Research Dialogue | Issue no. 184
January 2022

A cohort analysis of the investment performance of TIAA Traditional Annuities during working life

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1. Introduction

There is an abundant economic and public policy literature, along with a recognition among the general public, that providing an adequate income for retirement years is a significant challenge for a large portion of the U.S. population. Among the facts supporting that concern are the following.

- In 2019, the average annual expenditures for a "consumer unit" with a reference person aged 65 or older were estimated at $50,220, or $4,185 per month.[1]
- The average monthly Social Security benefit payment in December 2019 for 45 million retired workers was $1,502.85, which is about 36% of the average consumer expenditures for those 65 or older. For surviving spouses of deceased retired workers the average monthly benefit was $786.07, which is less than 20% of average consumer expenditures for those 65 or older.[2]
- The 2021 Federal Poverty Level Guideline for a family of two was $17,420, or $1,451.67 per month[3] — just $51.18 per month below the average Social Security benefit for retired workers.

1 U.S. Bureau of Labor Statistics, *Consumer Expenditure Surveys, CE Tables*, Table 1300, p. 1, at https://www.bls.gov/cex/tables/calendar-year/ mean-item-share-average-standard-error/reference-person-age-ranges-2019.pdf.

2 Social Security Administration, *Annual Statistical Supplement to the Social Security Bulletin*, 2020, SSA Publication No. 113-1170, February 2021, Table 5.A1 at https://www.ssa.gov/policy/docs/statcomps/supplement/2020/supplement20.pdf.

3 U.S. Department of Health & Human Services, 2021 Poverty Guidelines, January 26, 2021 at https://aspe.hhs.gov/2021-poverty-guidelines.

- A Federal Reserve Board 2019 survey of consumers found that: (1) 37% of respondents thought their "retirement savings program is currently on track" while 44% said it was not; (2) only 22% had a defined benefit pension as part of their retirement savings; (3) 22% had less than $10,000 in retirement savings, 25% had between $10,000 and $100,000 in retirement savings, and 23% had $100,000 to $500,000 in retirement savings; and (4) only 14% were "very comfortable…making your own investment decisions in your retirement accounts."[4]
- For many, amounts held in tax-qualified retirement savings programs may be low compared to their retirement income needs. For example, the overall average account balance for participants in a Vanguard 401(k) retirement savings program in 2019 was $106,478 while the median account balance was $25,775. For Vanguard 401(k) participants at least 65 years old, the average 2019 account balance was $216,720 while the median was $64,548.[5]
- The TIAA website annuity calculator reveals that a $100,000 payment yields $419 per month for the lives of two 65-year-old people on a joint life, full survivorship benefits basis. A $500,000 annuity payment yields $2,096 per month under similar asssumptions.[6] This means that average 401(k) balances for those 65 or older will purchase a joint life annuity paying less than $1,000 per month, or less than one-quarter of average consumer expenditures for those 65 or older.

The inability of a significant segment of the population to acquire sufficient savings to fund a retirement with average consumer expenditures for those 65 or older is troubling. And even those who have acquired a meaningful amount of assets have concerns over how best to convert the savings obtained into income to be used through their retirement given the volatility of capital markets over multiple decades.

This paper updates and extends prior research on a financial product—annuities—that can be useful in both the accumulation of savings for retirement and the provision of steady retirement income through the end of life. It does this by evaluating the historical performance of annuity products offered by one of the oldest and largest annuity providers in the U.S.—TIAA—against fee-adjusted index returns for major asset classes over the past fifty years. This research demonstrates that allocating a portion of retirement savings to TIAA Traditional Annuities in place of and in different combinations with other asset classes yields better overall financial performance for a retirement savings portfolio during the accumulation phase for all examined periods over the past fifty years.

TIAA Traditional Annuities deliver these results by capturing the higher returns available in fixed income markets when annuity holders forgo short-term liquidity and focus on the objective of providing income in retirement. As described more fully in this paper, TIAA Traditional Annuity holders are contractually limited in their ability to move assets out of their annuities. Economically as important, however, TIAA Traditional Annuities are designed to provide income in retirement —an inherently long-term objective. These contractual limitations combined with the behavioral objectives of the annuities in a retirement income program mean that TIAA can manage the annuity programs (both assets and liabilities) over a longer investment horizon than, for example, mutual fund investment managers. This means that TIAA can hold investments with less liquidity, longer duration, higher credit risk, etc. better than funds subject to unpredictable redemption demands in the face of market turbulence. This generates higher long-term returns. It also allows TIAA to present to annuity holders an account value not subject to the vagaries of mark-to-market valuations and to set crediting rates that are preannounced and effective for an entire year. TIAA bears the short-term asset valuation risk. Annuity holders do not experience the mark-to-market fluctuations and also benefit from higher returns available from a long-term investment horizon.

