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THE PERFORMANCE OF TIAA'S TRADITIONAL RETIREMENT ANNUITY FOR SELECTED INVESTMENT COHORTS, 1970 – 2005 THROUGH 2013

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1. INTRODUCTION

The retirement income needs of the average worker in the U.S. have never been met, and were never designed to be met, by exclusive reliance on Social Security (SS) retirement benefits. Defined benefit (DB) and defined contribution (DC) retirement plans provide substantial amounts of income for retirees fortunate to have access to such retirement saving programs.[1] Even combining the DB and DC retirement income payment streams with SS, however, there is growing perception among the general public that a retirement income crisis has been unfolding in the U.S. for some time now and that the crisis is likely to intensify unless far-reaching measures are adopted. The following facts illustrate the current magnitude of the U.S. retirement income predicament.

- In 2013, Social Security benefits for 37.9 million retired workers averaged $1,293.83 per month.[2]
- In 2013, the typical near-retirement household with a 401(k) balance had DC plan assets (in 401(k), IRA, 403(b), 457 programs) worth $111,000, implying an estimated $500 monthly payment for those retiring at age 65.[3]
- In 2013, among those workers aged 50-59, 49% had no DB or DC retirement plan, an increase of 8 percentage points over the pre-financial crisis level of 41% at the end of 2007.[4]
- In 2013, the average annual expenditures for a consumer unit with reference person aged 65 or older were estimated to be $41,403.[5]
- The 2013 Federal Poverty Level Guideline for a family of two was $1,292.50 per month, or $15,510.00 per year – almost exactly the average SS benefit paid.[6]

These figures imply a modest standard of living for many U.S. retired workers. While many seniors in the U.S. have sufficient assets and retirement income, half of all people on Medicare in 2013 had incomes less than $23,500, which is slightly more than two times the 2013 official poverty line of $11,490.[7] Moreover, these figures suggest that those employees nearing retirement with inadequate financial resources may be forced to stay working for many more years than planned. Compounding the situation, as the financial market performance of late 2007 through early 2009 has shown, the risk of having one's lifetime savings lose 30% to 40% of its value just before a planned retirement is a hard reality. The number of near retirees facing this type of financial market risk increases as defined contribution plans keep replacing defined benefit plans, as illustrated in Figure 1.1 below.

The dramatic replacement of defined benefit plans by defined contribution plans, with their modest participation rates and meagre average assets (Munnell (2012, 2014), combined with likely reductions in future Social Security benefits, suggest that the U.S. retirement income problem will worsen as those nearing retirement age begin to retire.

1 As of the end of 2010, Social Security and private pensions amounted to approximately 70% and 20%, respectively, of non-earned retirement income for those 65 and older. See Munnell (2012), page 2.

2 Annual Statistical Supplement to the Social Security Bulletin, 2014, Table 5.A1.

3 Munnell (2014), page 9. The corresponding figure for 2010 is $120,000 implying a $575 monthly payment, assuming that the $120,000 purchases an immediate annuity with joint-and-survivor monthly payments; See Munnell (2012). This, of course, does not take into account any assets the retired person may have accumulated outside of a qualified retirement plan, or the retirement funds of a spouse, if any.

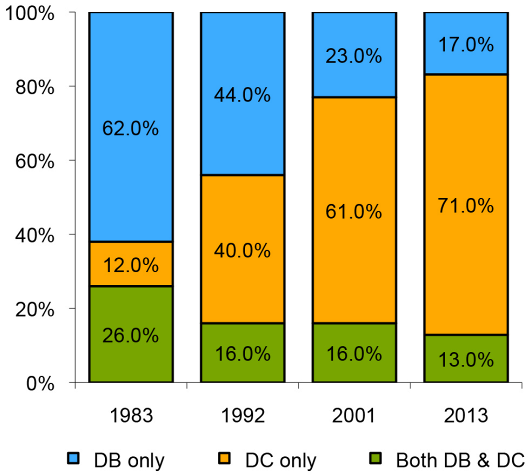
4 Ibid., page 13.

5 2013 Consumer Expenditure Survey, http://www.bls.gov/cex/2013/combined/age.pdf, accessed on 7/14/15.

6 http://aspe.hhs.gov/poverty/13poverty.cfm, accessed on 7/14/15.

7 Cubanski, Casillas, and Damico (2015), page 1.

FIGURE 1.1 EVOLUTION OF DB AND DC PLANS



Source: Munnell (2014)

In this paper we examine the role of an annuity as an investment option in the accumulation phase of a retirement income portfolio, such as those found in defined contribution plans. More specifically, we rigorously analyze the historical return performance of TIAA's Traditional Retirement Annuity ("RA") relative to other asset classes often found as investment options in DC plans.[8] We compare the performance of the TIAA RA to U.S. large and small stocks, long-term corporate and government bonds, intermediate-term government bonds, and money market instruments over the period 1970 - 2013.[9] The data allow us to examine a select number of "cohorts" associated with premiums (or contributions) assumed to have been invested on March 1 in the years 1970, 1975, 1980, ..., 2005, or eight such cohorts in total.[10] In so doing, we empirically demonstrate that adding an instrument such as TIAA's RA to a retirement income portfolio unambiguously improved the financial performance of a retirement income portfolio over the 1970 through 2013 and shorter periods.

In our analysis we employ three measures of financial performance to evaluate the use of the TIAA RA in a retirement income portfolio:

- Mean-variance analysis
- Related Sharpe and Sortino ratios
- Stochastic dominance analysis

Our goal is to determine how, according to these separate financial performance criteria, the asset classes we study rank in terms of investors' risk and return preferences; or even in terms of the full distribution of returns, as is the case with the stochastic dominance criterion. This allows us to conclude that adding substantial allocations of the TIAA RA to retirement income portfolios improves the financial performance of those portfolios.

The TIAA RA is a deferred fixed annuity that was first introduced in 1918, making it one of the longest continuously offered annuity products in the world.[11] During the accumulation or deferral phase, participating employees and individuals can contribute premiums on a regular basis, (e.g. monthly) and receive interest credits according to the rates declared by TIAA on March 1 of each year, and remaining in effect through February of the following year. The TIAA RA also has a retirement income, payout, or decumulation phase that we will not examine in any detail in this paper.

8 When applied to the TIAA RA, we use the term "asset class" somewhat loosely and similarly to the term "investment." The TIAA RA's crediting rates are based on market returns obtained by the underlying investments.

9 As we describe in Section 3 below, asset classes other than the TIAA Traditional Retirement Annuity are reference indices, whose returns are adjusted by average mutual fund fees and expenses. Therefore, these asset classes are not financial instruments that individuals or institutions can invest in.

10 We provide a detailed description of how TIAA's Traditional Retirement Annuity works in Section 2.

11 See Poterba and Warshawsky (2000), pages 191-192. During the period covered by our analysis, TIAA's Traditional Retirement Annuity has been available to individuals and to employees of firms sponsoring the annuity under a group plan.

The TIAA RA differs in several ways from the other asset classes we discuss in this paper. First, participation in the RA considerably limits the withdrawal or reallocation of funds from the RA by the employee – the RA is a "less liquid" retirement income portfolio than many alternatives. As this paper will demonstrate, however, the lack of liquidity is compensated by a higher and less variable return. Second, TIAA's RA is one of the few deferred annuities currently offered as an investment option in retirement plans where participants can also choose to allocate parts of their savings among a number of other such investment options as equity, bond, and money market funds. Third, in contrast to most other investment options typically found in defined contribution retirement plans, TIAA's RA offers payout options that are specifically linked to the persistence of investors' participation in the RA. Long-term participants in TIAA's RA receive payouts above the guaranteed payout rate depending on the length of the annuitant's participation, and on the ability of TIAA to distribute surplus contingency reserves.

The rest of this paper is organized as follows. Section 2 describes additional features of the TIAA RA. In particular, we illustrate how interest is credited to the premiums that annuitants contribute to the Traditional RA.

Section 3 describes the data used in our analysis and presents summary statistics.

Section 4 describes the results of the mean-variance analysis. We find the presence of the TIAA RA in a portfolio that also includes large and small U.S. stocks, corporate and government bonds, and Treasury bills (a proxy for money market instruments), has significantly enhanced portfolio returns for the degrees of return volatility likely to be preferred by those investors with moderate tolerance for risk. This result is consistent throughout the eight cohorts we consider.

Section 5 calculates Sharpe and Sortino ratios for all asset classes in our study, and determines this analysis is in line with our findings in the mean-variance analysis.

Section 6 looks at stochastic dominance results. We obtain the remarkable result that the distribution of TIAA RA returns stochastically dominates money market and intermediate-term government bond funds, generally in the second degree and even for money market funds in the first degree in cohorts since 1985. This is remarkable because stochastic dominance in the first degree obtains when the entire cumulative distribution of TIAA returns lies to the right of the cumulative distribution of money market returns. This implies that any investor, no matter what his or her risk tolerance, prefers the dominating asset to the dominated one. Exceptionally, for the 2000 cohort, we also find the distribution of TIAA RA returns, along with the distributions of long-term corporate and government bonds, and intermediate-term government bonds, stochastically dominate the distribution of large stock returns in the second (and, therefore, third, fourth, and subsequent) degrees. This result is not too surprising, given the burst of the dot.com bubble in early 2000, and the financial crisis of 2008. But it is, in any case, a result that highlights the resilience of asset classes like the TIAA Traditional Retirement Annuity in the face of major financial market disruptions.

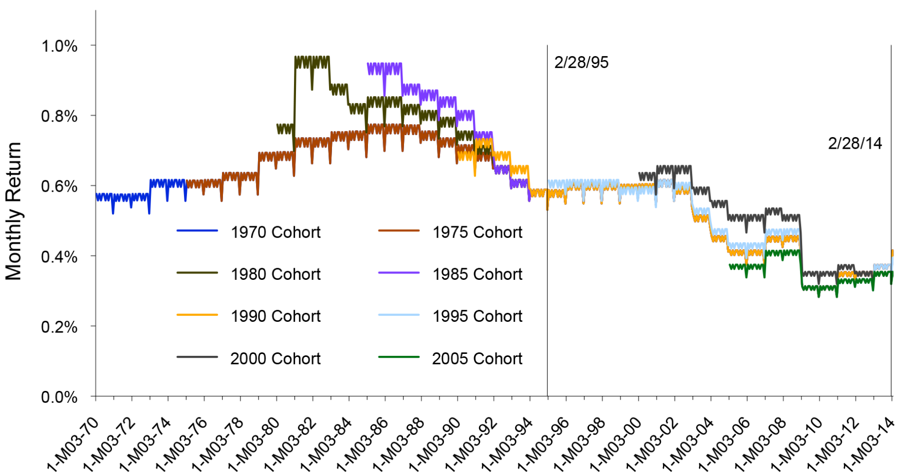
Section 7 contains concluding comments and outlines some directions for further research.

2. THE TIAA TRADITIONAL RETIREMENT ANNUITY

For the purposes of this study, we examine the performance of the TIAA RA during the accumulation phase of the retirement income portfolio, the time before the portfolio is tapped to provide retirement income.[12]

During the accumulation phase, participants in the individual or group Traditional Retirement Annuity may contribute premiums at regular intervals during their respective careers. TIAA receives the premiums during a given time period and pulls them into investment "vintages" that are invested in long-term assets (primarily fixed income) that are able to generate the returns to support the crediting rates declared on March 1 of every year for each vintage.[13] Given the long-term investment goals of the TIAA RA, this investment approach reflects the interest rate environment at the time the premiums are received and implies that the account balance of a participant who has been contributing regular premiums over a possibly large number of years will be credited for a given March 1 through next February 28 (or 29) with as many declared crediting rates as there are vintages in his or her portfolio. Older vintages tend to receive the same crediting rate as they mature so that, in practice, there are not a large number of different crediting rates for a given annuity holder after a certain amount of years have elapsed. The monthly crediting rate data we use in this study are summarized in Figure 2.1.

