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ASSET ALLOCATION AND FUND PERFORMANCE OF DEFINED BENEFIT PENSION FUNDS IN THE UNITED STATES, 1998-2014

Performance differences among defined benefit pension funds in the U.S. primarily result from differences in the asset allocation decisions they make. Between 1998 and 2014, large corporate sector funds distinguished themselves by having a much higher net return compared to public sector and small and mid-sized corporate sector funds. They achieved this by radically altering their allocations just prior to the global financial crisis. The key decision was a timely increase in their allocation to long duration fixed income through a decrease in allocation to large-cap U.S. stock and broad U.S. fixed income. Small public sector funds, by contrast, underperformed because they continued to use expensive fund-of-fund implementation styles when investing in unlisted real estate and private equity where less expensive options like listed equity REITs and small-cap U.S. stocks would have produced superior returns.

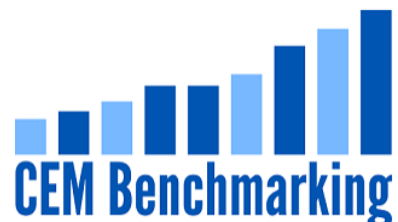


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Asset Allocation and Fund Performance of Defined Benefit Pension Funds in the United States, 1998-2014

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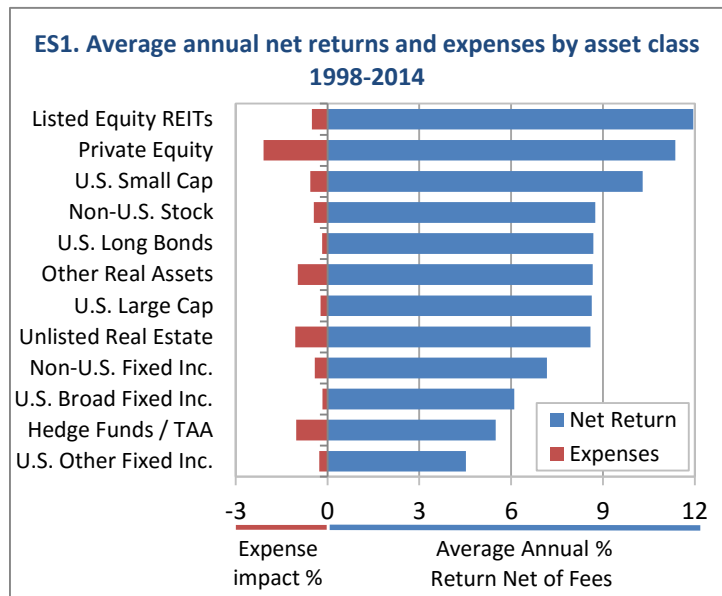
Executive Summary

Introduction

- Of the \$24.7 trillion of retirement assets in the United States at the end of 2014, approximately \$5.2 trillion were held in public sector defined benefit (DB) funds and \$3.2 trillion were held in corporate sector DB funds. Because millions of Americans rely on these pensions for their retirement security, the investment allocation decisions of these pension funds are of critical importance.
- This study provides a comprehensive look at investment allocations and realized investment performance across aggregate asset classes using a unique and proprietary dataset covering over 200 public and private sector pensions with over \$3 trillion in combined assets under management (AUM) over a 17-year period. One of the unique benefits of the dataset is that it provides the actual realized performance net of investment costs of the assets chosen by plan managers and trustees.

Asset returns

- This study compares annual average returns net of all investment costs across 12 aggregate asset classes with appropriate adjustments for reporting lags associated with illiquid asset classes (e.g., unlisted real estate and private equity).
- Over the 17-year period covered by this study there were striking differences in performance across aggregate asset classes. Exhibit ES1 summarizes arithmetic average annual net returns and average annual investment costs (both in percentage points) for the 12 asset classes covered in the study.
- Listed equity REITs had the highest average net return over the period,



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averaging 12.0%. Private equity had the highest average gross return, estimated as 13.5%, but had the second highest average net return of 11.4% because the impact of expenses.

- The two worst performing asset classes were hedge funds / tactical asset allocation (TAA) strategies and U.S. other fixed income. U.S. other fixed income however includes cash. If cash is excluded from U.S. other fixed income as an aggregate asset class, then hedge funds/TAA would have been the worst performing asset class with a 17-year arithmetic average annual net return of 5.5 percent.

Asset Allocations

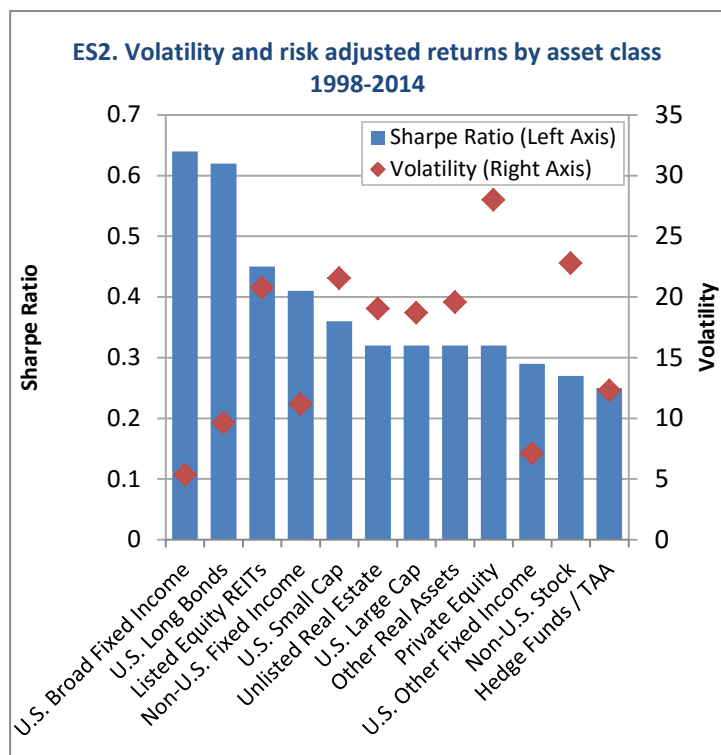
- The most material decrease in asset allocation was the decrease in allocation to U.S. large cap stock. In 1998 over 42 percent of the holdings of U.S. DB pension funds were dedicated to U.S. large cap stocks. By 2014 this had fallen to less than 19 percent.
- The most material increase in asset allocation was the increase in allocation to U.S. long bonds. In 1998 the allocation to U.S. long bonds was less than 2 percent whereas today it is over 16 percent. This increase was confined to corporate sector pension funds.
- Although they had the highest arithmetic average annual net return of 12.0 percent over the period, listed equity REITs were the least used asset class covered in the study. Allocations to listed equity REITs averaged just 0.6 percent of total assets. Unlisted real estate by contrast had a 3.5 percent allocation on average while having had an arithmetic average annual net return of 8.6 percent.

Total fund returns

- Large corporate sector plans (> \$10 billion in AUM) outperformed due to a timely increase in allocation to long duration fixed income just before the financial crisis of 2008.
- Small public sector plans (< \$2 billion in AUM) underperformed because of persistent underperformance in hedge funds, unlisted real estate, and private equity. The underperformance is due, in part, to the use of expensive fund-of-funds.

Volatility and Risk Adjusted Returns

- The study also compared volatilities and risk adjusted returns using the Sharpe ratio across asset classes. The data are summarized in Exhibit ES2.
- Two fixed income aggregate asset classes had the highest Sharpe ratios reflecting their extremely low volatilities, albeit with modest returns.
- Non-U.S. stocks and hedge funds / TAA had the lowest Sharpe ratios reflecting high volatility and poor returns respectively.
- After adjusting for reporting lags, private equity was the most volatile aggregate asset class by far at 28.0 percent. The large volatility reflects both the large standard deviation of average returns (market risk) as well as the large dispersion of returns between funds (idiosyncratic risk). The study shows that market risk of private equity at 20.9 percent is however comparable to U.S. small cap stocks at 20.1 percent.
- After adjusting for reporting lags, the study



found that listed equity REITs and unlisted real estate had comparable volatilities. Listed equity REITs and unlisted real estate had the 4th and 5th most volatile net returns with measure volatilities of 20.7 percent and 19.6 percent respectively.

Correlations

- The study also compared correlations of annual returns among the 12 asset classes as summarized in Exhibit ES3.
- The broadest group of highly correlated aggregate asset classes were equity asset classes together with hedge funds / TAA; this includes U.S. large cap stock, U.S. small cap stock, non-U.S. stocks, hedge funds, TAA, and private equity. The high correlation of listed equities to private equity only emerged after accounting for reporting lags. Correlations in this group ranged from 0.79 to 0.93.
- Listed equity REITs and unlisted real estate were highly correlated as well once reporting lags in unlisted real estate were accounted for. The correlation between the two asset classes is 0.91, among the highest of all. The high correlation is not surprising given both asset classes invest in fundamentally the same assets.
- Both listed equity REITs and unlisted Real Estate are not highly correlated to any other aggregate asset classes.
- Long duration U.S. bonds are anti-correlated to stocks and private equity, but positively correlated to U.S. broad fixed income.

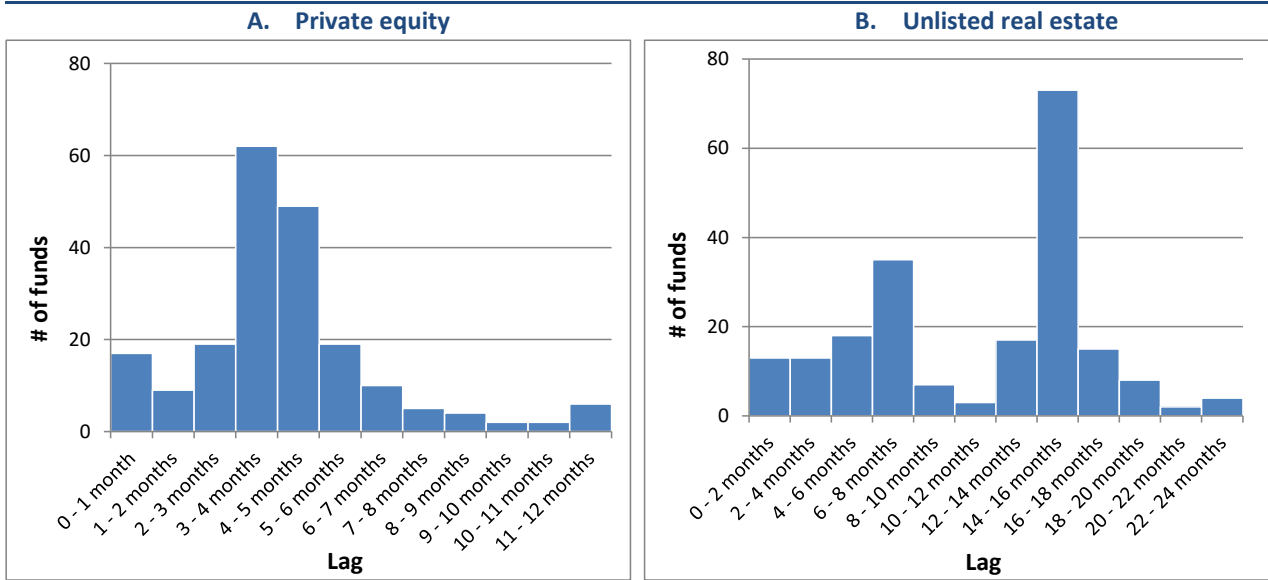
Reporting lags for illiquid assets

- Reporting lag is the time between when an underlying asset changes value and when that change in value is reported to the pension fund of investor. Illiquid assets like unlisted real estate and private equity have reporting lags.
- The unique CEM dataset allows adjustment for illiquid asset reporting lag at the individual fund level. Typically this type of adjustment is made using a single assumption applied to all investment returns in an illiquid asset class.
- In addition to improving the accuracy of the returns, volatilities and correlations, adjusting for reporting lag at the fund portfolio level allows the observation of the distribution of reporting lags across funds. The distributions are shown in Exhibit 4A and 4B.
- The distribution of reporting lags associated with private equity is fairly tightly clustered around 3 to 5 months.

ES3. Correlations between aggregate asset classes: 1998-2014

		Stock			Fixed Income				Real Assets			Other	
		U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
Stock	U.S. Large Cap	n/a	0.92	0.88	-0.03	-0.50	0.66	0.49	0.49	0.54	0.27	0.93	0.85
	U.S. Small Cap	0.92	n/a	0.89	-0.09	-0.62	0.66	0.48	0.57	0.63	0.39	0.79	0.89
	Non U.S.	0.88	0.89	n/a	-0.07	-0.62	0.73	0.58	0.55	0.57	0.54	0.86	0.91
Fixed Income	U.S. Broad	-0.03	-0.09	-0.07	n/a	0.61	0.57	0.65	0.36	0.42	0.01	0.09	-0.14
	U.S. Long Bonds	-0.50	-0.62	-0.62	0.61	n/a	-0.21	0.05	-0.11	-0.07	-0.38	-0.39	-0.68
	U.S. Other	0.66	0.66	0.73	0.57	-0.21	n/a	0.79	0.67	0.68	0.43	0.71	0.67
Real Assets	Non U.S.	0.49	0.48	0.58	0.65	0.05	0.79	n/a	0.49	0.62	0.24	0.52	0.39
	Unlisted Real Estate	0.49	0.57	0.55	0.36	-0.11	0.67	0.49	n/a	0.91	0.49	0.44	0.54
	Listed Equity REITs	0.54	0.63	0.57	0.42	-0.07	0.68	0.62	0.91	n/a	0.50	0.49	0.50
Other	Other	0.27	0.39	0.54	0.01	-0.38	0.43	0.24	0.49	0.50	n/a	0.35	0.50
	Hedge Funds / TAA	0.93	0.79	0.86	0.09	-0.39	0.71	0.52	0.44	0.49	0.35	n/a	0.80
	Private Equity	0.85	0.89	0.91	-0.14	-0.68	0.67	0.39	0.54	0.50	0.50	0.80	n/a

ES4 Distribution of reporting lag



- The distribution of reporting lags for unlisted real estate shows no such clustering and has a bimodal distribution with peaks at 6-8 months and 14-16 months.

Summary

- Aggregate asset class net returns, standardized to remove reporting lags in unlisted real estate and private equity, are summarized in Exhibit ES5.

ES5. Standardized aggregate asset class net returns for U.S. DB pension funds (in percent)

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	12.52	5.03	-1.78	6.91	19.39	1.79	2.85	25.41	20.19	2.37	4.75	2.54
2013	33.38	38.39	17.84	-2.09	-7.72	1.35	-0.39	-0.10	3.99	2.88	9.10	25.30
2012	16.27	16.00	17.72	7.14	10.51	5.41	11.54	14.91	20.55	3.84	7.54	15.98
2011	0.90	-3.08	-12.71	8.48	22.17	3.61	3.77	-3.66	2.05	-1.53	0.80	-7.22
2010	16.22	26.41	12.45	8.61	11.03	5.10	13.62	3.77	23.51	10.93	9.26	20.79
2009	29.52	33.41	39.57	11.88	4.18	13.13	20.38	33.43	29.89	5.65	14.84	40.58
2008	-38.10	-37.65	-44.44	0.07	13.96	-5.39	-8.67	-29.04	-38.20	-9.66	-17.84	-29.97
2007	5.81	2.24	14.30	6.51	7.66	4.89	7.88	-10.62	-10.75	14.40	8.07	3.01
2006	14.67	14.68	25.72	4.80	2.67	5.68	7.79	28.75	34.75	14.86	11.03	24.53
2005	6.75	7.21	16.72	3.15	5.99	3.32	1.93	10.83	14.16	19.19	7.44	5.75
2004	12.02	16.76	19.62	5.29	9.07	4.92	10.31	16.12	32.43	18.18	7.42	16.67
2003	30.80	43.17	37.56	6.11	6.87	8.12	18.10	25.91	33.09	9.56	15.61	28.23
2002	-21.45	-19.33	-14.12	9.38	15.21	2.35	14.11	-0.99	5.17	9.24	-12.17	-20.18
2001	-9.94	-1.27	-17.36	8.17	6.57	4.54	2.11	2.80	10.94	4.44	-5.02	-9.90
2000	-5.21	0.27	-12.45	11.42	16.14	6.33	4.65	31.31	26.58	18.95	1.50	6.25
1999	19.19	29.88	38.33	-0.63	-7.89	5.56	1.24	9.00	1.23	22.30	10.12	56.65
1998	23.59	2.94	11.80	8.50	11.90	6.19	10.64	-11.69	-6.39	1.75	21.09	14.34
Arit. Gross Ret.:	8.87	10.86	9.20	6.27	8.87	4.79	7.59	9.64	12.46	9.64	6.52	13.46
Avg. Invest. Cost:	0.23	0.56	0.44	0.17	0.18	0.27	0.42	1.05	0.51	0.97	1.02	2.08
Arit. Net Ret.:	8.64	10.30	8.75	6.10	8.69	4.52	7.17	8.59	11.95	8.67	5.50	11.37
Comp. Net. Ret.:	6.83	8.26	6.13	6.03	8.39	4.46	6.93	7.21	10.14	8.34	5.04	9.34
Std. Dev.:	18.39	20.13	22.22	3.88	7.89	3.59	7.11	16.79	18.62	8.34	9.51	20.88
Volatility:	18.71	21.54	22.77	5.33	9.63	7.11	11.19	19.03	20.74	19.56	12.30	28.00
Sharpe Ratio:	0.32	0.36	0.27	0.64	0.62	0.29	0.41	0.32	0.45	0.32	0.25	0.32

1 Introduction

Of the \$24.7 trillion of retirement assets in the United States, \$5.2 trillion are held in public sector defined benefit (DB) funds and \$3.2 trillion are held in corporate sector DB funds [1]. The striking difference between the two is exemplified by their unfunded liabilities, estimated by the same source to be \$3.1 trillion for public sector DB funds compared to only \$20 billion for corporate sector DB funds. Given this funding challenge it is critical that funds maximize returns given risk appetite. That requires unbiased data on performance attributes.

In the inaugural version of this series of papers [2], released in June 2014, we addressed the question of how public and corporate defined benefit (DB) pension funds in the U.S. performed over the period 1998-2011 and why. The primary conclusions of that initial paper are not too different from our updated conclusions and may be summarized as follows:

- Large corporate sector plans with \$10 billion or more in assets under management (AUM) outperformed as a group due to a well-timed move into liability driven investing (LDI), characterized by an increase in allocations to U.S. long duration bonds funded by a decrease in allocations to broad U.S. fixed income. This embrace of LDI fortuitously just preceded the financial crisis in 2008.
- Small public sector plans with less than \$2 billion (USD) in AUM underperformed not because of differences in asset allocation but because of the overuse of expensive fund-of-fund implementation of hedge funds, unlisted real estate, and private equity.
- The best performing asset classes net of investment costs were listed equity REITs on an arithmetic average return basis and other real assets such as commodities and infrastructure on a compound average return basis. Both asset classes, however, are largely ignored by U.S. DB pension funds.

A notable update to our conclusions concerns the relative performance of the asset classes listed equity REITs and other real assets. During the span 2011-2014, the additional years included in this update, listed equity REITs showed continued strong performance whereas other real assets performed poorly. As a consequence, listed equity REITs is now the best performing asset class on both an arithmetic and compound basis over the period 1998-2014.

This paper includes several notable improvements to the original analysis published in 2014 [2]. First, the time span covered has been extended by three years to 1998-2014. Second, we have significantly improved the standardization of illiquid asset returns in order to obtain more reliable comparisons to their liquid counterparts. With this improvement we are able to compare asset class returns on a risk adjusted basis via Sharpe ratios as well as observing the true correlations between liquid and illiquid assets.

Given three new years of data together with a greatly improved analysis of unlisted real estate and private equity, new and updated conclusions may be drawn. At the total fund level, large corporate sector funds continue to be the best performing cohort of funds with an average annualized compound return of 8.25 percent over the period studied (in comparison to an all-cohort average annualized compound return of 7.49 percent). Once again, his outperformance may be attributed to a timely shift towards LDI beginning in 2008.

The underperformance of small public sector DB pension funds has been greatly tempered over the past three years. This recovery is almost entirely due to the cohort's above-average allocation to large and small-cap U.S. equities in 2013. That said, small public sector funds continue to underperform their expected return given their allocation alone. This underperformance is still due, in part, to an over-reliance on expensive fund-of-fund investments in hedge funds, unlisted real estate, and private equity.

Listed Equity REITs are the best performing asset class on an arithmetic return and compound return basis. Over the 17 years considered here, 1998-2014, its average annualized return net of all investment costs was 11.95 percent (arithmetic) and 10.14 percent (compound). The best performing asset class on a compound return basis in the inaugural study, other real assets, has since experienced three consecutive years of low returns (average annualized compound net return of 3.03 percent during 2012-2014).

The worst performing asset class was fixed income (e.g., cash, high yield, mortgages) which experienced the worst return, compound or arithmetic, over the past three years as well as over the whole period of study. The average annualized return net of all investment costs spanning 1998-2014 was 4.52 percent (arithmetic) and 4.46 percent (compound). This underperformance was, however, caused by a single dominant component of the asset class - cash. Excluding cash, the worst performing asset class was hedge funds / TAA at 5.50 percent (arithmetic) and 5.04 percent (compound). The worst performing asset class in the inaugural study was large-cap U.S. stock. The asset class has since experienced three consecutive years of high returns (average compound net return of 20.39 percent during 2012-2014) and consequently, it was no longer the worst performing asset class over the full period of this study.

A new feature is our presentation of asset class volatilities. In the inaugural study we did provide (and one could have easily calculated) asset class population standard deviations. However, standard deviation of the average annual returns should not be confused with volatility because it ignores the idiosyncratic risk taken by active management (i.e., within any particular year, a fund's actual return can vary strongly from the average which results in increased volatility). In addition, the fact that returns for both unlisted real estate and private equity possess different reporting (or valuation) lags for different funds implies that annual average return data were significantly smoothed even with the standardizations we originally applied. Conceptually, smoothing of illiquid asset returns is the result of the market peaks and troughs not lining up for different funds because of their different reporting lags.

By The Numbers: 1998-2014		
<ul style="list-style-type: none"> • More than \$3.4 trillion of U.S. DB assets included in the study 	40%	Portion of all U.S. DB funds†
<ul style="list-style-type: none"> • Liability driven investing: Large corporate DB plans continue to outperform 	8.3%	Annualized net return‡
<ul style="list-style-type: none"> • The high cost of fund-of-funds: Small public sector plans continue to underperform 	7.1%	Annualized net return‡
<ul style="list-style-type: none"> • Listed equity REITs: The best performing asset class 	10.1%	Annualized net return
<ul style="list-style-type: none"> • Hedge funds / TAA: The worst performing asset class (excluding cash) 	5.0%	Annualized net return
<ul style="list-style-type: none"> • Private equity: The riskiest asset class 	28.0%	Annualized volatility
<ul style="list-style-type: none"> • Fund-of-fund real estate: The most expensive asset class 	4.8%	Investment cost in percent

† Fraction of the U.S. DB market contained in this study as of December 31st 2014. See reference 1 for details.

‡ Calculated average annualized compound net return on physical assets only.

In this paper we use a unique approach to de-smooth illiquid asset returns. Specifically, we exploit the fact that since we have fund level private equity and unlisted real estate data, we are able to determine the amount of reporting lag present in each funds return series. Standardizing each funds unlisted real estate and private equity performance data to remove their fund specific lag has the effect of removing the smoothing which results from fund-averaging annual returns with different reporting lags. Our approach is fundamentally different from typical de-smoothing procedures [3] whereby the annual average data are processed in order to increase volatility.

