use the total returns of the Bank of America US High Yield Index. Before 1998, there is no global high yield index available. However, the US has dominated the global corporate high yield market. To illustrate this, the correlation between monthly returns of the Bank of America Merrill Lynch Global High Yield Index and the Bank of America US High Yield Index is 0.98 in the three-year period 1998-2000, while the average compounded annual returns have been 3.1% and 4.0% respectively. The 90 basis-point return gap between the two indices might seem large, but the annualized standard deviation of the monthly returns is 6.4% and 7.2% respectively in this three year period. So, the difference in returns is limited given this standard deviation.[33]

[33] The correlation between monthly returns of the US dollar hedged Bank of America Merrill Lynch Global High Yield Index and the Bank of America US High Yield Index is 0.97 in the three year period 1998-2000, while the average compounded annual return for the US dollar hedged Bank of America Merrill Lynch Global High Yield Index has been 2.9% with a standard deviation of 6.3%. The marginal difference itself between the unhedged and the US dollars hedged global index also suggests the dominance of the US in the global high yield market in these early years of the global index.

Government Bonds Broad

Government bonds

Period 2010-2015

For the period 2010-2015 we base the returns on the Bloomberg Barclays Multiverse Government Index in which we replaced the Bloomberg Barclays Global Treasuries Index by the Bloomberg Barclays Global Treasuries Float Adjusted Index. Hereby, we created a global multiverse government index with a free float adjustment. Prior to 2010, there are no annual free float adjusted returns for global treasuries available.

Period 2001-2009

From 2001 until 2009, we use the Bloomberg Barclays Multiverse Government Index. This index has the broadest coverage of the global government bonds irrespective from its credit rating. This is the union of the Bloomberg Barclays Global Treasuries Index, the Bloomberg Barclays Emerging Markets Local Currency Government Bond Index, the Bloomberg Barclays Euro Treasury High Yield Index, and the native-currency segments of "Agencies" and "Local Authorities" from the Bloomberg Barclays Global Government-Related Index, and the Bloomberg Barclays Global High Yield Index.[34]

Period 1987-2000

From 1987 until 2000, we use the Bloomberg Barclays Global Treasuries Index, like Doeswijk, Lam and Swinkels (2014). Unfortunately, there is no information on the other Bloomberg Barclays indexes that make up the Multiverse Government Index before 2001. Note that on 31 January 2001, the Bloomberg Barclays Global Treasuries Index is about 80% of the market value of the Bloomberg Barclays Multiverse Government Index.[35] The correlation between the total monthly returns of both series is over 99.8% over the period January 2001 to December 2015.

Period 1960-1986

We construct a market capitalization based total return index for government bonds. Although we solely need this index for the period 1960-1986, we construct our own global government bond index for the period 1960-2010 as it enables us to perform a robustness check of our index versus an external global bond index.[36] We use 20 countries to construct our index. The Dimson, Marsh, and Staunton (2015b) database contains annual returns for each of them.[37] Next, we need market capitalization data.

[34] Note that countries with capital constraints or limited currency convertibility are not included in this index. Examples of countries that are not included are Brazil, China, and India.

[35] On 31 January 2001, the Barclays Global Treasury Index has a market value of US dollar 6.24 trillion, while the Barclays Multiverse Government Index has a market value of US dollar 7.91 trillion. About US dollar 0.73 trillion is due to differences in the Treasury segment of both indexes, and US dollar 0.94 trillion due to the Agencies and Local Authorities.

[36] Our data source for debt-to-GDP ratios ends in December 2009 as we will discuss further on.

[37] Note that the Barclays Global Treasury index covers 19 countries when the index is launched in 1992, while this was 13 in January 1987, the date that the index series was backfilled.

We calculate debt amounts in US dollars to derive market capitalization-based portfolio weights. However, these historical debt data are not available. Hence, we use debt-to-GDP ratios and GDP data to calculate the debt amount data. This is an important difference with the Dimson, Marsh, and Staunton (2015b) global government bond portfolio, as they only use GDP-weights and do not adjust for differences in debt-to-GDP ratios. We multiply the debt-to-GDP ratios data with the GDP, as shown in Equation A6.

$$Debt_t = GDP_t * \frac{Debt_t}{GDP_t} \tag{A6}$$

where:

GDP_t = GDP in USD at the end of the year *t*

$\frac{Debt_t}{GDP_t}$ = Debt-to-GDP ratio at the end of year *t*.

Our main source for the GDP data is the World Bank. However, their US dollar GDP data start at the end of 1960. Since the first year we calculate returns for is 1960, we need to obtain portfolio weights from the end of 1959. In order to calculate the missing GDP data for each country at the end of 1959, we use the GDP growth rates in 1960. For this purpose, we take the GDP data in local currencies from Dincecco and Prado (2013). Since the growth rates are in local currencies, we also adjust the growth rates for changes in the exchange rate of the US dollar versus the local currency of each country by using the exchange rates *(ER)* from the Dimson, Marsh and Staunton (DMS) database, as shown in Equation A7.[38]

$$GR_t^{\$USD} = \frac{GDP_t^{DP}}{GDP_{t-1}^{DP}} * \frac{ER_{t-1}}{ER_t} - 1 \tag{A7}$$

where

$GR_t^{\$USD}$ = Growth rate of GDP in USD for the year t

GDP_t^{DP} = GDP at the end of year t in local currencies from Dincecco and Prado (2013)

ER_t = Exchange rate of foreign currency per one USD at the end of year t.

The final step to calculate the missing GDP data in US dollars at the end of 1959 for the World Bank is shown in Equation A8.

$$GDP_{1959} = \frac{GDP_{1960}}{1+GR_{1960}^{\$USD}} \tag{A8}$$

For GDP data of the countries Germany, New Zealand and Switzerland we have additional missing data for certain years. Germany has missing data for the period 1960-1969, New Zealand has missing data for 1970 and Switzerland has missing data for the period 1970-1979. We use Equation A7 and Equation A8 again to calculate the missing data with the growth rates of GDP data from Dincecco and Prado (2013), like we did for the missing data at the end of 1959 for all countries.

Now we turn to the data for the debt-to-GDP ratios. The World Bank starts reporting central government debt from 1990. The OECD starts publishing public debt since 1970 and the IMF's database does not have a

[38] The exchange rates are expressed as the number of local currencies equivalent to one unit of the US dollar.

consistent definition of public debt across countries, especially before 1980, see Abbas, Belhocine, El-Ganainy, and Horton (2010). Therefore, we use the central government debt-to-GDP ratios from Reinhart and Rogoff (2010). They focus on gross central government debt as time series for other broader measures of government debt are not available for many countries.[39] They provide central government debt data for the following seventeen countries: Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Japan, Norway, South Africa, Spain, Sweden, Switzerland, United Kingdom and the United States.

For the other three remaining countries Italy, the Netherlands and New Zealand we use the International Monetary Fund's (IMFs) debt-to-GDP ratios as described by Abbas, Belhocine, El-Ganainy, and Horton (2010).[40] Hereby we might overestimate the amount of debt for these three countries. However, as the central government represents by far the largest part of the general government debt, the bias is probably negligible.