FIGURE 2.1 MONTHLY RETURNS FOR SELECTED INVESTMENT COHORTS



Source: TIAA

We observe that the crediting rates declared for the selected investment cohorts respond to the interest rate environment prevailing at the time these rates were declared, especially during the volatile early and mid-eighties.

To illustrate the crediting rate pattern associated with the vintage system just described, we can use the crediting rate series shown in Figure 2.1 to construct the hypothetical amounts that participants would accumulate by contributing to the RA with a specific crediting rate vintage. More specifically, we posit that a hypothetical participant makes premium payment every five years beginning on March 1, 1970 through March 1, 2005 – eight investment cohorts in all – and observe that a hypothetical annuity holder who made premium payments every five years beginning on March 1, 1970 through March 1, 2005 would have received, for the year ending on February 28, 1995, the same crediting rate of 7.15% for each of the five original premiums (plus accumulated interest) which add up to his or her total account balance as of February 28, 1995. For the year ending on February 28, 2014 the eight crediting rates applied to the annuitant's account would have had two different levels: 4.5% for the first six original premiums, and 4.25% for the remaining two.[14]

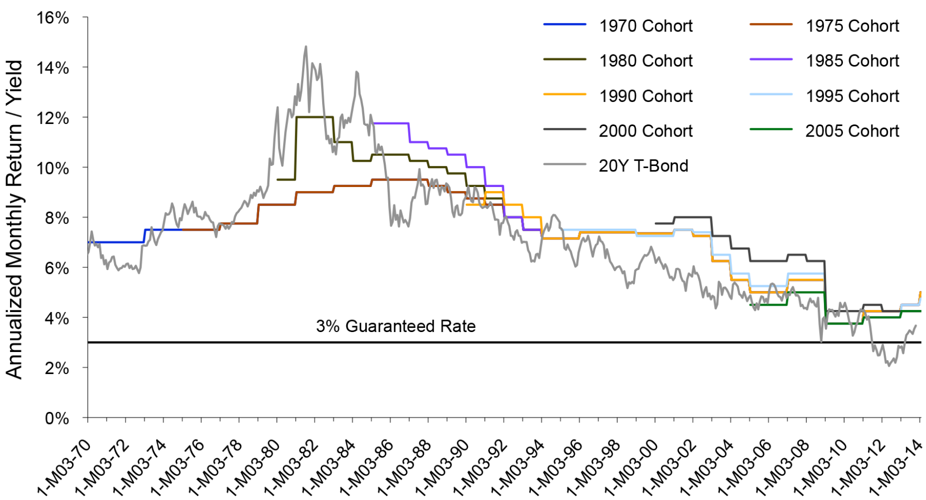
12 For a detailed description the TIAA RA, see James Poterba and Mark Warshawsky, "The Costs of Annuitizing Retirement Payout from Individual Accounts," in "Administrative Aspects of Investment-Based Social Security Reform," edited by John Shoven, University of Chicago Press, January 2000, Chapter 5, Section 5.3. The accumulation phase is sometimes called the deferral period.

13 See Goodman and Richardson (2014) for a detailed exposition of the TIAA RA vintage system of crediting and payout rates.

14 The hypothetical participant we consider is simply used to illustrate how the vintage system works using the data we have. Actual participants may contribute regular premiums at much shorter intervals, possibly every month. We do not have the full array of crediting rates declared for each TIAA RA vintage.

For the period under study, the TIAA RA offered a minimum guaranteed annual interest rate of 3% and the Company systematically provided additional interest amounts well in excess of this guarantee, as shown in Figure 2.2 below. We also chart the evolution of yields (but not total returns, which were positive and negative over time) on 20-year U.S. Treasury bonds.[15]

FIGURE 2.2 ANNUALIZED MONTHLY RETURNS FOR TIAA RA AND 20-YEAR T-BOND YIELDS



Sources: TIAA, Ibbotson SBBI 2014 Classic Yearbook

As noted previously, the TIAA RA is a relatively illiquid investment in the sense that withdrawals of previously contributed premiums and earnings are limited. This restricted liquidity allows the funds to be invested in long-term and relatively less-liquid assets further allowing TIAA to obtain overall higher than expected yields. The illiquidity is not absolute, as there is the possibility of withdrawals over a period of at least ten years as well as transfers when participants change jobs. In our view, this illiquidity is not to be thought of as a detriment, especially when compared with asset classes that, in principle and because of their liquidity, give investors significantly more flexibility in terms of how they manage their investments. As we describe in more detail below, the actual behavior of the average U.S. investor regarding the flexibility that liquidity affords, consistently results in significant return underperformance compared to a disciplined buy-and-hold strategy, whether the investment is in equities, bonds, or a portfolio of mixed assets.[16] Given the disappointing average investor performance when invested in essentially liquid assets (mostly due to investors often selling after market declines and purchasing when asset prices are too high and always paying, whether the timing is right or wrong, the concomitant trading commissions) we think that TIAA's illiquidity has a benefit above and beyond allowing the TIAA to invest long-term and into relatively illiquid assets. Arguably, this additional benefit includes avoiding sub-optimal, emotionally-driven decisions by the average investor.

During the payout or decumulation phase, withdrawals can be made according to various life-time or period-certain options. A significant benefit is the generally larger payout rates annuitants receive compared to what would be the case if the account value at the start of the decumulation phase had been instead invested in a non-TIAA immediate annuity for the same payout option. The ability of the Company to pay additional interest amounts during the payout phase in excess of a minimum guaranteed rate of at least 2% (which depends on the vintage of the amounts being withdrawn), rests

15 We note that unlike the yields on 20-year U.S. Treasuries, the crediting rates on the RAs are both yields and total rates of return.

16 See *Dalbar's 20th Annual Quantitative Analysis of Investor Behavior*, 2014 Advisor Edition. See also Ilia Dichev, "What Are Stock Investors' Actual Historical Returns? Evidence from Dollar-Weighted Returns," *The American Economic Review*, March 2007, pages 386–401 and Ilia Dichev and Gwen Yu, "Higher Risk, Lower Return: What Hedge Fund Investors Really Earn," *Journal of Financial Economics*, (100) 2011, pages 248–263.

on earnings in excess of the guaranteed minimum rate and on distributions of surplus contingency reserves paid out by TIAA.[17] Due to TIAA's ability to increase decumulation phase payouts above the minimum guaranteed level, the value of these payouts compare very favorably to competing immediate annuities.[18]

3. DATA

3.1 TIAA TRADITIONAL RETIREMENT ANNUITY DATA

TIAA provided us with crediting rate data for various investment vintages applying to premiums paid on March 1 of the years 1970, 1975, 1980... 2005. These data are summarized in Figures 2.1 and 2.2, respectively showing monthly returns and their annualized rates for each of these cohorts. Figure 2.2, in particular, allows us to see how the vintage system used by TIAA to credit interest to the annuitants' accounts results in declared actual crediting rates that respond to the interest rate environment prevailing at the time premiums are received.

3.2 STOCK, BOND, AND T-BILL DATA

The other asset classes we consider in this study are large and small U.S. stocks ("LS" and "SS," respectively), long-term U.S. corporate and government bonds ("LTCB" and "LTGB," respectively), intermediate-term U.S. government bonds ("ITGB"), and 3-month U.S. Treasury Bills, a proxy for money market instruments ("MM"). These data are from Morningstar's Ibbotson SBBI 2014 Classic Yearbook.[19]

The stock, bond, and T-bill data we use are indices and, therefore, investors cannot trade them at the reported rates of return. In order to not pick brand-name traded funds tracking each of these particular indices or asset classes, we have used average mutual fund fees and expenses for stock, bond, and money market funds from the Investment Company Institute ("ICI") to calculate net monthly returns for the SBBI data. The net monthly returns are the data used in this study.[20] Mutual fund fees and expenses have decreased dramatically over the last few decades as the industry has grown and competition has intensified. Figure 3.1 shows the evolution of average annual fees for stock, bond and money market mutual funds estimated by the ICI.

We convert the annual ICI fees and expense estimates into monthly figures and subtract the monthly fee and expense amount from the corresponding stock, bond, or money market monthly return. Since the ICI data do not go back before 1980, we use the 1980 monthly fees and expenses figures to calculate pre-1980 monthly returns. To the extent that for the years 1970 through 1979 average mutual fund fees and expenses were higher than those in 1980, our results will be slightly biased in favor of assets other than the TIAA Traditional RA.

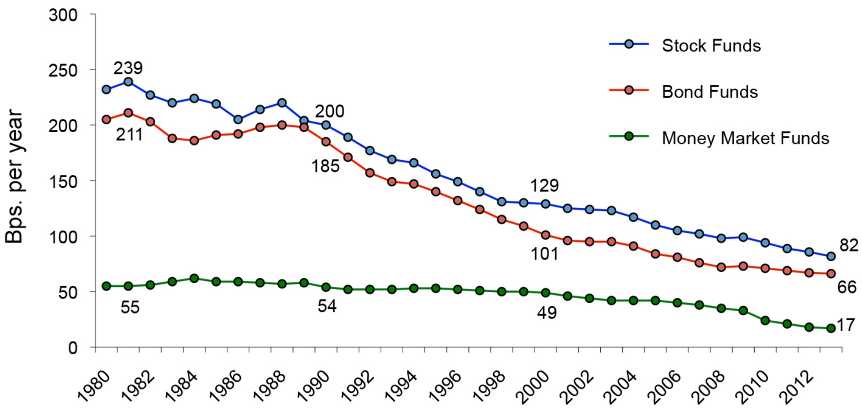
17 TIAA Traditional Annuity: Adding Safety and Stability to Retirement Portfolios, TIAA-CREF Asset Management, April, 2014, page 3.

18 James Poterba and Mark Warshawsky, "The Costs of Annuitizing Retirement Payout from Individual Accounts," in *Administrative Aspects of Investment-Based Social Security Reform*, edited by John Shoven, University of Chicago Press, January 2000, Chapter 5, Section 5.3.2.

19 Where possible we have used Bloomberg for these data. This is the case for large stocks (total return on the S&P 500 Index) and long-term corporate bonds (Citigroup Long-term High-Grade Corporate Bond Index). SBBI's basic series are described in Chapter 3. Data are reported in Appendix A for monthly and annual rates and in Appendix B for end-of-month and end-of-year index values.

20 The small stock returns reported in the SBBI yearbooks are net of fees and expenses. Consequently, we do not adjust them.

FIGURE 3.1 AVERAGE MUTUAL FUND FEES & EXPENSES



Source: ICI

Table 3.1 reports summary statistics for the net monthly returns of the asset classes we study. For each of the eight investment cohorts we consider, the mean and standard deviation of net monthly returns are reported in this table.