Removing the reporting lags from unlisted real estate and private equity fund-by-fund has several rather dramatic effects on the data. First, it reveals that the standardized (i.e., true) correlation between listed and unlisted assets was much higher than as reported: For private equity the true correlation to small-cap U.S. stock is 0.89 compared to 0.43 as-reported, whereas for unlisted real estate the true correlation to listed equity REITs is 0.91 compared to 0.09 as-reported. Second, it shows that the true volatility of unlisted real estate is 30% greater than as reported, and for private equity 20% greater than as reported. Quite simply, illiquid assets had much higher correlations and much greater volatilities than is typically accepted.

Finally, removing the reporting lags from the illiquid asset data allows us to plot returns vs. volatility for the 12 aggregate asset classes considered in this paper. Only two asset classes demonstrated superior risk-reward trade-off relative to the group: long-duration fixed income and listed equity REITs. By contrast, several asset classes demonstrated inferior risk-reward trade-off; large-cap U.S. stock, non-U.S. stock, other U.S. fixed income (mortgages, high yield, cash, etc.), and hedge funds / TAA.

2 The CEM database

The CEM database contains detailed information regarding asset allocation (policy weights and actual weights) and investment returns, both gross and net of investment costs, for more than 1,000 large institutional investors, some with histories as far back as 1990. Participating funds include traditional DB pension funds, defined contribution pension funds, buffer funds, sovereign wealth funds and endowment funds around the world (CEM has clients representing six of the seven continents). Funds participate in the CEM investment benchmarking service to benchmark their investment costs against their peers. While funds enter and exit the database over time, the database remains free of bias with respect to investment returns because performance [4] does not motivate fund participation.

A particularly valuable attribute of the CEM database is the detailed investment cost data that support comparative studies of asset class returns net of investment costs, the true measure of returns received by investors. The costs collected include (but are not limited to) manager base fees, manager-of-manager fees, commitment fees and performance fees, along with the usual costs associated with running an investment team (salaries and benefits for staff, travel, research, IT, etc.). Where costs cannot be separated from returns, they are netted from 'gross' returns. This level of detail allows for a separation of those costs directly associated with an investment and those not directly associated with an investment (e.g., oversight costs of the pension fund, actuarial costs, etc.). The net returns studied here are net only of those costs directly associated with an investment.

Prior studies of DB pension fund performance using the CEM database have focused on a number of topics, including: abnormal returns of domestic equity [4], outperformance of large funds relative to small funds by virtue of increased focus on alternatives including private equity and private real estate [5], outperformance of large funds relative to benchmarks of large funds due to market timing and security selection [6], and value added by large funds through private markets [7], noting that larger funds invest primarily in direct real estate but also are more likely than smaller funds to hold complementary investments in REITs, whereas smaller funds are more likely than larger funds to invest only in direct real estate.

Tables 1A and 1B. Assets under management (AUM) for U.S. public sector (top) and corporate sector (bottom) pension funds by year expressed in \$millions (USD) within the CEM database. Statistics shown are the number of funds (#), annual average (avg.), population standard deviations (std. dev.), minimum (min.), 25th percentile (Q1), 50th percentile (med.), 75th percentile (Q3), maximum (max.) and the total of the in-year average AUM. Any differences from earlier versions of this manuscript are caused by either data revisions, data exclusions, or new data submissions. (The 2007 increase in corporate sector DB funds was a result of a partnership between CEM and an external organization.)

Table 1A. Assets Under Management: U.S. Public Sector DB Pension Funds (in \$millions USD)

Year	#	Avg.	Std. Dev.	Min.	Q1	Med.	Q3	Max.	Total
2014	62	\$38,600	\$54,629	\$837	\$5,390	\$16,075	\$42,904	\$287,947	\$2,393,191
2013	64	\$33,828	\$48,252	\$989	\$5,903	\$14,763	\$39,599	\$263,404	\$2,164,985
2012	68	\$31,244	\$43,229	\$927	\$5,295	\$13,667	\$36,827	\$235,389	\$2,124,617
2011	68	\$30,068	\$41,631	\$867	\$6,271	\$13,072	\$34,583	\$225,228	\$2,044,656
2010	73	\$23,804	\$36,400	\$813	\$3,080	\$9,871	\$23,795	\$215,814	\$1,737,684
2009	73	\$21,410	\$32,703	\$320	\$3,081	\$8,632	\$21,596	\$195,277	\$1,562,899
2008	72	\$25,508	\$40,166	\$710	\$3,306	\$8,858	\$24,107	\$222,213	\$1,836,579
2007	80	\$22,364	\$39,052	\$621	\$2,808	\$7,500	\$22,592	\$243,745	\$1,789,094
2006	69	\$23,801	\$37,362	\$422	\$3,293	\$7,842	\$22,175	\$216,422	\$1,642,253
2005	72	\$18,868	\$32,835	\$393	\$2,596	\$6,324	\$17,865	\$194,502	\$1,358,529
2004	76	\$17,827	\$30,330	\$369	\$2,350	\$5,678	\$16,034	\$175,296	\$1,354,833
2003	74	\$15,849	\$25,427	\$325	\$2,126	\$5,571	\$15,256	\$146,841	\$1,172,830
2002	74	\$15,205	\$25,304	\$314	\$2,061	\$5,016	\$13,684	\$142,563	\$1,125,203
2001	83	\$15,400	\$26,473	\$147	\$1,826	\$5,466	\$13,058	\$158,116	\$1,278,235
2000	80	\$17,134	\$30,773	\$502	\$2,284	\$5,449	\$12,713	\$167,867	\$1,370,738
1999	83	\$15,911	\$27,745	\$305	\$1,588	\$4,947	\$12,294	\$161,527	\$1,320,607
1998	69	\$15,124	\$25,913	\$292	\$1,552	\$4,963	\$11,671	\$139,930	\$1,043,527

Table 1B. Assets Under Management: U.S. Corporate Sector DB Pension Funds (in \$millions USD)

Year	#	Avg.	Std. Dev.	Min.	Q1	Med.	Q3	Max.	Total
2014	97	\$10,302	\$12,569	\$469	\$2,749	\$5,354	\$12,335	\$58,866	\$999,256
2013	112	\$9,073	\$12,184	\$152	\$2,187	\$3,994	\$11,660	\$59,191	\$1,016,147
2012	120	\$8,031	\$11,366	\$47	\$1,879	\$3,518	\$9,859	\$61,469	\$963,749
2011	124	\$7,579	\$12,512	\$37	\$1,573	\$3,153	\$8,282	\$93,529	\$939,748
2010	121	\$7,162	\$12,005	\$34	\$1,434	\$2,529	\$7,432	\$85,991	\$866,645
2009	122	\$6,475	\$11,381	\$160	\$1,258	\$2,494	\$6,437	\$86,296	\$789,957
2008	130	\$6,268	\$12,043	\$78	\$1,185	\$2,423	\$5,728	\$94,962	\$814,814
2007	121	\$7,093	\$12,703	\$90	\$1,630	\$3,141	\$7,355	\$102,587	\$858,221
2006	64	\$9,154	\$16,144	\$424	\$1,864	\$3,721	\$9,189	\$105,719	\$585,882
2005	69	\$8,988	\$14,764	\$375	\$1,972	\$3,588	\$8,950	\$92,692	\$620,189
2004	78	\$7,525	\$12,941	\$37	\$1,592	\$3,276	\$7,031	\$85,437	\$586,963
2003	71	\$7,089	\$11,992	\$55	\$1,362	\$2,678	\$6,277	\$73,289	\$503,314
2002	69	\$7,159	\$11,506	\$82	\$1,397	\$2,783	\$6,451	\$62,327	\$494,000
2001	81	\$6,750	\$11,741	\$26	\$1,270	\$2,664	\$6,103	\$71,398	\$546,710
2000	72	\$7,471	\$13,257	\$123	\$1,144	\$2,402	\$6,833	\$76,600	\$537,927
1999	85	\$5,835	\$10,932	\$128	\$1,080	\$1,908	\$4,749	\$74,550	\$495,979
1998	91	\$5,385	\$10,363	\$120	\$979	\$1,928	\$3,904	\$71,850	\$490,017

This study is focused on the asset allocation and fund performance of U.S. public sector and corporate sector DB pension funds spanning 1998-2014, updating our inaugural work [2] on the same topic and which originally spanned 1998-2011. We chose 1998 as the starting point for our study as it coincides with the introduction of several new asset classes in the CEM Benchmarking Inc. database - among them listed equity REITs and hedge funds - which were previously included with other, broader, asset classes within the database. Thus, the analysis is more in tune with the myriad of asset classes available to pension funds today.

Summary data for total fund holdings are shown for U.S. public sector DB funds in Table 1A and for U.S. corporate sector DB funds in Table 1B. The holdings for a particular fund and year represent the average holdings over that year and not the holdings at year end. When funds choose not to provide their average holdings over a year, CEM estimates the average by averaging the start- and end-of-year holdings. A comparison of the two Tables shows that the average public sector plan in the CEM database is significantly larger than the average corporate sector plan within the CEM database. That said, while the database is skewed towards large funds in general, public sector DB

funds tend to be larger than corporate sector DB funds and so the database is not skewed more so towards larger funds for one group compared to the other.

3 Asset classes

3.1 Aggregation

As of 2014, CEM collects data for 216 distinct asset class / investment style / management styles. For liquid assets (e.g., stocks, bonds) investment styles are either active or passive and management styles are either internal or external. For illiquid assets (e.g., unlisted real estate, private equity) the investment style is exclusively active while management styles are for the most part either internal direct (i.e., buy/sell decisions are managed in-house by internal teams), direct LP (i.e., typical limited partner-general partner private equity model), fund-of-fund, or co-investment. For this research we do not distinguish between investment and management styles since performance gaps between them are, on average, small compared to the performance of the asset classes themselves. The exceptions are the illiquid asset classes where predictable performance differences exist between management styles that can be almost exclusively attributed to differences in investment management costs.

Even after aggregating asset class data at the investment style / management style level, there remain some 57 asset classes that funds invest in, of which 38 are actively invested in by U.S. funds. In order to make the study manageable we have aggregated the data into a much smaller set of 12 *aggregate asset classes*. A complete discussion of asset class aggregation, as well as a complete list of distinct asset classes included in the CEM global database and applicable to U.S. funds, appears in Appendix A. Here we provide only those details necessary for the topic at hand.

Our aggregation is based on four factors. The first three factors are centered on fitting the net return series for each of CEM's global database asset classes to a simple linear model:

$$r_a = \alpha + \beta r_r$$

where r_a is the net return of the asset class, r_r is the net return of a reference asset class, and α and β are the usual 'excess return' and 'correlated volatility' parameters used in investment benchmarking. (The implied meaning of the terms is not necessarily applicable here, but the model is useful nonetheless.) We have solved the equation using linear least squares for all pairs of asset classes, yielding estimates of α , β , and the correlation coefficient ρ .

In general, we look to the linear model to illustrate three desirable qualities in the returns of an asset class and a reference asset class if they are to be aggregated together without meaningful distortion of the data. These three qualities are:

1. The 'excess return' parameter α should be near zero: if α is either large positive or large negative, then aggregation of the two asset classes will combine markedly different series of returns, obscuring their unique characteristics.
2. The 'correlated volatility' parameter β should be close to one: if β is not close to one, then aggregation of the two asset classes will combine markedly different series of returns obscuring their unique characteristics while also causing a suppression of the volatility through diversification.
3. The correlation coefficient ρ should be close to one: if ρ is significantly less than one then the model fails to describe the relationship between the two series of net returns and estimates of α and β cannot be trusted.

A fourth factor is an *ad-hoc* one, based on data checking. For a handful of asset classes, none of the above criteria is strictly met, yet other widely-recognized characteristics of each of these asset classes imply that each one should belong to a particular aggregate asset class. All twelve private equity asset classes, for example, fall into this fourth category because they do not clearly align with the three qualities specified above. A detailed analysis,

summarized later, demonstrates that, after standardization, the private equity aggregate asset classes in fact do align with all three qualities specified above.

Tables A1, A2 and A3 in Appendix A show the regression parameters α , β and ρ for 3,969 (63 x 63) pairs of asset classes / investment styles / management styles combinations. (We have excluded from the Tables those asset classes which had few invested assets and so would not meaningfully contribute to the net returns of any of the aggregate asset classes).

Along the top and sides of Tables 1-3 in Appendix A we list the 12 aggregate asset classes (we use going forward. These 12 classes are:

1. Large-cap U.S. stock (*e.g.*, large-cap equities appearing in the S&P 500)
2. Small-cap U.S. stock (*e.g.*, Russell 2000 small-cap equities + mid cap equities)
3. Non-U.S. stock (*e.g.*, non-U.S. equities such as EAFE and emerging market equities)
4. Broad U.S. fixed income (*e.g.*, investment grade U.S. corporate bonds, U.S. Treasuries)
5. Long-duration U.S. bonds (*e.g.*, strategies dedicated to long-duration bonds)
6. Other U.S. fixed income (*e.g.*, non-investment grade bonds, mortgages, cash)
7. Non-U.S. fixed income (*e.g.*, non-U.S. bonds)
8. Unlisted real estate (*e.g.*, direct real estate holdings, real estate limited partnerships)
9. Listed equity REITs (publicly traded real estate)
10. Other real assets (*e.g.*, commodities, infrastructure, natural resources)
11. Hedge funds / TAA (*e.g.*, hedge funds and tactical asset allocation teams)
12. Private equity (*e.g.*, venture capital, diversified private equity, private equity fund-of-funds)

The aggregation of the three stock asset classes, broad U.S. fixed income, long duration U.S. bonds, unlisted real estate, and listed equity REITs are each straightforward. Some salient features of our aggregations of other U.S. fixed income, non-U.S. fixed income, other real assets, hedge funds / TAA, and private equity deserve mention.

First, we aggregated inflation indexed bonds (TIPs), high yield bonds, mortgages and cash into a U.S. other fixed income aggregate asset class. This grouping of diverse categories of fixed incomes is necessary to limit the number of fixed income aggregate asset classes used in the analysis. We have checked that this aggregation is relatively robust with respect to our conclusions, but we note that this aggregate asset class has a lower standard deviation than its components through diversification effects.

Second, while EAFE fixed income and global fixed income show all the traits of a good asset aggregation, emerging fixed income does not. However, emerging market fixed income represents less than 0.5 percent of the holdings of U.S. DB pension funds and so we included this return data into a non-U.S. fixed income aggregate asset class with little impact on our conclusions.

Third, commodities, infrastructure, and natural resources have been rolled into a single aggregate asset class, other real assets, despite not sharing much in the way of similar net returns, akin to the situation experienced with U.S. other fixed income. Our choice is again driven by the importance of using a manageable number of meaningful aggregate asset classes in the analysis, together with the fact that total allocations to these asset classes are small. Note that this imperfect aggregation decreases dramatically the standard deviation of the asset class, but not its volatility as we will discuss in Section 3.2.

Fourth, TAA and hedge funds have been aggregated together because the excess returns are small and correlations near 1. However, TAA is significantly more volatile than hedge funds, especially for internal active TAA where β is near 2. Indeed, internal active TAA is more similar to large-cap U.S. stock. Once again, we remark that internal active TAA makes up a very small portion of the total holdings and so our placement of it within an aggregate asset class hardly affects the results. For simplicity we leave it in the hedge funds / TAA aggregate asset class.

Finally, as noted above, the various private equity asset classes least conform to the qualities we seek in using the linear model. As we will show later, however, the low correlation between the private equity asset classes owes largely to the significant reporting lag of net returns. When the data are standardized by removing the lag, private equity net returns are very similar to the net returns of the asset class stock: U.S. small-cap, with $\alpha = 1.9$ percent, $\beta = 0.92$, and $\rho = 0.89$.

3.2 Performance measures

We use several different performance measures in this research. We first define them and discuss their interpretation before presenting results. (Most readers can skip this section.)

For each aggregate asset class a we define the return in year y for fund i as:

$$r_{i,y}(a) = \frac{\sum_j h_{i,j,y}(a)r_{i,j,y}(a)}{\sum_j h_{i,j,y}(a)}$$

where the sum aggregates over all asset class/investment style/management styles j in each of the 12 aggregate asset classes, and $h_{i,j,y}$ and $r_{i,j,y}$ are the holdings and returns respectively. The fund-average return and standard deviation for each aggregate asset class in year y are:

$$\langle r_y(a) \rangle = \frac{1}{N} \sum_i r_{i,y}(a)$$

$$\sigma_y(a) = \sqrt{\frac{1}{N} \sum_i (r_{i,y}(a) - \langle r_y(a) \rangle)^2}$$

where the sums aggregate over the N funds with holdings in the aggregate asset class (funds without holdings do not contribute to the average or standard deviation). We use two measures of time-average return over the 17 year period, the average annual arithmetic return $\langle\langle r_{arith.} \rangle\rangle$ and the annualized average compound return $\langle\langle r_{comp.} \rangle\rangle$:

$$\langle\langle r_{arith.}(a) \rangle\rangle = \frac{1}{Y} \sum \langle r_y(a) \rangle$$

$$\langle\langle r_{comp.}(a) \rangle\rangle = \left(\prod (1 + \langle r_y(a) \rangle) \right)^{1/Y} - 1$$

where the sum and product aggregate over all years of data from 1 to Y . The arithmetic return is larger than the compound return by an amount roughly proportional to the standard deviation of the annual return series:

$$\sigma(a) = \sqrt{\frac{1}{Y} \sum (\langle r_y(a) \rangle - \langle\langle r_{arith.}(a) \rangle\rangle)^2}$$

We show both the arithmetic and compound returns for each asset class to give an upper and lower bounds on the contribution to total fund returns from each aggregate asset class. The reason neither time-average can be considered a sole measure of performance is because nearly all funds rebalance their portfolios more often than annually and therefore each aggregate asset class' contribution to total fund return is greater than its compound return.

In addition to the standard deviation of average annual returns, we measure the volatility of each aggregate asset class via:

$$\sigma_{vol.}(a) = \sqrt{\sigma(a)^2 + \frac{1}{Y} \sum_y \sigma_y(a)^2}$$

The formula formally takes into account the fact that the return experienced by any one fund in any asset class and year will deviate from the average return proportional to $\sigma_y(a)$. That is, the in-year dispersion in returns (i.e., idiosyncratic risk) – sourced almost entirely by active management – serves to increase the volatility of each asset class which would otherwise be equal to the standard deviation of the average return, $\sigma(a)$. Note that imperfect aggregation does not reduce volatility because while imperfect aggregation gives rise to small standard deviations, it also gives rise to larger in-year dispersion of returns.

Finally, given a proper definition of the volatility we can calculate the Sharpe ratio for each aggregate asset class. The Sharpe ratio is given by:

$$S(a) = \frac{\langle r_{comp}(a) - r_{risk\ free} \rangle}{\sigma_{vol.}(a - r_{risk\ free})}$$

where $r_{risk\ free}$ is the return from a risk free asset and $\sigma_{vol.}(a - r_{risk\ free})$ is the volatility of the aggregate asset class return less the return of the risk free asset. For the risk free asset we use the total return from 3-month U.S. Treasury bills.

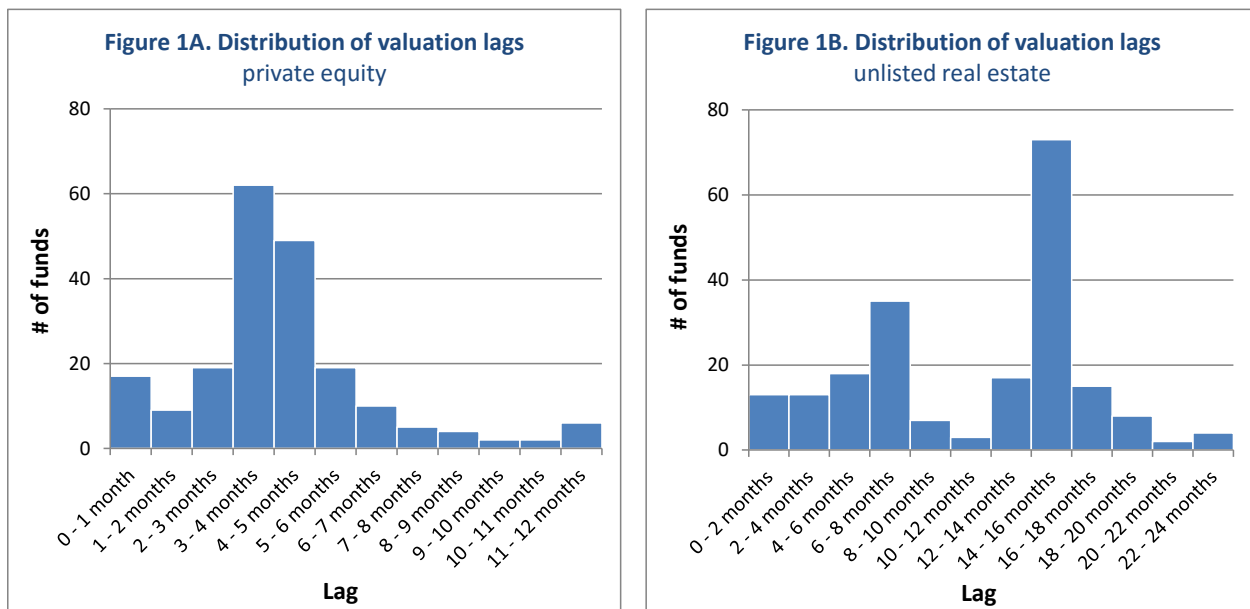
3.3 As-reported aggregate asset class net returns

Average annual returns by aggregate asset class are shown in Table 2 spanning the full 17 years included in this

Table 2. Annual average net returns by aggregate asset class as reported to CEM (in percent). Summary statistics include the arithmetic average return, the compound average net return, the standard deviation of annual average net returns, the volatility (which includes the effects of in-year standard deviation of annual average net returns), and the sharp ratio (the risk free rate of return used are 3-month T-bills).