The study "The Performance of TIAA's Traditional Retirement Annuity for Selected Investment Cohorts, 1970 – 2005 through 2013" (Babbel, et al., 2015) identified and quantified the significant contribution

4 Board of Governors of the Federal Reserve System, *Supplemental Appendixes to the Report on the Economic Well-Being of U.S. Households in 2019*, May 2020, Appendix B, Questions K0, K2, K20, DC4, respectively, at https://www.federalreserve.gov/publications/2020-supplementalappendixes-2019-Appendix-B-Consumer-Responses-to-2019-Survey-Questions.htm.

5 The Vanguard Group, Inc., *How America Saves 2020*, p. 51, Figure 54, at https://institutional.vanguard.com/ngiam/assets/pdf/has/howamerica-saves-report-2020.pdf. Vanguard is one of the nation's largest providers of 401(k) program service providers with 5 million participant accounts holding over $530 billion in assets. (Page 9, Figure 1.)

6 This is for the purchase of a new annuity with a single premium payment, which differs from the annuity products under consideration in this study. TIAA website, *Lifetime Income Calculator,* at https://shared.tiaa.org/public/publictools/targetincome/annuityEstimator.

that including the TIAA Traditional Retirement Annuity (the "RA") could make to the risk-return tradeoff in the accumulation phase of a retirement portfolio, particularly for investors with moderate to high levels of risk aversion. The TIAA Traditional RA is one of the longest continuously offered annuity products in the world, and rigorously examining its financial performance in a retirement savings portfolio revealed that this annuity, and others like it, can improve both the accumulation of retirement savings and reduce the risk of inadequate income in retirement. This report first updates the 2015 analysis for the Traditional RA through February 2021, adding over seven years of monthly data points reflecting capital market returns during challenging economic conditions. In addition, this study extends the analysis to include two additional TIAA retirement annuity products: TIAA's Supplemental Retirement Annuity (the "SRA," first offered in 1973) and TIAA's Retirement Choice Plus Annuity (the "RCP," first made available in 2006).

Our present analysis focuses (as did our previous one) on the notion of an "investment cohort," where an initial investment is made at the start of the cohort year and held to a specified end point. The cohorts considered in our previous study for the Traditional RA began on March 1, 1970 and then in five year increments to 2005 (a total of eight cohorts). The analysis in the 2015 study for all eight investment cohorts ended on December 31, 2013. For the analysis in the current study, we extend each of the previous cohorts through February 28, 2021 (adding over seven years of data, which means that we have over 50 years of RA performance data for the 1970 cohort) and we add a new investment cohort starting in 2010. As the SRA was initiated in 1973 we start our analysis for the SRA with a 1973 cohort and also examine cohorts starting in 1975 and every five thereafter year to 2010.[7] As the RCP started in June 2006, our analytical efforts here would entail only one or two cohorts of limited length. Instead of examining just one or two short cohorts for the RCP, however, we think it sufficient to examine the performance of the RCP relative to the RA and SRA over the relatively short period of common existence as outlined later.

The next section of this paper briefly describes the TIAA annuity products and the data used in the analyses. Section 3 presents a statistical summary of the financial performance data used in this paper and serves as an introduction to the financial performance of the TIAA annuities and the alternative asset classes as proxied by the fee-adjusted indexes. We then employ three measures of financial performance to evaluate the use of the TIAA RA and SRA in a retirement savings portfolio: mean-variance analysis as measured by Sharpe and Sortino ratios (Section 4), an evaluation of the role of the TIAA annuities in retirement saving portfolios using efficient frontier and optimal portfolio methods (Section 5), and stochastic dominance analysis (Section 6). In Sections 4 and 5 our goal is to explain how the asset classes we study (including the TIAA RA and SRA) rank in terms of investors' risk and return preferences and how this might be implemented in retirement saving portfolios. In Section 6 we use stochastic dominance analysis to evaluate the financial performance of the asset classes in terms of the full distribution of returns. We demonstrate in this study that adding substantial allocations of annuities like the TIAA RA and SRA to retirement savings portfolios improves the financial performance of those portfolios during the accumulation phase. A retirement savings portfolio with a TIAA annuity has a better risk-return result before retirement than a retirement savings portfolio without a TIAA annuity.