TABLE 3.1 SUMMARY STATISTICS FOR NET MONTHLY RETURNS

Cohort	Statistic	Large stocks	Small stocks	Long- term corp. bonds	Long- term gov't bonds	Interm.- term gov't bonds	Money market	TIAA RA
1970 (526)	Mean:	0.79%	1.23%	0.61%	0.59%	0.50%	0.38%	0.58%
	STDEV:	4.46%	6.26%	2.80%	3.12%	1.59%	0.26%	0.13%
1975 (466)	Mean:	0.88%	1.40%	0.63%	0.62%	0.51%	0.37%	0.58%
	STDEV:	4.36%	5.98%	2.83%	3.19%	1.61%	0.27%	0.14%
1980 (406)	Mean:	0.89%	1.21%	0.72%	0.72%	0.56%	0.35%	0.61%
	STDEV:	4.43%	5.79%	2.88%	3.28%	1.61%	0.28%	0.18%
1985 (346)	Mean:	0.85%	1.09%	0.67%	0.69%	0.49%	0.27%	0.58%
	STDEV:	4.44%	5.82%	2.56%	3.01%	1.34%	0.20%	0.18%
1990 (286)	Mean:	0.77%	1.18%	0.60%	0.61%	0.44%	0.23%	0.52%
	STDEV:	4.28%	5.90%	2.58%	2.92%	1.30%	0.18%	0.12%
1995 (226)	Mean:	0.75%	1.17%	0.58%	0.58%	0.41%	0.20%	0.49%
	STDEV:	4.47%	6.24%	2.76%	3.07%	1.28%	0.18%	0.11%
2000 (166)	Mean:	0.36%	0.87%	0.61%	0.56%	0.41%	0.13%	0.49%
	STDEV:	4.52%	6.27%	3.00%	3.28%	1.34%	0.16%	0.11%
2005 (106)	Mean:	0.60%	0.90%	0.49%	0.46%	0.35%	0.11%	0.35%
	STDEV:	4.43%	6.07%	3.28%	3.48%	1.26%	0.16%	0.04%

Notes: Each cohort's data span the period from March of the indicated year through December of 2013. The figure in parenthesis under each cohort year is the number of monthly observations in the cohort.

Based on the means and standard deviations reported in Table 3.1, we can make the following observations:

- The collapse of large stock returns from mid-2000 through 2002, and again during the late 2007 through early 2009 financial crisis, significantly brought the average monthly return of large stocks down for the 2000 cohort.
  - The decline was so severe for the 2000 large stocks cohort that average returns for this cohort were inferior to comparable average long-term corporate and government bond, intermediate-term government bond, and TIAA RA returns.
- The environment of low interest rates lowered the average monthly return for money markets starting in the mid-1980s; but, is especially obvious for the 2000 and 2005 cohorts.
- TIAA RA average returns are generally higher than comparable returns for intermediate-term government bonds and money market instruments. The only exception is for the 2005 cohort, where both intermediate-term government bond and TIAA RA average monthly returns equaled 0.35%.
- The volatility of most asset classes remains fairly stable across the different cohorts. The exceptions are money market instruments and the TIAA RA, for which the volatility declines progressively beginning with the 1985 cohort.
  - This decline in volatility is far more pronounced for the TIAA RA returns than it is for money market returns; 0.18% in 1985 and 0.04% in 2005 for the TIAA RA returns compared to 0.20% and 0.16% for the corresponding money market cohorts.

These characteristics of the return distributions across the various cohorts give a very summary glimpse of the main results we obtain in this paper. We next discuss these results in detail.

4. MEAN-VARIANCE ANALYSIS

We begin our examination of the TIAA RA financial performance with a mean-variance analysis, more because of its simplicity and ubiquitous use in practice than its theoretical financial economic properties.[21] Strictly speaking, a sufficient and necessary condition for the validity of the mean-variance approach under expected utility is that investor preferences must be satisfactorily modeled using quadratic utility.[22] Under other forms of investor preferences, normality of returns imply the validity of the mean-variance framework. In either case, these two conditions, quadratic utility and/or normally distributed returns, are hard to justify on empirical grounds.

Beginning as early as 1967, Arditti determined that investors considered measures of downside risk beyond variance, and countless additional studies along similar lines have continued to demonstrate variance is an inadequate measure of either security or portfolio risk.[23] However, if the distribution of market returns can be fully described by its first two moments, then restricting one's performance analysis to a mean-variance analysis can be justified, even if investors would otherwise be concerned about higher moments of the return distribution. But all tests with which we are familiar demonstrate return distributions for stocks, bonds, and money market instruments cannot adequately be characterized by their means and variances; nor, does modified Brownian motion fully capture the movement in these asset returns. Despite these shortcomings, the mean-variance approach provides useful insights into the ability of the TIAA RA to dominate other asset classes in terms of overall financial performance and thereby replace some asset classes in a retirement portfolio.

21 An excellent treatise on this approach is provided by Markowitz (1987).

22 D. J. Johnstone and D. V. Lindley, "Elementary proof that mean–variance implies quadratic utility," *Theory and Decision*, February 2011, Volume 70, Issue 2, pages 149-155.

23 Indeed, as reported by Douglas (1969), John Lintner's initial cross sectional tests conducted in 1965 found that residual risk, which according to the Capital Asset Pricing Theory's version of mean-variance analysis is not supposed to be priced by the marketplace, was indeed important to investors. More rigorous studies since then have reconfirmed these early findings. Recently, Cvitanic, Polimenis, and Zapatero (2008) have found that ignoring higher moments can lead to significant overinvestment in risky securities, especially when volatility is high.

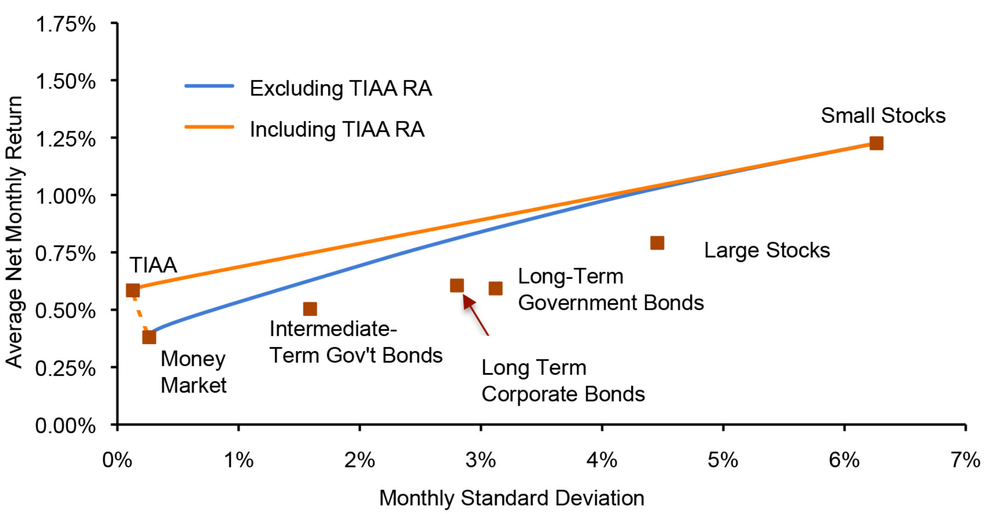
In this section we present evidence supporting the conclusion that, when included in optimal mean-variance portfolios, the TIAA RA enhances the financial characteristics of the retirement portfolios during the accumulation phase. Indeed, the TIAA RA advantage for retirement portfolios leads to the exclusion of some or all of the following asset classes, depending on the investment cohort considered: money market, intermediate-term government bonds, long-term corporate and government bonds, and even large stocks. In other words, optimal mean-variance portfolios *always* include TIAA RA investments and small stocks in proportions that vary with the expected return; or, alternatively, the expected volatility of the optimal portfolio, and sometimes will also include one or more of the other asset categories.

4.1 THE 1970 TIAA RA COHORT

When discussing summary statistics for our net monthly return data in Table 3.1, we observed that, across all of the investment cohorts we consider, TIAA RA returns exhibited both a higher mean return and lower volatility than money market or intermediate-term government bond returns, with the exception of intermediate-term government bonds for the 2005 cohort. This feature can be seen in Figure 4.1, below, where we plot two efficient frontiers, one including all seven asset classes in our study and one that excludes TIAA RA returns for the 1970 investment cohort.

It is interesting to note the potentially large scope for improvement that inclusion of TIAA RA investments brings to an optimal mean-variance portfolio for more than two thirds of the expected return range.

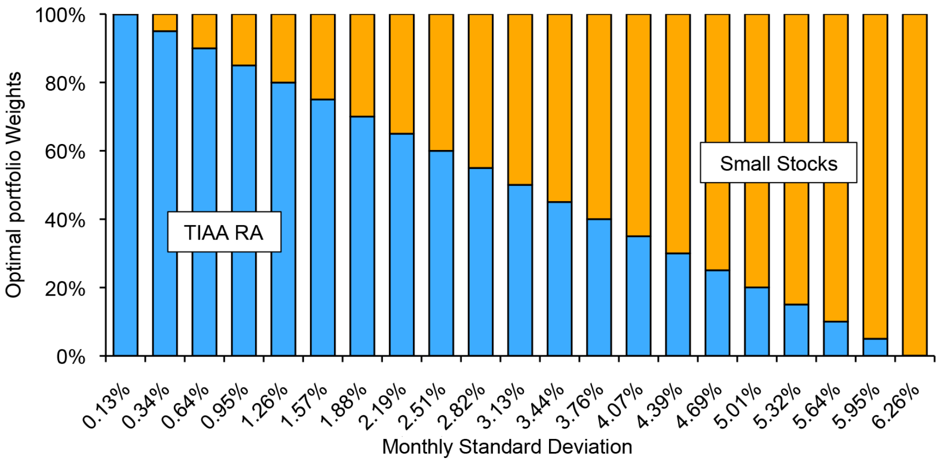
FIGURE 4.1 EFFICIENT FRONTIERS FOR ALTERNATIVE ASSET CLASSES (MAR-1970 - DEC-2013)



As revealing as Figure 4.1 is, it does not show the full extent to which the TIAA RA contributes to an optimal portfolio since it says nothing about the relative allocations of wealth among TIAA RA investments, and other investments at different points along the efficient frontier.

Figure 4.2 reports these optimal weights (again based solely on historical returns) for selected expected monthly volatility ranging from 0.13%, the standard deviation of historical TIAA RA returns, to 6.26%, the historical standard deviation of small stock returns.

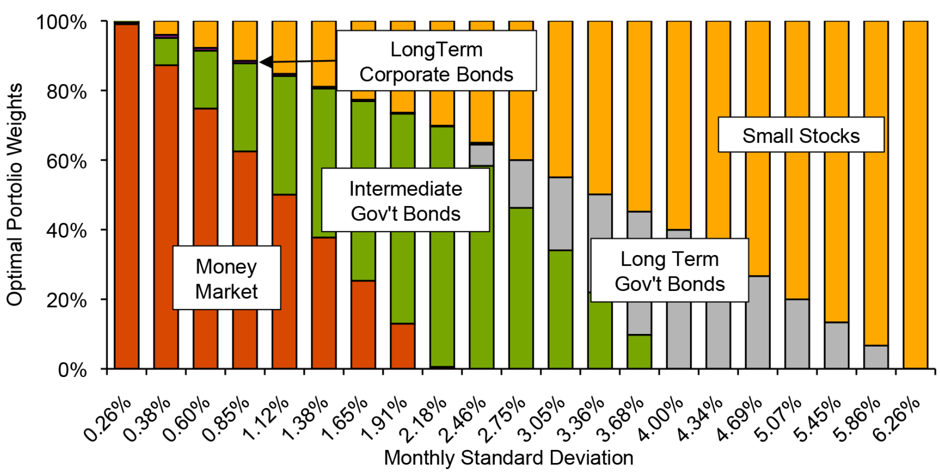
FIGURE 4.2 EFFICIENT PORTFOLIO WEIGHTS INCLUDING TIAA RA (MAR-1970 - DEC-2013)



No optimal mean-variance portfolio along the efficient frontier for this cohort includes money market instruments, intermediate-term bonds or long-term corporate or government bonds. Not even large U.S. stocks are included. We also observe that TIAA RA investments predominate in the lower portion of the expected return range, where one would conventionally anticipate seeing money market and intermediate-term bond investments.