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	12.52	5.03	-1.78	6.91	19.39	1.79	2.85	12.73	20.19	2.37	4.75	15.37
2013	33.38	38.39	17.84	-2.09	-7.72	1.35	-0.39	12.00	3.99	2.88	9.10	15.43
2012	16.27	16.00	17.72	7.14	10.51	5.41	11.54	9.74	20.55	3.84	7.54	11.91
2011	0.90	-3.08	-12.71	8.48	22.17	3.61	3.77	13.37	2.05	-1.53	0.80	10.53
2010	16.22	26.41	12.45	8.61	11.03	5.10	13.62	9.01	23.51	10.93	9.26	12.42
2009	29.52	33.41	39.57	11.88	4.18	13.13	20.38	-29.69	29.89	5.65	14.84	-3.97
2008	-38.10	-37.65	-44.44	0.07	13.96	-5.39	-8.67	-8.14	-38.20	-9.66	-17.84	-10.79
2007	5.81	2.24	14.30	6.51	7.66	4.89	7.88	15.42	-10.75	14.40	8.07	20.46
2006	14.67	14.68	25.72	4.80	2.67	5.68	7.79	19.08	34.75	14.86	11.03	16.99
2005	6.75	7.21	16.72	3.15	5.99	3.32	1.93	23.12	14.16	19.19	7.44	18.94
2004	12.02	16.76	19.62	5.29	9.07	4.92	10.31	13.51	32.43	18.18	7.42	15.64
2003	30.80	43.17	37.56	6.11	6.87	8.12	18.10	9.63	33.09	9.56	15.61	9.02
2002	-21.45	-19.33	-14.12	9.38	15.21	2.35	14.11	5.22	5.17	9.24	-12.17	-12.19
2001	-9.94	-1.27	-17.36	8.17	6.57	4.54	2.11	6.00	10.94	4.44	-5.02	-18.19
2000	-5.21	0.27	-12.45	11.42	16.14	6.33	4.65	12.63	26.58	18.95	1.50	28.98
1999	19.19	29.88	38.33	-0.63	-7.89	5.56	1.24	9.91	1.23	22.30	10.12	33.76
1998	23.59	2.94	11.80	8.50	11.90	6.19	10.64	13.81	-6.39	1.75	21.09	13.51
Arit. Gross Ret.:	8.87	10.86	9.20	6.27	8.87	4.79	7.59	9.72	12.46	9.64	6.52	12.54
Avg. Invest. Cost:	0.23	0.56	0.44	0.17	0.18	0.27	0.42	1.05	0.51	0.97	1.02	2.08
Arit. Net Ret.:	8.64	10.30	8.75	6.10	8.69	4.52	7.17	8.67	11.95	8.67	5.50	10.46
Comp. Net. Ret.:	6.83	8.26	6.13	6.03	8.39	4.46	6.93	7.93	10.14	8.34	5.04	9.55
Std. Dev.:	18.39	20.13	22.22	3.88	7.89	3.59	7.11	11.52	18.62	8.34	9.51	13.69
Volatility:	18.71	21.54	22.77	5.33	9.63	7.11	11.19	14.58	20.74	19.56	12.30	23.14
Sharpe Ratio:	0.32	0.36	0.27	0.64	0.62	0.29	0.41	0.44	0.45	0.32	0.25	0.35

Figures 1A and 1B. Distribution of reporting lags for private equity (left) and unlisted real estate (right).



study (1998-2014) as reported by funds to CEM. The Table also shows summary statistics for: the arithmetic average gross return, the average investment cost, the arithmetic average net return, the compound average net return, the standard deviation, the volatility, and the Sharpe ratio.

The as reported returns for illiquid asset classes are smoothed significantly because different funds have different reporting lags built into their illiquid asset performance data. Reporting lag refers to the fact that calendar year returns which *should* span December 31 of the prior year to December 31 of the current year actually span, say, July 31 of the prior year to July 31 of the current year for illiquid assets that are not marked-to-market. Smoothing occurs because while one fund is lagged, say, 4 months, another will show a lag of 6 months. This distribution of lags spread over hundreds of funds has the effect of smoothing out the peaks and valleys in the annual return series of similar assets.

The existence of reporting lags in illiquid asset valuations makes the annual returns between liquid and illiquid assets un-comparable, while the distribution of reporting lags smooths out the returns also making the volatility un-comparable. Correcting for the lags and smoothing allows appropriate comparisons of annual returns and volatilities, as well as computation of correlations between asset classes.

The impact of illiquid asset smoothing can be quite dramatic. For example, the best average as-reported return by year of any asset class was for small-cap U.S. stock in 2003, at 43.17 percent. However once returns are corrected for reporting lags, the data indicates that the best return by year was actually achieved by private equity for 2009 at the height of the tech bubble.

3.4 Standardizing illiquid asset net returns

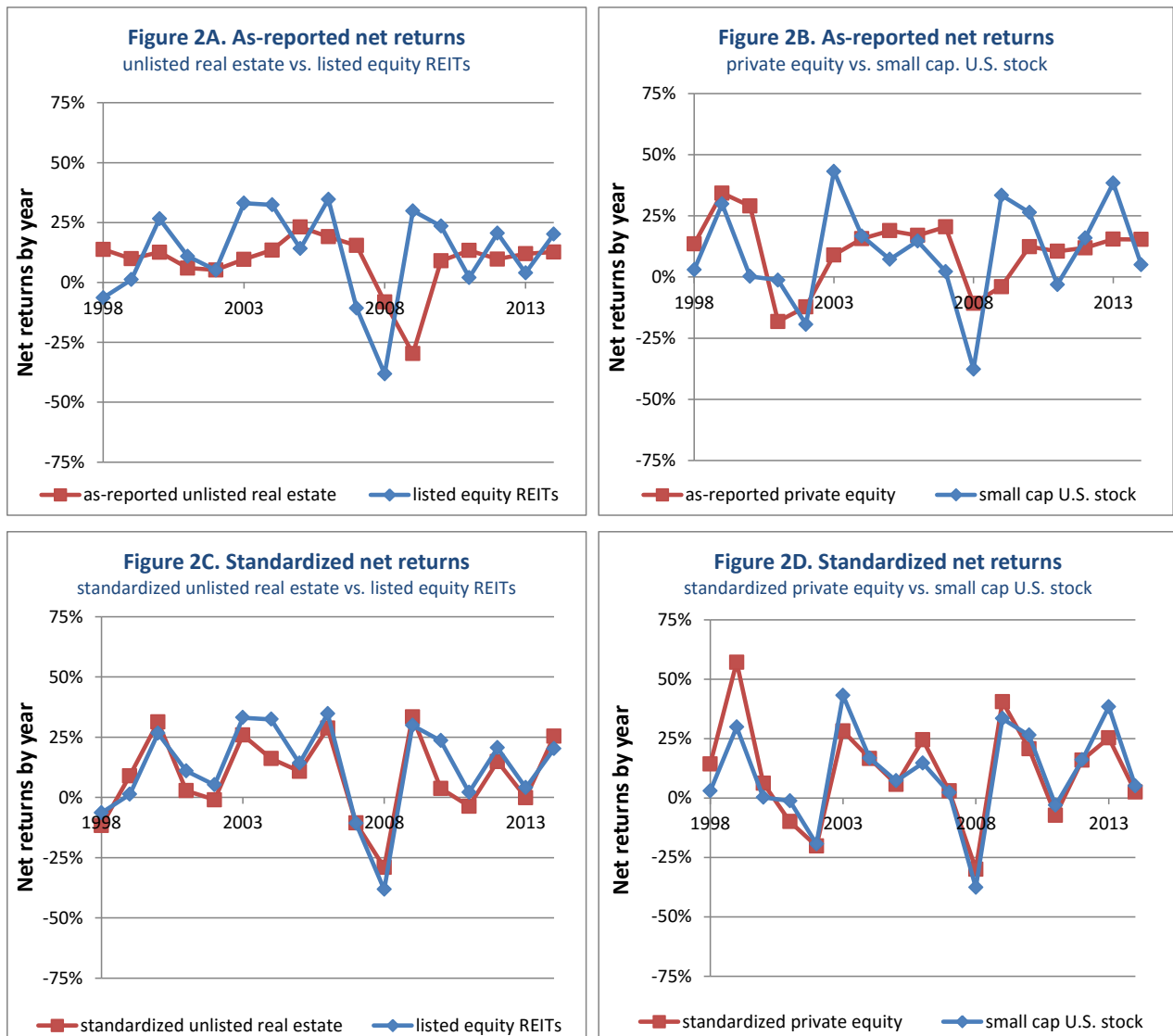
Our standardization of illiquid asset returns in this study occurs at the fund level. For each fund with three or more years of private equity returns, we compare the annual series of returns to a simple small-cap U.S. stock benchmark with lag ranging from zero days to 260 days, a calendar trading year. For each fund, the correlation between the two is maximized (sometimes spectacularly so) at a given number of days which we conclude is the best estimate of the reporting lag in the return series. The same process is repeated for each fund with three or more years of unlisted real estate data using a benchmark made up of a listed equity REIT index, de-levered by inclusion of long BBB corporate bond index at a ratio of 65:35. For unlisted real estate we allow the benchmark to

lag from between 0 and 520 days (two calendar trading years) because our data shows that unlisted real estate valuations are more lagged than private equity valuations.

The distribution of lags inferred from the as-reported data is displayed for each aggregate asset class in Figure 1. In the case of private equity, more than half of funds have an inferred lag between 3 and 5 months (65-108 trading days). The average lag is 92 days and the median 85. For unlisted real estate the distribution of lags is quite different, showing two peaks, one at 6-8 months (130-173 trading days) and another at 14-16 months (303-346 trading days). We conclude that the majority of pension funds real estate valuations are either a bit more than half a year or a bit more than a whole year stale. The average lag is 242 days and the median 302. The double peaked distribution of inferred lags for unlisted real estate is especially interesting, but a discussion of it is beyond the scope of the present paper.

In order to standardize the unlisted real estate and private equity returns with the liquid assets returns reporting lag must be removed. To do so we first calculate the lagged value added from each asset class, which is the

Figure 2A-D. Average annual as-reported (top) and standardized (bottom) net returns for unlisted real estate (left) and private equity (right) together with their listed counterparts, listed equity REITs and small-cap U.S. stock.



difference between the lagged return and the lagged benchmark. Second, we calculate a standardized de-lagged return that preserves the value added, that is the 0-day lagged benchmark plus the lagged value added. In this way we preserve the performance relative to the benchmark, effectively shifting a portion of the return from the lagged data back into the prior year. (A complete discussion of our standardization method and its consequence on the data is provided in Appendix B.)

Annual average net returns, pre- and post-standardized, for both listed real estate and private equity are shown in Figure 2 A through D. For comparison we show the listed counterparts of each, listed equity REITs and small-cap U.S. stock from Table 1.

Looking first at Figure 2A, pre-standardized unlisted real estate vs. listed equity REITs, the timing of the global financial crisis appears to be separated by a year, with listed equity REITs posting a small loss in 2007 followed by a large one in 2008 whereas unlisted real estate posted a small loss in 2008 followed by a large loss in 2009. This behavior clearly indicates the presence of lag in the as-reported unlisted real estate returns.

Post-standardization, unlisted real estate returns “line-up” with the returns of listed equity REITs. In fact, the correlation between listed equity REITs and unlisted real estate increased 10-fold from 9 percent to 91 percent. The fund-by-fund de-lagging process is so successful in removing the smoothing that there is no need to further de-smooth the data once we have de-lagged the unlisted real estate net returns³. Indeed, in the pre-standardized data, unlisted real estate had a standard deviation of only 11.5 percent whereas in Figure 2C the standard deviation is 16.8 percent, close to but less than the 18.6 percent of listed equity REITs.

Pre- and post-standardized private equity net returns show similar behavior to unlisted real estate. The standard deviation increases from 13.69 percent pre-standardization to 20.88 post-standardization. Correlation to small-cap U.S. stock increases from 43 percent pre-standardization to 89 percent post-standardization⁴. Most interesting is the clear emergence of a peak in net returns coinciding with the tech bubble of 1999, followed by a decline in returns and the subsequent crash of 2001-2002.

3.5 Standardized aggregate asset class net returns

Average annual returns by aggregate asset class are shown in Table 3 spanning the full 17 years included in this study (1998-2014) with both unlisted real estate and private equity returns standardized for reporting lag as described in the prior sub-section. Table 3 also shows summary statistics for: the arithmetic average gross return, the average investment cost⁵, the arithmetic average net return, the compound average net return, the standard deviation, the volatility, and the Sharpe ratio.

³ In the inaugural version of this paper [2] we used a two-step process to remove the lag and smoothing in unlisted real estate. First we removed the lag from the average return by shifting the unlisted real estate data by one year. Doing so preserves the volatility of unlisted real estate, necessitating a de-smoothing of the data in step two. The de-smoothing process we applied was the same of Geltner [3]. In this version we apply no de-smoothing at all. Instead, removing the reporting lag fund-by-fund appears all that is required to de-smoothing the unlisted real estate returns, and no further processing of the data is required to recover volatility. We conclude that smoothing of aggregate unlisted real estate data is due to differences in reporting lag.

⁴ The larger correlation between stock: U.S. small cap and pre-standardized private equity (43 percent) compared to the correlation between listed equity REITs and pre-standardized unlisted real estate (9 percent) is due to the fact that the private equity reporting lag is, on average, only 92 days – less than half a year. As such, much of the underlying private equity daily return series remains contemporaneous with the market and so some residual correlation remains. For unlisted real estate with an average lag of 242 days – nearly a full calendar year – the overlap with the liquid market is much less and so the measured correlation is much less.

⁵ The average investment costs shown in Table 2 and Table 3 are ‘as-reported’ investment costs. For a handful of asset classes -- unlisted real estate, hedge funds, and private equity funds – investors typically are unaware of their full costs, and so for these

Gross of investment costs, the best performing aggregate asset class in terms of the arithmetic average return was once again private equity, as in the original version of this study. We stress that this gross return, 13.46 percent, is understated because it may net out other costs as will be discussed in more detail in section 7. This measurement issues does not affect the accuracy of net returns.

Net returns are the key measure because that is the measure of what returns are actually experienced by investors. In terms of net returns, the best performing aggregate asset class was listed equity REITs at 11.95 percent and 10.14 percent for the arithmetic and compound average return respectively. By comparison, the second best performing asset class net of investment costs was private equity at 11.37 (arithmetic average) and 9.34 percent (compound average), some 60 – 80 basis points less than for listed equity REITs. A primary reason for the high rate of net return is the substantially lower costs associated with REITs compared to private equity, only 0.51 percent compared to (at least) 2.08 percent.

The worst performing asset class is other U.S. fixed income. Here the net return was 4.52 percent and 4.46 percent for the arithmetic and compound average return respectively. As discussed, the aggregate asset class is composed of a somewhat diverse set of asset classes including inflation indexed bonds, high yield bonds, mortgages, and cash, the latter of which is the worst performing of them by far. The average arithmetic returns are 6.64 percent, 7.45 percent, 8.37 percent, and 2.70 percent for inflation indexed bonds, high yield bonds, mortgages, and cash respectively while the average compound returns are 6.46 percent, 6.70 percent, 8.03 percent, and 2.67 percent for the same set of asset classes.

Table 3 shows that while cash is the worst performer, the other three components of other U.S. fixed income all

Table 3. Standardized annual average net returns by aggregate asset class (in percent). Unlisted real estate and private equity net returns have been corrected for stale valuations in order to better compare actual net returns from liquid and illiquid assets across years. Summary statistics include the arithmetic average return, the compound average net return, the standard deviation of annual average net returns, the volatility (which includes the effects of in-year standard deviation of annual average net returns), and the sharp ratio (the risk free rate of return used are 3-month T-bills).

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	12.52	5.03	-1.78	6.91	19.39	1.79	2.85	25.41	20.19	2.37	4.75	2.54
2013	33.38	38.39	17.84	-2.09	-7.72	1.35	-0.39	-0.10	3.99	2.88	9.10	25.30
2012	16.27	16.00	17.72	7.14	10.51	5.41	11.54	14.91	20.55	3.84	7.54	15.98
2011	0.90	-3.08	-12.71	8.48	22.17	3.61	3.77	-3.66	2.05	-1.53	0.80	-7.22
2010	16.22	26.41	12.45	8.61	11.03	5.10	13.62	3.77	23.51	10.93	9.26	20.79
2009	29.52	33.41	39.57	11.88	4.18	13.13	20.38	33.43	29.89	5.65	14.84	40.58
2008	-38.10	-37.65	-44.44	0.07	13.96	-5.39	-8.67	-29.04	-38.20	-9.66	-17.84	-29.97
2007	5.81	2.24	14.30	6.51	7.66	4.89	7.88	-10.62	-10.75	14.40	8.07	3.01
2006	14.67	14.68	25.72	4.80	2.67	5.68	7.79	28.75	34.75	14.86	11.03	24.53
2005	6.75	7.21	16.72	3.15	5.99	3.32	1.93	10.83	14.16	19.19	7.44	5.75
2004	12.02	16.76	19.62	5.29	9.07	4.92	10.31	16.12	32.43	18.18	7.42	16.67
2003	30.80	43.17	37.56	6.11	6.87	8.12	18.10	25.91	33.09	9.56	15.61	28.23
2002	-21.45	-19.33	-14.12	9.38	15.21	2.35	14.11	-0.99	5.17	9.24	-12.17	-20.18
2001	-9.94	-1.27	-17.36	8.17	6.57	4.54	2.11	2.80	10.94	4.44	-5.02	-9.90
2000	-5.21	0.27	-12.45	11.42	16.14	6.33	4.65	31.31	26.58	18.95	1.50	6.25
1999	19.19	29.88	38.33	-0.63	-7.89	5.56	1.24	9.00	1.23	22.30	10.12	56.65
1998	23.59	2.94	11.80	8.50	11.90	6.19	10.64	-11.69	-6.39	1.75	21.09	14.34
Arit. Gross Ret.:	8.87	10.86	9.20	6.27	8.87	4.79	7.59	9.64	12.46	9.64	6.52	13.46
Avg. Invest. Cost:	0.23	0.56	0.44	0.17	0.18	0.27	0.42	1.05	0.51	0.97	1.02	2.08
Arit. Net Ret.:	8.64	10.30	8.75	6.10	8.69	4.52	7.17	8.59	11.95	8.67	5.50	11.37
Comp. Net. Ret.:	6.83	8.26	6.13	6.03	8.39	4.46	6.93	7.21	10.14	8.34	5.04	9.34
Std. Dev.:	18.39	20.13	22.22	3.88	7.89	3.59	7.11	16.79	18.62	8.34	9.51	20.88
Volatility:	18.71	21.54	22.77	5.33	9.63	7.11	11.19	19.03	20.74	19.56	12.30	28.00
Sharpe Ratio:	0.32	0.36	0.27	0.64	0.62	0.29	0.41	0.32	0.45	0.32	0.25	0.32

perform better than hedge funds / TAA. If cash is excluded as an asset class, then hedge funds must be considered the worst performing asset class with a 17-year average arithmetic return of 5.50 percent and an average compound return of 5.04 percent.

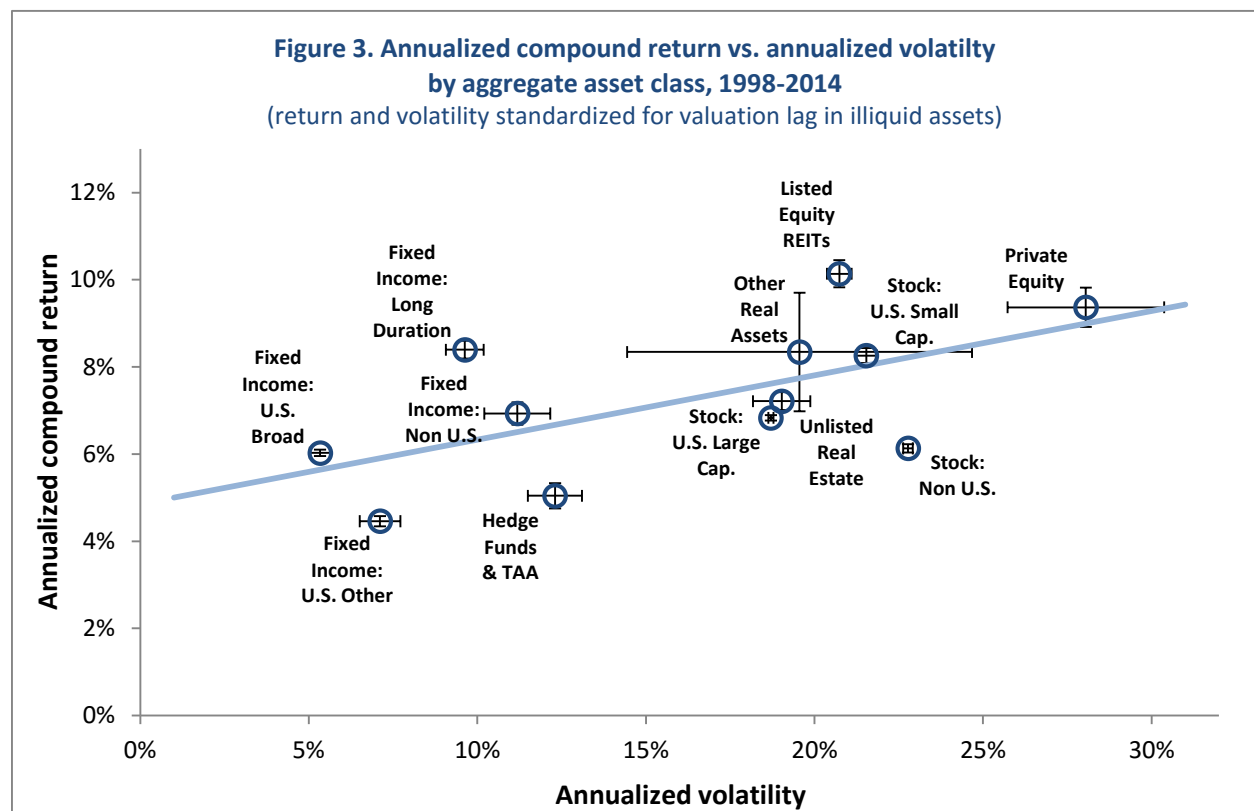
3.6 Standardized aggregate asset class risk

Comparison of the aggregate asset classes by net return alone ignores the different risks present in each asset class. One measure of investment risk, the average annual volatility, ranged from a low of 5.33 percent for fixed income: U.S. broad to a high of 28.00 percent for private equity. The fact that private equities volatility was so much higher than its standard deviation, only 20.88 percent, reflects the fact that the dispersion of net returns in any given year is on average much broader than for other asset classes, with the exception of other real assets.

The risk – reward tradeoff is best visualized by plotting risk vs. reward as in Figure 3 (data taken from Table 3). Here we have chosen the average compound net return as a measure of reward. Funds above the linear least square fit are superior asset classes as they produce outsized returns given their risk, whereas funds below the linear least squares fit are inferior (ignoring differences in correlations). In order to aid the determination of superior and inferior asset classes we have also included in the Figure error bars for both the average compound return and the average volatility. Note that the large errors on real assets - other was caused by a combination of small sample size and imperfect aggregation whereas the large error on the volatility of private equity was caused by the extremely broad distribution of idiosyncratic risk during the tech bubble in 1999.

Only two asset classes were significantly above the fitted line: long duration fixed income, and listed equity REITs.

Figure 3. Average annualized compound return vs. average annual volatility. Error bars represent 1σ confidence intervals on both the return and volatility respectively. Significant error bars on both the return and volatility of the aggregate asset class 'other real assets' are due to a combination of small sample size and the disparate nature of the assets included in the aggregate asset class (itself caused by small sample size).



Several asset classes are significantly below the fitted line: other U.S. fixed income, hedge funds / TAA, large-cap U.S. stock, and non-U.S. stock. Broad U.S. fixed income, non-U.S. fixed income, other real assets, small-cap U.S. stock, unlisted real estate and private equity are all more or less on the best fitted line.

A common measure of the risk-reward tradeoff is the Sharpe ratio. Calculated values over the full 17 years are shown at the bottom of Table 3. They ranged from a high of 0.64 for broad U.S. fixed income (close to but larger

Table 4A. Arithmetic average annualized returns in percent by aggregate asset class for selected multi-year time spans. Unlisted real estate and private equity have been standardized for reporting lag. Maximum values within each time span are highlighted in green while lows are highlighted in red.