Next, for the return of the market portfolio, we need the returns of the entire government bond market, also named 'all maturities'. In most cases, government bond returns from the DMS database do not reflect all maturity returns. Based on the description of the DMS data sources, we categorized the government bond returns for all countries and each year into one out of the three following categories: a return that reflects an all maturity return, a return that reflects the return on a ten-year bond or a return of a bond that has a maturity above ten year (which in practice appears to imply a maturity around twenty).

Figure A7 illustrates the weight of these three maturity categories in our debt-weighted index with returns from DMS. We need a maturity adjustment for most countries to come closer to the return of an all maturities global government bond index.[41]

The maturity distribution of DMS data does not come close to the maturities reported for Bloomberg Barclays indices, shown in Figure A8.[42] For the period 1987-2015, the median maturity for the Bloomberg Barclays Global Treasury Index is 7.9 and for the Bloomberg Barclays US Government Index this is 8.1. For the Bloomberg Barclays US Government Long Index the median maturity is 22.7 for that period. Before 1987 we do not have global maturities data from Bloomberg Barclays available, but for the Bloomberg Barclays US Government Index the median maturity is 5.9 for the period from 1973 through 1986. It is likely, that the maturity for the global index also would have been lower in the period 1973-1986, at least for the simple reasons that the US is a heavy weight in the index.

[39] In footnote 3 (page 574) they state: *"Our focus on gross central government debt owes to the fact that time series of broader measures of government are not available for many countries…"*

[40] Because of a change in data sources for debt-to-GDP in 2002 from the New Zealand government to the IMF World Economic Outlook, this year has no observation in the dataset by Abbas et al. (2010). We linearly interpolate between 2001 and 2003 to obtain the estimate for 2002. For South-Africa, we used the growth rate in debt-to-GDP from 2009 to 2010 from the IMF to estimate the 2010 debt-to-GDP ratio with the 2009 observation from Reinhart and Rogoff (2010) as they lacked this data point for 2010.

[41] For corporate bonds we do not make a maturity adjustment. The market capitalization weighted maturity of our non-US corporate bond index averages 8.1. US returns are based on ISL'85 and are market capitalization weighted returns for intermediate and long term bonds. On their turn, they partly rely on the Lehman Brothers Kuhn Loeb corporate bond indexes which define intermediate bonds as one to ten years and long term as a maturity of ten years or more.

[42] For the construction of this graph, we suppose all maturities returns in the DMS database to have an average maturity of 6 before 1984 and 8 afterwards. This assumption has little relevance, as all maturities returns constitute a small portion of our debt weighted index, as shown in Figure A7.

Figure A7

The weight of maturity categories in the debt weighted global government bond market, based on DMS government bond returns

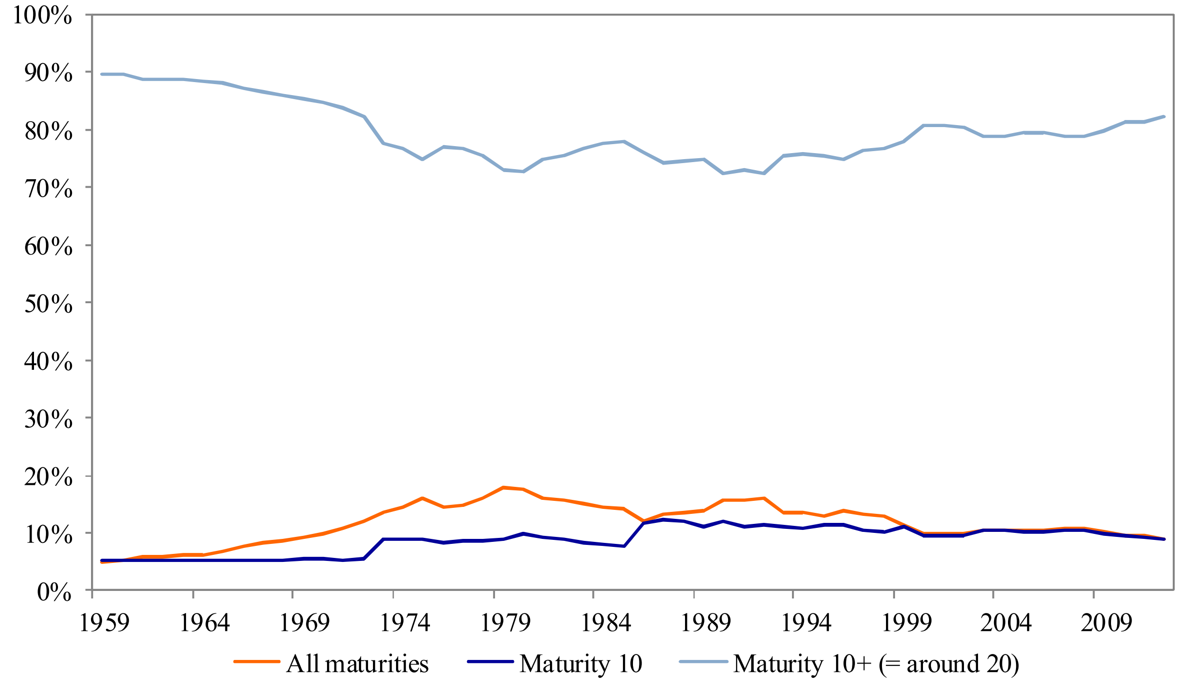
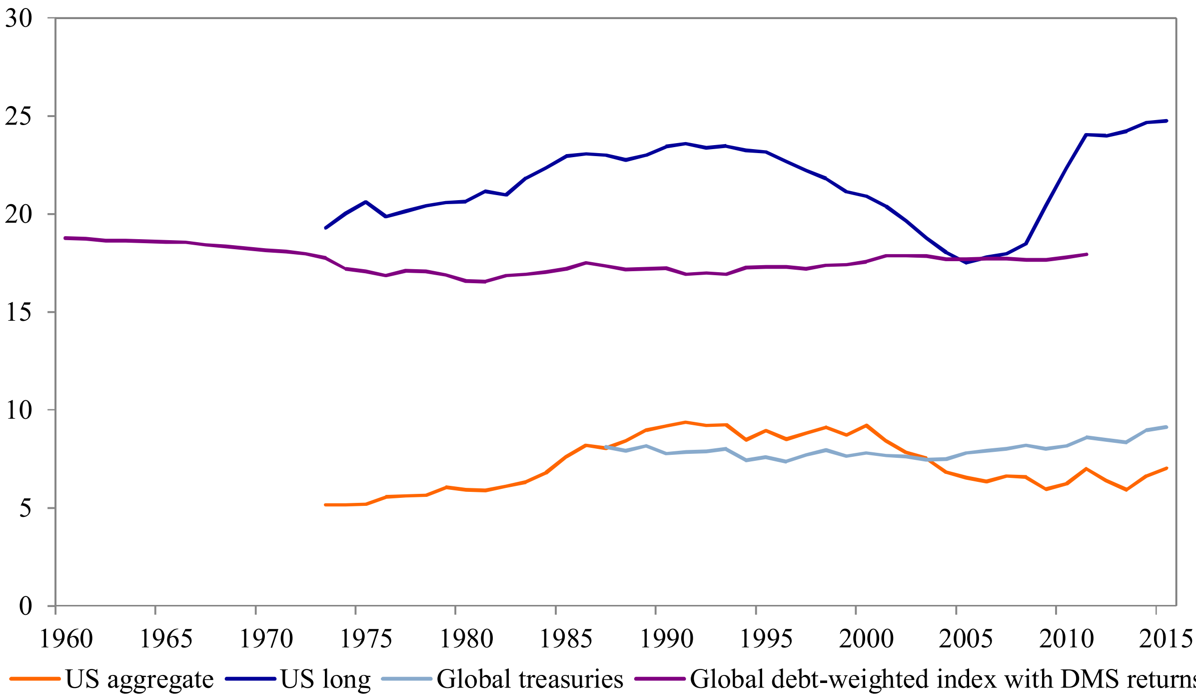