2. Description of annuity products, asset classes, and data used

2.1 The TIAA annuities and their crediting rates

TIAA offers annuities under several different contracts/structures to plan sponsors and participants in retirement savings programs. This study focuses on three major TIAA annuity products, as described below. All three annuity products are supported by TIAA's general account assets.

Offered since 1918, the **TIAA Traditional Retirement Annuity** is among the longest-lived financial retirement savings and income products. For over 100 years the RA has been a leading retirement contract for employer retirement plans. In its modern (since at least 1970) form it has been used in 403(b), 401(a), 401(k) and 457(b) public retirement programs. The TIAA Traditional RA is a guaranteed insurance contract and is an individually owned contract or certificate where the plan participant determines the amounts deposited as well as the start of annuity payments.

7 We present information on nine cohorts for the SRA (1973, 1975, 1980, 1985, 1990, 1995, 2000, 2005, and 2010) and for ten cohorts for the RA (adding a 1970 cohort).

During the accumulation (or deferral) phase, participating employers and employees 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 Traditional RA has a 3% minimum annual crediting rate for all premiums remitted since 1979 and from 1970 to 1979 the actual credited rate was never below 7%. The RA crediting rates use the TIAA vintage structure (characterized more fully below) for both new and old money.

Upon retirement, RA account holders can elect lifetime income, interest-only, and IRS required minimum distribution payment options. TIAA annuity lifetime income payments (the retirement income method designed into the RA and the most commonly selected by account holders) are made of two pieces: A minimum guaranteed payment plus the potential for a larger payment based on additional amounts. The additional amounts may be declared on a year-by-year basis. The higher the additional amount, the higher the total payment.[8] Lump-sum withdrawals are not available. Subject to the terms of an employer's plan, all withdrawals and transfers from an RA account as an employee must be paid in ten annual installments.

The **TIAA Supplemental Retirement Annuity** has been offered since March 1973. It has been the historical retirement contract from TIAA for supplemental retirement plans. The SRA is an individually owned contract or certificate where the plan participant determines the amounts deposited and timing of the commencement of annuity payments.

The SRA's minimum crediting rate is 3.0% for all premiums since 1979, and prior to that year the actual crediting rate was never below 7.0%. The SRA crediting rates use the TIAA vintage structure (characterized more fully below) for both new and old money.

SRA annuity holders can elect a lifetime income distribution payment, fixed period annuities, and required minimum distribution payment withdrawal options. The SRA lifetime income payments have a minimum guarantee and the potential for larger payouts similar to those available in the RA. SRA annuity holders can also elect systematic and lump-sum cash withdrawal options. The systematic and lump-sum cash withdrawal options make the SRA a more liquid investment than the RA. The fixed period annuity option (e.g., five years, ten years, etc.) available for the SRA is not available for the RA and, therefore, represents another liquidity improvement for the SRA over the RA. The tradeoff for these additional withdrawal options is a reduced crediting rate—typically between 50 to 75 basis points— as discussed in more detail below.

The **TIAA Retirement Choice Plus Annuity** ("RCP") has been offered since June 2006. It differs from the RA and SRA in several significant features. First, the RCP is a group contract controlled by the employing plan sponsor. The employing plan sponsor controls the funding options in the plan, can add or delete investment options, and can "map" assets to other funds. Unlike the RA and SRA, the plan sponsor can eliminate the RCP as an available option for participating employees under specified conditions. The RCP is generally used for supplemental retirement plans. With the RCP, the plan sponsor is allowed to direct plan level expenses deductions. As a newer product, the RCP can be used in more types of plan structures than the RA and SRA.