Time Span	Table 4A. Annualized arithmetic average net return by time span (in percent)											
	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
3-year												
2012 - 2014	20.72	19.80	11.26	3.99	7.39	2.85	4.67	13.41	14.91	3.03	7.13	14.60
2011 - 2013	16.85	17.10	7.62	4.51	8.32	3.46	4.97	3.72	8.86	1.73	5.81	11.35
2010 - 2012	11.13	13.11	5.82	8.08	14.57	4.71	9.64	5.01	15.37	4.42	5.87	9.85
2009 - 2011	15.55	18.91	13.11	9.66	12.46	7.28	12.59	11.18	18.48	5.02	8.30	18.05
2008 - 2010	2.55	7.39	2.53	6.85	9.73	4.28	8.44	2.72	5.07	2.31	2.08	10.47
2007 - 2009	-0.92	-0.67	3.14	6.15	8.60	4.21	6.53	-2.08	-6.36	3.46	1.69	4.54
2006 - 2008	-5.87	-6.91	-1.47	3.79	8.10	1.73	2.33	-3.64	-4.73	6.53	0.42	-0.81
2005 - 2007	9.08	8.04	18.91	4.82	5.44	4.63	5.87	9.65	12.72	16.15	8.85	11.09
2004 - 2006	11.15	12.88	20.69	4.41	5.91	4.64	6.68	18.57	27.11	17.41	8.63	15.65
2003 - 2005	16.52	22.38	24.63	4.85	7.31	5.45	10.11	17.62	26.56	15.64	10.16	16.88
2002 - 2004	7.12	13.53	14.35	6.93	10.39	5.13	14.17	13.68	23.56	12.32	3.62	8.24
2001 - 2003	-0.20	7.52	2.03	7.89	9.55	5.00	11.44	9.24	16.40	7.74	-0.53	-0.62
2000 - 2002	-12.20	-6.78	-14.64	9.66	12.64	4.41	6.96	11.04	14.23	10.87	-5.23	-7.94
1999 - 2001	1.34	9.63	2.84	6.32	4.94	5.47	2.67	14.37	12.92	15.23	2.20	17.67
1998 - 2000	12.52	11.03	12.56	6.43	6.72	6.03	5.51	9.54	7.14	14.33	10.90	25.75
5-year												
2010 - 2014	15.86	16.55	6.71	5.81	11.08	3.45	6.28	8.06	14.06	3.70	6.29	11.48
2009 - 2013	19.26	22.22	14.98	6.81	8.03	5.72	9.78	9.67	16.00	4.36	8.31	19.08
2008 - 2012	4.96	7.02	2.52	7.24	12.37	4.37	8.13	3.88	7.56	1.85	2.92	8.03
2007 - 2011	2.87	4.27	1.84	7.11	11.80	4.27	7.40	-1.23	1.30	3.96	3.02	5.44
2006 - 2010	5.62	7.82	9.52	6.37	7.90	4.68	8.20	5.26	7.84	7.24	5.07	11.79
2005 - 2009	3.73	3.98	10.37	5.28	6.89	4.33	5.86	6.67	5.97	8.89	4.71	8.78
2004 - 2008	0.23	0.65	6.38	3.96	7.87	2.68	3.85	3.21	6.48	11.39	3.22	4.00
2003 - 2007	14.01	16.81	22.78	5.17	6.45	5.39	9.20	14.20	20.74	15.24	9.91	15.64
2002 - 2006	8.56	12.50	17.10	5.75	7.96	4.88	10.45	16.12	23.92	14.20	5.87	11.00
2001 - 2005	3.64	9.31	8.48	6.42	8.74	4.65	9.31	10.93	19.16	12.12	2.65	4.11
2000 - 2004	1.24	7.92	2.65	8.07	10.77	5.25	9.86	15.03	21.64	12.07	1.47	4.22
1999 - 2003	2.68	10.54	6.39	6.89	7.38	5.38	8.04	13.60	15.40	12.90	2.01	12.21
1998 - 2002	1.23	2.50	1.24	7.37	8.39	4.99	6.55	6.08	7.51	11.34	3.10	9.43
10-year												
2005 - 2014	9.79	10.26	8.54	5.55	8.99	3.89	6.07	7.37	10.01	6.29	5.50	10.13
2004 - 2013	9.74	11.44	10.68	5.38	7.95	4.20	6.82	6.44	11.24	7.87	5.76	11.54
2003 - 2012	9.49	11.91	12.65	6.20	9.41	4.88	8.66	9.04	14.15	8.54	6.42	11.83
2002 - 2011	5.71	8.38	9.47	6.43	9.88	4.57	8.92	7.45	12.61	9.08	4.44	8.22
2001 - 2010	4.63	8.56	9.00	6.40	8.32	4.67	8.76	8.09	13.50	9.68	3.86	7.95
2000 - 2009	2.49	5.95	6.51	6.68	8.83	4.79	7.86	10.85	13.81	10.48	3.09	6.50
1999 - 2008	1.45	5.60	6.39	5.43	7.63	4.03	5.94	8.40	10.94	12.14	2.61	8.11
1998 - 2007	7.62	9.65	12.01	6.27	7.42	5.19	7.88	10.14	14.12	13.29	6.51	12.54
15-year												
2000 - 2014	6.94	9.48	6.58	6.39	9.58	4.34	7.33	9.92	13.89	8.22	4.15	8.16
1999 - 2013	7.39	11.14	9.25	5.89	7.76	4.59	7.22	8.83	12.63	9.55	4.51	11.76
1998 - 2012	6.74	8.78	8.85	6.59	9.07	4.92	7.96	8.05	11.93	9.47	5.31	11.03
17-year												
1998 - 2014	8.64	10.30	8.75	6.10	8.69	4.52	7.17	8.59	11.95	8.67	5.50	11.37

than the 0.62 for long duration fixed income) to a low of 0.25 for hedge funds / TAA.

3.7 How did risk and return depend on the chosen time span?

Tables 4 A-D show for a wide variety of time spans the primary summary statistics used in this paper (i.e., the arithmetic average return, the compound average return, the volatility, and the Sharpe ratio). Included are 15 three-year time spans, 13 five-year time spans, eight 10-year time spans, three 15-year time spans, and the

Table 4B. Compound average annualized returns in percent by aggregate asset class for selected multi-year time spans. Unlisted real estate and private equity have been standardized for reporting lag. Maximum values within each time span are highlighted in green while lows are highlighted in red.

Time Span	Table 4B. Annualized compound average net return by time span (in percent)											
	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
3-year												
2012 - 2014	20.39	19.02	10.86	3.90	6.78	2.83	4.55	12.91	14.64	3.03	7.12	14.22
2011 - 2013	16.10	15.87	6.59	4.40	7.60	3.44	4.86	3.41	8.56	1.70	5.75	10.47
2010 - 2012	10.89	12.43	4.94	8.08	14.45	4.70	9.56	4.73	14.97	4.29	5.80	9.13
2009 - 2011	14.95	17.79	11.07	9.65	12.22	7.20	12.38	10.08	17.86	4.89	8.14	16.36
2008 - 2010	-2.33	1.69	-4.46	6.74	9.65	4.00	7.70	-0.59	-0.29	1.92	1.02	5.95
2007 - 2009	-5.33	-5.26	-3.94	6.04	8.53	3.93	5.85	-5.42	-10.52	2.97	0.65	0.47
2006 - 2008	-9.10	-9.91	-7.23	3.76	8.00	1.60	2.03	-6.54	-9.42	5.88	-0.47	-3.51
2005 - 2007	9.01	7.92	18.81	4.81	5.42	4.62	5.83	8.44	11.14	16.13	8.83	10.70
2004 - 2006	11.10	12.81	20.63	4.41	5.88	4.64	6.62	18.33	26.77	17.39	8.62	15.39
2003 - 2005	16.08	21.47	24.30	4.84	7.30	5.43	9.91	17.45	26.25	15.56	10.09	16.52
2002 - 2004	4.80	10.48	12.22	6.91	10.33	5.10	14.13	13.12	22.84	12.25	2.94	6.09
2001 - 2003	-2.55	4.47	-0.80	7.88	9.48	4.98	11.23	8.62	15.80	7.72	-1.20	-2.66
2000 - 2002	-12.47	-7.22	-14.67	9.65	12.56	4.39	6.83	10.15	13.88	10.71	-5.40	-8.58
1999 - 2001	0.58	8.74	0.03	6.19	4.46	5.47	2.66	13.74	12.44	14.96	2.01	14.46
1998 - 2000	11.77	10.26	10.63	6.30	6.18	6.03	5.44	8.12	6.25	13.97	10.61	23.93
5-year												
2010 - 2014	15.40	15.61	5.99	5.73	10.55	3.44	6.14	7.55	13.69	3.62	6.24	10.80
2009 - 2013	18.69	21.28	13.71	6.70	7.58	5.65	9.54	8.89	15.47	4.28	8.21	18.01
2008 - 2012	1.80	3.40	-2.17	7.16	12.22	4.20	7.65	1.69	4.05	1.60	2.24	5.05
2007 - 2011	-0.10	0.83	-2.74	7.04	11.64	4.10	6.94	-3.29	-2.02	3.59	2.34	2.59
2006 - 2010	2.49	4.28	4.62	6.30	7.82	4.51	7.75	2.48	3.58	6.83	4.34	8.81
2005 - 2009	0.76	0.90	5.40	5.21	6.82	4.16	5.44	3.84	1.96	8.37	3.99	5.96
2004 - 2008	-2.13	-1.76	2.20	3.94	7.81	2.60	3.61	1.00	2.36	10.83	2.61	2.08
2003 - 2007	13.67	16.01	22.51	5.17	6.43	5.37	9.08	13.27	19.33	15.19	9.87	15.21
2002 - 2006	7.10	10.64	15.70	5.73	7.88	4.86	10.31	15.61	23.31	14.13	5.41	9.48
2001 - 2005	2.04	7.38	6.39	6.40	8.69	4.63	9.12	10.52	18.61	11.98	2.16	2.62
2000 - 2004	-0.35	5.95	0.45	8.05	10.70	5.23	9.70	14.34	21.09	11.93	1.01	2.71
1999 - 2003	0.89	8.23	3.41	6.81	7.02	5.36	7.83	12.90	14.75	12.70	1.51	8.95
1998 - 2002	-0.25	1.32	-0.79	7.28	8.01	4.98	6.43	5.17	6.95	11.05	2.46	6.48
10-year												
2005 - 2014	7.83	8.00	5.69	5.47	8.67	3.80	5.79	5.68	7.67	5.97	5.11	8.35
2004 - 2013	7.78	9.15	7.80	5.31	7.70	4.11	6.53	4.87	8.71	7.50	5.38	9.76
2003 - 2012	7.57	9.53	9.48	6.16	9.29	4.79	8.36	7.33	11.43	8.18	5.99	10.01
2002 - 2011	3.43	5.62	6.08	6.38	9.74	4.48	8.61	5.74	9.92	8.73	3.86	5.98
2001 - 2010	2.27	5.81	5.50	6.35	8.26	4.57	8.43	6.43	10.84	9.37	3.25	5.67
2000 - 2009	0.20	3.39	2.89	6.62	8.74	4.69	7.55	8.96	11.11	10.14	2.49	4.32
1999 - 2008	-0.63	3.11	2.80	5.36	7.41	3.97	5.70	6.78	8.38	11.76	2.06	5.46
1998 - 2007	6.49	8.42	10.24	6.22	7.22	5.18	7.75	9.14	12.97	13.10	6.10	10.76
15-year												
2000 - 2014	5.03	7.31	3.91	6.32	9.34	4.27	7.08	8.49	11.96	7.92	3.73	6.44
1999 - 2013	5.43	8.84	6.31	5.81	7.47	4.53	6.96	7.48	10.69	9.21	4.07	9.49
1998 - 2012	4.90	6.72	5.94	6.53	8.86	4.85	7.72	6.60	9.92	9.13	4.80	8.82
17-year												
1998 - 2014	6.83	8.26	6.13	6.03	8.39	4.46	6.93	7.21	10.14	8.34	5.04	9.34

maximal 17-year time span considered.

3.7.1 Arithmetic average net return by time span

Arithmetic average net returns for different time spans are shown in Table 4A. Over three-year time spans, listed equity REITs are by this measure the best performing aggregate asset class for six of the 15 three-year periods, and the worst for one span that covered the financial crisis, 2007-2009. Other real assets was the worst performing aggregate asset class by this measure for three consecutive three-year periods, 2009-2011, 2010-2012, and 2011-

Table 4C. Annualized volatility in percent by aggregate asset class for selected multi-year time spans. Unlisted real estate and private equity have been standardized for reporting lag. Maximum values within each time span are highlighted in green while lows are highlighted in red.

Time Span	Table 4C. Annualized volatility by time span (in percent)											
	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
3-year												
2012 - 2014	9.34	14.29	9.81	5.32	12.16	4.53	7.94	11.49	10.78	10.32	5.46	12.35
2011 - 2013	13.47	17.29	14.75	6.27	13.26	5.04	8.47	9.45	10.91	11.84	6.88	15.05
2010 - 2012	7.51	12.66	13.53	4.11	7.24	5.08	10.27	10.07	12.39	12.02	6.98	13.90
2009 - 2011	12.08	16.65	21.96	5.80	11.07	10.39	13.94	18.62	15.30	15.25	9.60	22.20
2008 - 2010	29.42	32.42	35.41	7.93	11.87	13.07	18.96	27.81	32.73	24.35	16.87	32.47
2007 - 2009	28.20	29.64	35.62	7.74	11.77	13.40	17.07	28.45	30.49	25.54	16.60	32.26
2006 - 2008	23.19	22.68	30.91	5.23	9.85	8.68	11.83	26.25	31.90	29.14	14.96	25.76
2005 - 2007	4.44	6.34	5.98	1.79	2.73	4.64	5.44	20.82	20.23	19.36	4.85	15.19
2004 - 2006	3.70	4.99	4.77	1.43	3.28	2.90	6.09	14.81	11.90	21.68	4.70	15.52
2003 - 2005	10.57	15.99	9.91	2.06	2.43	5.90	9.77	13.34	12.34	16.27	8.06	17.79
2002 - 2004	21.73	26.18	21.69	2.60	4.14	6.53	8.34	12.73	15.60	16.96	16.93	26.23
2001 - 2003	22.60	27.37	25.52	2.37	4.49	6.41	10.49	13.69	14.31	16.82	17.27	25.89
2000 - 2002	7.93	12.37	5.28	2.79	4.66	4.12	8.63	16.47	11.32	20.59	12.70	29.93
1999 - 2001	13.85	20.75	26.43	5.94	9.98	3.29	7.70	14.65	13.11	22.05	8.85	44.67
1998 - 2000	14.03	19.78	22.29	6.03	10.54	3.89	9.39	19.32	17.65	18.57	9.85	41.77
5-year												
2010 - 2014	10.64	15.19	12.48	5.53	11.56	4.76	9.79	12.17	11.83	11.99	6.66	14.33
2009 - 2013	11.83	15.44	17.31	6.63	11.85	8.90	12.71	15.57	13.98	13.06	8.20	17.93
2008 - 2012	23.52	25.89	29.11	6.84	11.01	10.61	15.48	22.63	26.70	20.42	13.72	26.62
2007 - 2011	22.89	25.61	28.82	6.78	11.09	10.84	15.16	22.64	26.74	21.71	13.91	26.92
2006 - 2010	23.31	25.56	29.03	6.24	9.64	10.71	14.81	25.84	29.92	24.21	14.01	27.06
2005 - 2009	22.74	23.82	29.18	6.15	9.49	10.49	13.81	26.89	29.04	24.98	13.63	27.10
2004 - 2008	19.56	20.18	25.90	4.18	7.81	7.07	10.35	23.65	29.25	25.81	12.39	23.21
2003 - 2007	9.28	14.91	9.00	1.86	2.84	5.74	7.87	17.84	19.58	18.79	7.15	17.01
2002 - 2006	17.14	20.52	17.48	2.63	4.65	5.29	8.83	15.13	14.27	19.14	13.65	22.52
2001 - 2005	18.23	21.61	21.41	2.76	3.98	5.31	9.61	13.87	13.80	17.88	14.19	23.27
2000 - 2004	18.62	22.33	22.42	3.13	4.51	5.51	9.21	14.63	14.16	19.59	14.12	29.65
1999 - 2003	19.83	25.80	26.66	4.97	8.81	5.42	10.64	14.76	14.69	19.21	14.45	39.65
1998 - 2002	18.04	20.04	22.32	4.95	8.95	4.13	9.42	16.13	14.29	19.04	15.09	39.41
10-year												
2005 - 2014	18.76	20.94	22.52	5.85	10.78	8.16	11.97	20.88	22.54	19.77	10.76	21.72
2004 - 2013	18.75	20.95	22.44	5.72	10.03	8.18	11.96	20.28	23.41	20.75	10.81	22.07
2003 - 2012	18.44	21.69	23.81	5.12	8.57	8.54	12.29	21.02	24.32	20.73	11.49	22.66
2002 - 2011	20.42	23.57	25.03	5.18	8.72	8.54	12.50	21.12	24.23	21.10	13.85	24.98
2001 - 2010	20.95	23.68	25.51	4.82	7.39	8.45	12.50	20.93	23.98	21.42	14.15	25.53
2000 - 2009	20.82	23.17	26.30	5.08	7.68	8.39	11.91	22.05	24.15	22.50	13.97	28.49
1999 - 2008	19.73	23.68	26.29	4.82	8.33	6.44	10.70	20.39	23.57	22.76	13.47	32.75
1998 - 2007	15.70	19.05	20.14	3.90	6.71	5.00	8.78	17.49	18.37	19.02	12.29	30.51
15-year												
2000 - 2014	19.14	21.44	22.65	5.25	9.22	7.41	11.27	19.37	20.87	19.89	12.13	24.80
1999 - 2013	19.41	22.69	24.02	5.53	9.65	7.40	11.55	18.93	21.01	20.39	12.27	29.14
1998 - 2012	18.72	21.61	23.93	5.09	8.71	7.37	11.46	19.58	21.73	20.23	12.89	29.35
17-year												
1998 - 2014	18.71	21.54	22.77	5.33	9.63	7.11	11.19	19.03	20.74	19.56	12.30	28.04

2013, explaining why this asset class went from one of the best performing asset classes in our inaugural version of this study to an average one in this version.

As the time span builds, the superior performance of listed equity REITs coalesces. For the 10-year spans, it is the best performing asset class by arithmetic average return in five of the eight spans. For the 15-year spans it is the best in all three spans.

Table 4D. Sharpe ratios by aggregate asset class for selected multi-year time spans. The risk free rates used are the total returns from 3 month U.S. treasury bills. Unlisted real estate and private equity have been standardized for reporting lag. Maximum values within each time span are highlighted in green while lows are highlighted in red.

Time Span	Table 4D. Sharpe ratios by time span											
	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
3-year												
2012 - 2014	2.21	1.38	1.14	0.73	0.60	0.61	0.58	1.16	1.38	0.29	1.29	1.18
2011 - 2013	1.24	0.98	0.51	0.70	0.62	0.67	0.58	0.38	0.80	0.14	0.83	0.75
2010 - 2012	1.47	1.03	0.42	1.93	1.99	0.90	0.93	0.48	1.23	0.36	0.82	0.70
2009 - 2011	1.28	1.13	0.59	1.64	1.11	0.69	0.89	0.59	1.20	0.32	0.85	0.81
2008 - 2010	0.06	0.20	0.05	0.70	0.76	0.25	0.39	0.06	0.12	0.06	0.07	0.29
2007 - 2009	-0.12	-0.11	0.02	0.43	0.52	0.12	0.23	-0.16	-0.28	0.04	-0.05	0.06
2006 - 2008	-0.45	-0.51	-0.19	-0.06	0.39	-0.29	-0.16	-0.30	-0.28	0.09	-0.26	-0.20
2005 - 2007	1.10	0.58	2.47	0.36	0.37	0.06	0.30	0.25	0.41	0.61	0.94	0.45
2004 - 2006	2.27	1.80	4.20	0.61	0.63	0.50	0.55	1.08	2.02	0.66	1.25	0.82
2003 - 2005	1.31	1.24	2.18	1.13	1.91	0.58	0.80	1.15	1.91	0.86	1.00	0.83
2002 - 2004	0.26	0.46	0.59	2.26	2.29	0.56	1.53	0.95	1.40	0.64	0.13	0.26
2001 - 2003	-0.11	0.18	-0.02	2.14	1.38	0.38	0.78	0.47	0.93	0.31	-0.17	-0.12
2000 - 2002	-2.54	-0.97	-3.46	1.88	1.68	0.07	0.29	0.45	1.00	0.33	-0.78	-0.41
1999 - 2001	-0.28	0.21	-0.09	0.20	-0.03	0.09	-0.33	0.65	0.61	0.46	-0.34	0.28
1998 - 2000	0.49	0.28	0.31	0.17	0.12	0.14	0.00	0.21	0.10	0.48	0.54	0.48
5-year												
2010 - 2014	1.48	1.08	0.53	1.03	0.95	0.70	0.63	0.65	1.18	0.30	0.93	0.79
2009 - 2013	1.62	1.43	0.86	1.01	0.67	0.63	0.76	0.61	1.14	0.32	1.00	1.06
2008 - 2012	0.18	0.24	0.07	0.91	1.07	0.35	0.47	0.14	0.26	0.06	0.16	0.27
2007 - 2011	0.06	0.10	0.01	0.74	0.89	0.24	0.37	-0.12	-0.01	0.11	0.10	0.14
2006 - 2010	0.13	0.20	0.24	0.54	0.53	0.19	0.37	0.10	0.18	0.20	0.18	0.34
2005 - 2009	0.03	0.04	0.25	0.32	0.39	0.11	0.19	0.13	0.10	0.23	0.12	0.21
2004 - 2008	-0.16	-0.13	0.12	0.16	0.54	-0.09	0.05	0.00	0.11	0.31	-0.01	0.03
2003 - 2007	1.06	0.85	1.99	0.83	0.87	0.37	0.71	0.60	0.86	0.64	0.90	0.72
2002 - 2006	0.36	0.48	0.84	0.98	0.99	0.44	0.85	0.92	1.51	0.62	0.25	0.38
2001 - 2005	0.07	0.31	0.28	1.38	1.40	0.41	0.67	0.60	1.16	0.54	0.02	0.07
2000 - 2004	-0.09	0.21	-0.01	1.96	1.83	0.39	0.66	0.84	1.28	0.46	-0.10	0.04
1999 - 2003	-0.05	0.26	0.10	0.60	0.40	0.29	0.37	0.68	0.78	0.49	-0.12	0.22
1998 - 2002	-0.19	-0.10	-0.15	0.54	0.42	0.12	0.20	0.10	0.21	0.36	-0.10	0.13
10-year												
2005 - 2014	0.42	0.40	0.31	0.61	0.65	0.27	0.36	0.27	0.37	0.24	0.36	0.39
2004 - 2013	0.41	0.45	0.40	0.58	0.60	0.29	0.41	0.23	0.40	0.30	0.37	0.44
2003 - 2012	0.40	0.45	0.45	0.74	0.82	0.34	0.53	0.34	0.50	0.33	0.39	0.43
2002 - 2011	0.18	0.27	0.30	0.75	0.84	0.29	0.53	0.25	0.43	0.34	0.18	0.25
2001 - 2010	0.10	0.25	0.25	0.72	0.75	0.25	0.48	0.26	0.45	0.34	0.10	0.21
2000 - 2009	-0.03	0.12	0.13	0.68	0.74	0.20	0.38	0.35	0.44	0.33	0.00	0.12
1999 - 2008	-0.10	0.09	0.11	0.39	0.47	0.08	0.22	0.24	0.31	0.38	-0.07	0.14
1998 - 2007	0.24	0.30	0.40	0.60	0.51	0.26	0.42	0.36	0.54	0.50	0.22	0.29
15-year												
2000 - 2014	0.24	0.33	0.19	0.79	0.79	0.30	0.45	0.40	0.56	0.31	0.17	0.24
1999 - 2013	0.25	0.38	0.28	0.59	0.53	0.29	0.40	0.34	0.48	0.36	0.17	0.32
1998 - 2012	0.21	0.27	0.25	0.67	0.67	0.28	0.43	0.27	0.41	0.34	0.20	0.28
17-year												
1998 - 2014	0.32	0.36	0.27	0.64	0.62	0.29	0.41	0.32	0.45	0.32	0.25	0.32

It is worth noting that hedge funds / TAA are the worst performing aggregate asset class in two of eight 10-year periods, two of three 15-year periods, and were it not for the cash component of other U.S. other fixed income, would be the worst performing aggregate asset class in all three 15-year periods as well as the full 17-year period.