Figure 4.3 repeats the optimal portfolio analysis, but eliminates the TIAA RA as an available asset class.

FIGURE 4.3 OPTIMAL PORTFOLIO WEIGHTS EXCLUDING TIAA RA (MAR-1970 - DEC-2013)



Two observations are important in Figure 4.3. First, money market instruments, intermediate-term bonds, and long-term corporate bonds now enter the optimal portfolios at various levels of portfolio risk, along with small stocks and long-term government bonds. Second, large stocks never enter mean-variance-efficient portfolio model when calibrations are based on the past 43- years of historical returns and correlations.

4.2 1975 AND SUBSEQUENT COHORTS

Figures 4.4 through 4.10, respectively, show the efficient frontiers and optimal portfolio weights (excluding and including the TIAA RA asset class) for the 1975 through 2005 cohorts.

In general, our findings for these cohorts are similar to those for the 1970 cohort. Small stocks are in the portfolios both with and without the TIAA RA investment. Also, the TIAA RA replaces every other asset class except small stocks when it is allowed as an investment. There are, however, some differences in these cohorts worth noting.

First, when the TIAA RA is excluded, long-term corporate bonds now show up in efficient portfolios for intermediate levels of volatility for the 1980, 1985, 1990, and 2000 cohorts, as shown, respectively in Figures 4.5 (b), 4.6 (b), somewhat in Figure 4.7 (b), and Figure 4.9 (b). The absence of large stocks in any significant level across all cohorts is also quite remarkable.

When the TIAA RA returns are included in cohorts subsequent to 1970, the ability of the TIAA RA to replace asset classes other than small stocks in optimal portfolios is reduced by the significant presence of long-term government bonds in every cohort (Figures 4.4 (c) to 4.10 (c). In addition, we observe the appearance of long-term corporate bonds in the 2000 cohort (Figure 4.9 (c), and of money market investments for low volatility levels in the 1985 cohort (Figure 4.6 (c) and, to a smaller degree, in the 2000 cohort (Figure 4.9 (c), for which we also see long-term corporate bonds alongside long-term government bonds and for similar levels of volatility.

In conclusion, the analysis of the various cohorts indicates significant support for the presence of the TIAA RA in efficient retirement income portfolios, especially those that span about the lower half of the available volatility ranges within the group of asset classes.