Figure A8

Maturities for Bloomberg Barclays Capital indices and our global debt weighted index with DMS returns



To come closer to the true global bond market return with the DMS returns, we target a maturity of 6 for the period 1960-1984 and 8 for the period 1985-2011. For 1985-2011 we base the target maturity on the Bloomberg Barclays Capital Global Treasury Index, for the period 1960-1984 we target the maturity two years less, as the largest component of the index, the US, has a lower maturity in the seventies and early eighties than after 1984. In order to arrive at a certain target maturity, we firstly determine the yearly (multiplicative) relative performance of a 20-year bond over a 5-year bond, using data from Ibbotson (2015). Furthermore, we assume that the relative performance has a linear pattern. So, by dividing the relative performance by 15 years, which is the difference in maturity, we know the performance for each additional year of maturity a bond has over a 5-year maturity bond. Equation A9 describes this calculation:

$$RM_{i,t}^{1} = \frac{\frac{(1+R_t^{20})}{(1+R_t^{5})} - 1}{M_{Ibbotson}^{20} - M_{Ibbotson}^{5}} \quad \text{(A9)}$$

where

$RM_{i,t}^{1}$ = return for one and each year of additional maturity a bond has over a 5-year maturity bond for country i, in year t,

$R_{i,t}^{20}$ = return of 20-year maturity bond for country i in year t,

$R_{i,t}^{5}$ = return of 5-year maturity bond for country i in year t,

$M_{Ibbotson}^{20}$ = 20

$M_{Ibbotson}^{5}$ = 5.

Now we determine the maturity adjustment so we can end up in maturity adjusted returns. For both maturity categories, 10 and 20 years, we multiply the relative return of a bonds' one year of additional maturity with the difference of its maturity and the targeted maturity. For example, if we want to adjust the category with 10 year maturity bonds to a target maturity of 6 years the multiplication factor is 4, i.e. 10-6. For each country and for each year we determine this multiplication factor. We describe this in Equation A10.

$$MA_{i,t} = RM_{i,t}^{1} * (M_{i,t} - TM_t) \quad \text{(A10)}$$

where

$MA_{i,t}$ = maturity adjustment for country i in year t,

$M_{i,t}$ = maturity category for country i in year t,

TM_t = targeted maturity in year t, which equals 6 from 1960 to 1984 and 8 for 1985 to 2011.

Now, for all years and for all countries we have arrived at a maturity adjustment and we can derive the maturity adjusted returns, as shown in Equation A11. Obviously, we do not correct the all maturities category, as we perform this adjustment to arrive at an all maturities estimate. In other words, the maturity adjustment is zero for the all maturities category.

$$RA_{i,t} = \left(1 + RU_{i,t}\right) * (1 - MA_{it}) - 1 \quad \text{(A11)}$$

where

$RA_{i,t}$ = adjusted return for country i in year t, reflecting an estimated all maturity return,

$RU_{i,t}$ = unadjusted return for country i in year t,

$MA_{i,t}$ = maturity adjustment for country i in year t.

In the maturity adjustment process, we assume that the relative performance of the 20 year versus the 5 year bond in the US is representative for all 19 other countries in our sample, as we only have US data available for both five and twenty year government bond returns.[43] This might seem far stretching at first sight. However, in the period 1960-2011 for which we construct our global bond index, local government bond returns for all countries show a positive correlation to US government bond returns. The correlations vary from 0.15 to 0.87, with an average of 0.50 and a median of 0.49. A further analysis in Appendix B suggests that the assumption is not as far stretching as one might think. Our index comes very close to global all maturity indices that are available for sub-periods.

Inflation linked bonds

Period 1998-2015

For inflation linked bonds we use the Bloomberg Barclays Capital Global Aggregate Inflation-Linked Index for the period 1998-2015. This index includes securities which offer the potential for protection against inflation as their cash flows are linked to an underlying inflation index. All securities included in the index need to be issued by an investment-grade rated sovereign in its local currency.

Period 1997

For 1997 we use the Bank of America Merrill Lynch World Government Inflation-Linked All Maturities Index.

Period 1985-1996

We use the Bank of America Merrill Lynch UK Government Inflation-Linked All Maturities Index for the period 1985-2006. Although inflation-linked bonds have existed for a long time, the UK was the first major country to offer them as alternatives to nominal government bonds to the public. The US created treasury inflation protected securities (TIPS) in 1997.

Emerging market debt

The asset class emerging market debt (EMD) requires a different approach than the other asset classes in this study as it contains four sub-asset classes with different characteristics, following Doeswijk, Lam and Swinkels (2014a). We distinguish external hard currency debt, hard currency corporate debt, local currency nominal government debt and inflation linked debt. There is no global index available, which contains all these four categories. Therefore, we compose a comprehensive market capitalization weighted global emerging market debt total return index for the period 1994-2015.

[43] Here, we use the data from the Ibbotson SBBI 2015 Classic Yearbook – Market Results for Stocks, Bonds, Bills and Inflation 1926-2014, published by Morningstar Inc., Chicago.

We use the JP Morgan Emerging Markets Bond Index Global Composite (EMBI) for external hard currency debt, the JP Morgan Corporate Emerging Markets Bond Index Broad (CEMBI) for US dollar-denominated emerging-market corporate bonds, the JP Morgan Government Bond Index - Emerging Markets Global Composite (GBI) for local currency debt and the Bloomberg Barclays Capital Emerging Markets Government Inflation-Linked Index (EMGILI) for inflation-linked bonds.

Figure A9 illustrates the relative market capitalization weights for all four categories in our EMD index, using the methodology of Doeswijk, Lam and Swinkels (2014a) to estimate the market capitalization of each category. Figure A9 also shows the availability of return data. Dotted data indicate that there are no return data available, whereas we do have an estimation of the relative market capitalization weights for each year. Thus, in 1994 we start with the EMBI only, which covers 83% of the EMB index at that time as there are no return data for the other three indices.[44] Afterwards, the coverage gradually falls to 65% until return data for CEMBI and GBI become available in 2002. Then, the market coverage of our EMD index jumps to almost 100%. When return data for EMGILI become available in 2004, the coverage reaches 100%.