3.7.2 Compound average net return by time span

Compound average net returns for different time spans are shown in Table 4B. The results are broadly similar to the results for the arithmetic average net return. Since compound returns are “short on volatility”, the main difference compared to Table 4A is that more volatile aggregate asset classes have their compound net returns reduced below their arithmetic net return to a greater degree than for less volatile aggregate asset classes.

For example, in terms of the arithmetic average net return (Table 4A) large-cap U.S. stock was the worst performer for two 10-year spans (1999-2008, 2000-2009) while hedge funds / TAA was the worst performer for the subsequent two 10-year spans (2001-2010, 2002-2011). By contrast, in terms of average compound net return shown in Table 4B, large-cap U.S. stock is the worst performer for all four of these 10-year spans because the asset class is more volatile than hedge funds / TAA.

Interestingly, listed equity REITs, one of the more volatile aggregate asset classes, is the best performing asset class by this measure in, now, seven of the 15 three-year time spans, but again the worst in the period spanning the financial crisis, 2007-2009. Similarly, listed equity REITs remain the best performing aggregate asset class in more time spans than any other aggregate asset class over five-year and 10-year spans, and is the best performing aggregate asset class in all three 15-year spans.

3.7.3 Volatility by time span

Where net returns over short time spans were somewhat unpredictable, the volatility shown in Table 4C converges to a familiar hierarchy⁶ among the aggregate asset classes over time spans as short as three years. The least volatile aggregate asset class is broad U.S. fixed income with the lowest volatility in 11 of 15 three-year time spans, 11 of 13 five-year time spans, and all ten- and fifteen-year time spans. (Cash would of course be the least volatile aggregate asset classes were it considered separately from other U.S. fixed income.)

At the other extreme, the most volatile aggregate asset class is nearly always private equity. The exceptions in the three-year time spans overlap with either the buildup to the financial crisis, the financial crisis itself, or the subsequent equity bull market. That this is the case is clearer on looking at five-year time spans; listed equity REITs are the most volatile for 2003-2007, 2004-2008, and 2006-2010 while non-U.S. stock is most volatile in 2005-2009, 2007-2012, and 2008-2012. The most volatile from 2010-2014 was small-cap U.S. stock, also the best performing asset class during the same period. That high volatilities are associated with aggregate asset classes with high returns is to be expected.

3.7.4 Sharpe ratio by time span

Sharpe ratios by time span are shown in Table 4D. Like the volatilities by time span, Sharpe ratios fall into a familiar hierarchy in relatively short order. While the values fluctuated, the highest Sharpe ratio in any given time span was typically long duration fixed income while hedge funds / TAA was typically the lowest.

3.8 Correlations

Correlations between all pairs of average annual aggregate asset class net returns are shown in Table 5A pre-standardization and 5B post-standardization. The only differences between the two tables are the correlations to the two aggregate asset classes that have had their returns standardized for reporting lags. Our post-standardized

⁶ From least to most volatile: bonds, hedge funds, real estate, stock, private equity.

results are generally consistent with forward looking views of others (see for example Ref. [9]), the exception being the correlations to unlisted real estate.

The most highly correlated assets were the three stock asset classes, where correlations ranged from 0.88 to 0.92 over the full 17 year period. Interestingly, hedge funds / TAA and private equity were about as correlated to listed stocks as listed stocks were between themselves, having ranged from 0.79 to 0.93 in the case of hedge funds / TAA correlations to stocks and 0.85 to 0.91 for private equity correlations to stocks.

The other aggregate asset classes that showed high correlation to each other were listed equity REITs and post-standardized unlisted real estate at 0.91. This finding comes as no surprise given that both aggregate asset classes invest in the same assets – real estate. We remark that the correlations between *pre-standardized* unlisted real estate and other asset classes is consistent with the forward looking views of others (for example Ref. [9]) demonstrating that their remains a mistaken belief in the investment industry that unlisted real estate returns are

Table 5A and 5B. Correlations between aggregate asset classes pre-standardization (5A) and post-standardization (5B).

Table 5A. Correlations (pre-standardized)

		Stock			Fixed Income				Real Assets			Other	
		U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
Stock	U.S. Large Cap	n/a	0.92	0.88	-0.03	-0.50	0.66	0.49	0.08	0.54	0.27	0.93	0.49
	U.S. Small Cap	0.92	n/a	0.89	-0.09	-0.62	0.66	0.48	0.01	0.63	0.39	0.79	0.43
	Non U.S.	0.88	0.89	n/a	-0.07	-0.62	0.73	0.58	0.03	0.57	0.54	0.86	0.49
Fixed Income	U.S. Broad	-0.03	-0.09	-0.07	n/a	0.61	0.57	0.65	-0.24	0.42	0.01	0.09	-0.23
	U.S. Long Bonds	-0.50	-0.62	-0.62	0.61	n/a	-0.21	0.05	0.03	-0.07	-0.38	-0.39	-0.25
	U.S. Other	0.66	0.66	0.73	0.57	-0.21	n/a	0.79	-0.23	0.68	0.43	0.71	0.20
Real Assets	Non U.S.	0.49	0.48	0.58	0.65	0.05	0.79	n/a	-0.24	0.62	0.24	0.52	-0.07
	Unlisted Real Estate	0.08	0.01	0.03	-0.24	0.03	-0.23	-0.24	n/a	0.09	0.40	0.16	0.56
	Listed Equity REITs	0.54	0.63	0.57	0.42	-0.07	0.68	0.62	0.09	n/a	0.50	0.49	0.23
Oth	Other	0.27	0.39	0.54	0.01	-0.38	0.43	0.24	0.40	0.50	n/a	0.35	0.62
	Hedge Funds / TAA	0.93	0.79	0.86	0.09	-0.39	0.71	0.52	0.16	0.49	0.35	n/a	0.56
	Private Equity	0.49	0.43	0.49	-0.23	-0.25	0.20	-0.07	0.56	0.23	0.62	0.56	n/a

Table 5B. Correlations (post-standardized)

		Stock			Fixed Income				Real Assets			Other	
		U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
Stock	U.S. Large Cap	n/a	0.92	0.88	-0.03	-0.50	0.66	0.49	0.49	0.54	0.27	0.93	0.85
	U.S. Small Cap	0.92	n/a	0.89	-0.09	-0.62	0.66	0.48	0.57	0.63	0.39	0.79	0.89
	Non U.S.	0.88	0.89	n/a	-0.07	-0.62	0.73	0.58	0.55	0.57	0.54	0.86	0.91
Fixed Income	U.S. Broad	-0.03	-0.09	-0.07	n/a	0.61	0.57	0.65	0.36	0.42	0.01	0.09	-0.14
	U.S. Long Bonds	-0.50	-0.62	-0.62	0.61	n/a	-0.21	0.05	-0.11	-0.07	-0.38	-0.39	-0.68
	U.S. Other	0.66	0.66	0.73	0.57	-0.21	n/a	0.79	0.67	0.68	0.43	0.71	0.67
Real Assets	Non U.S.	0.49	0.48	0.58	0.65	0.05	0.79	n/a	0.49	0.62	0.24	0.52	0.39
	Unlisted Real Estate	0.49	0.57	0.55	0.36	-0.11	0.67	0.49	n/a	0.91	0.49	0.44	0.54
	Listed Equity REITs	0.54	0.63	0.57	0.42	-0.07	0.68	0.62	0.91	n/a	0.50	0.49	0.50
Oth	Other	0.27	0.39	0.54	0.01	-0.38	0.43	0.24	0.49	0.50	n/a	0.35	0.50
	Hedge Funds / TAA	0.93	0.79	0.86	0.09	-0.39	0.71	0.52	0.44	0.49	0.35	n/a	0.80
	Private Equity	0.85	0.89	0.91	-0.14	-0.68	0.67	0.39	0.54	0.50	0.50	0.80	n/a

uncorrelated with listed real estate returns.

3.9 Listed versus unlisted assets

It is interesting to compare the risk and return of unlisted assets and their listed counterparts once the annual returns for unlisted assets have been standardized to account for reporting lags that otherwise prevent comparison. Prior to doing so, we stress that we have made no effort here to adjust for differences in leverage which account for some of the differences in risk and return. The reason for this is simple; here we are only interested in the performance of the aggregate asset classes themselves, including the effects of leverage.

Looking first at private equity in Table 3, net returns spanning 1998-2014 were significantly better than for either small-cap U.S. stock or large-cap U.S. stock, and outperformed by 2.51 percentage points over the former and by 1.08 percentage points over the latter on a compound basis. Of course, private equity was riskier as well, with an excess volatility of 9.29 percentage points over large-cap U.S. stock and 6.46 percentage points over small-cap U.S. stock. The added risk and return tended to balance such that the Sharpe ratios were similar.

Our prior studies of private equity [10] have shown that when compared to small-cap returns, correction for differences in leverage were unnecessary. The signal for this is found in the standard deviation of the two asset classes which are nearly identical (the volatility of private equity is greater than that of small-cap U.S. stock because of the much greater idiosyncratic risk taken in and not excess market β). The same finding holds here.

One difference with our prior work on private equity concerns the observed outperformance. When we compared the entire global CEM database of private equity returns from 1996-2012 against a custom region blended and lagged small-cap benchmark [10] we found that, on average private equity outperformed by 0.28 percentage points, much less than the outperformance found here.

Turning to unlisted real estate, net returns spanning 1998-2014 were significantly worse than for listed equity REITs, underperforming by 3.36 percentage points on an arithmetic basis and 2.92 percentage points on a compound basis. The volatility of unlisted real estate was lower than for listed equity REITs as well by 1.71 percentage points, but not by enough to adequately compensate for the lower net return. Comparing Sharpe ratios demonstrates that even on a risk adjusted basis, listed equity REITs with a Sharpe ratio of 0.45 was a significantly better investment than unlisted real estate with a Sharpe ratio of 0.32.

One reason for the difference in risk and return is the use of leverage by listed equity REITs. Pagliari et al. [11] estimated that the ratio of debt to debt plus equity between 1991 and 2001 averaged 40% for listed equity REITs. Leverage used at listed equity REITs has come down since the financial crisis however and is closer to 33% today. Differences in leverage do not explain the gap in net returns: a de-levered portfolio of 65 percent listed equity REIT returns plus 35 percent broad U.S. fixed income would have a net return of 9.90 percent (arithmetic) and 9.09 percent (compound) respectively, greater than the net return of unlisted real estate by 1.31 percentage points and 1.87 percentage points respectively. The use of a sub-investment grade bond index to de-lever REITs would only serve to increase this gap. A likely explanation for the gap in net return that remains after adjusting for leverage is a difference in investment costs as discussed in section 6.

4 Asset allocation

Average asset allocation by aggregate asset class for U.S. DB pension funds is shown by year in Table 6. Also shown are the absolute changes over the full 17 year period, and the changes per year. The most prominent change was the dramatic reduction in allocation to large-cap U.S. stock, going from more than 40 percent in 1998 to less than 20 percent by 2014. The total change in average allocation over the full 17-year period was -23.42 percent.

The second most prominent features are two-fold: a -14.56 percent reduction in average allocation to broad U.S. fixed income, and a 15.52 percent increase in average allocation to long duration U.S. bonds. This trend, extension of the duration of fixed income by increasing long bond holdings and decreasing broad fixed income holdings, is a

Table 6. Average asset allocation for U.S. DB pension funds by year. Summary statistics include the average over all years, the absolute change (i.e., 2014 value - 1998 value), the absolute change per year, and the trend per year.

Table 6. Average asset allocation of U.S. DB pension funds by year (in percent)

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	18.70	3.38	20.90	12.11	16.43	4.84	2.89	4.46	0.62	1.39	8.36	5.93
2013	20.94	4.03	20.92	13.13	14.63	4.89	2.58	4.20	0.56	1.37	7.13	5.63
2012	21.59	4.47	18.86	15.12	14.44	4.78	2.31	4.06	0.55	1.36	6.60	5.86
2011	22.62	4.80	18.92	14.88	13.17	5.07	2.82	3.72	0.62	1.30	6.40	5.67
2010	25.50	5.52	19.87	17.04	9.65	4.98	2.15	3.36	0.50	1.18	5.14	5.11
2009	25.83	5.19	18.25	20.44	7.83	5.65	1.90	3.89	0.48	0.94	4.57	5.03
2008	28.91	5.17	18.13	20.64	6.55	4.53	1.92	4.29	0.66	0.71	4.14	4.34
2007	32.76	6.10	20.07	19.24	4.12	4.03	1.69	3.82	0.73	0.57	3.48	3.39
2006	35.53	6.84	19.74	20.53	1.79	3.95	1.34	3.54	0.86	0.31	2.89	2.67
2005	37.40	6.81	18.60	21.14	1.35	4.09	1.53	3.03	0.88	0.22	2.43	2.52
2004	38.60	6.75	17.92	21.63	1.38	4.17	1.42	2.73	0.84	0.19	1.70	2.67
2003	38.12	6.26	16.79	23.73	1.60	3.56	1.80	2.87	0.75	0.23	1.39	2.88
2002	37.39	6.10	15.39	27.19	1.37	2.42	2.01	3.32	0.55	0.08	1.43	2.74
2001	37.77	7.18	15.33	27.44	0.82	1.64	1.77	2.98	0.53	0.06	1.50	2.98
2000	38.18	6.65	16.37	26.41	0.87	1.54	2.21	2.87	0.52	0.05	1.30	3.04
1999	41.24	6.57	15.63	25.42	1.09	1.61	2.12	2.55	0.46	0.03	1.09	2.19
1998	42.11	5.63	13.63	26.67	0.90	1.96	2.40	2.90	0.36	0.01	1.46	1.97
Average:	31.95	5.73	17.96	20.75	5.76	3.75	2.05	3.45	0.62	0.59	3.59	3.80
Absolute change:	-23.42	-2.26	7.27	-14.56	15.52	2.88	0.49	1.56	0.27	1.38	6.90	3.96
Change per year:	-1.38	-0.13	0.43	-0.86	0.91	0.17	0.03	0.09	0.02	0.08	0.41	0.23

clear indication of the emergence of liability driven investment (LDI) by some U.S. DB pension funds – the practice of matching the cash inflows from investments and contributions to the cash outflows to pensioners.

The third most prominent set of features in the average asset allocation of U.S. DB pension funds are three-fold: a 7.27 percent increase in allocation to non-U.S. stock, a 6.90 percent increase in allocation to hedge funds, and a 3.96 percent increase in allocation to private equity. These trends illustrate the dramatic change in the way U.S. DB pension funds have invested over the past 20-years, with funds moving away from typical 60/40 stock/bond allocations towards more diverse allocations, especially in alternative investments.

Finally, we remark that among the other six aggregate asset classes the average allocation to:

- Small-cap U.S. stock has halved, from a peak at 7.18 percent in 2001 to a low of 3.38 percent in 2014.
- Other U.S. fixed income has tripled, from a low of 1.54 percent in 2000 to a peak of 5.07 percent in 2014.
- Non U.S. fixed income increased slightly from 2.40 percent in 1998 to 2.89 percent in 2014, having dipped below 2 percent for a decade in between.
- Unlisted real estate increased by 50 percent, from 2.90 percent in 1998 to 4.46 percent in 2014.
- Listed equity REITs remained small at just 0.62 percent.
- Other real assets increased over 100 fold, but remained small at 1.39 percent.

4.1 Asset allocation by fund cohort

While these trends are true for the whole group, distinct differences exist between funds. In what follows we describe in brief the differences in asset allocation by funds for six groups, public sector vs. corporate sector for three size bands, large funds with more than \$10 billion in AUM, mid-sized funds with between \$2 billion and \$10 billion in AUM, and small funds with less than \$2 billion in AUM. What is remarkable about the data is that, for the most part, large differences in asset allocation between the six groups only emerge around the time of the financial crisis (2008).

Large (e.g., more than \$10 billion AUM) corporate sector funds showed a very distinct pattern in terms of their asset allocation. The well-timed embrace of LDI in 2008 - a 30 percent overweight deviation in long duration fixed income - is the most pronounced deviation in asset allocation relative to the all fund average among all six cohorts and aggregate asset classes. This change in asset allocation was funded by a sharp reduction in allocation to large-cap U.S. stock and broad U.S. fixed income. Also notable is that this cohort held an above average allocation to private equity in every year from 1998-2014.

Where large (e.g., more than \$10 billion AUM) corporate sector funds moved into LDI, their large public sector counterparts did not. Indeed, the primary notable feature of the average deviation in asset allocation for the group is it being increasingly underweight long duration fixed income approaching, during, and following the financial

Tables 7A and 7B. Average deviation from the all fund average asset allocation by year in percent for large (A) U.S. corporate sector DB pension funds and (B) U.S. public sector DB pension funds with more than \$10 billion AUM.

Table 7A. Average deviation from the all fund average asset allocation (in percent) - large corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-1.5	-2.2	-2.4	-7.5	14.1	-2.0	-0.9	-1.2	-0.3	0.3	-1.1	4.7
2013	-8.1	-2.2	-5.1	-5.6	11.3	0.0	-0.4	-0.1	-0.2	1.5	2.8	6.0
2012	-9.6	-3.0	-2.4	-7.0	11.5	-1.7	0.3	0.0	0.0	1.9	3.9	6.1
2011	-10.5	-2.7	-1.8	-7.3	12.3	-2.5	-0.2	0.2	-0.1	1.5	4.5	6.6
2010	-11.8	-3.5	-0.9	-8.0	14.6	-2.4	-0.4	-0.2	-0.2	1.3	4.9	6.6
2009	-9.4	-3.5	-0.8	-9.6	16.9	-3.4	-1.2	-0.9	-0.2	1.2	4.8	6.3
2008	-13.9	-3.3	-1.7	-19.7	30.0	-2.1	-1.4	-2.4	-0.4	1.1	6.9	7.0
2007	-6.2	-3.4	-2.3	-1.7	6.3	0.9	-1.7	-2.2	-0.6	0.4	4.4	6.0
2006	-0.9	-1.8	0.3	6.0	-1.8	-1.8	-1.3	-0.4	-0.9	-0.2	2.0	0.8
2005	-6.3	1.8	1.3	2.0	-1.4	-1.8	-1.5	1.0	-0.8	2.2	-1.3	4.8
2004	-8.5	4.2	0.9	1.0	-1.4	-1.9	-1.4	1.5	-0.8	2.0	-1.1	5.5
2003	-3.9	3.1	-0.7	-2.0	-1.6	-2.8	-0.5	3.5	-0.7	0.8	-1.4	6.1
2002	2.2	1.7	-1.3	-7.0	-1.4	-1.8	-1.3	4.4	-0.3	0.3	-1.4	5.9
2001	4.0	-0.6	-0.2	-9.1	-0.8	-1.0	-1.8	4.7	0.2	0.1	-1.5	5.9
2000	-5.5	0.9	3.9	-7.4	-0.9	-0.8	-2.2	4.5	0.6	0.0	-1.1	8.2
1999	-7.7	0.2	4.1	-6.3	-1.1	1.1	-0.5	4.3	0.6	0.0	-1.1	6.4
1998	-1.8	0.6	1.3	-5.5	-0.9	1.3	-0.8	2.6	0.5	0.0	-0.4	3.2
Average:	-5.9	-0.8	-0.5	-5.6	6.2	-1.3	-1.0	1.1	-0.2	0.8	1.4	5.7

Table 7B. Average deviation from the all fund average asset allocation (in percent) - large public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	3.3	-0.8	2.9	3.5	-15.9	1.6	1.0	2.8	0.2	0.3	-2.3	3.4
2013	1.1	-0.2	2.9	3.9	-14.6	1.5	0.7	2.6	0.3	-0.2	-1.8	3.8
2012	0.8	-0.4	2.7	3.5	-14.2	2.0	0.3	2.8	0.2	-0.2	-1.3	3.8
2011	1.7	-0.8	2.1	4.3	-12.9	2.0	0.1	2.1	0.2	-0.5	-1.6	3.2
2010	0.8	-1.2	1.0	3.6	-9.2	1.5	0.6	1.5	0.3	-0.5	-1.3	2.9
2009	0.2	-1.9	0.6	1.1	-7.4	1.8	1.0	2.1	0.4	-0.5	-0.7	3.2
2008	1.5	-2.1	0.5	1.6	-6.3	1.8	0.4	2.2	0.3	-0.4	-1.9	2.4
2007	2.1	-1.7	0.2	1.6	-4.1	1.7	0.1	1.1	0.3	-0.5	-1.8	1.0
2006	2.0	-2.1	0.9	0.7	-1.8	0.9	-0.3	0.7	0.3	-0.1	-2.5	1.3
2005	2.6	-3.3	1.0	1.6	-1.4	0.3	-0.4	0.7	0.2	-0.2	-2.2	1.0
2004	3.3	-4.4	0.0	2.4	-1.4	0.0	-0.3	0.9	0.4	-0.2	-1.4	0.6
2003	2.1	-3.5	0.2	4.3	-1.6	-0.9	-0.8	1.1	0.1	-0.2	-0.8	0.1
2002	1.0	-2.3	-0.8	2.6	-1.4	-0.5	-0.4	1.4	0.2	-0.1	-0.7	1.0
2001	0.6	-3.0	0.7	1.4	-0.8	-0.3	0.3	1.1	0.1	-0.1	-0.8	0.5
2000	0.8	-2.0	0.5	-1.2	0.3	0.2	0.6	1.1	0.1	0.0	-0.9	0.5
1999	2.1	-3.0	-1.1	1.0	-0.5	-0.1	0.5	0.8	0.1	0.0	0.0	0.2
1998	1.0	-2.4	-2.4	2.1	-0.9	0.3	0.3	1.2	0.1	0.0	0.3	0.3
Average:	1.6	-2.1	0.7	2.2	-5.5	0.8	0.2	1.6	0.2	-0.2	-1.3	1.7

crisis. In addition, large public sector funds have traditionally been overweight U.S. large-cap stock, broad U.S. fixed income, unlisted real estate and private equity.

Two features of the asset allocation of mid-sized (e.g., more than \$2 billion, less than \$10 billion AUM) corporate sector funds stand out. One, much like their large corporate sector counterparts, this cohort of funds clearly embraced LDI investing; the group is overweight long duration fixed income in every year from 1998-2014. However, where large corporate plans timed the asset shift to being around 30 percent overweight in 2008, mid-sized funds corporate funds were only 3 percent overweight. Since the financial crisis the average deviation in

Tables 7 C and D. Average deviation from the all fund average asset allocation by year in percent for mid-sized (C) U.S. corporate sector DB pension funds and (D) U.S. public sector DB pension funds with more than \$2 billion and less than \$10 billion AUM.