FIGURE 4.4 (A) 1975 COHORT – EFFICIENT FRONTIERS

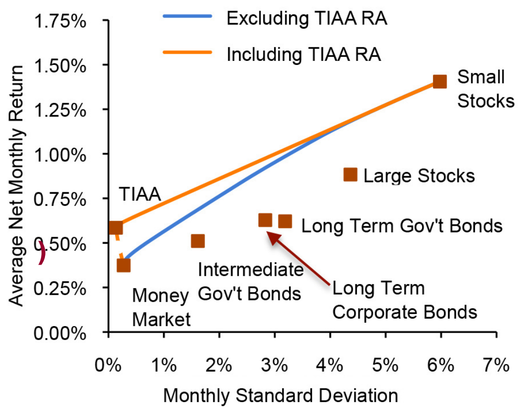


FIGURE 4.5 (A) 1980 COHORT – EFFICIENT FRONTIERS

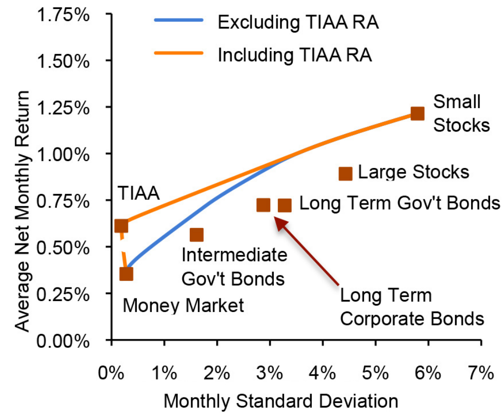


FIGURE 4.4 (B) 1975 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

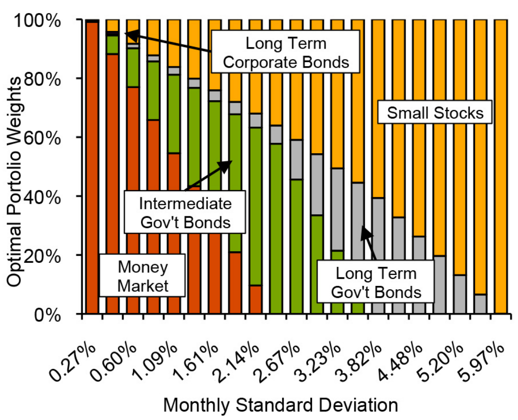


FIGURE 4.5 (B) 1980 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

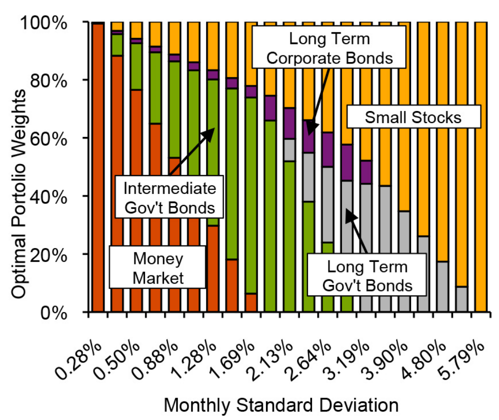


FIGURE 4.4 (C) 1975 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

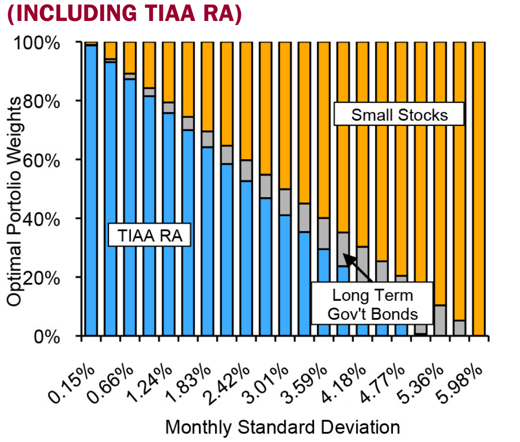


FIGURE 4.5 (C) 1980 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

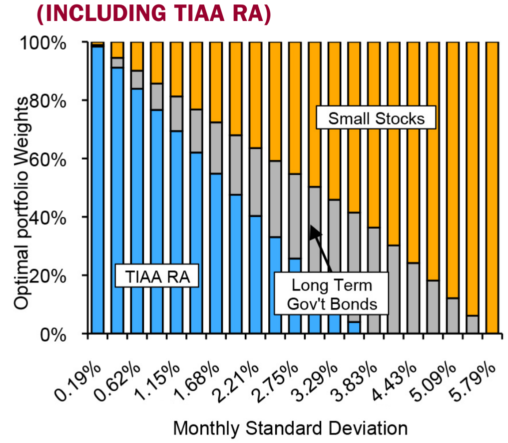


FIGURE 4.6 (A) 1985 COHORT – EFFICIENT FRONTIERS

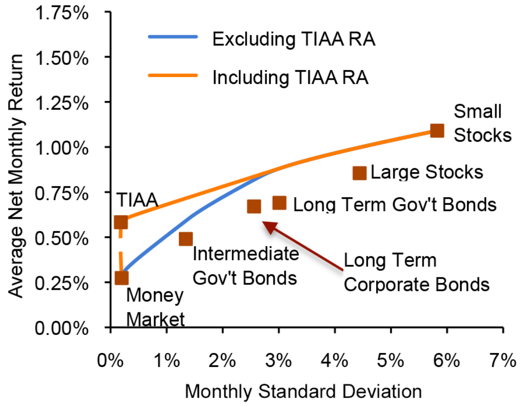


FIGURE 4.7 (A) 1990 COHORT – EFFICIENT FRONTIERS

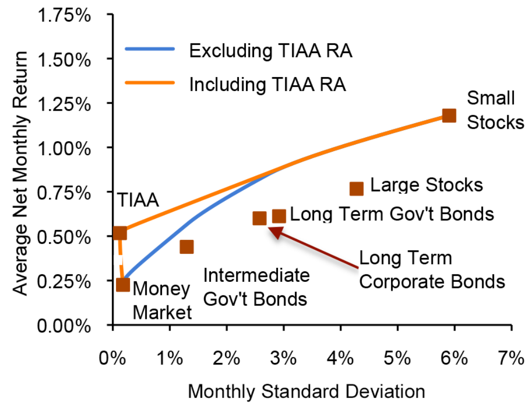


FIGURE 4.6 (B) 1985 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

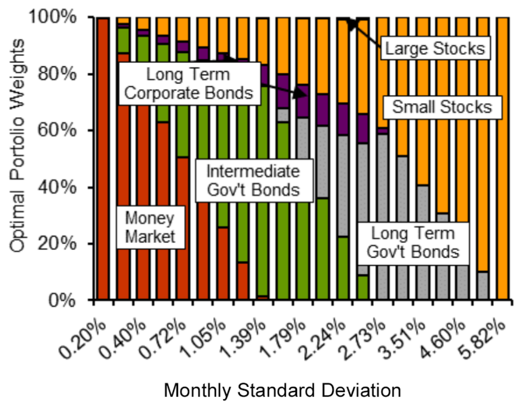


FIGURE 4.7 (B) 1990 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

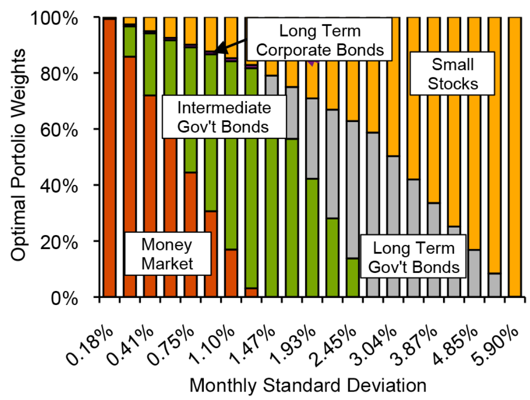


FIGURE 4.6 (C) 1985 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

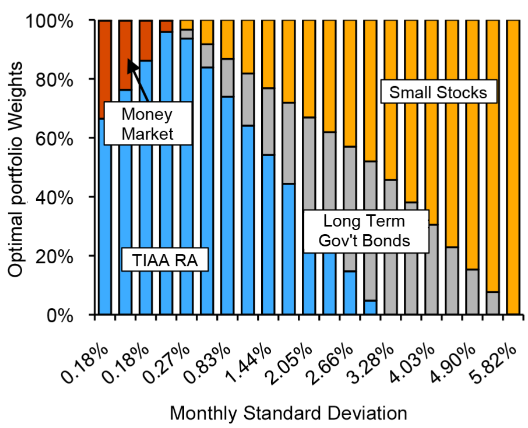


FIGURE 4.7 (C) 1990 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

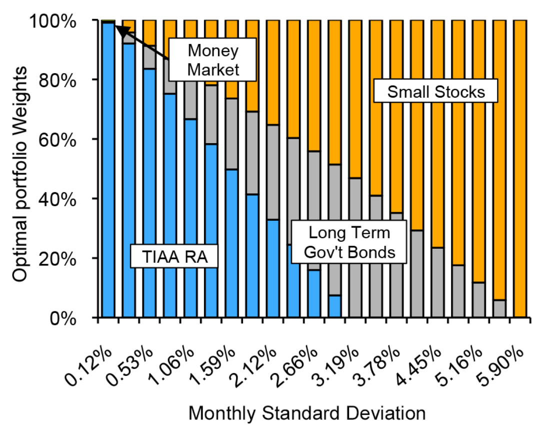


FIGURE 4.8 (A) 1995 COHORT – EFFICIENT FRONTIERS

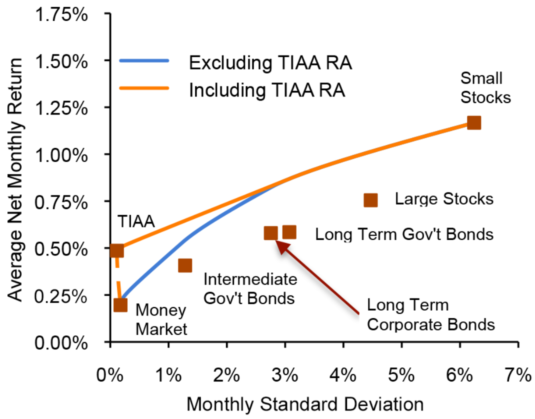


FIGURE 4.9 (A) 2000 COHORT – EFFICIENT FRONTIERS

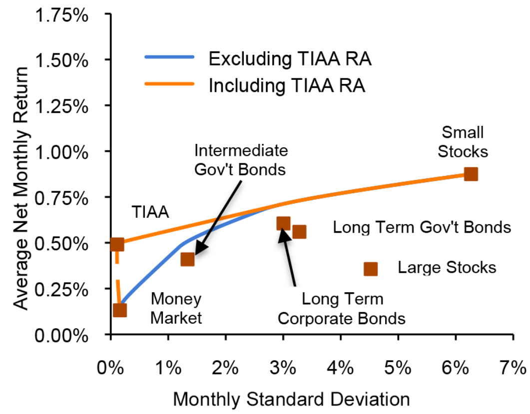


FIGURE 4.8 (B) 1995 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

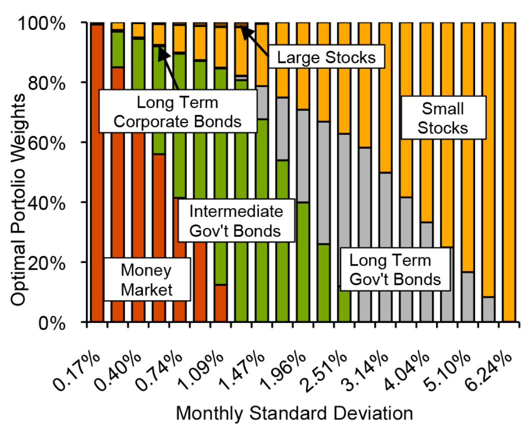


FIGURE 4.9 (B) 2000 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

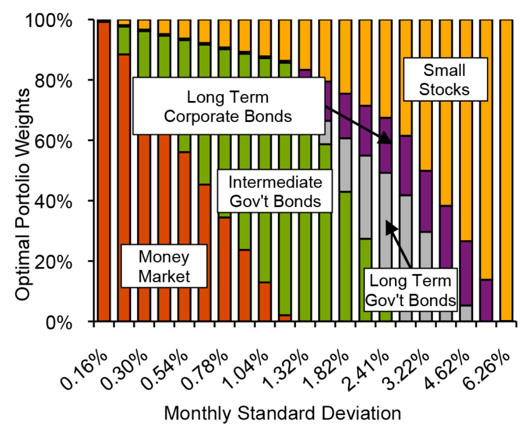


FIGURE 4.8 (C) 1995 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

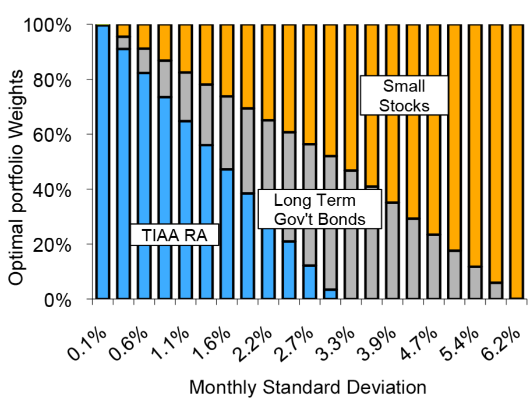


FIGURE 4.9 (C) 2000 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)

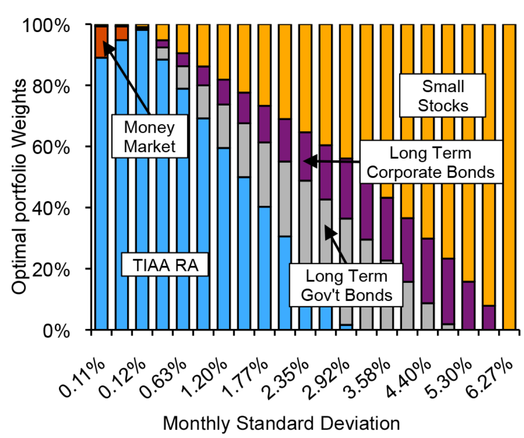


FIGURE 4.10 (A) 2005 COHORT – EFFICIENT FRONTIERS

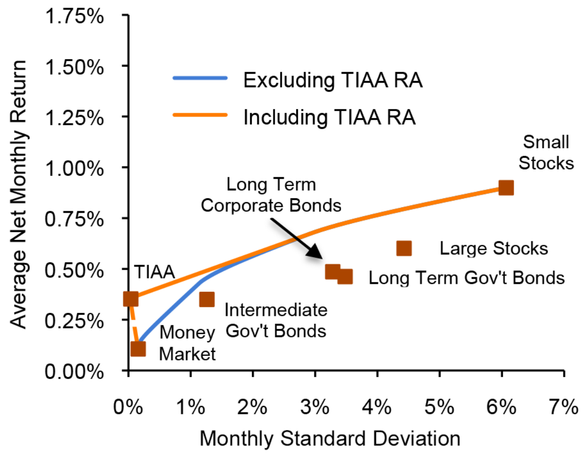


FIGURE 4.10 (B) 2005 COHORT – OPTIMAL PORTFOLIO WEIGHTS (EXCLUDING TIAA RA)

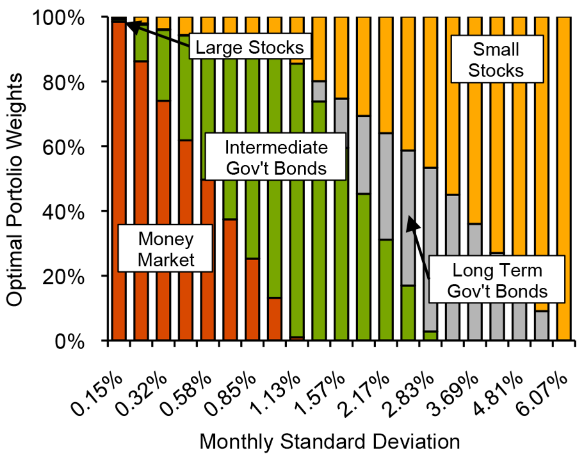
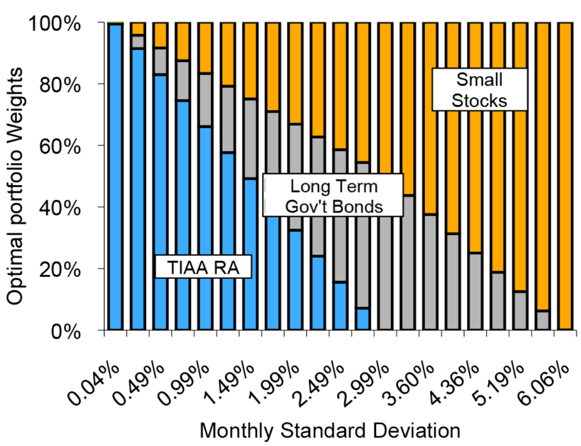


FIGURE 4.10 (C) 2005 COHORT – OPTIMAL PORTFOLIO WEIGHTS (INCLUDING TIAA RA)



5. SHARPE AND SORTINO RATIOS: THE 1970 COHORT

Related to the spirit of mean-variance analysis, we turn to the Sharpe ratio commonly used in asset allocation and performance measurement.[24] The Sharpe ratio measures excess return per unit of risk according to the formula:

$$\text{Sharpe Ratio} = \frac{E[R-R_f]}{\sqrt{Var[R-R_f]}}, \tag{1}$$

where R is the asset return, R_f is the risk-free rate of return, $E\,[R - R_f\,]$ is the expected value of the excess of the asset return over the risk-free rate, and $Var\,[R - R_f\,]$ is the variance of the excess return. This ratio is used as a measure of how well an investor is compensated per unit of risk taken. Higher ratios denote greater return for the same level of risk. In this analysis we take the risk-free rate to be the money market monthly return.

We also use the Sortino ratio to focus more on the downside risk.[25] The Sortino ratio is based on the Sharpe ratio, but penalizes for only those returns that fall below the target return, which in our case will be the average riskless rate of return over the period of analysis. The Sortino ratio gives the actual rate of return in excess of the risk-free rate per unit of downside risk, and is calculated as:

$$\text{Sortino Ratio} = \frac{E[R-R_f]}{\sqrt{\left(\int_{-\infty}^{R_f} (R-R_f)^2 f(R)\,dR\right)}}. \tag{2}$$

The denominator in Expression (2) is the variance formula of the excess returns calculated over the range of return values where the asset returns of interest are below the risk-free rate. The Sharpe and Sortino ratios for monthly net return data are reported in Table 5.1.

TABLE 5.1 SHARPE AND SORTINO RATIOS FOR MONTHLY RETURNS – 1970 COHORT

	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Intermediate-term gov't bonds	TIAA RA
Sharpe ratio	0.092	0.135	0.080	0.068	0.078	1.075
Sortino ratio	0.133	0.203	0.125	0.105	0.121	11.737

We note that the Sharpe ratio values for five of the asset classes are mostly clustered together, with an ordering that favors small stock returns among the five classes other than the TIAA RA; however, that for the TIAA RA returns the ratio is about eight times greater than the highest of other asset classes. This pattern is even more pronounced for the Sortino ratio. The extremely high Sortino ratio assigned to the TIAA RA asset class, relative to those assigned to other asset classes, results from the fact that throughout the entire 526-month period under consideration the risk-free rate exceeded the TIAA RA credited rate only for 60 months (or 11.4% of the number of monthly observations), and even then by small amounts. Hence, there were only a few, small observations that factored into the denominator.

What is most noteworthy about these ratios is how much higher they are for TIAA RA returns than for the other asset classes. Although our calculations are based primarily on monthly data, when comparing Sharpe and Sortino ratios it is customary to "time-aggregate" them and express them as annualized ratios. Conventionally, this is done by multiplying the ratio based on monthly data by the factor √12 (or by the factor √3 to express them in quarterly terms).[26] This factor, however, assumes that excess returns are serially uncorrelated. While this may be approximately correct for the equity and bond asset classes in our analysis, it is not the case for the TIAA RA returns which exhibit significant positive serial correlation. In this case,

24 The original "Reward-to-Variability" performance ratio, of William Sharpe, better known as simply the "Sharpe ratio," was modified by him in 1994. The modified version of his ratio is used in this analysis. See Sharpe (1994).