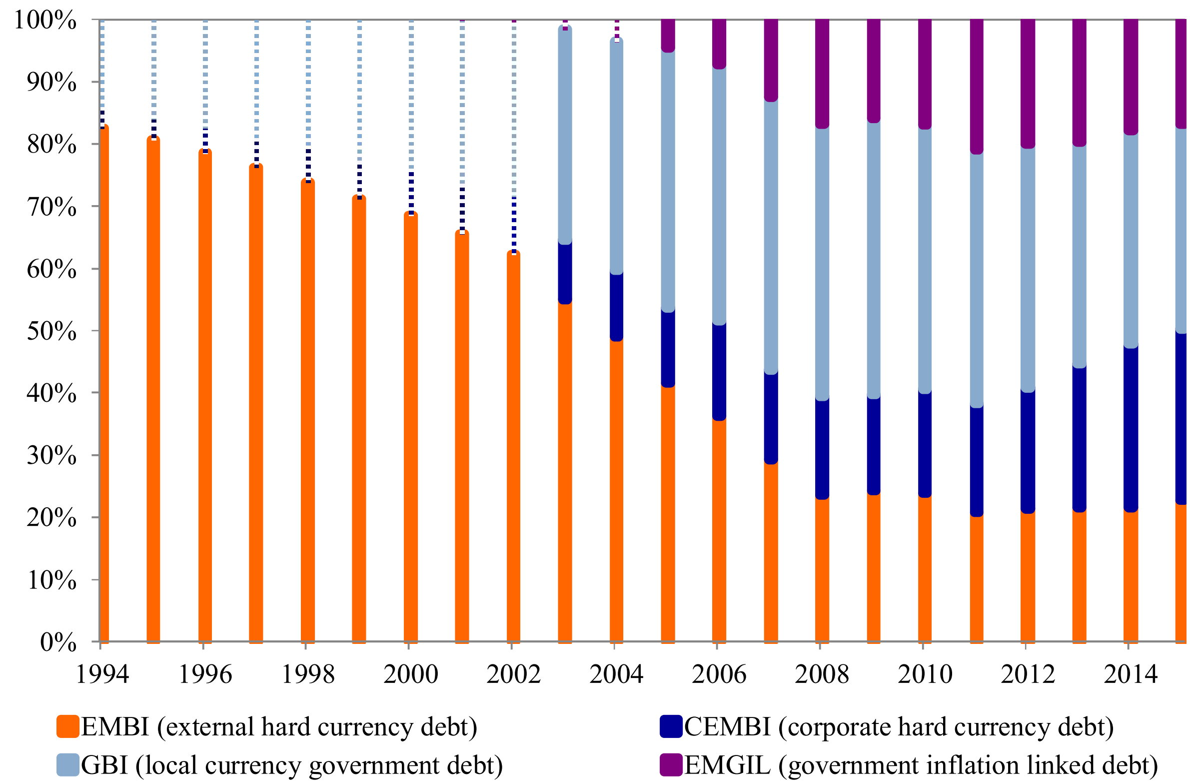
The limited return data availability for the period 1994 to 2001 introduces a bias in our EMD index, but as the total returns of EMBI are positively correlated to CEMBI (0.86) as well as to GBI (0.71) in the 2002-2015 period, it seems our EMD is a reasonable proxy for the 1994-2001 period. In any case, the impact of any bias in our EMD index on the global multi-asset market portfolio will be marginal as EMD represents less than 1% of the market portfolio at the end of 1993. This also applies to its impact on our government broad index with a weight of less than 3%.

For each year t from 1994 to 2015 we determine the return of our EMD index by summing the multiplications of the relative market capitalization weights at the end of year t-1 and the accompanying returns in year t. Subsequently, we divide this sum by the total relative market capitalization that we consider. This last step is necessary as the availability of return data, or market coverage in other words, is less than 100% in several years.

[44] We use the year-end market capitalization in year [t-1] to calculate market capitalization weighted return in year [t]. The 83% figure represents the relative market capitalization of EMBI at the end of 1993, which we use in combination with the return of 1994.

Figure A9

Previous year-end relative market capitalizations and the availability of return data in a year for each category of emerging markets debt. Dotted data indicate that there is no return data available for that year.



Appendix B. Robustness checks

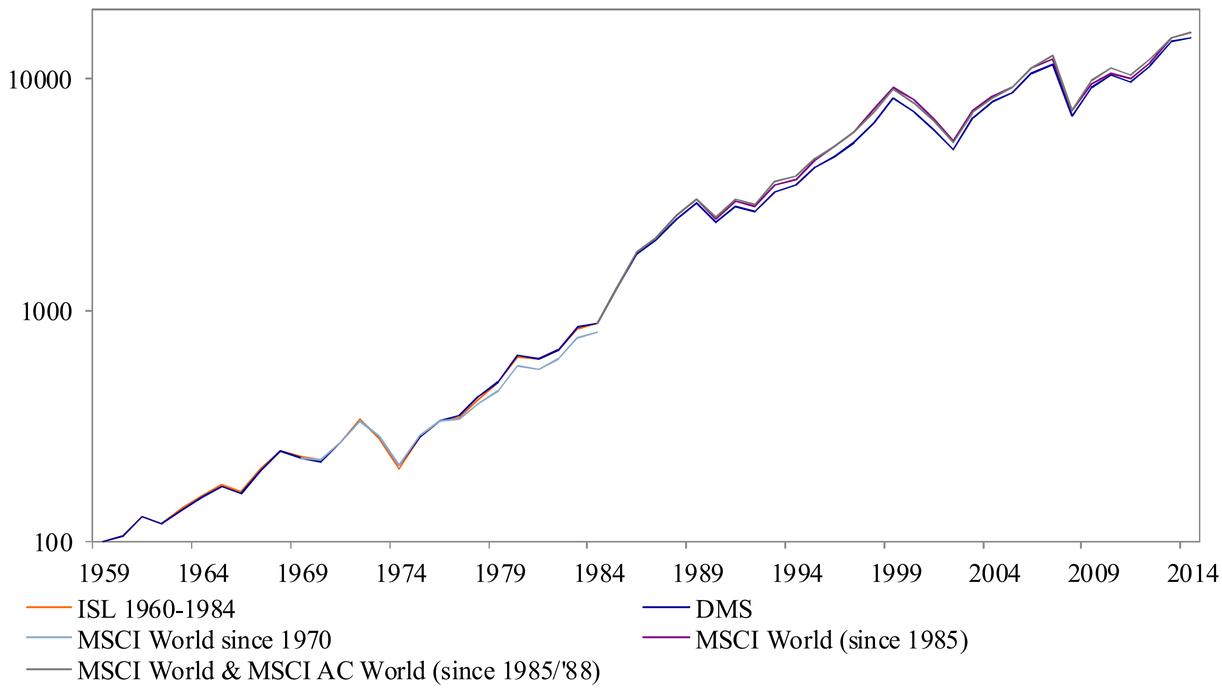
In this appendix, we compare our data to alternative data sources to get insight into the sensitivity of the results for the use of other sources, i.e. we check the robustness of our approach. We perform this check only for the asset classes equities, real estate, government bonds and investment grade credits. For these asset classes, we do have decades long data available from alternative data sources, which enables us to do robustness checks.