Table 7C. Average deviation from the all fund average asset allocation (in percent) - mid-sized corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-2.4	0.4	-3.2	-1.8	10.0	-1.3	-0.6	-1.7	0.0	0.0	2.2	-1.6
2013	-0.1	-0.7	-2.4	-1.6	7.9	-1.3	-0.7	-1.5	0.0	0.2	1.5	-1.2
2012	0.6	-0.2	-0.2	-0.6	6.7	-1.3	-1.3	-1.5	-0.1	0.1	-0.8	-1.4
2011	1.3	-0.2	-0.8	-0.8	4.6	-1.1	-0.4	-1.4	-0.2	0.3	-0.4	-0.8
2010	-0.4	-0.4	-1.4	0.0	4.1	-0.5	-1.0	-1.1	0.0	0.2	0.8	-0.3
2009	0.8	-0.7	-0.4	0.8	2.6	-1.2	-0.7	-0.9	0.0	0.0	-0.3	0.0
2008	1.5	-0.8	0.4	-1.9	3.2	-1.0	-0.6	-1.1	-0.2	0.1	0.5	0.0
2007	0.5	-0.4	0.1	-1.7	2.5	-1.2	-0.2	-0.8	-0.1	0.2	0.8	0.3
2006	1.8	-1.4	-0.1	-2.0	2.6	-0.7	-0.1	-0.6	-0.2	0.0	0.9	-0.2
2005	1.8	-0.7	0.5	-2.2	2.2	-0.7	-0.6	-0.2	-0.2	0.0	0.6	-0.3
2004	2.0	0.1	0.1	-3.2	2.5	-0.3	-0.5	-0.6	-0.2	-0.1	0.4	-0.2
2003	1.3	-0.3	2.7	-5.8	2.8	-0.2	-0.2	-0.9	0.0	0.0	0.3	0.4
2002	3.6	-0.1	1.6	-6.1	2.0	0.6	-0.5	-1.3	0.1	0.0	0.0	0.2
2001	3.7	-0.7	1.7	-3.9	0.8	-0.2	-0.8	-1.1	-0.1	0.0	0.2	0.4
2000	3.9	-1.6	2.8	-4.3	1.0	-0.2	-1.3	-1.0	-0.2	0.0	0.7	0.1
1999	2.5	-0.7	2.6	-4.8	1.9	-0.3	-1.0	-0.7	-0.2	0.0	0.4	0.4
1998	2.1	-1.3	2.0	-2.7	1.5	-0.4	-1.5	-0.6	-0.1	0.0	0.4	0.7
Average:	1.4	-0.6	0.4	-2.5	3.5	-0.7	-0.7	-1.0	-0.1	0.0	0.5	-0.2

Table 7D. Average deviation from the all fund average asset allocation (in percent) - mid-sized public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	0.2	0.8	3.5	-1.8	-13.3	-0.1	2.2	0.7	-0.2	0.4	6.9	0.7
2013	-0.1	-1.3	5.9	0.9	-12.6	0.8	0.9	2.1	0.0	0.7	2.0	0.7
2012	1.5	-1.9	4.1	2.3	-14.4	0.9	1.8	2.1	0.0	0.6	2.7	0.4
2011	-2.6	0.5	4.5	2.7	-12.8	1.5	0.6	1.8	0.0	1.4	1.7	0.8
2010	-2.5	-0.7	5.0	1.6	-9.2	1.3	0.7	1.6	-0.1	0.9	0.8	0.5
2009	-2.0	-0.1	3.6	0.4	-7.2	1.4	1.1	1.4	0.0	0.6	1.5	-0.7
2008	-3.7	0.4	1.8	0.4	-6.3	1.2	1.6	1.7	0.1	0.9	2.1	-0.3
2007	-3.3	-0.5	1.9	1.9	-4.1	1.1	1.5	0.9	0.1	0.6	0.2	-0.3
2006	-5.0	0.6	1.7	-0.1	-1.8	2.2	1.3	0.4	-0.2	0.4	0.8	-0.4
2005	-4.7	0.3	1.5	-0.3	-1.4	2.2	1.1	0.1	-0.2	0.3	1.2	-0.1
2004	-5.4	1.7	1.6	-0.5	-1.4	2.3	1.1	0.2	-0.3	0.2	0.8	-0.3
2003	-3.0	1.2	-1.2	1.8	-1.6	1.8	0.6	0.1	-0.1	0.2	0.5	-0.2
2002	-3.9	0.7	-0.8	3.6	-1.4	0.6	0.5	0.7	0.2	0.2	0.4	-0.8
2001	-3.2	1.0	-1.6	3.5	-0.8	0.8	0.3	0.5	0.0	0.1	-0.1	-0.4
2000	-3.5	0.7	-3.0	6.3	-0.9	0.3	-0.1	0.4	-0.1	0.1	0.2	-0.5
1999	-2.6	0.5	-2.1	6.5	-1.1	-0.2	0.5	0.3	-0.1	0.1	-0.8	-1.1
1998	-3.5	0.1	-1.4	6.9	-0.9	0.2	0.9	-0.2	0.0	0.0	-1.0	-1.1
Average:	-2.8	0.2	1.5	2.1	-5.4	1.1	1.0	0.9	0.0	0.4	1.2	-0.2

allocation to long duration fixed income had risen to 10 percent.

Mid-sized (e.g., more than \$2 billion, less than \$10 billion AUM) public sector funds differed in average asset allocation in a handful of notable ways. One, like large public sector plans, the cohort was underweight long duration fixed income. Two, from 1998-2011 the cohort was underweight large-cap U.S. stock. Three, the cohort was overweight non-U.S. stock from 2004-2014, a trend generally shared by all public sector U.S. DB pension funds. Finally from 1998 to 2003 they were overweight U.S. fixed income.

The asset allocation of small (e.g., less than \$2 billion AUM) corporate sector funds had been, until recent,

Tables 7 E and F. Average deviation from the all fund average asset allocation by year in percent for small (E) U.S. corporate sector DB pension funds and (F) U.S. public sector DB pension funds with less than \$2 billion AUM.

Table 7E. Average deviation from the all fund average asset allocation (in percent) - small corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-3.3	-0.3	-1.5	5.6	8.7	-0.8	-0.5	-1.9	-0.3	-0.5	-1.0	-4.3
2013	-0.3	1.9	-2.0	1.2	6.7	-0.8	-0.2	-2.1	-0.2	-0.5	-0.1	-3.7
2012	2.8	2.3	-3.7	1.4	5.2	-1.2	-0.4	-2.2	0.0	-0.5	0.5	-4.1
2011	2.1	1.9	-3.1	-0.1	6.6	-0.8	-0.3	-1.3	0.1	-0.6	-0.5	-4.0
2010	3.5	3.2	-2.1	-1.8	3.7	-0.2	-0.1	-1.6	-0.2	-0.2	-1.3	-3.1
2009	2.0	2.1	-1.9	-1.1	3.1	0.1	-0.1	-1.5	-0.2	0.1	-0.7	-2.0
2008	2.4	2.4	-1.3	0.5	1.2	-0.4	-0.2	-1.3	0.0	-0.2	-1.2	-1.9
2007	2.4	2.3	-2.7	2.0	0.9	-0.3	-0.7	-0.8	-0.1	-0.3	-0.9	-1.7
2006	5.4	3.2	-2.8	2.0	0.1	-1.8	-0.9	-1.3	-0.2	-0.3	-1.5	-2.0
2005	3.5	3.1	-3.1	0.6	0.2	-0.4	-0.4	-0.8	-0.2	-0.2	-0.3	-1.9
2004	4.8	1.2	-2.5	1.7	-0.1	-1.1	-1.0	-0.4	-0.3	-0.2	-0.6	-1.6
2003	3.4	1.4	-1.9	-1.0	1.7	0.0	-1.3	-0.4	-0.4	0.0	0.0	-1.5
2002	2.5	1.0	-0.2	-2.2	2.0	0.3	-1.4	-1.2	-0.4	0.0	0.6	-0.9
2001	1.1	2.8	-0.7	-1.5	1.6	-0.4	-1.1	-0.8	-0.2	0.0	0.5	-1.3
2000	0.4	3.9	-0.6	-3.0	0.8	-0.1	-0.6	-0.8	0.0	0.0	0.4	-0.3
1999	0.5	2.3	-0.7	-2.0	0.7	0.1	-1.0	-0.3	0.1	0.0	0.3	0.0
1998	1.0	2.2	-0.1	-2.7	0.5	0.2	-0.8	-0.3	0.0	0.0	0.2	-0.1
Average:	2.0	2.2	-1.8	0.0	2.5	-0.4	-0.6	-1.1	-0.2	-0.2	-0.3	-2.0

Table 7F. Average deviation from the all fund average asset allocation (in percent) - small public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	8.0	3.0	8.6	3.8	-16.4	2.2	-0.7	-1.1	1.4	1.3	-6.9	-3.3
2013	9.7	3.4	1.1	3.3	-14.6	0.2	1.8	-0.5	0.1	0.3	-2.5	-2.5
2012	0.9	3.3	4.1	1.0	-14.4	0.3	4.5	0.7	0.4	0.9	0.0	-1.7
2011	-1.8	0.8	6.4	0.7	-13.2	-0.2	3.4	1.6	0.4	0.4	2.2	-0.7
2010	4.3	1.0	4.2	3.6	-9.7	-3.0	2.0	2.1	0.4	-0.2	-1.5	-3.2
2009	4.4	2.7	1.7	9.9	-7.8	-2.6	-1.4	0.7	-0.1	-0.3	-2.7	-4.5
2008	5.5	0.6	1.4	1.2	-6.6	-2.6	-1.2	-0.1	0.1	-0.7	-3.9	-3.7
2007	0.8	4.1	0.0	2.1	-4.1	-1.5	0.0	1.5	-0.1	0.0	-0.5	-2.2
2006	-2.3	5.9	-1.2	3.6	-1.8	-3.0	-0.4	0.4	0.4	-0.3	0.3	-1.7
2005	-1.2	5.6	-4.2	5.2	-1.4	-2.8	0.3	-0.2	1.1	-0.2	-1.1	-1.3
2004	-4.5	3.9	-1.8	4.6	-1.4	-2.5	0.9	-0.3	1.0	0.0	0.4	-0.3
2003	-2.4	1.9	-1.5	3.6	-1.6	-1.7	2.2	-0.4	1.1	0.0	0.0	-1.1
2002	-2.9	0.6	-1.1	5.5	-1.4	-1.5	2.7	-0.1	0.1	-0.1	-0.2	-1.7
2001	-3.7	0.4	-1.5	3.9	-0.8	-0.2	2.1	0.0	0.3	-0.1	0.6	-1.0
2000	0.5	-1.4	-0.8	3.4	-0.9	-0.8	2.6	-0.3	0.2	0.0	-0.2	-2.4
1999	-0.1	-0.2	-0.3	1.1	-1.1	0.2	1.7	-0.7	0.1	0.0	0.5	-1.1
1998	-1.0	0.3	-0.2	1.1	-0.9	-0.7	2.8	-0.4	0.0	0.0	0.3	-1.2
Average:	0.8	2.1	0.9	4.0	-5.8	-1.2	1.4	0.2	0.4	0.1	-0.9	-2.0

consistently overweight large and small-cap U.S. stock and underweight non-U.S. stock, unlisted real estate, and private equity. The recent change beginning in 2009 saw small corporate sector funds follow large and mid-sized corporate funds into LDI by becoming overweight long duration fixed income.

Small (e.g., less than \$2 billion AUM) public sector funds have, as a group, differed in average asset allocation by consistently being overweight U.S. small-cap stock and broad U.S. fixed income, and by being underweight long duration fixed income and private equity. Since private long duration and fixed income are two of the best performing aggregate asset classes, in terms of arithmetic average net return, compound average net return, or Sharpe ratio it is not surprising that this cohort underperforms the average fund.

5 Total fund performance

Summary data for total fund net returns on investments, as reported to CEM Benchmarking, are shown for public sector funds in Table 8A (left-hand set of columns) and for corporate sector funds in Table 8B (left-hand set of columns). A comparison of the two Tables demonstrates that the smaller, corporate sector funds outperformed their larger, public sector counterparts over the period 1998-2014 by a significant margin, 7.11 percent versus 6.61 percent⁷, or 0.50 percentage points, with the outperformance concentrated in a handful of years (3.22 percentage points of outperformance in 2008, 4.56 percentage points of outperformance in 2011 and 3.52 percentage points of outperformance in 2014). The only year corporate sector funds underperformed public sector funds by a wide margin was 2013 (4.88 percentage points of underperformance). Total fund net returns are, however, a composite measure of returns from physical assets, which is of primary concern for our study, and from overlay strategies (i.e., derivatives and unfunded strategies), which are not.

The middle set of columns in Tables 8A and 8B show physical-asset-only returns for both sets of funds. Physical-asset-only returns are calculated for each fund from a weighted sum of physical asset holdings multiplied by their corresponding net returns, and therefore exclude sources of return arising from non-physical assets. We caution that the differences between as-reported total fund net returns and physical-asset-only net returns cannot solely be attributed to the use of derivatives and overlays as it also includes effects such as market timing and rebalancing. Typically the difference between the two columns is small but negative (i.e., physical asset only returns are higher than total fund returns).

More importantly, the difference between total fund net return and physical-asset-only net return is consistent for both public sector and corporate sector funds, independent on how they are calculated. That is, where corporate sector funds outperform public sector funds by 0.50 percentage points in terms of as-reported total fund net returns, they also outperform by 0.41 percentage points in terms of physical-asset-only returns. Thus, differences in performance between the two groups can be attributed nearly entirely to differences in asset allocation and performance of physical assets rather than effects such as market timing, rebalancing frequency or the use of derivatives and overlays.

The right-hand set of columns in Table 8A shows physical-asset-only results for public sector funds and Table 8B for corporate sector funds standardized for reporting lag. From the discussion in section 3.4, we expect that total fund net returns are smoothed because the unlisted components of total funds net returns are lagged. We correct for this source of noise by standardizing every funds illiquid asset net returns for reporting lag individually, asset class by asset class, fund by fund, revealing the true volatility of physical-asset-only total fund net returns for U.S. DB pension funds. Standardizing the physical-asset-only net returns for reporting lag in illiquid assets preserves the performance gap between corporate sector and public sector plans, now 0.45 percentage points, again reinforcing the notion that differences in asset allocation and asset class net returns are the primary reason for differences in total fund net returns.

⁷ Here our performance focus rests on comparisons of compound average net return in contrast to section 4 where we focused equally on arithmetic average and compound average return for individual aggregate asset classes.

Table 8A and 8B. Average annual total fund returns by year with population standard deviations (σ) and standard errors (σ/\sqrt{n}) for U.S. public sector (top) and corporate sector (bottom) pension funds spanning 1998-2014. 'As-reported' total fund net returns are calculated from total fund returns reported to CEM. 'As-reported' total fund net returns include returns produced from physical assets (i.e., stocks, bonds) and synthetic assets (derivatives and other overlays). 'Physical-asset-only' net returns are calculated by CEM from each funds' holdings weighted sum of physical asset net returns, stripping out in part the effects of derivatives and other overlays. 'Standardized physical-asset-only' net returns are calculated in the same fashion with the exception that returns for unlisted real estate and private equity have each been corrected for stale valuations (i.e., reporting lag). (See section 3.4.)

Summary statistics include the arithmetic average net return (7.35% 'as-reported' for public sector funds), the standard error on the arithmetic average net return (0.07% 'as-reported' for public sector funds), the standard deviation of the average annual net returns (11.85% 'as-reported' for public sector funds), the compound average of annual average net returns (6.61% 'as-reported' for public sector funds), the standard error on the compound average net return (0.08% 'as-reported' for public sector funds), and lastly the average volatility (12.14% 'as-reported' for public sector funds).

Table 8A. Net returns by year: U.S. public sector DB pension funds (in percent)

Year	#	As-reported			Physical-asset-only			Standardized physical-asset-only		
		Avg.	Std. Err.	Std. Dev.	Avg.	Std. Err.	Std. Dev.	Avg.	Std. Err.	Std. Dev.
2014	62	6.61	0.22	1.70	6.72	0.20	2.01	6.69	0.20	2.03
2013	64	15.40	0.40	3.21	16.13	0.47	3.73	16.03	0.45	3.59
2012	68	13.10	0.14	1.12	12.97	0.15	1.25	13.40	0.16	1.35
2011	68	0.99	0.19	1.60	1.27	0.20	1.65	-0.71	0.21	1.70
2010	73	13.34	0.19	1.59	13.10	0.18	1.50	13.29	0.23	1.95
2009	73	19.96	0.49	4.22	21.24	0.52	4.41	27.06	0.43	3.67
2008	72	-26.99	0.33	2.82	-24.11	0.44	3.76	-26.39	0.46	3.89
2007	80	8.43	0.19	1.70	8.39	0.20	1.79	6.50	0.17	1.56
2006	69	14.16	0.18	1.48	14.46	0.20	1.62	15.11	0.23	1.94
2005	72	8.42	0.20	1.71	8.62	0.23	1.95	7.82	0.18	1.53
2004	76	11.98	0.15	1.32	12.14	0.15	1.35	12.30	0.16	1.43
2003	74	22.95	0.34	2.89	23.70	0.31	2.69	24.67	0.33	2.81
2002	74	-8.76	0.31	2.63	-7.53	0.28	2.42	-7.92	0.29	2.51
2001	83	-4.30	0.26	2.41	-3.88	0.27	2.48	-3.85	0.26	2.41
2000	80	0.06	0.43	3.86	0.75	0.42	3.72	0.89	0.42	3.74
1999	83	14.56	0.45	4.14	16.33	0.52	4.71	16.65	0.54	4.91
1998	69	15.10	0.41	3.37	15.55	0.42	3.45	14.88	0.45	3.71
Arithmetic Avg. Ret.:		7.35	0.07	11.85	7.99	0.08	11.47	8.02	0.08	12.51
Compound Avg. Ret.:		6.61	0.08	n/a	7.31	0.08	n/a	7.22	0.08	n/a
Avg. Volatility:		12.14	n/a	n/a	11.82	n/a	n/a	12.83	n/a	n/a

Table 8B. Net returns by year: U.S. corporate sector DB pension funds (in percent)

Year	#	As-reported			Physical-asset-only			Standardized physical-asset-only		
		Avg.	Std. Err.	Std. Dev.	Avg.	Std. Err.	Std. Dev.	Avg.	Std. Err.	Std. Dev.
2014	97	10.13	0.36	3.57	10.04	0.35	3.47	9.82	0.35	3.42
2013	112	10.52	0.65	6.85	11.63	0.62	6.61	11.70	0.62	6.61
2012	120	12.95	0.17	1.84	12.83	0.16	1.80	13.30	0.17	1.85
2011	124	5.55	0.55	6.15	5.24	0.53	5.91	3.82	0.55	6.13
2010	121	13.53	0.18	1.93	13.17	0.18	1.93	13.35	0.15	1.69
2009	122	18.24	0.60	6.65	19.96	0.55	6.12	24.21	0.53	5.85
2008	130	-23.77	0.76	8.70	-21.35	0.73	8.36	-22.86	0.72	8.26
2007	121	8.94	0.20	2.18	8.85	0.19	2.06	7.33	0.18	1.98
2006	64	13.79	0.20	1.62	14.26	0.21	1.67	14.77	0.23	1.80
2005	69	8.72	0.22	1.87	8.75	0.22	1.81	8.05	0.18	1.48
2004	78	12.23	0.18	1.56	12.33	0.19	1.66	12.43	0.20	1.75
2003	71	23.96	0.37	3.14	24.59	0.38	3.19	25.66	0.39	3.28
2002	69	-10.51	0.39	3.25	-9.59	0.36	2.98	-10.00	0.36	2.97
2001	81	-4.94	0.32	2.88	-4.87	0.28	2.54	-4.64	0.27	2.47
2000	72	1.02	0.67	5.66	1.88	0.85	7.21	1.47	0.77	6.57
1999	85	16.89	0.74	6.81	18.54	0.75	6.94	19.12	0.76	7.03
1998	91	14.94	0.34	3.28	15.57	0.37	3.55	14.84	0.39	3.77
Arithmetic Avg. Ret.:		7.78	0.11	11.32	8.34	0.11	11.10	8.37	0.11	11.83
Compound Avg. Ret.:		7.11	0.12	n/a	7.72	0.12	n/a	7.67	0.12	n/a
Avg. Volatility:		12.21	n/a	n/a	12.00	n/a	n/a	12.66	n/a	n/a

Comparing the volatility of as-reported total fund net returns and, first, physical-asset-only net returns reveals that total fund net returns are riskier than physical-asset-only net returns, by about 3 percent for public sector funds (12.14 percent compared to 11.82 percent) and by about 2 percent for corporate sector funds (12.21 percent compared to 12.00 percent). That total fund net returns are more volatile than physical-asset-only net returns demonstrates that market timing, rebalancing, and derivatives and overlays add risk, on average.

Dwarfing this difference is the amount of volatility hidden from view through the smoothing of total fund net returns by use of illiquid assets with stale valuations. Comparing the volatilities of physical-asset-only net returns

Tables 9A and 9B. Standardized physical-asset-only net returns by year for U.S. public sector pension funds (top) and corporate sector pension fund (bottom) by size cohort. For comparison, the averages of all six cohorts' average net returns are 8.24 percent (arithmetic) and 7.49 percent (compound).