25 See Sortino and Price (1994) and Sortino and Van der Meer (1991) for a description of the Sortino Ratio. The theoretical foundations for the Sortino Ratio are provided in Pedersen and Satchell (2004).

26 See Andrew Lo, "The Statistics of Sharpe Ratios," *Financial Analysts Journal*, July/August, 2002, pages 36-52.

time-aggregated Sharpe and Sortino ratios overestimate the correct ratio. An alternative approach, which we follow in Table 5.2 below, is to compound monthly returns into quarterly or annual returns and calculate the corresponding quarterly or annual ratios directly from the quarterly or annual returns. There is, however, a loss in the precision of these ratio estimates compared to the ratios based on monthly returns, due to the smaller number of observations in the quarterly or annual samples.

TABLE 5.2 SHARPE AND SORTINO RATIOS FOR QUARTERLY AND ANNUAL RETURNS – 1970 COHORT

	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Intermediate-term gov't bonds	TIAA RA
			Quarterly returns			
Sharpe ratio	0.155	0.217	0.137	0.119	0.123	1.094
Time-aggregated Sharpe ratio	*0.159*	*0.233*	*0.139*	*0.118*	*0.135*	*1.862*
Sortino ratio	0.230	0.365	0.227	0.194	0.218	11.567
			Annual returns			
Sharpe ratio	0.281	0.397	0.274	0.259	0.264	1.133
Time-aggregated Sharpe ratio	*0.319*	*0.466*	*0.278*	*0.236*	*0.271*	*3.723*
Sortino ratio	0.467	0.915	0.641	0.656	0.587	9.851

In Table 5.2; we report quarterly and annual Sharpe and Sortino ratios calculated with quarterly and annual returns. In the case of the Sharpe ratio, we also report the time-aggregated ratios calculated by multiplying the monthly Sharpe ratio in Table 5.1 by the factor $\sqrt{3}$ to express them as quarterly ratios and by the factor $\sqrt{12}$ to express them as annual ratios.

In Table 5.2 we observe the same pattern revealed in Table 5.1, that is, Sharpe and Sortino ratios for the TIAA RA returns are significantly larger than for the alternative investments. Inspection of the time-aggregated Sharpe ratios shows that the serial correlation for stock and bond excess returns is very small or non-existent as indicated by the similarity of the quarterly and annual ratios and their corresponding time-aggregated versions. For example, the Sharpe ratio for large stocks based on annual returns is 0.281 and the corresponding time-aggregated, annualized ratio is 0.319. This indicates that multiplying the monthly Sharpe ratio of 0.092 by the factor $\sqrt{12}$ (0.092 x 3.464 = 0.319) gives an appropriate estimate of the annual Sharpe ratio. Indeed, monthly large stocks excess returns exhibit no significant serial correlation. This is also the case for long-term-government bonds, while small stocks, long-term corporate bonds and intermediate-term government bonds exhibit mild degrees of positive serial correlation. This is the reason why the corresponding quarterly and annual time-aggregated Sharpe ratios are slightly larger than the correct quarterly and annual ones.[27]

By contrast, TIAA RA monthly excess returns do exhibit significant positive serial correlation. The first order autocorrelation coefficient for monthly TIAA RA excess returns is 0.934. This is the reason quarterly and annualized time-aggregated Sharpe ratios are much higher than the corresponding ratios based on quarterly and annual excess TIAA RA returns since time-aggregation based on the factors $\sqrt{3}$ (for quarterly aggregation) and $\sqrt{12}$ (for annual aggregation) ignore the fact that serial positive correlation increases the magnitude of the time-aggregated variances (and standard deviations).[28]

27 The largest lag-one autocorrelation coefficient among these three asset classes, at 0.150, corresponds to intermediate-term government bonds. This implies that the time-aggregated Sharpe ratio, which assumes no serial correlation at all, will be slightly biased upwards. See Andrew Lo, "The Statistics of Sharpe Ratios," *Financial Analysts Journal*, July/August, 2002, pages 36-52 for a thorough discussion of the impact of serial correlation on time-aggregated Sharpe ratios.

28 The impact of serial correlation on time-aggregated Sortino ratios is, qualitatively, the same as in the case of Sharpe ratios. For this reason we do not report time-aggregated Sortino ratios in Table 6.2.

Therefore, Table 5.2 reports Sharpe and Sortino ratios based on quarterly and annual excess returns, which incorporate the serial correlation in compounded returns. As was the case with ratios based on monthly excess returns, the TIAA RA ratios are well above the corresponding ratios for other asset classes.

5.1 SHARPE AND SORTINO RATIOS: 1975 AND SUBSEQUENT COHORTS.

In this section we report the Sharpe and Sortino ratios for the other seven cohorts analyzed in this study. Table 5.3 reports this information for monthly and annual excess returns. For brevity, and because the pattern is similar to that observed in the 1970 cohort results, we do not report time-aggregated Sharpe ratios or quarterly figures.

The results shown in Table 5.3 are in line with those we discussed for the 1970 cohort (also included in Table 5.3 for easy reference), but, there are a few additional findings that are worth mentioning.

TABLE 5.3 SHARPE AND SORTINO RATIOS FOR MONTHLY AND ANNUAL RETURNS – 1970 TO 2005 COHORTS

	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Intermediate-term gov't bonds	TIAA RA
1970 Cohort			Monthly returns			
Sharpe ratio	0.092	0.135	0.080	0.068	0.078	1.075
Sortino ratio	0.133	0.203	0.125	0.105	0.121	11.737
			Annual returns			
Sharpe ratio	0.281	0.397	0.274	0.259	0.264	1.133
Sortino ratio	0.467	0.915	0.641	0.656	0.587	9.851
1975 Cohort			Monthly returns			
Sharpe ratio	0.117	0.172	0.090	0.078	0.086	1.080
Sortino ratio	0.169	0.260	0.140	0.121	0.134	12.808
			Annual returns			
Sharpe ratio	0.353	0.494	0.301	0.293	0.286	1.127
Sortino ratio	0.600	1.190	0.710	0.763	0.642	10.361
1980 Cohort			Monthly returns			
Sharpe ratio	0.121	0.148	0.129	0.113	0.133	1.554
Sortino ratio	0.174	0.217	0.209	0.180	0.221	21.761
			Annual returns			
Sharpe ratio	0.358	0.405	0.470	0.457	0.485	1.716
Sortino Ratio	0.613	0.929	1.715	1.792	1.316	16.593
1985 Cohort			Monthly returns			
Sharpe ratio	0.131	0.140	0.155	0.139	0.164	2.461
Sortino ratio	0.186	0.203	0.251	0.221	0.256	N/A
			Annual returns			
Sharpe ratio	0.382	0.367	0.592	0.582	0.567	2.569
Sortino ratio	0.654	0.845	2.043	2.765	1.677	N/A
1990 Cohort			Monthly returns			
Sharpe ratio	0.126	0.161	0.145	0.133	0.167	2.257
Sortino ratio	0.181	0.243	0.231	0.205	0.260	N/A
			Annual returns			
Sharpe ratio	0.339	0.409	0.645	0.705	0.632	2.326
Sortino ratio	0.578	0.970	1.909	3.129	1.913	N/A
1995 Cohort			Monthly returns			
Sharpe ratio	0.125	0.155	0.139	0.127	0.165	2.347
Sortino ratio	0.177	0.234	0.224	0.196	0.263	N/A
			Annual returns			
Sharpe ratio	0.318	0.384	0.630	0.699	0.658	2.407
Sortino Ratio	0.551	0.902	1.945	3.950	2.366	N/A

2000 Cohort			Monthly returns			
Sharpe ratio	0.050	0.118	0.157	0.130	0.210	2.779
Sortino ratio	0.068	0.173	0.257	0.203	0.342	N/A
			Annual returns			
Sharpe ratio	0.110	0.273	0.787	0.796	0.900	2.778
Sortino ratio	0.184	0.602	3.285	6.905	4.483	N/A
2005 Cohort			Monthly returns			
Sharpe ratio	0.112	0.130	0.115	0.102	0.193	1.812
Sortino ratio	0.154	0.188	0.196	0.165	0.333	N/A
			Annual returns			
Sharpe ratio	0.221	0.269	0.550	0.656	0.874	1.708
Sortino ratio	0.374	0.527	2.338	5.603	16.735	N/A

First, a systematic pattern is that the TIAA RA portfolio has higher Sharpe and Sortino ratios across all the cohorts we study, the same qualitative finding we observe in the 1970 cohort. This is strong evidence in favor of the resilience of the TIAA RA investment.

Second, for the 1985 through the 2005 cohorts, the Sortino ratio is not defined. The reason for this unusual result is that *not a single TIAA RA excess return in these cohorts happens to be below the corresponding money market return*. In other words, the denominator of Expression (2) is zero because $(R \geq R_f)$ for all returns and months in cohorts 1985 through 2005.

Third, when comparing the Sharpe and Sortino ratios across large and small stocks, long-term corporate and government bonds, and intermediate-term government bonds, small stocks generally enjoy larger Sharpe and Sortino ratios for the 1970, 1975, and 1980 cohorts. These are long-time periods, long enough for small stock returns to overcome the bear market of 1973-1982 related to the energy crisis, the 2000-2002 dot.com bubble crash, and the 2007-2009 financial crisis. For the 1985 through the 2005 cohorts, the largest Sharpe and Sortino ratios generally correspond to intermediate-term and long-term government bonds.

What we can say from this ratio analysis is that the structure of TIAA RA returns appears to be very different from that of other asset classes, and that this structure does not lend itself well to traditional mean-variance metrics for comparison. Moreover, these mean-variance findings are derived from return distributions that, for most investment classes, are decidedly not normal. Accordingly, we now turn to present alternative and more powerful analyses that buttress the implications of our mean-variance analyses.

6. STOCHASTIC DOMINANCE ANALYSIS

Next, we measure the comparative investment performance of the TIAA RA against the other asset class indices using stochastic dominance analysis. Introduced in 1969 by Hanoch and Levy and by Hadar and Russell to remedy shortcomings of mean-variance analysis, stochastic dominance approaches have the clear advantage of taking into account all moments and other characteristics of the return distributions. It also provides a type of empirical investment analysis that does not depend on knowing (or assuming) the exact shapes of investor preference functions. This is a distinct advantage over the mean-variance approach, which cannot be valid for various horizons simultaneously because mean-variance relies on log-normally distributed returns, which if valid (under certain conditions) for single-period returns, is not valid for multi-period returns. By contrast, the stochastic dominance approach remains valid because it is distribution-free. The limitations and additional virtues of this approach are discussed at length in the authoritative treatise by Levy (2006).

While some of the residual limitations of stochastic dominance analysis have been overcome by a plethora of research, dating from the 1970s to the present, there remain two:

- Stochastic dominance methods provide no guidance into the construction of a portfolio from various individual securities, and
- Stochastic dominance methods do not yield an equilibrium price for securities.

Stochastic dominance provides evaluative criteria under very general conditions with respect to an investor's attitudes toward risk and considers higher moments of the asset return distributions. The various degrees of stochastic dominance described below refer to different aspects of investors' attitudes toward risk.