Equities

Figure A10 shows the cumulative total performance of five global equity series. It contains data from ISL (1985) who provide total return data from 1960 through 1984. Next, it shows the total return performance from 1960-2014 from the DMS-database. We also show the total return performance for the MSCI World Index from its inception in 1970 to 1984 (with the starting value of the DMS-index at the end of 1969), a separate series shows the total return performance of the MSCI World index from 1985 (with the starting value of the Dimson, Marsh, and Staunton (2015b) index at the end of 1984) and finally it contains a series from 1985 (with the starting value of the DMS-index at the end of 1984) that replaces the MSCI World Index with MSCI AC World Index.

Figure A10

Cumulative total performance of five global equity series



For the period till 1984 the data from ISL and DMS resemble each other very closely with an average annualized compounded return of 9.07% and 9.05% respectively, while the correlation of annual returns is a rounded 1.00. For the period 1970-1984 these data are 9.30%, 9.36% and 1.00 respectively. The return for MSCI World Index comes in at 8.73% for this period, which is 60 basis points behind the other two indices, while the correlation of the total return with both indices is 0.99.

After 1984 there are hardly any differences between data from DMS and MSCI. For the period 1985-2014 the return is 9.97% according to DMS, while the MSCI World Index returns 10.15%. The index that we have composed for this study returns 10.21% during that period (before 1985 we use the ISL (1985) data). For the period 1987-2014, these figures are 7.74%, 7.85% and 7.91% respectively, while the MSCI AC World Index generates an average return of 7.84% during this period. Correlations are close to 1.00. In short, this analysis suggests that the results for equities are robust.

Real estate

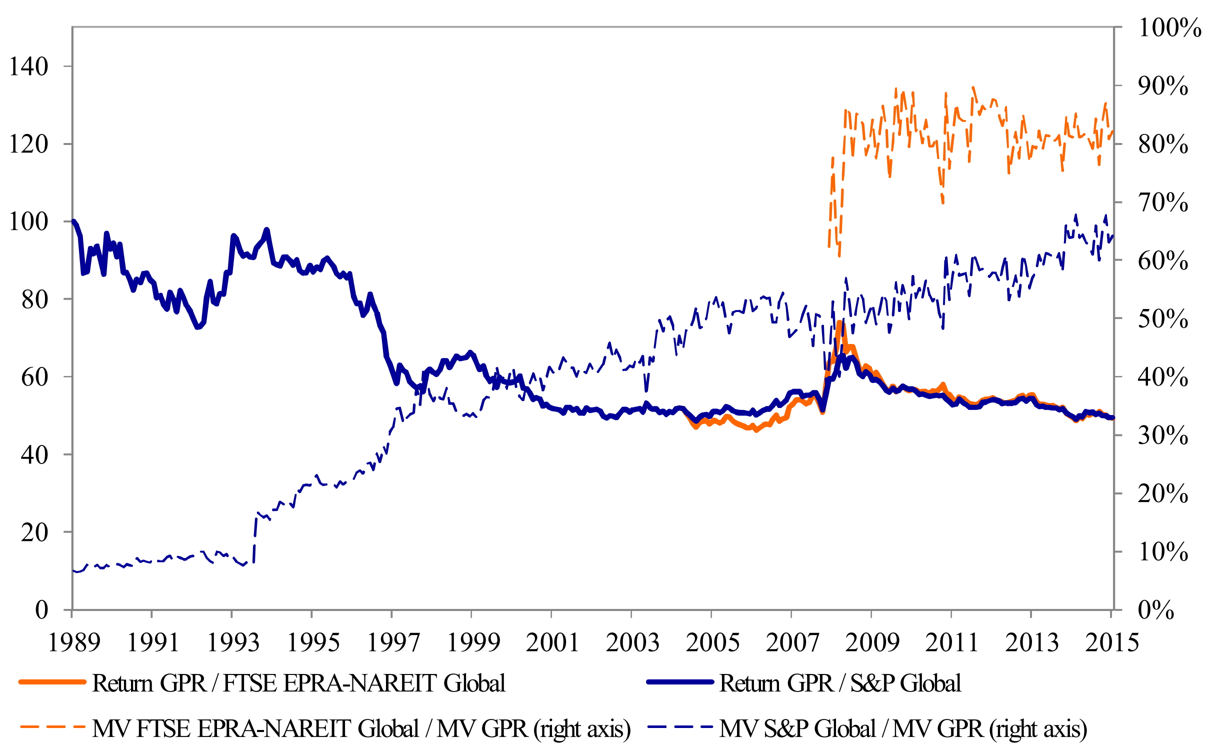
For real estate, we show two alternative data sources with a limited return history, the FTSE EPRA / NAREIT Global Index and the S&P Global Real Estate Investment Trusts (REITs) Index. As can be seen in Figure A11, both have a market value that is clearly below the market value of the GPR Index which implies their universe differs from GPR's. On balance, both perform roughly in line with the GPR Index in the period 2005-2015. The GPR index returns an average compounded annual return of 6.4% during the start of the S&P Global REITs Index in 1995, while the FTSE EPRA / NAREIT Global Index and the S&P Global Real Estate Investment Trusts (REITs) Index deliver 6.4% and 6.8% respectively. Since 1995, the correlation of monthly total returns with the GPR Index is 0.99 and 0.96 respectively. In 2008, 2009 and 2010, the relative performance of GPR differs from the FTSE EPRA / NAREIT and S&P indices, as a result of different universes. At the end of 2008 the market capitalization of GPR is 1.3 respectively 1.9 times as large as the other two index providers.

Before 2005, the relative total return performance of the GPR differs from the S&P Global REITs Index. The further we go back in time, the less we can compare them. Back in 1990, the market capitalization of the S&P Global REITs Index equals 7% of GPR's market capitalization, as also can be seen in Figure A11.

The GPR Index seems to be the best suited index for this study since its inception in 1984. It has the largest market capitalization and an extensive history.