Tables 9A. Standardized physical-asset-only net returns by year for U.S. public sector pension funds by size (in percent)

Year	Less than \$2 billion AUM				\$2 billion to \$10 billion AUM				More than \$10 billion AUM			
	Avg.	Std. Err.	Std. Dev.	#	Avg.	Std. Err.	Std. Dev.	#	Avg.	Std. Err.	Std. Dev.	#
2014	6.23	0.66	1.75	7	6.58	0.86	3.21	14	6.80	0.23	1.46	41
2013	18.29	1.14	3.41	9	14.90	1.22	4.87	16	15.97	0.43	2.66	39
2012	13.58	0.43	1.37	10	12.90	0.33	1.26	15	13.53	0.20	1.34	43
2011	-1.42	0.44	1.33	9	-0.72	0.34	1.54	20	-0.54	0.29	1.81	39
2010	12.73	0.80	3.09	15	13.46	0.28	1.26	21	13.41	0.26	1.59	37
2009	26.60	1.04	3.89	14	27.53	0.63	3.24	26	26.88	0.67	3.86	33
2008	-26.36	1.02	3.06	9	-26.44	0.56	3.08	30	-26.36	0.81	4.67	33
2007	6.09	0.42	1.59	14	6.63	0.32	1.78	31	6.55	0.22	1.30	35
2006	14.22	0.44	1.52	12	14.38	0.34	1.74	26	16.06	0.32	1.80	31
2005	7.16	0.37	1.42	15	7.93	0.24	1.33	31	8.06	0.33	1.70	26
2004	11.94	0.37	1.50	16	12.28	0.23	1.34	33	12.54	0.28	1.45	27
2003	24.13	0.53	2.18	17	25.38	0.54	3.05	32	24.14	0.54	2.68	25
2002	-7.22	0.57	2.43	18	-7.76	0.46	2.66	33	-8.71	0.44	2.13	23
2001	-3.14	0.58	2.67	21	-3.55	0.43	2.56	35	-4.80	0.30	1.56	27
2000	0.73	0.77	3.38	19	1.54	0.75	4.48	36	0.07	0.49	2.43	25
1999	15.65	0.86	4.24	24	16.62	0.86	4.88	32	17.56	1.02	5.31	27
1998	14.34	0.92	4.21	21	14.40	0.66	3.42	27	16.03	0.71	3.24	21
Arith. Avg. Ret.:	7.86	0.17	12.38	n/a	8.00	0.14	12.48	n/a	8.07	0.12	12.71	n/a
Comp. Avg. Ret.:	7.07	0.18	n/a	n/a	7.20	0.14	n/a	n/a	7.24	0.13	n/a	n/a
Avg. Volatility:	12.67	n/a	n/a	n/a	12.83	n/a	n/a	n/a	12.99	n/a	n/a	n/a

Tables 9B. Standardized physical-asset-only net returns by year for U.S. corporate sector pension funds by size (in percent)

Year	Less than \$2 billion AUM				\$2 billion to \$10 billion AUM				More than \$10 billion AUM			
	Avg.	Std. Err.	Std. Dev.	#	Avg.	Std. Err.	Std. Dev.	#	Avg.	Std. Err.	Std. Dev.	#
2014	10.43	1.46	5.45	14	9.84	0.44	3.07	48	9.53	0.46	2.70	35
2013	11.68	1.53	7.97	27	11.98	0.88	6.33	52	11.28	1.00	5.74	33
2012	13.33	0.36	2.09	34	13.32	0.21	1.62	58	13.21	0.37	1.96	28
2011	4.18	1.01	6.46	41	3.77	0.83	6.38	59	3.33	0.97	4.74	24
2010	13.42	0.28	1.85	44	13.34	0.23	1.72	55	13.20	0.26	1.22	22
2009	24.24	0.88	6.38	52	24.39	0.79	5.77	53	23.58	1.01	4.16	17
2008	-22.81	1.11	8.56	59	-24.68	0.93	6.84	54	-17.28	2.13	8.79	17
2007	6.95	0.35	2.22	40	7.40	0.24	1.93	63	7.90	0.32	1.34	18
2006	14.03	0.36	1.53	18	14.73	0.30	1.75	35	16.12	0.48	1.60	11
2005	7.16	0.28	1.18	18	8.21	0.24	1.47	38	8.83	0.35	1.25	13
2004	11.98	0.29	1.34	22	12.50	0.28	1.85	44	13.01	0.52	1.82	12
2003	24.37	0.49	2.57	27	26.63	0.67	3.83	33	25.93	0.45	1.49	11
2002	-9.72	0.71	3.78	28	-10.24	0.43	2.33	30	-10.06	0.59	1.97	11
2001	-4.16	0.38	2.16	33	-4.87	0.45	2.66	35	-5.23	0.69	2.50	13
2000	1.96	1.10	6.15	31	0.90	1.44	7.64	28	1.52	1.30	4.67	13
1999	16.96	0.98	6.47	44	21.17	1.36	7.34	29	22.11	1.57	5.44	12
1998	14.55	0.60	4.14	48	15.60	0.55	3.18	27	13.72	1.00	3.17	10
Arith. Avg. Ret.:	8.15	0.20	11.50	n/a	8.47	0.17	12.41	n/a	8.86	0.23	11.24	n/a
Comp. Avg. Ret.:	7.48	0.21	n/a	n/a	7.69	0.18	n/a	n/a	8.25	0.25	n/a	n/a
Avg. Volatility:	12.45	n/a	n/a	n/a	13.19	n/a	n/a	n/a	11.86	n/a	n/a	n/a

to standardized physical-asset-only net returns demonstrates that volatilities are actually about 9 percent higher than reported for public sector funds (12.83 percent rather than 11.82 percent) and about 6 percent higher for corporate sector funds (12.66 percent rather than 12.00 percent).

Tables 10A and 10B. Deviation in average net return from the all fund average caused by deviations in asset allocation by year in basis points for large (A) U.S. corporate sector DB pension funds and (B) U.S. public sector DB pension funds with more than \$10 billion AUM.

Table 10A. Deviation in net return caused by deviation in asset allocation (in basis points) - large corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-6.0	7.5	25.0	11.9	153.6	13.3	4.8	-20.8	-3.3	-1.7	4.2	-27.9
2013	-188.5	-63.0	-39.2	68.5	202.6	0.0	3.8	0.8	1.0	-11.1	-2.9	91.1
2012	-38.4	-11.2	-13.0	35.8	-20.5	11.5	-0.2	0.1	-0.1	-15.6	-18.4	22.7
2011	2.5	11.5	25.4	-53.9	58.9	-6.1	-0.5	-1.0	-0.1	-4.0	-1.5	-55.4
2010	-32.4	-45.6	0.9	38.7	-35.6	19.9	-0.1	1.8	-1.5	-3.3	-20.5	48.1
2009	-61.1	-36.5	-13.7	107.0	317.9	34.0	3.3	-9.7	-1.6	-21.1	-39.5	110.9
2008	45.6	56.6	40.7	404.4	32.0	-31.3	-16.8	21.0	6.6	11.4	17.7	-66.5
2007	-8.4	7.4	-23.0	-3.5	20.3	0.4	-5.8	33.3	9.5	4.4	16.0	-8.6
2006	1.0	2.1	3.0	-66.0	23.5	18.4	10.8	-5.2	-16.3	0.2	-9.8	7.1
2005	11.3	-2.4	11.0	-10.9	3.4	9.6	10.1	2.3	-4.4	23.1	1.5	-13.5
2004	17.5	11.4	4.7	-9.2	6.9	17.3	5.3	3.1	-14.0	8.2	7.4	14.3
2003	-34.2	65.4	-11.6	31.2	24.1	38.2	1.8	13.9	-8.0	-10.5	8.7	38.5
2002	-41.2	-28.8	14.8	-84.3	-24.6	-9.0	-22.6	7.7	-2.4	3.2	13.5	-102.1
2001	-38.7	0.6	3.6	-77.0	-5.7	-4.7	-4.3	14.7	2.2	0.4	7.0	-56.9
2000	77.5	-7.7	-82.2	-19.4	-6.4	2.1	9.2	100.3	10.0	-0.5	8.0	-21.1
1999	-29.0	2.6	92.9	100.7	25.4	-11.1	6.6	-27.8	-8.0	-0.2	5.8	263.5
1998	-28.3	-3.0	4.9	-3.4	-3.6	-2.2	-2.1	-51.2	-7.2	0.0	-5.8	20.4
Sub-total:	-1.1	-0.1	4.0	-34.0	79.1	4.8	0.0	6.9	-1.2	0.3	1.2	9.2
Total:	64.5 bps of 76.1 bps of outperformance is explained by differences in asset allocation											

Table 10B. Deviation in net return caused by deviation in asset allocation (in basis points) - large public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	13.4	2.7	-29.9	-5.5	173.3	-10.7	-5.5	47.9	2.3	-1.8	8.6	-20.1
2013	25.7	-6.6	22.5	-48.0	61.4	-12.9	-7.2	-27.1	-2.0	1.2	2.0	57.6
2012	3.1	-1.4	14.5	-18.0	25.2	-13.9	-0.2	7.4	1.7	2.0	6.3	14.1
2011	-0.4	3.2	-28.9	31.9	271.5	5.0	0.3	-10.1	0.2	1.3	0.5	-26.5
2010	2.2	-16.0	-1.0	-17.7	22.5	-12.4	0.1	-14.7	3.3	1.2	5.4	21.0
2009	1.4	-19.7	10.2	-11.9	139.0	-17.5	-2.8	22.3	2.8	7.9	5.9	55.8
2008	-26.8	36.7	-11.6	33.2	217.3	27.1	5.2	-19.1	-4.6	-4.5	-4.9	-23.3
2007	2.9	3.7	2.0	3.3	-13.3	0.8	0.3	-16.7	-4.4	-4.7	-6.7	-1.4
2006	-2.3	2.4	8.5	-8.1	23.5	-9.2	2.6	9.5	6.4	0.1	11.9	11.0
2005	-4.6	4.4	8.3	-8.4	3.4	-1.7	2.6	1.7	1.1	-1.8	2.4	-2.7
2004	-6.7	-11.8	0.1	-21.1	6.9	0.1	1.1	1.9	7.5	-0.6	9.5	1.6
2003	18.5	-74.1	2.6	-68.4	24.1	13.1	3.1	4.5	1.1	2.6	5.3	0.6
2002	-19.0	37.9	8.8	31.1	-24.6	-2.8	-7.4	2.5	1.4	-0.9	6.4	-17.5
2001	-6.2	2.8	-12.6	12.1	-5.7	-1.4	0.8	3.6	1.4	-0.3	3.6	-5.0
2000	-11.4	16.9	-10.7	-3.1	1.9	-0.5	-2.7	24.4	2.0	-0.5	6.7	-1.3
1999	7.8	-42.7	-25.6	-15.7	11.2	0.6	-7.6	-5.3	-1.0	-0.2	0.0	6.8
1998	16.0	12.0	-9.2	1.3	-3.6	-0.5	0.7	-23.8	-1.5	0.0	3.8	2.2
Sub-total:	0.1	0.1	-3.0	-3.6	-20.5	-0.7	-0.3	0.7	1.5	0.5	4.3	3.1
Total:	-22.1 bps of -24.7 bps of underperformance is explained by differences in asset allocation											

5.1 Total fund performance by cohort

Total fund performance, as measured by standardized physical-asset-only net returns, is shown in Table 9A for

Tables 10C and 10D. Deviation in average net return from the all fund average caused by deviations in asset allocation by year in basis points for mid-sized (C) U.S. corporate sector DB pension funds and (D) U.S. public sector DB pension funds with more than \$2 billion and less than \$10 billion AUM.

Table 10C. Deviation in net return caused by deviation in asset allocation (in basis points) - mid-sized corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-9.5	-1.6	32.4	2.9	108.6	8.9	3.2	-29.3	-0.4	0.3	-8.2	9.5
2013	-3.3	-20.4	-18.4	19.6	-141.7	11.7	7.3	15.9	0.0	-1.7	-1.6	-18.0
2012	2.5	-0.7	-1.3	3.1	-11.9	9.2	1.0	-3.8	-0.9	-1.2	3.7	-5.3
2011	-0.3	0.8	11.1	-5.7	96.3	-2.8	-1.0	6.8	-0.2	-0.7	0.1	6.8
2010	-1.0	-5.3	1.4	-0.2	-9.9	4.0	-0.2	10.5	-0.5	-0.5	-3.2	-2.1
2009	5.3	-6.9	-6.2	-8.5	-49.3	12.1	1.9	-9.4	0.1	0.7	2.5	-0.2
2008	-26.3	13.3	-9.0	-39.9	110.1	-14.8	-7.6	9.4	3.1	1.1	1.2	0.2
2007	0.6	0.8	1.2	-3.5	8.2	-0.5	-0.7	12.3	1.1	1.8	2.8	-0.4
2006	-2.1	1.6	-0.8	22.0	-34.6	6.9	1.2	-7.6	-3.1	0.0	-4.1	-2.2
2005	-3.2	1.0	4.0	12.0	-5.7	3.6	4.1	-0.6	-1.3	-0.4	-0.6	0.8
2004	-4.1	0.1	0.4	28.3	-12.4	3.0	1.7	-1.1	-3.3	-0.4	-2.5	-0.4
2003	11.3	-6.3	41.8	91.2	-41.7	2.2	0.7	-3.7	-0.5	0.5	-1.7	2.8
2002	-66.8	1.9	-18.0	-73.6	36.5	3.3	-8.3	-2.3	0.6	-0.3	0.0	-2.8
2001	-35.7	0.6	-28.4	-33.4	5.3	-0.7	-1.9	-3.5	-1.5	0.0	-1.2	-3.5
2000	-55.1	13.3	-59.8	-11.2	7.6	0.6	5.6	-22.7	-2.8	-0.5	-5.2	-0.3
1999	9.3	-10.4	60.5	77.2	-43.5	2.9	14.2	4.2	3.3	-0.2	-2.0	16.4
1998	32.7	6.7	7.8	-1.6	6.0	0.6	-4.2	11.7	1.8	0.0	4.7	4.3
Sub-total:	-10.1	0.6	0.3	1.8	7.2	3.0	1.2	0.0	0.4	0.6	-0.3	0.9
Total:	1.1 bps of 19.8 bps of outperformance is explained by differences in asset allocation											

Table 10D. Deviation in net return caused by deviation in asset allocation (in basis points) - mid-sized public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	0.9	-2.7	-36.2	2.8	-145.3	0.5	-12.6	11.9	-2.6	-2.2	-25.9	-4.0
2013	-2.0	-37.8	45.3	-11.0	224.8	-7.3	-9.9	-21.1	0.1	-4.9	-2.1	11.3
2012	5.9	-7.2	22.5	-11.8	25.6	-5.9	-1.3	5.5	0.1	-5.2	-12.9	1.3
2011	0.6	-2.0	-61.7	19.7	-270.3	3.8	1.6	-8.9	0.0	-3.6	-0.6	-6.5
2010	-6.9	-9.4	-5.1	-7.8	22.6	-10.9	0.1	-15.8	-0.7	-2.3	-3.5	3.9
2009	-13.1	-0.8	60.1	-4.3	136.3	-13.7	-2.9	14.4	0.2	-10.2	-12.2	-11.5
2008	65.2	-7.3	-43.4	8.7	-216.5	17.8	18.9	-14.8	-1.4	9.7	5.5	2.6
2007	-4.5	1.2	18.7	3.9	-13.3	0.5	5.2	-13.7	-2.1	5.9	0.9	0.5
2006	5.8	-0.7	16.9	1.2	23.5	-22.7	-10.4	4.8	-4.3	-0.4	-3.9	-3.2
2005	8.3	-0.3	12.4	1.9	3.4	-11.3	-7.5	0.2	-1.0	3.0	-1.3	0.3
2004	11.0	4.5	8.9	4.7	6.9	-21.5	-4.0	0.4	-4.6	1.0	-5.2	-0.9
2003	-26.8	25.9	-19.3	-27.9	24.1	-25.3	-2.4	0.3	-1.3	-2.0	-3.3	-1.4
2002	72.3	-11.8	9.6	43.7	-24.6	3.2	8.0	1.2	1.4	1.8	-3.7	13.1
2001	31.1	-0.9	27.0	29.3	-5.7	3.7	0.6	1.6	0.5	0.5	0.6	3.8
2000	48.7	-5.8	63.3	16.5	-6.4	-0.8	0.3	9.4	-1.2	1.1	-1.2	1.4
1999	-9.8	6.7	-47.0	-103.9	25.4	2.1	-7.7	-1.6	1.5	0.9	4.0	-44.0
1998	-55.4	-0.4	-5.5	4.2	-3.6	-0.3	2.4	3.8	-0.3	-0.2	-13.1	-7.0
Sub-total:	11.7	-2.7	3.3	0.7	-20.5	-3.5	0.1	-1.1	-0.3	0.6	-3.6	-1.2
Total:	-21.1 bps of -28.3 bps of underperformance is explained by differences in asset allocation											

public sector funds and in Table 9B for corporate sector funds further broken down by size cohort: large funds with more than \$10 billion in AUM, mid-sized funds with between \$2 billion and \$10 billion in AUM, and small funds with less than \$2 billion in AUM. For comparison, the all fund average return is 8.24 percent (arithmetic) and 7.51

Tables 10E and 10F. Deviation in average net return from the all fund average caused by deviations in asset allocation by year in basis points for small (E) U.S. corporate sector DB pension funds and (F) U.S. public sector DB pension funds with less than \$2 billion AUM.

Table 10E. Deviation in net return caused by deviation in asset allocation (in basis points) - small corporate sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	-13.3	1.2	15.2	-8.9	94.4	5.1	2.6	-31.6	-3.5	2.9	3.7	25.4
2013	-6.7	53.1	-15.2	-15.0	-120.1	7.1	1.6	21.7	1.2	3.3	0.1	-56.1
2012	11.0	8.5	-20.1	-7.2	-9.3	8.5	0.3	-5.9	-0.4	4.0	-2.2	-15.0
2011	-0.5	-8.1	43.3	-0.4	138.9	-2.1	-0.8	6.1	0.1	1.7	0.2	33.1
2010	9.7	41.3	2.1	8.5	-9.0	1.4	0.0	15.1	-2.3	0.4	5.3	-22.4
2009	12.9	22.1	-30.9	12.0	-58.5	-1.4	0.3	-15.2	-1.5	-1.8	6.1	-35.2
2008	-41.8	-42.0	32.0	10.3	40.4	-6.5	-2.5	10.9	-0.2	-2.1	-3.0	17.8
2007	3.2	-5.1	-26.4	4.0	2.7	-0.1	-2.5	12.0	2.0	-2.7	-3.4	2.4
2006	-6.3	-3.7	-27.7	-22.3	-1.2	18.1	7.2	-16.5	-3.5	0.3	7.0	-17.8
2005	-6.3	-4.1	-25.3	-3.2	-0.5	2.2	2.8	-1.9	-1.1	-2.3	0.3	5.2
2004	-9.8	3.3	-13.7	-15.2	0.7	9.6	3.8	-0.8	-5.1	-0.8	3.8	-4.3
2003	30.6	29.2	-29.8	15.4	-24.9	-0.6	5.0	-1.6	-4.6	-0.4	0.2	-9.5
2002	-46.2	-15.8	2.4	-26.7	35.5	1.7	-22.8	-2.0	-3.3	-0.5	-5.4	16.3
2001	-10.4	-2.6	11.3	-12.9	10.9	-2.0	-2.6	-2.5	-2.6	0.0	-2.5	12.7
2000	-5.7	-33.7	12.8	-7.7	5.5	0.3	2.7	-18.4	-0.7	0.0	-3.0	0.9
1999	2.0	32.8	-15.3	32.7	-17.4	-1.1	14.0	1.8	-0.8	-0.2	-1.4	0.6
1998	16.2	-10.9	-0.5	-1.7	1.8	-0.3	-2.3	5.5	0.2	0.0	2.8	-0.6
Sub-total:	-5.1	2.2	-2.5	-2.0	8.9	2.7	0.5	-0.5	-0.9	0.7	0.9	-0.6
Total:	-0.1 bps of -1.1 bps of underperformance is explained by differences in asset allocation											

Table 10F. Deviation in net return caused by deviation in asset allocation (in basis points) - small public sector funds

Year	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other	Hedge Funds / TAA	Private Equity
2014	32.3	-10.5	-88.8	-6.0	-179.0	-15.0	3.7	-18.4	16.2	-7.8	25.8	19.6
2013	26.1	95.3	8.6	-40.4	261.5	-2.2	-19.5	4.8	-0.4	-2.5	2.6	-37.8
2012	3.7	12.4	22.3	-5.0	25.7	-2.3	-3.4	1.8	3.3	-7.4	-0.1	-6.2
2011	0.4	-3.5	-88.1	5.1	277.2	-0.6	8.9	-7.8	0.3	-1.1	-0.8	5.7
2010	11.9	13.1	-4.3	-17.4	23.6	25.6	0.3	-20.0	3.9	0.4	6.4	-23.6
2009	28.5	27.9	27.9	-110.5	147.7	26.2	3.6	7.2	-0.6	4.8	21.9	-78.6
2008	-96.7	-10.9	-33.5	29.3	225.3	-39.3	-13.5	0.8	-1.5	-7.7	-10.0	35.8
2007	1.1	-9.0	-0.4	4.3	-13.3	-0.7	0.1	-23.1	1.5	-0.4	-1.9	3.2
2006	2.6	-6.8	-11.7	-39.7	23.5	30.3	3.2	4.5	7.9	0.3	-1.5	-14.5
2005	2.1	-7.5	-34.0	-28.2	3.4	14.6	-1.9	-0.5	6.5	-2.1	1.2	3.8
2004	9.2	10.4	-10.2	-40.5	6.9	23.1	-3.4	-0.5	17.9	0.2	-2.4	-0.8
2003	-21.6	40.5	-23.0	-57.4	24.1	23.7	-8.5	-1.7	11.8	0.6	-0.1	-7.1
2002	55.2	-10.6	12.5	66.2	-24.6	-7.6	45.4	-0.1	0.7	-1.0	1.6	29.0
2001	35.2	-0.3	25.7	33.5	-5.7	-1.0	5.0	0.0	3.8	-0.3	-2.9	10.0
2000	-6.9	11.9	16.3	8.9	-6.4	1.9	-10.8	-6.1	3.5	-0.5	1.3	6.2
1999	-0.6	-2.2	-7.1	-17.2	25.4	-2.0	-24.0	4.7	-1.8	-0.2	-2.5	-46.2
1998	-15.9	-1.5	-0.7	0.6	-3.6	1.2	7.6	7.8	0.3	0.0	4.2	-7.9
Sub-total:	13.7	8.0	-11.3	8.1	-21.1	3.3	0.6	-2.2	4.8	-1.1	2.7	-3.3
Total:	-2.3 bps of -41.8 bps of underperformance is explained by differences in asset allocation											

percent (compound). It is immediately clear that all public sector cohorts had below average net returns while all corporate sector funds had above average net returns.

In Tables 10A through 10F we present detailed attributions of each cohorts annual net return deviation caused by that cohorts annual aggregate asset class allocation deviation. That is:

$$\Delta r_i = \Delta w_i(r_i - \langle r_i \rangle)$$

where Δr_i is the difference in annual net return caused by a deviation in asset allocation Δw_i (Table 7), and $r_i - \langle r_i \rangle$ is the excess return from aggregate asset class i compared to the average for that year (easily calculated from Table 3).

Three major features of the tables:

1. Asset allocation describes nearly the entire return for each cohort. The average compound return over all six cohorts is 7.49 percent. Given for example that large corporate funds returned on average 8.25 percent, this cohort outperformed by 0.76 percent, or 76 basis points. The average net return expected of the cohort given their asset allocation alone (i.e., assuming their returns in each aggregate asset class equaled the average in Table 3) is 8.13 percent, demonstrating that 65 basis points of outperformance should be expected.
2. The most important difference in asset allocation was large corporate sector funds embrace of LDI. Of all the impacts, the two largest are seen in Table 10A for large corporate sector plans in 2008: underweight U.S. broad fixed income and overweight long duration U.S. bonds. We associate both with an embrace of LDI that is the single most important (and timely) asset allocation decision of the past 17 years.
3. Small public sector funds underperform their expected return. The simple model of attribution does not work well for small public sector funds. Where the model predicts them to have average performance, they in fact underperform the cohort average return of 7.49 percent by 0.42 percent, or 41.8 basis points. The reason small public sector funds underperform is therefore not attributable to asset allocation. Instead, small public sector funds underperform because the returns they achieved from unlisted real estate and private equity lagged behind the all fund average. The reason for this is cost.

6 Investment costs

Average investment costs by aggregate asset class as reported to CEM Benchmarking are shown in Table 2 and Table 3. The average costs appearing in the tables include all reported costs, and therefore excludes un-reported costs. Where costs are not reported by funds it is for the simple reason that they do not know their costs because they do not monitor them. Unknown costs are nearly always for the following asset classes: unlisted real estate, hedge funds, and private equity. Furthermore, in the case of private equity, it is not uncommon for funds to consider costs such as carried interest (which provided real drag in net returns [10]) as costs at all, instead referring to them as “profit-sharing” [8,10].

In Table 11 we provide estimates of the average total investment cost broken down by management style and investment style, scaled to the lowest cost management style/investment style by aggregate asset class⁹. Data appearing in Table 11 is limited to those U.S. DB pension funds cost sets that are complete, and furthermore is limited to 2012-2014 in order to be contemporary. The following trends are observed: internal management is less expensive than external management, passive management is less expensive than active management, and finally, fund-of-fund investments are the most expensive.

⁹ CEM Benchmarking has investment costs for all asset classes, investment styles and management styles described here at the level of internal investment costs, external base management fees, performance fees paid to external managers, carried interest, internal monitoring costs and underlying fund-of-fund fees.

Table 11. Average relative investment costs by aggregate asset class, investment implementation style and investment management style for U.S. DB pension funds. In the table, the lowest cost style combination for each aggregate asset class is scaled to be 1.0. (Relative costs between aggregate asset classes are available in Table 3.) For example, if internal passive large cap U.S. stock costs on average 1.3 basis points, internal active large cap U.S. stock costs 8.8 times this, or about 11.4 basis points. The multiplier effect is most dramatic for unlisted assets where internal active implementation is already expensive. For example, internal active unlisted real estate costs are of the order of 30 basis points implying that fund-of-fund unlisted real estate costs over 480 basis points.