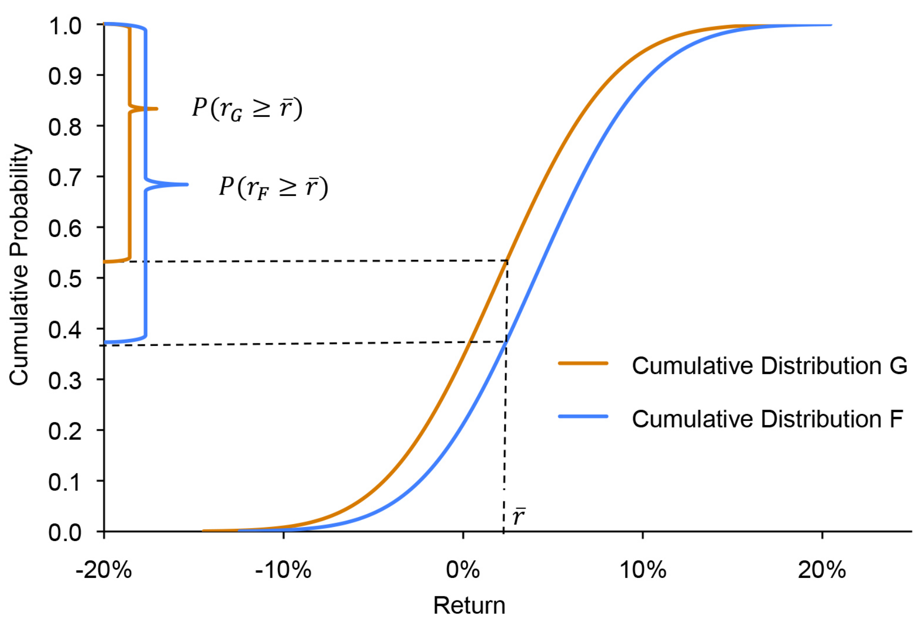
First-degree stochastic dominance (FSD) imposes only one preference restriction – investors prefer more wealth to less wealth – they prefer a higher return to a lower return. Essentially, if an investment stochastically dominates another in the first degree, any investor, irrespective of his or her degree of risk aversion, would prefer the dominating investment. Formally, we say that distribution *F* stochastically dominates distribution *G* in the first degree if and only if

$$Pr(r_F \geq \bar{r}) > Pr(r_G \geq \bar{r}), \text{ for any return } \bar{r}\,, \tag{3}$$

where r_F and r_G are, respectively, returns from distributions *F* and *G*. This condition means that the probability of obtaining returns equal to, or higher, than any given return $\bar{r}$ is greater for the dominating distribution than it is for the dominated one.

To better understand the special conditions imposed by first degree stochastic dominance, Figure 6.1 shows the basic relationship that the two return distributions, *F* and *G*, would have to maintain for one of them (*F*) to stochastically dominate the other (*G*) in the first degree. This condition is that for any possible return $\bar{r}$ the cumulative distribution function (CDF) of the dominating investment is below the CDF of the dominated one, so that Expression (3) obtains at all times.

FIGURE 6.1 FIRST DEGREE STOCHASTIC DOMINANCE



In addition to the requirements of first-degree stochastic dominance, *second-degree dominance* (SSD) requires investors to be risk averse; i.e., to dislike a drop in wealth more than they like a wealth increase of the same magnitude, at least across some portion of the wealth spectrum. This implies that a return distribution that stochastically dominates another in the second degree will be preferred by any risk-averse investor.

Figure 6.2 illustrates the conditions for return distribution F to dominate return distribution G in the second degree:

- The distribution F is above the distribution G for part of the range of returns,
- G starts at a lower return than F, and
- The area where the CDF of F is above the CDF of G is smaller than the area where the CDF of G is above the CDF of F.

Unless all of these conditions are met, second-degree stochastic dominance does not obtain. Figure 6.3 shows a case where conditions 1. and 2. are met but condition 3. is not because the area where the CDF of F is above the CDF of G is shown to be larger than the area where the CDF of G is above the CDF of F.

Stochastic dominance in the first and second degrees is particularly relevant because return distributions that exhibit dominance in any of these degrees ought to appeal to a very large fraction of investors, especially when dominance obtains in the first degree. Because of the strong implications of first and second degree, it is not common to observe these degrees of stochastic dominance in the actual return distributions.

FIGURE 6.2 SECOND-DEGREE STOCHASTIC DOMINANCE

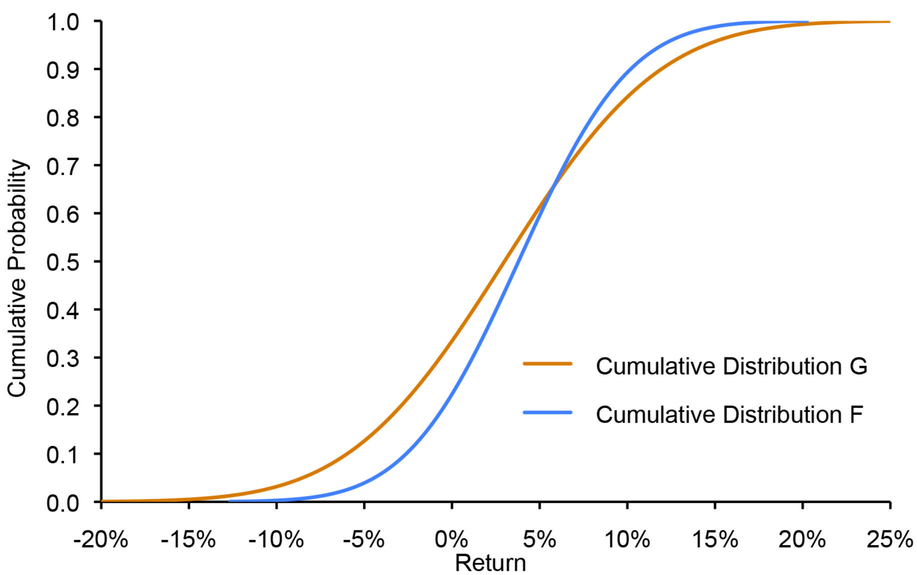
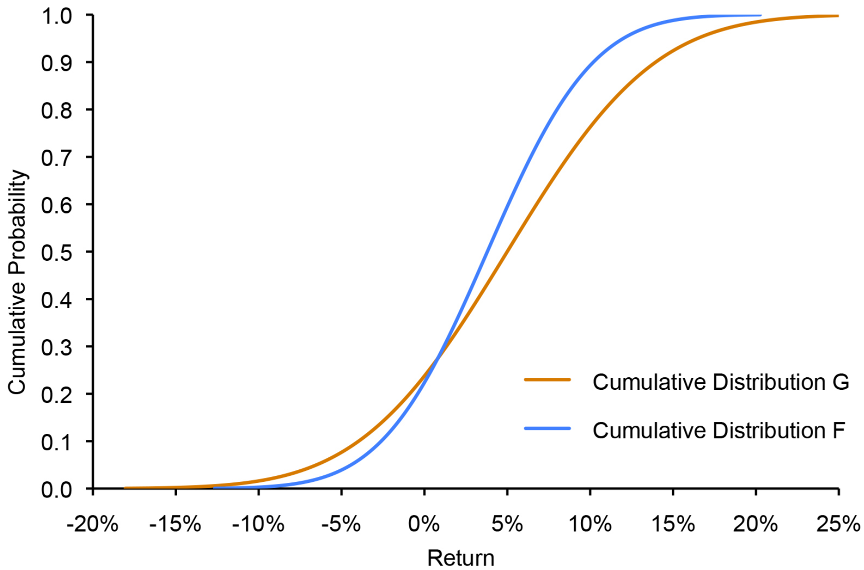


FIGURE 6.3 ABSENCE OF SECOND-DEGREE STOCHASTIC DOMINANCE



The development of *third-degree stochastic dominance (TSD)* was motivated by a long observed preference among some investors for positively skewed (i.e. asymmetric) returns.

A subset of the class of investors who prefer returns exhibiting third-degree stochastic dominance is the important group whose preferences are characterized by decreasing absolute risk aversion (DARA). Such investors are generally willing to pay less for insuring against a given sized risk as they accumulate greater wealth, which appears to accord with observed behavior toward risk.

Fourth-degree stochastic dominance (4SD) was developed to capture investors' aversion toward kurtosis, where returns are characterized by peaked distributions and fat tails, such that losses can be extreme. Of course, kurtosis can favor investors who have asymmetric claims toward returns, such as investors in call options, but for investors who have equal claims to both tails of a distribution, such as investors in stocks and bonds, the fatter tails cause a disproportionate loss in utility.[29]

A corollary of stochastic dominance is that a return distribution which stochastically dominates another one in a given degree also dominates in all subsequent degrees. For example, second-degree dominance implies dominance in the third, fourth, and subsequent degrees.

29 See the detailed exposition in Levy (2006) for a complete characterization of the necessary and sufficient conditions for SD. In this study, we have investigated stochastic dominance up to the fourth degree.

6.1 THE 1970 TIAA RA COHORT

Table 6.1 presents the SD results among the seven asset classes in our study, based solely on historical returns.[30]

TABLE 6.1 STOCHASTIC DOMINANCE FOR THE 1970 COHORT (MAR-1970 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		3rd, 4th, … Degrees	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	2nd, 3rd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

The results in Table 6.1 are, in most cases, what is to be expected in the sense that it is not common for empirical return distributions to stochastically dominate other distributions. This table shows that out of the forty-two possibilities, there are only three cases where a return distribution dominates another and that in two of these three cases the TIAA RA return distribution dominates.

Long-term corporate bonds dominate long-term government bonds in the third (and higher) degree. As can be seen in Table 3.1 and illustrated in Figure 4.1, and 4.4 (a) through 4.10 (a), these two asset classes are close to each other in terms of their means and standard deviations across all of the sample periods implicated by the 1970 through the 2005 cohorts. In this sense, the return distributions of long-term corporate and government bonds are close, but there might be other distributional features such as skewness or kurtosis that help differentiate them. This is the case for these return distributions: both are skewed to the right (longer right tails than left tails), but the corporate bond returns are about 16% more right-skewed than government bond returns.[31] We note this result is not stable across all the cohorts. As we show below, there is no stochastic dominance of long-term government bonds by long-term corporate bonds for the 1985, 1990, and 1995 cohorts. There is second-degree dominance for the 1980 and the 2000 cohorts.

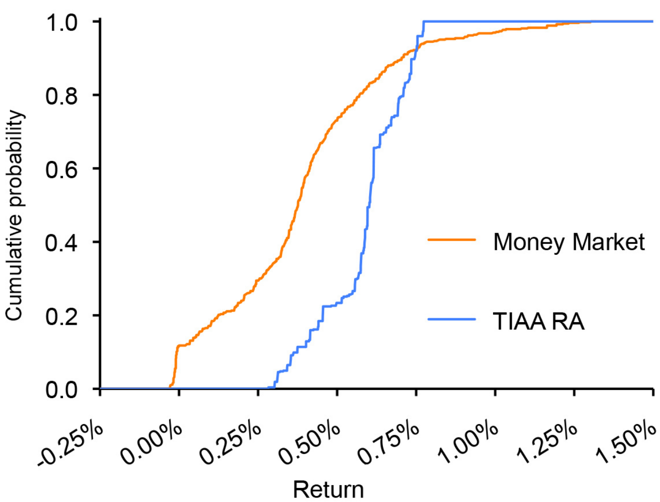
The more remarkable result is that the TIAA RA return distribution dominates the distribution of both intermediate-term government bond returns and money market returns in the second (and higher) degree. This means that TIAA RA returns are large enough, and happen often enough, compared to intermediate-term government bond returns and money market returns, that risk-averse investors ought to prefer the TIAA RA asset to any of these other two asset classes.

30 Stochastic dominance analysis is not restricte to basing return and risk expectations solely on historical returns, but this is the approach we take in this study.