Figure A11

Total performance of the GPR Index relative to the FTSE EPRA / NAREIT Global Index and the S&P Global REITs Index, and the market capitalization of the FTSE EPRA / NAREIT Global Index and the S&P Global Real Estate Investment Trusts Index relative to the GPR Index



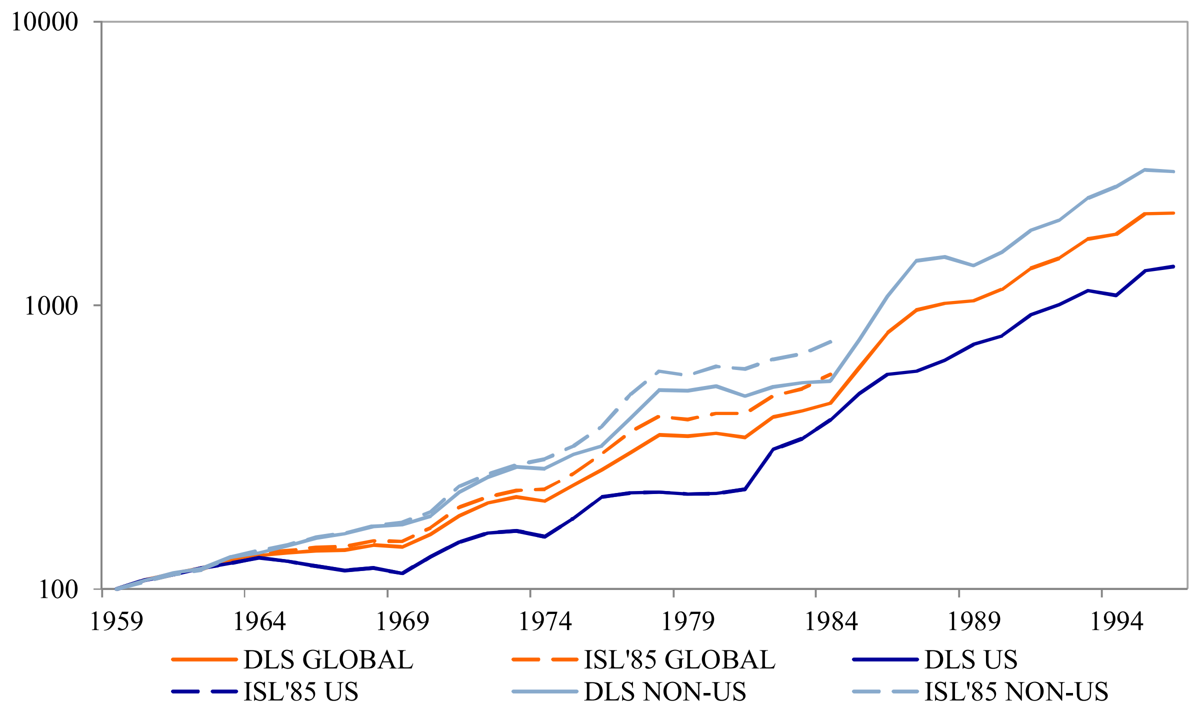
Investment grade credits

As an indicator of the performance of investment grade credits we constructed an investment grade corporate bond index. Figure A12 illustrates the performance of our index at global level, US-level and non-US level. Also, it contains the indices for the ISL (1985) study. We are not aware of any other study documenting global corporate bond returns from the sixties through the eighties.

At global level, for the period 1960-1984, the returns of our index have a correlation of 0.94 to those of ISL, while average annual compounded returns are 6.22% and 7.21% respectively. For the US we use ISL'85 data for the period 1960-1984, and another data source afterwards. The yearly compounded return in the first 25 years is 5.65%. For non-US corporate bonds, we compose our own index from 1960. The correlation with ISL'85 at non-US level is 0.89. At non-US level, returns are 7.00% for our index and 8.35% for the ISL'85 index.

Figure A12

Performance indices for IG corporate bonds with Doeswijk, Lam and Swinkels (DLS) and Ibottson, Siegel and Love (ILS) data

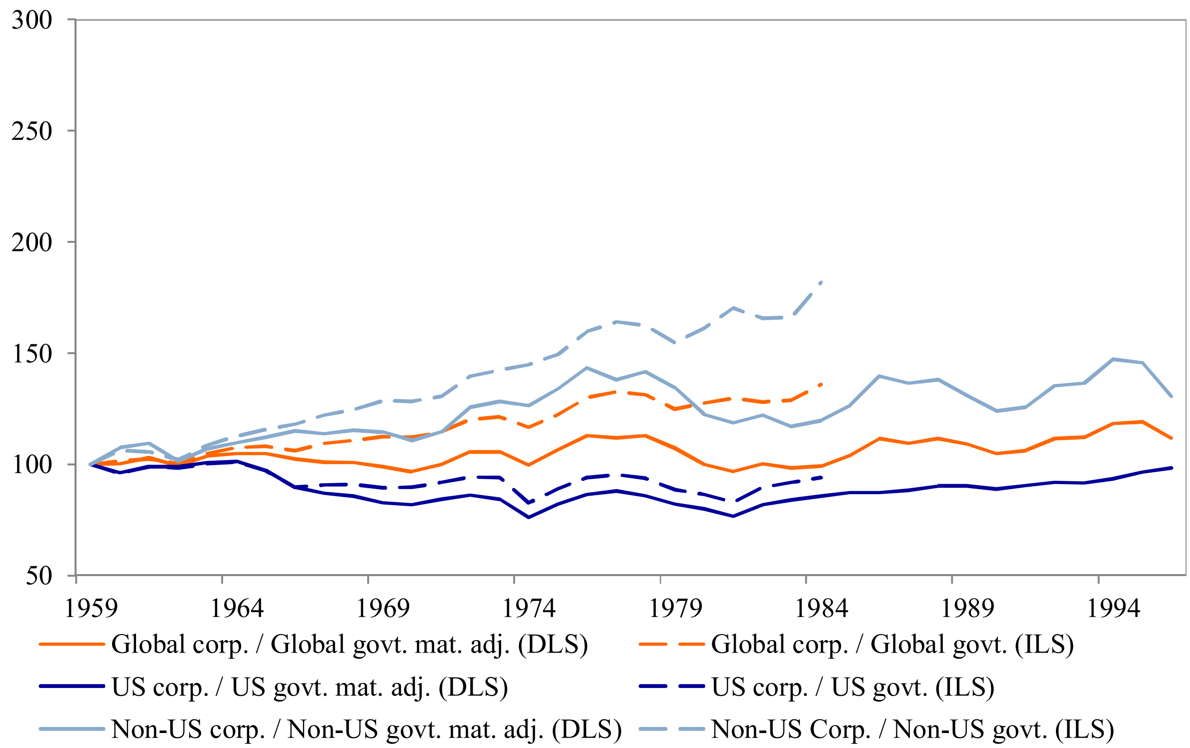


We also examined the total return performance of corporate bonds relative to government bonds for our data set and for ISL'85. Figure A13 provides a graphical illustration of the differences. For the period 1960-1984, we report an average compounded underperformance of global corporate bonds compared to government bonds of 3 bps a year, while ISL'85 report an outperformance of 123 bps. Both series have a correlation of 0.64. For US corporate bonds, the correlation is 0.96. Our data results show that the corporate index for the US lags our government bond index by a yearly average of 62 bps, while its lags a yearly average of 25 bps with ISL'85 data. However, there is a larger difference for the non-US region where we report an average outperformance of corporate bonds over government bonds of 72 bps a year. ISL’85 document an annual outperformance of 242 bps. This is a rather large difference over a 25-year period. In our data set, there is a correlation of 0.34 between the annual premium of corporate bonds in the US and in the non-US region. The ISL’85 data result in a correlation of 0.09.