Table 11. Scaled investment costs by aggregate asset class and investment style¹ for U.S. DB pension funds

Investment Implementation / Management Style	Stock			Fixed Income				Real Assets			Other	
	U.S. Large Cap	U.S. Small Cap	Non U.S.	U.S. Broad	U.S. Long Bonds	U.S. Other ²	Non U.S.	Unlisted Real Estate	Listed Equity REITs	Other ³	Hedge Funds / TAA	Private Equity
Internal Passive	1.0	1.0	1.0	1.0	1.0	1.0	1.0	n/a	1.0	n/a	n/a	n/a
Internal Active	8.8	5.0	3.2	6.0	5.6	5.4	6.7	1.0	2.4	1.0	1.0	1.0
External Passive	3.5	3.4	1.4	5.5	5.8	1.9	17.5	n/a	10.2	n/a	n/a	n/a
External Active	35.4	30.3	8.8	19.7	17.5	19.8	29.3	4.1	24.7	3.1	9.0	n/a
External LP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	9.6	n/a	5.9	20.5	8.4
Fund of Fund	n/a	n/a	n/a	n/a	n/a	n/a	n/a	15.5	n/a	6.7	34.2	12.9
Co-Investment	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.2

1. Internal passive refers to indexed investments managed in-house. Internal active refers to investments managed in-house with the expectation of beating an index, while for hedge funds / TAA, internal active refers to internally managed funded TAA programs. External passive refers to index investments managed by an external provider. External active for listed assets (i.e., excluding unlisted real estate, other real assets, hedge funds/TAA, and private equity) refers to investments managed by an external provider with the expectation of beating an index. For both unlisted real estate and other real assets, external active refer to real estate investments where buy/sell decisions are taken by an external manager (i.e., perpetuals, joint ventures, pooled funds etc.), while for hedge funds / TAA external active refers to externally managed funded TAA programs. External LP for unlisted real estate, other real assets, and private equity refer to investments managed in a limited lifetime LP/GP structure. Externally managed hedge funds are classified here under hedge funds / TAA as external LP in order to distinguish them from externally managed TAA. Fund-of-fund are pools of unlisted investments managed by a fund-of-fund manager which incurs two layers of fees; base fees and performance fees paid to the fund-of-fund manager in addition to the underlying base fees and underlying performance fees paid to external LPs.

2. Investment costs for fixed income: U.S. other excludes cash investment costs.

3. Investment costs for real assets: other includes costs only for unlisted investments to ensure comparability (natural resources, infrastructure and timberland). It excludes investment costs for commodities.

The last contention, that fund-of-funds are expensive, is not a commonly held belief, as they are often sold to investors as inexpensive access points into otherwise difficult to access asset classes. However, the cost comparison between external LPs and fund-of-funds typically omits the underlying base fees and performance fees paid by the fund-of-fund manager to external LPs.

In prior CEM research, we have found a remarkable correlation between the difference in net returns and the total inferred cost of investing in unlisted real estate and private equity [10], and more recently in hedge funds [12]. As small public sector funds predominantly invest in unlisted real estate, hedge funds, and private equity through fund-of-funds, and given fund-of-funds historic underperformance, small public sector pension funds continue to underperform what their asset allocation alone suggests.

7 Final remarks

Asset allocation is the primary driver of risk and returns. At U.S. DB pension funds, a handful of key decisions drove one cohort of funds, large corporate sector funds, to outperform. The key decision was an embrace LDI in 2008 prior to the global financial crisis. This outperformance was largely unpredictable and likely unrepeatable.

For small public sector funds, by contrast, asset allocation alone should have led to average performance, yet the cohort of funds underperformed. The reason for their continued underperformance is their embrace of fund-of-fund implementation styles for unlisted assets (e.g., unlisted real estate, hedge funds, and private equity) that their peers invest in at comparatively lower cost. This “chasing the herd” mentality leads to predictable, repeated, and likely to be repeated underperformance.

While quantifying the performance difference of aggregate asset classes, we find remarkable correspondence between small-cap U.S. stock and private equity on one hand and between listed equity REITs and unlisted real estate on the other (see Figure 2 A through D). The correspondence is only revealed after accounting for lagged results. If funds and other investment managers accept the fact that the reported lack of correlation between these unlisted assets and their listed counterparts is fictitious, safely substituting inexpensive listed alternatives for expensive fund-of-funds will become the norm.

8 About CEM Benchmarking

CEM Benchmarking is a Toronto based provider of investment cost and performance benchmarking for large institutional investors including pension funds (defined benefit and defined contribution), sovereign wealth funds, buffer funds, and others. For information on benchmarking with CEM or other data inquiries please contact:

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Appendix A: Asset class aggregation

As of 2014, the CEM Benchmarking Inc. included 216 different asset class / investment style / management style combinations in its global database, of which 118 are applicable to U.S. funds. Publicly traded asset classes used by CEM are differentiated on whether they are managed internally or externally and whether the mandate is actively or passively managed. Privately traded asset classes, by contrast, cannot be managed passively and are instead differentiated based on whether they are managed internally, externally, by operating subsidiaries, by limited partnerships, as co-investments, or by means of fund-of-funds. The partial list of asset classes defined by CEM and applicable to U.S. participating funds is listed below:

- Stock: U.S. broad (if large, medium, and small-cap stock cannot be differentiated)
- Stock: U.S. large-cap
- Stock: U.S. mid cap
- Stock: U.S. small-cap
- Stock: EAFE
- Stock: Emerging
- Stock: All country world ex-U.S.
- Stock: Global (approximately 30 percent U.S. 70 percent non-U.S.)
- Stock: Employer stock
- Stock: Other
- Fixed income: U.S. investment grade
- Fixed income: U.S. long bonds
- Fixed income: U.S. TIPs
- Fixed income: High yield
- Fixed income: Mortgages (not mortgage backed bonds)
- Fixed income: EAFE
- Fixed income: Emerging
- Fixed income: Global
- Fixed income: Other
- Fixed income: Cash
- Real assets: Commodities
- Real assets: Listed equity REITs
- Real assets: Private real estate
- Real Assets: Infrastructure
- Real Assets: Natural resources (privately traded)
- Real Assets: Other
- Tactical asset allocation (funded TAA programs)
- Hedge Funds
- Private equity: Diversified
- Private equity: Venture capital
- Private equity: Leveraged buy out
- Private equity: Other

To make studying the performance of asset classes manageable, we have aggregated the 104 asset classes, including the above asset types further divided by investment style, into a much smaller set of 12 aggregate asset classes based on four primary factors. The first three factors are centered on fitting net return series for each of the asset classes to a simple linear model:

$$r_a = \alpha + \beta r_r$$

where r_a is the net return of the asset class, r_r is the net return of a reference asset class, and α and β are the usual 'excess return' and 'correlated volatility' parameters used in investment benchmarking. (The implied meaning of

the terms is not necessarily applicable here, but the model is useful nonetheless). We have solved the equation using linear least squares for all 118 x 118 pairs of asset classes, yielding estimates of α , β , and the correlation coefficient ρ .

We look to the linear model to illustrate three desirable qualities in the returns of an asset class and a reference asset class if they are to be aggregated. These three qualities include:

1. The 'excess return' parameter α should be near zero: if α is either large positive or large negative, then aggregation of the two asset classes will average out markedly different series of returns.
2. The 'correlated volatility' parameter β should be close to one: if β is not close to one, then aggregation of the two asset classes will average out markedly different series of returns while also causing a suppression of the volatility through diversification.
3. The correlation coefficient ρ should be close to one: if ρ is significantly less than one, the model fails to describe the relationship between the two series of net returns and estimates of α and β cannot be trusted.

A fourth factor we use is an ad-hoc one, based on data checking. For a handful of asset classes, none of the above criteria is strictly met, yet other widely-recognized characteristics of each of these asset classes imply that each one should belong to a particular aggregate asset class. All of the private equity asset classes, for example, fall into this fourth category because they do not clearly align with the three qualities specified above prior to standardizing the data for smoothing and reporting lag.

Tables A1, A2 and A3 show the linear regression parameters α , β , and ρ for 3712 (61 x 61) pairs of asset classes (a subset of the full 13,974 pairs). Along the top and sides of the tables we list the 12 aggregate asset classes we use going forward. These 12 classes are:

- Stock: Large-cap U.S. stock (e.g., large-cap equities appearing in the S&P 500)
- Stock: Small-cap U.S. stock (e.g., Russell 2000 small-cap equities + mid cap equities)
- Stock: Non U.S. stock (e.g., non US equities such as EAFE and emerging market equities)
- Fixed income: Broad U.S. fixed income (e.g., investment grade U.S. corporate bonds)
- Fixed income: Long duration U.S. bonds (e.g., strategies dedicated to long duration bonds)
- Fixed income: Other U.S. fixed income (e.g., non-investment grade bonds, mortgages, cash)
- Fixed Income: Non U.S. fixed income (e.g., non US bonds)
- Real Assets: Listed equity REITs (publicly traded real estate)
- Real Assets: Private real estate (e.g., direct real estate holdings, real estate limited partnerships)
- Real Assets: Other (e.g., commodities, infrastructure, natural resources)
- Other: Hedge funds / TAA (e.g., hedge funds and tactical asset allocation teams)
- Other: Private equity (e.g., venture capital, diversified private equity)

We have removed from the tables in Appendix A those asset classes which were sparsely populated, and so do not meaningfully contribute to the aggregated asset classes. Where these omitted results are notable, we discuss them here.

The interested reader may note the lack of symmetry in Tables A1 and A2 where typically $\alpha_{ij} \neq -\alpha_{ji}/\beta_{ji}$ and $\beta_{ij} \neq -1/\beta_{ji}$. The reason for this is two-fold. First, since the parameters are obtained by fits no symmetry can be expected when the correlation is low, indicating a poor goodness of fit. Where the correlation is close to one the symmetry is observed. Second, linear least squares fits are subject to the phenomenon of regression dilution whereby noise in the x-axis reduces β and increases α . Regression dilution is inherently asymmetrical since noise in the x-axis affects α_{ij} and β_{ij} whereas noise in the y-axis affects α_{ji} and β_{ji} .

A.1 Stock

Beginning with the 21 x 21 stock pairings, it is evident that we may aggregate these into three aggregate asset classes rather easily: large-cap U.S. stock, small-cap U.S. stock, and non-U.S. stock. The four stock: U.S. broad and four stock: U.S. large-cap all had α 's of the order of one percent, β 's between 0.9 and 1.1, and ρ 's > 0.97. As such, these eight asset classes may safely be aggregated without distorting the data. We note that internal active and external active large-cap U.S. stock had negative α 's which, given the high degree of correlation, indicate that active managers underperformed for this aggregate asset class.

Similar considerations apply to the 4 x 4 small-cap stock pairings with one exception; here α was greater than zero for internal active managers, indicating outperformance, while for external active manager α was less than zero, like for large-cap U.S. stock, indicating underperformance.

For the 9 x 9 non-U.S. stock pairings shown, EAFE, global and ACWI ex-U.S. all showed high degrees of similarity whereas emerging stock did not (it had large β 's and lower correlations). However, allocations to emerging stock were small and we include it in non-U.S. stock in order to limit the number of asset classes.

Finally, deviations between these three stock aggregate asset classes are strong enough to prevent aggregation into a single category of stock; for example, the large α 's of small-cap U.S. stock over large-cap U.S. stock, or the large β 's of non-U.S. stock over large-cap U.S. stock.

A.2 Fixed income

Fixed income is more problematic. Even within the 4 x 4 pairings of U.S. investment grade fixed income, their β 's deviated significantly from one, especially between internal passive and external active and passive mandates. These deviations are all caused by outlier data from 2008 when, for example, external active mandates suffered large losses in comparison with internal passive mandates. The cause of this deviation is an over-exposure to credit risk by external bond managers relative to internal passive bond managers, and the source of the positive α earned as well. Removing the data point results in β 's near 1 and near perfect correlation, and so we aggregate these four assets into a single aggregate asset class, broad U.S. fixed income.

Long duration U.S. bonds show clear hallmarks of being a single aggregate asset class, displaying a high degree of similarity in returns with each other, but not with any other asset classes, and so are aggregated together in long bonds asset class. Fixed income: EAFE and fixed income: global also show the traits of a good asset aggregation, while fixed income: emerging does not. However, as emerging market fixed income represents less than 0.5 percent of the holdings of U.S. DB pension funds, we roll the data into a non-U.S. fixed income aggregate asset class, confident that it does not alter our conclusions.

Finally, we have aggregated TIPs, high yield bonds, mortgages and cash into a other U.S. fixed income aggregate asset class. This aggregation is not ideal, but is required in order to limit the number of fixed income aggregate asset classes. We have checked that this aggregation does not fundamentally alter our conclusions. However, we remark that this aggregate asset class is significantly less volatile than its components through diversification effects.

A.3 Real assets

The four unlisted real estate asset classes fit reasonably well into a single asset class, here even before standardizing the results for reporting lags. The exception is internal active managers who produce significant positive α over fund-of-fund managers and direct LPs. The reason for this difference is differences in cost (see Section 6).

The four listed equity REIT asset classes all fit comfortably into a single aggregate asset class, with α 's of the order of plus/minus one percent, β 's between 0.86 and 1.13, and ρ 's > 0.98. We note that internal active and external active managers have produced positive α of around 1-1.5 percent relative to their passive counterparts.

Commodities, infrastructure, and other real assets are rolled into a single aggregate asset class despite not sharing much in the way of similar net returns, akin to the situation experienced with fixed income U.S. other. The choice is driven by the need for a manageable number of aggregate asset classes, together with the fact that allocation to these asset classes is small.

A.4 Hedge funds / TAA

Hedge funds and TAA programs are highly correlated and display moderate excess returns to stocks. The main difference between hedge funds and TAA are their different β 's, where hedge funds fall closer to 0.5 relative to stocks and TAA fall closer to 1. This is indicative of TAA being closer to pure equity exposure while hedge funds lay between stock and bonds. TAA programs, however, make up a very small percentage of total assets and are included under hedge funds in order to limit the total number of aggregate asset classes studied.

A.5 Private equity

The final aggregate asset class, private equity, includes a number of asset classes that are the least to conform to the three desirable qualities we seek to identify using the linear model. As we show in section 3.4 however, the low correlation between the private equity asset classes results largely from the significant reporting lag. When the lag is removed from the data, the private equity net returns are very similar to that of all three stock asset classes.

Table A3. Correlation coefficient ρ from fitting as reported net returns between fine grained CEM asset classes to reference asset classes. Dark borders indicate the coarse grained aggregate asset classes used in the present study. Color code is a guide to the eye (white indicates parameters which are in the acceptable range for good aggregation, red below acceptable, and blue above acceptable).

Stock:	Stock: U.S. Large Cap	Stock: U.S. Small Cap	Stock: Non U.S.	Fixed Income: U.S. Broad	Fixed Income: U.S. Long Bonds	Fixed Income: U.S. Other	Fixed Income: Non U.S.	Unlisted Real Estate	Listed Equity REITs	Real Assets: Other	TAA/Hedge Funds	Other: Private Equity
Stock: U.S. Large Cap	1.00	0.18	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Stock: U.S. Small Cap	0.18	1.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Stock: Non U.S.	0.02	0.02	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fixed Income: U.S. Broad	0.01	0.01	0.01	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Fixed Income: U.S. Long Bonds	0.01	0.01	0.01	0.95	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Fixed Income: U.S. Other	0.01	0.01	0.01	0.95	0.95	1.00	0.95	0.95	0.95	0.95	0.95	0.95
Fixed Income: Non U.S.	0.01	0.01	0.01	0.95	0.95	0.95	1.00	0.95	0.95	0.95	0.95	0.95
Unlisted Real Estate	0.01	0.01	0.01	0.95	0.95	0.95	0.95	1.00	0.95	0.95	0.95	0.95
Listed Equity REITs	0.01	0.01	0.01	0.95	0.95	0.95	0.95	0.95	1.00	0.95	0.95	0.95
Real Assets: Other	0.01	0.01	0.01	0.95	0.95	0.95	0.95	0.95	0.95	1.00	0.95	0.95
TAA/Hedge Funds	0.01	0.01	0.01	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.00	0.95
Other: Private Equity	0.01	0.01	0.01	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.00

Appendix B: Standardizing illiquid asset returns

Our standardization for reporting lags and smoothing of illiquid asset returns used in this paper is fundamentally different from the approach used in the inaugural version of this research [2] and attributable to Geltner [3]. In both, a de-smoothing is applied to the data which has the effect of increasing the volatility of the asset class. The de-smoothing function assumes that the observed, smoothed, return is equal to a weighted sum of the actual (e.g., de-smoothed) return plus the prior periods smoothed return, the weighting being a property of the appraiser. De-smoothing is accomplished by extracting the actual return given the two observed returns given an estimate of the weighting (the so called “appraisal parameter”).

The primary difference between our approach in the inaugural version of this paper [2] and that of Geltner [3] was that we first accounted for the lag in the data prior to applying the de-smoothing. The lag in the data is readily apparent for unlisted real estate because of the fingerprint left by the financial crisis. There, listed equity REITs experienced a downturn in 2008 whereas unlisted real estate recorded the loss a year late in 2009 (see Figure 2A). To remove the lag in the inaugural version of this series of papers we simply shifted the unlisted real estate data back by one year. This simple transformation has the effect of increasing the correlation between the two data series, listed equity REITs and unlisted real estate 10-fold, but has no effect on the volatility which remains smoothed. To remedy this we de-smoothed the data in an effort to recover lost volatility.

In this updated version we exploit the fact that CEM Benchmarking has fund level return data. Like the original, we once again remove the lag in the unlisted real estate and private equity data. However, the key innovation is that the lag is removed instead on a fund-by-fund basis as opposed to the fund-averaged aggregate data as a whole. When the data is standardized to remove the lag at the fund level, we find that the fund-averaged aggregate data is effectively de-smoothed. This demonstrates that the source of the smoothing in the fund-averaged aggregate is differences in reporting lag.

To determine the lag present in each funds unlisted asset return series (e.g. unlisted real estate and private equity) we compare the individual return series to a listed benchmark with varying lag. The listed benchmarks used in this paper are: 65% U.S. REIT index + 35% BBB bond index for unlisted real estate, and small-cap U.S. stock index for private equity. For nearly all funds the correlation grows steadily with increasing applied lag, peaks (sometimes spectacularly so), and then decreases. The expected behavior is shown in Figure B1 while actual behavior for a real fund is shown in Figure B2.

Determining the lag for each fund in this manner is straightforward. After doing so, we need to remove the lag in the unlisted asset return series. Our method is to first note that the annual as-reported return in year y with lag l , $R_{l,y}^{reported}$, is a product of n actual (unobserved) daily returns $r_{t,y}^{actual}$:

$$R_{l,y}^{reported} = \prod_{t=n-l+1}^n (1 + r_{t,y-1}^{actual}) \prod_{t=1}^{n-l} (1 + r_{t,y}^{actual}) - 1.$$

Defining $\alpha_{l,y}$ as the annual excess return over the lagged benchmark return we can re-write this as:

$$R_{l,y}^{reported} = \prod_{t=n-l+1}^n (1 + r_{t,y-1}^{benchmark}) \prod_{t=1}^{n-l} (1 + r_{t,y}^{benchmark}) - 1 + \alpha_{l,y}$$

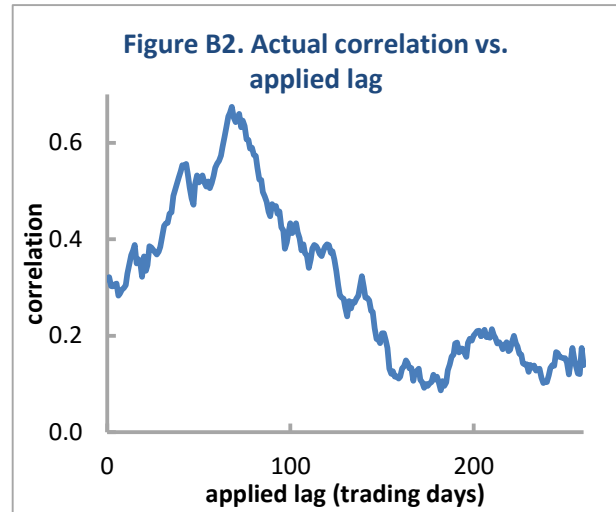
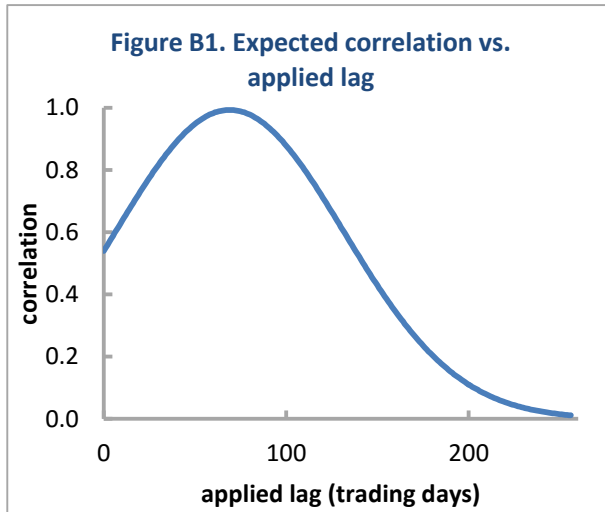
where $r_{t,y}^{benchmark}$ is the (observed) daily benchmark return. Removing the lag is now straightforward as well. To remove the lag we need to make an assumption about the lagged excess return. Our assumption is that the lagged excess return should be equal to the de-lagged excess return. This assumption plus the inferred lag determines our standardized de-lagged return as:

$$R_{0,y}^{de-lagged} = (1 + R_{l,y}^{reported}) \left(\frac{\prod_{t=n-l+1}^n (1 + r_{t,y}^{benchmark})}{\prod_{t=n-l+1}^n (1 + r_{t,y-1}^{benchmark})} \right) - 1 + \alpha_{l,y} \left(1 - \frac{\prod_{t=n-l+1}^n (1 + r_{t,y}^{benchmark})}{\prod_{t=n-l+1}^n (1 + r_{t,y-1}^{benchmark})} \right)$$

The first term serves to remove trailing market return from the prior year $y - 1$ while adding market return from the end of the actual year y . The last term ensures that the excess return is invariant under the transformation.

We note that all of the information about unlisted asset returns is contained in the set of excess return parameters $\alpha_{l,y}$. If the lagged unlisted asset returns are equal to the lagged benchmark returns (e.g., the set of $\alpha_{l,y}$ are all zero), then the de-lagged unlisted asset return is equal to the zero lag benchmark return. If the lagged unlisted asset returns deviate from the lagged benchmark return (e.g., the set of $\alpha_{l,y}$ are non-zero), the de-lagged unlisted asset deviate from the zero lag benchmark by the same amounts. The only effect of this transformation is to remove prior year market return and add current year market return.

Figures B1 & B2. Figure B1 illustrates the expected correlation between lagged unlisted asset annual returns and listed benchmark annual returns with increasing applied lag. Figure B2 shows the observed correlation vs. applied lag for a real private equity portfolio (the inferred lag is 68 trading days). The primary difference between the expectation and reality is the fact that the observed correlation is usually considerably less than one. The reason is two-fold. First, real unlisted asset returns possess real idiosyncratic risk, providing the return series with noise different from the benchmark. Two, real portfolios of unlisted assets are actually composed of many different sub-portfolios all of which can be expected to have different lags.





CEM Benchmarking