31 The respective skewness measures for corporate and government bond returns are 0.4318 and 0.3719, with zero indicating perfect symmetry.

Figure 6.4 illustrates this result, comparing the TIAA RA return distribution to the money market return distribution. During the early 1980s, money market returns were higher than those provided by the TIAA RA. This happened in 32 cases out of 526 months in the 1970 cohort sample.[32] In the remaining months, the TIAA RA returns exceeded those posted by money market funds. In the case of the TIAA RA returns compared to intermediate-term government bond returns, there were 210 occasions when the latter (sorted) returns where larger than the former (sorted) returns. Bearing in mind that there are 526 months in the sample, the case is that TIAA RA returns were larger enough, often enough to result in second degree stochastic dominance. The much narrower range of TIAA RA returns is just another way of visualizing their much smaller volatility compared to that of any other return distribution, as the figures in Section 4 above also illustrate.

FIGURE 6.4 EMPIRICAL DISTRIBUTION OF MONEY MARKET AND TIAA RA RETURNS (MAR-70 - DEC-13)



6.2 1975 – 2005 COHORTS

In this section we discuss our stochastic dominance results for other cohorts. These results follow a general pattern similar to that discussed in detail for the 1970 cohort.[33] This pattern is one where:

- Long-term corporate bond returns stochastically dominate long-term government bond returns in the third degree. The reasons for this dominance continue to be the similarity, in terms of means and variances, of the two distributions and the greater positive skewness of corporate bond returns.
- TIAA RA returns stochastically dominate intermediate-term government bonds and money market returns in the second degree.

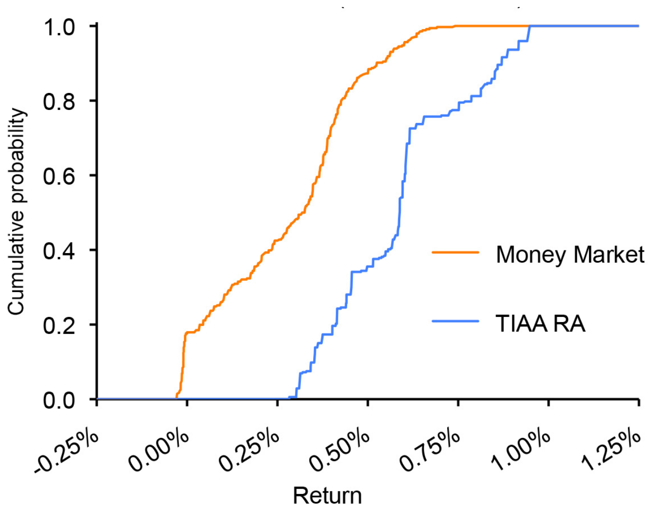
More importantly, there are cohorts and asset classes, especially the TIAA RA class, for which these results can be strengthened considerably. Table 6.2 summarizes these findings.

Two kinds of findings are particularly interesting.

32 Note that this comparison is not for contemporaneous pairs of returns. Rather it is a comparison between the sorted returns for each asset class.

33 Tables A1 – A7 in Appendix A present our stochastic dominance results for these cohorts in the same format as in Table 6.1 above for the 1970 Cohort.

FIGURE 6.5 EMPIRICAL DISTRIBUTION OF MONEY MARKET AND TIAA RA RETURNS (MAR-85 - DEC-13)



First, for cohorts 1985 through 2005, TIAA RA returns dominate money market returns in the first degree. As indicated in the discussion at the beginning of this section, this degree of dominance implies that *any investor* who prefers more wealth to less wealth ought to disregard money market investments when the TIAA RA asset is available. Consistent with the hypothetical distributions in Figure 6.1, the empirical distributions of these two return classes do not cross. Figure 6.5 illustrates this situation for the 1985 cohort.

The second finding is the second-degree dominance of long-term (LT) corporate and government bonds, intermediate-term (IT) government bonds, and the TIAA RA returns over large stocks observed for the period spanned by the 2000 cohort, Mar-2000 – Dec-2013.

TABLE 6.2 STOCHASTIC DOMINANCE RESULTS FOR COHORTS 1975 – 2005, DIFFERENT FROM RESULTS FOR THE 1970 COHORT

1975 Cohort	Unchanged with respect to the 1970 cohort		
1980 Cohort	Long-term corporate bonds dominate long-term government bonds in the *2nd* degree		
1985 Cohort	Long-term corporate bonds *do not* dominate long-term government bonds	TIAA RA returns dominate money market returns in the *1st* degree	
1990 Cohort	Long-term corporate bonds *do not* dominate long-term government bonds	TIAA RA returns dominate money market returns in the *1st* degree	
1995 Cohort	Long-term corporate bonds *do not* dominate long-term government bonds	TIAA RA returns dominate money market returns in the *1st* degree	
2000 Cohort	Long-term corporate bonds dominate long-term government bonds in the *2nd* degree	TIAA RA returns dominate money market returns in the *1st* degree	LT corporate and government bonds, IT government bonds, and the TIAA RA dominate large stocks in the *2nd* degree
2005 Cohort		TIAA RA returns dominate money market returns in the *1st* degree	

The results in this section are remarkable. With the exception of the 2000 cohort, where stock returns were severely depressed by the consequences of the dot.com bubble burst of March 2000 through 2002 and the financial crisis of August 2007 through March 2009, there is no significant stochastic dominance of any one traditional class over another; indeed, dominance is rarely encountered. Accordingly, it is remarkable that TIAA RA investments systematically dominated two of the major traditional investment classes, and, also did so over large stocks (along with other asset classes) for the 2000 cohort. In Tables A1 to A7 in Appendix A, we report the full stochastic dominance results for the 1975 through 2005 cohorts.

7. CONCLUDING REMARKS

The analyses in this paper demonstrate (using three different techniques) that permitting a deferred annuity such as the TIAA Traditional Retirement Annuity into the set of investment options available in retirement savings plans, and then allocating a substantial portion of the funds, contributes to the retirement savings plan to the deferred annuity, and improves the overall financial performance of a retirement savings plan such as a 401(k), 403(b), 457, or IRA over the studied period. This comes about because, in a retirement savings program, the deferred annuity can be invested prudently in longer dated, more illiquid, higher yielding underlying securities than money market and short-term fixed income alternatives.

The empirical analyses presented above also demonstrate that over the 1970 through 2013 period covered by our study, the TIAA RA had both a higher return and lower variability than a number of other asset classes commonly used as investment options in retirement savings programs. The use of the TIAA RA as an investment option increased the efficient investment frontier in mean-variance space; for example, meaning the investor can obtain higher returns for a given level of risk or lower risk for a given level of returns. The TIAA RA stochastically dominated money market and intermediate-term government bond instruments, while not being stochastically dominated by any other asset class.

An insight from our study is that TIAA's ability to manage interest rate risk for participants in the TIAA RA led to significantly improved portfolio performance in cases where the TIAA RA was combined with conventional bond and stock investments. These gains in portfolio performance happened for a wide range of risk tolerance levels among investors, especially for the more risk-averse ones.

The results of this study can be placed in wider context, as briefly described in the introductory Section, of the modest and even poor retirement income prospects that a great many U.S. workers face. In this respect, we believe the general availability, and corresponding financial education among the public at large of investment options such as the TIAA RA would be a useful step in the right direction.

Looking forward, we see two primary ways to extend this analysis. First, we could perform an analysis that includes the full crediting rate triangles for each year, thereby allowing the hypothetical investors to contribute monies on a monthly basis. This would better capture typical TIAA-CREF (and DC plan) participant behavior. It is well established that, on average, investors engage in frequent trading in and out of stock and bond mutual funds, often selling after big price decreases or buying when prices are already on the rise.[34] Therefore, the liquidity restrictions in the TIAA RA could actually be conducive to even larger advantages for retirement portfolios including when compared to the way average investors participate in more liquid stock and bond financial markets. More ambitiously, we could extend the analysis in the accumulation phase by implementing behaviorally-based investment decisions into a Monte Carlo model of retirement savings programs. This could have participants changing some investment allocations in response to market conditions.

34 See *Dalbar's 20th Annual Quantitative Analysis of Investor Behavior*, 2014 Advisor Edition. See also Ilia Dichev, "What Are Stock Investors' Actual Historical Returns? Evidence from Dollar-Weighted Returns," *The American Economic Review*, March 2007, pages 386–401 and Ilia Dichev and Gwen Yu, "Higher Risk, Lower Return: What Hedge Fund Investors Really Earn," *Journal of Financial Economics*, (100) 2011, pages 248–263.

Second, we can extend the analysis into the payout or decumulation phase by comparing annuity payout patterns to sustainable withdrawal patterns from a more mutual fund approach. One of the major advantages of an annuity is the steady provision of a known amount of retirement income. The risk of asset price drops is transferred from the participant to the annuity provider. It is our belief that including options such as TIAA's RA offers benefits to participants in both the accumulation and decumulation phases. This paper documented the benefits in the accumulation phase. We fully expect the benefits of the RA to be even more evident in the decumulation phase.

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APPENDIX

Tables A1 – A7 show the stochastic dominance results for cohorts 1975 through 2005 in the same format used for the 1970 cohort in Section 6.2.

TABLE A.1 STOCHASTIC DOMINANCE FOR THE 1975 COHORT (MAR-1975 – DEC-2013)

Does an Investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		3rd, 4th, … Degrees	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	2nd, 3rd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

Note that the results for the 1975 cohort are qualitatively the same as those for the 1970 cohort.

TABLE A.2 STOCHASTIC DOMINANCE FOR THE 1980 COHORT (MAR-1980 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		2nd, 3rd, … Degrees	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	2nd, 3rd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

TABLE A.3 STOCHASTIC DOMINANCE FOR THE 1985 COHORT (MAR-1985 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term Gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		N	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, ... Degrees	1st, 2nd, ... Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

TABLE A.4 STOCHASTIC DOMINANCE FOR THE 1990 COHORT (MAR-1990 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		N	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	1st, 2nd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

TABLE A.5 STOCHASTIC DOMINANCE FOR THE 1995 COHORT (MAR-1995 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		N	N	N	N
Long-term government bonds	N	N	N		N	N	N
Intermediate-term government bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	1st, 2nd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

TABLE A.6 STOCHASTIC DOMINANCE FOR THE 2000 COHORT (MAR-2000 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	2nd, 3rd, … Degrees	N		2nd, 3rd, … Degrees	N	N	N
Long-term government bonds	2nd, 3rd, … Degrees	N	N		N	N	N
Intermediate-term government bonds	2nd, 3rd, … Degrees	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	2nd, 3rd, … Degrees	N	N	N	2nd, 3rd, … Degrees	1st, 2nd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.

TABLE A.7 STOCHASTIC DOMINANCE FOR THE 2005 COHORT (MAR-2005 – DEC-2013)

Does an investment in a given row below stochastically dominate investments in Columns?	Large stocks	Small stocks	Long-term corporate bonds	Long-term gov't bonds	Interm.-term gov't bonds	Money market	TIAA RA
Large stocks		N	N	N	N	N	N
Small stocks	N		N	N	N	N	N
Long-term corporate bonds	N	N		3rd, 4th, … Degrees	N	N	N
Long-term Government Bonds	N	N	N		N	N	N
Intermediate-term Government Bonds	N	N	N	N		N	N
Money market	N	N	N	N	N		N
TIAA RA/GRA	N	N	N	N	2nd, 3rd, … Degrees	1st, 2nd, … Degrees	

Note: An entry of "N" indicates that the asset class in the corresponding row does not stochastically dominate the asset class in corresponding column in any of the first four degrees.