We do not know where the differences in non-US corporate bond returns and corporate bonds’ premiums over government bonds arise from. Unfortunately, we have no source data of the ISL’85 study available for a more detailed comparison. Possibly, there is a significant difference between currency and maturity mismatches between the two corporate bond datasets. However, on balance, we do feel comfortable with our data. Our data show a higher correlation between the US and non-US return differences relative to government bonds. Next, the non-US premium of corporate bonds over government bonds in our data set is more in line with what we ex-ante would have expected for a period with two oil crises and a huge recession in the early eighties.

Figure A13

Performance indices for IG corporate bonds versus government bonds with Doeswijk, Lam and Swinkels (DLS) and Ibottson, Siegel and Love (ILS) data



Government bonds

We compare several global government bond indices in Table A2. The indices in columns two to five are our indices that we described in the previous appendix with data details of returns. Column six contains the global bond index from the Dimson, Marsh, and Staunton (2015b) database, column seven shows the returns for an index based on Ibbotson, Siegel and Love (1985), we refer to this study as ISL'85, and column eight contains data for the Bloomberg Barclays Capital Global Treasury Index. All data are total returns in unhedged US dollars.

Table A2

Return characteristics for several global government bond indices (total returns, unhedged USD)

(1)	GDP weighted (2)	Debt weighted (3)	GDP w. mat. adj. (4)	Debt w. mat. adj. (5)	DMS (6)	ISL'85 (7)	BBC global tr. (8)
1960-1984							
Average compounded return (%)	6.02	4.92	7.27	6.26	6.09	5.91	NA
Standard deviation (%)	6.21	6.46	4.52	4.64	6.25	5.56	NA
Correlations							
GDP weighted index	1.00	0.97	0.87	0.83	1.00	0.93	NA
Debt weighted index		1.00	0.82	0.86	0.97	0.94	NA
GDP weighted maturity adj. index			1.00	0.94	0.86	0.89	NA
Debt weighted maturity adj. index				1.00	0.83	0.90	NA
DMS global bond index					1.00	0.93	NA
ISL'85 global bond index						1.00	NA
Bloomberg BC global treasury							1.000
1987-2011							
Average compounded return (%)	9.43	9.31	7.91	7.68	9.53	NA	7.37
Standard deviation (%)	8.69	8.93	7.07	7.24	8.28	NA	7.18
Correlations							
GDP weighted index	1.00	0.99	0.86	0.84	1.00	NA	0.89
Debt weighted index		1.00	0.84	0.85	0.99	NA	0.88
GDP weighted maturity adj. index			1.00	0.98	0.86	NA	0.94
Debt weighted maturity adj. index				1.00	0.84	NA	0.93
DMS global bond index					1.00	NA	0.87
ISL'85 global bond index						1.000	NA
Bloomberg BC global treasury							1.000
1960-2011							
Average compounded return (%)	8.55	7.97	8.21	7.63	8.65	NA	NA
Standard deviation (%)	8.88	9.29	6.68	6.94	8.72	NA	NA

For the robustness check, we composed a market capitalization weighted global government bond index from ISL'85 returns by using the reported market capitalizations and returns for United States government bonds and foreign domestic government bonds to create a market capitalization weighted government bond index. The ISL'85 data contain returns for bonds with a maturity that differs by country, but we distracted from the description of the data sources that the index is closer to an all maturity index than the global bond index from DMS which is primarily based on 20-year bond returns.[45]

The average compounded annual return for the 1960-1984 period has been 5.91% according to ISL'85. Surprisingly, this is close to the 6.09% from DMS. However, this is coincidence, as a further analysis shows that US and non-US returns do not come close to each other, but both deviations cancel each other out during the time frame 1960-1984. This can be found in Table A3 and Table A4 to which we return later. Our GDP weighted global index also comes close with a return of 6.02%, but this index actually is comparable to the global index of DMS. The DMS global government bond index is a GDP weighted index, with weights unreported. We use their returns and our GDP-weights to arrive at an index that is basically the same with comparable returns, standard deviations and correlation. So, again, US and non-US returns do not match ISL'85 data. Our debt weighted maturity adjusted index is 35 bps above the return reported by ISL'85. This obviously comes closer than the debt weighted index or the GDP-weighted maturity adjusted index, with differences of -99 bps and 136 bps respectively.

The return of our global maturity adjusted index also comes closest to the Bloomberg Barclays Capital Global Treasury Index during the period 1987-2011 with a difference of average compounded annual returns of 31 bps above Bloomberg Barclays'. For this period, DMS reports an average return 216 bps above the Bloomberg Barclays Capital Global Treasury Index as they primarily use bonds with a 20-year maturity. Again, the debt weighted maturity adjusted index mirrors the return of the Bloomberg Barclays index better than the GDP weighted maturity adjusted index as its return is 53 bps higher than Bloomberg Barclays.

For the period 1987-2011, the standard deviation of our government debt weighted maturity adjusted index is almost identical to the one for the Bloomberg Barclays index. For the period 1960-1984, standard deviations were all in a range of 1% around the standard deviation of ISL'85. For both sub periods, correlations are (very) high with ISL'85 and the index from Bloomberg Barclays.

For the period 1960-2011, the compounded return of our global debt weighted maturity index is 102 bps below the DMS global bond index, which is GDP weighted and contains maturities mostly around 20. Both the weighting method and the maturity adjustment attribute to this difference.

This robustness check shows that the return of our debt weighted maturity adjusted global government bond index comes very close to other benchmark indices in both sub-periods, referring to the ISL'85 index and the

[45] Unfortunately, the appendix at request with the data details of the ISL'85 study, as well as the data themselves, have gone lost during the past 30 years, as we noticed from the authors. However, they informed us that their study was basically an update from the Ibbotson and Siegel (1983) paper. On its turn, this paper refers for some details to the Ibbotson, Carr and Robinson (1982) study. There, we found information on the maturity of government bonds.

Bloomberg Barclays Capital Global Treasury Index. As a further examination, we also will check the US and non-US returns.

Table A3 shows return characteristics for several US government bond market indices. Column two contains the returns from DMS, column three shows our maturity adjusted return data, column four contains the ISL'85 data for the US, columns five and six contain data based on the Ibbotson SBBI 2015 Classic Yearbook and reflect the return on intermediate (five year) and long term (twenty year) bonds and finally column seven and eight are from Bloomberg Barclays Capital and show the US Aggregate Index for all maturities and long term government bonds respectively.

DMS and Ibbotson's long term bonds data are the same for the period 1960-1984. Their returns are 1.21% below the return for ISL'85. Our maturity adjusted US index comes closest to the ISL'85 data with a return of 5.91% versus 6.63% for ISL'85, almost matching standard deviations and a correlation of 0.98.

For the 12-year period 1973-1984, the Ibbotson intermediate bonds data come closest to the Bloomberg Barclays US Aggregate Index, while our maturity adjusted index and the ISL'85 show approximately the same return characteristics. It should be noted that returns for twenty year bonds are way off returns for indices that intend to reflect all maturity returns, i.e. our maturity adjusted index, the ISL'85 index and the Bloomberg Barclays US Aggregate Index, with returns around 2% higher for the all maturity indices. For the period 1973-2014 both our maturity adjusted index and the Ibbotson intermediate bond index come close to the Bloomberg Barclays US Aggregate Index.

Also for the US, the robustness check suggests our maturity adjusted index to be a good estimate of the return of the US government bond market. It comes close to both the ISL'85 and the Bloomberg Barclays US Aggregate Index. We now turn to the non-US market as a final check.

We provide return characteristics of the non-US government bond market in Table A4. The non-US GDP weighted unadjusted returns from DMS are 1.2% higher than from ISL'85, while for the US it was the other way around with a gap of -1.2%. Hereby, at a global level it seemed that a GDP weighted index with unadjusted DMS returns were a proper reflection of the performance of the global bond market. Our non-US maturity adjusted index comes close to ISL'85 again. This suggests that GDP weighted unadjusted returns are not as suitable for the purpose of reflecting the performance of the global bond market as the debt weighted maturity adjusted returns. Table A2, Table A3 and Table A4 suggest that debt weighting instead of GDP weighting as well as using maturity adjusted returns instead of unadjusted returns contribute to creating a global all maturity benchmark.

Our debt weighted maturity adjusted global government bond index seems a good estimate of the return of the global government bond market. It has shown to be close to two other all maturity indices at different sub-periods. Also, the analysis for the US and non-US underpin the global results. As mentioned in the previous appendix, we use our debt weighted maturity adjusted global government bond index in this study for the period 1960 through 1986. From 1987 onwards, we use the returns from the Bloomberg Barclays Capital Global Treasury Index.

Table A3

Return characteristics for several US government bond indices (total returns)

(1)	DMS (2)	Maturity Adjusted (3)	ISL '85 (4)	Ibbotson intermediate (5)	Ibbotson long (6)	BBC aggregate (7)	BBC aggr. long (8)
1960-1984							
Average compounded return (%)	4.70	6.31	5.91	6.63	4.70	NA	NA
Standard deviation (%)	9.90	6.50	6.57	6.40	9.90	NA	NA
Correlations							
DMS	1.00	0.95	0.95	0.92	1.00	NA	NA
Maturity adj. index		1.00	0.98	1.00	0.95	NA	NA
ISL '85			1.00	0.97	0.95	NA	NA
Ibbotson intermediate index				1.00	0.92	NA	NA
Ibbotson long index					1.00	NA	NA
Bloomberg BC US aggregate						1.00	NA
Bloomberg BC US aggregate long							1.00
1973-1984							
Average compounded return (%)	6.10	8.02	7.99	8.44	6.10	8.52	6.61
Standard deviation (%)	12.57	7.64	7.21	7.48	12.57	7.09	12.72
Correlations							
DMS	1.00	0.98	0.97	0.97	1.00	0.96	1.00
Maturity adj. index		1.00	0.99	1.00	0.98	0.99	0.97
ISL '85			1.00	0.98	0.97	0.99	0.96
Ibbotson intermediate index				1.00	0.97	0.99	0.96
Ibbotson long index					1.00	0.96	1.00
Bloomberg BC US aggregate						1.00	0.95
Bloomberg BC US aggregate long							1.00
1973-2014							
Average compounded return (%)	8.65	7.34	NA	7.42	8.65	7.49	8.76
Standard deviation (%)	12.59	7.28	NA	6.61	12.59	6.44	12.36
Correlations							
DMS	1.00	0.91	NA	0.86	1.00	0.88	1.00
Maturity adj. index		1.00	NA	0.99	0.91	0.99	0.91
ISL '85			1.00	NA	NA	NA	NA
Ibbotson intermediate index				1.00	0.86	0.99	0.87
Ibbotson long index					1.00	0.88	1.00
Bloomberg BC US aggregate						1.00	0.89
Bloomberg BC US aggregate long							1.00

Table A4

Return characteristics for several non-US government bond indices (total returns, unhedged USD)

(1)	GDP weighted (2)	Debt weighted (3)	GDP w. mat. adj. (4)	Debt. w. mat. adj. (5)	ISL'85 (6)
1960-1984					
Average compounded return (%)	6.95	5.13	7.93	6.23	5.79
Standard deviation (%)	7.14	7.88	7.02	7.67	7.56
Correlations					
GDP weighted index	1.00	0.93	0.94	0.87	0.92
Debt weighted index		1.00	0.86	0.94	0.95
GDP weighted maturity adj. index			1.00	0.92	0.84
Debt weighted maturity adj. index				1.00	0.87
ISL'85 non-US bond index					1.00

Appendix C. Market capitalizations

We use the market capitalizations from Doeswijk, Lam and Swinkels (2014a) which we update for the period 2013-2015 as described in their study. Following the discussion in Westerling (2014) and Doeswijk, Lam and Swinkels (2014b) we correct market capitalizations for financial assets held by some major central banks. We subtract the market value of the Bloomberg Barclays Capital Global Aggregate Float Adjusted Index from the market value of the Bloomberg Barclays Global Aggregate Index for both government bonds and investment-grade securities to determine the free float correction that we make to our market capitalization data.[46,47] For all other data details and a description of our methodology for the composition of the GMP we refer to Doeswijk, Lam and Swinkels (2014a).[48]

[46] Here follows a description from a Barclays Capital research report of Myers and Upbin (2009): "With an inception date of July 1, 2009, the Barclays Capital Global Aggregate Float Adjusted Index provides a broad-based measure of the global investment-grade fixed-rate debt markets that excludes government holdings and quantitative easing purchases. The underlying constituents of the Global Aggregate Float Adjusted Index are the same as the flagship Global Aggregate Index and conform to the same general conventions, but currently deduct net holdings of US treasuries, US agencies, and fixed-rate MBS pass-throughs held in Federal Reserve SOMA accounts, as well as Sterling Gilts and Japanese Yen held by the Bank of England and the Bank of Japan, respectively".

[47] We do not take ECB holdings into account. Adjustments for ECB holdings bring a lot of uncertainty as one has to work with estimates due to a lack of details. It would also introduce a hindsight bias as data are not timely available.

[48] There is one difference as in this study we combine the asset classes equities and private equity into the asset category Equities Broad for the entire 1960-2015 period. Doeswijk, Lam, Swinkels (2014a) estimate the market capitalization for the asset class private equity from 1990 onwards. Before 1990, we assume the market capitalization of private equity to have grown in line with the market capitalization of the asset class equities. This assumption has a limited quantitative impact, as private equity represents just 1.7% of the asset category Equities Broad in 1990 and 0.9% of the global market portfolio.