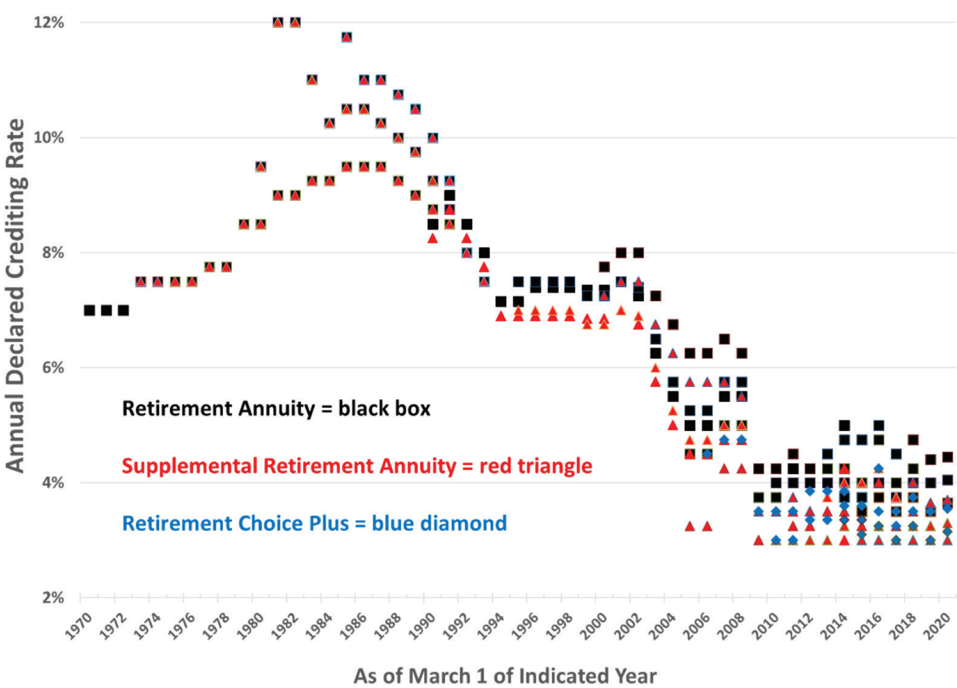
The RCP's minimum crediting rate during accumulation ranges between 1% and 3%, depending in part upon interest rate conditions. Its crediting rate, therefore, can fall below the 3% minimum specified for the RA and SRA. The RCP's lower minimum rate provides TIAA greater flexibility managing capital requirements, which can result in higher crediting rates than the RA/SRA in higher interest rate environments. The RCP crediting rates use the TIAA vintage structure (characterized more fully below) for both new and old money.

RCP annuity holders can elect a lifetime income distribution payment, interest-only, and required minimum distribution payment options. The RCP lifetime income payments have a minimum guarantee and the potential for larger payouts similar to those specified for the RA. RCP annuity holders can also elect systematic and lump-sum cash withdrawal options. The RCP, therefore, has liquidity similar to that of the SRA while the RA is designed for lifetime income. Fixed period annuity payment options are not available with the RCP because of the flexibility allowed in the RCP for withdrawals.

8 The focus of this current study is on the accumulation phase. Detailed examination of the options available during the withdrawal phase is deferred to future research. Annuitization of TIAA retirement annuities in the withdrawal phase is not required. Other types of withdrawals and transfers are available.

Figure 1 below depicts the TIAA annuity credited rates from March 1, 1970 through February 28, 2021. The traditional RA crediting rates are represented by the black boxes. The SRA crediting rates are represented by the red triangles and the RCP crediting rates are represented by the blue diamonds.

Figure 1. TIAA annuity credited rates, 1970–2020



As Figure 1 shows, RA and SRA rates were the same from 1973 into 1987. During that period, the SRA charged a front-end load of 0.5% from 1973 through 1981 and then 1.5% from 1982 through 1987. From 1988 on, the SRA eliminated the front-end load and instead credited a lower rate. The front-end load from 1973 through 1987 and the lower crediting rate thereafter for the SRA compared to the RA reflects the cost of supplying the SRA's liquidity compared to the RA. Allowing SRA holders the ability to take lump-sum withdrawals or move funds in the SRA to other investments available in the retirement saving programs requires TIAA to keep more lower-yielding liquid assets in its general account investments compared with the RA accounts. The RCP has liquidity characteristics similar to the SRA and, therefore, also has lower crediting rates than the RA. Our later analysis of the SRA performance adjusts appropriately for the front-end loads from 1973 through 1987 and their subsequent elimination.

When retirement plan participants make contributions to annuity products in their plans, insurers invest those contributions in financial assets such as bonds and mortgages. Since market yields change over time and participants contribute to their retirement plans over long periods of time, an insurer holds a portfolio of invested assets of various ages and yields.

TIAA, like many insurers, follows an investment generation, or "vintage," approach where annuity crediting rates reflect the yields of the mix of assets purchased by each contribution. The yields earned by old vintages, however, are not fixed forever; they change over time as the purchased assets provide interest payments or cash upon maturity. The vintage approach invests the interest payments and principal repayments of previously held assets into new assets at new interest rates. The cash flow produced by old assets is reinvested at currently available rates. As coupon payments and the principal of maturing older bonds are reinvested at current rates, the aggregate yields earned by old vintages tend to move toward new vintage yields. The annually credited rates on the TIAA annuities reflect these changing yields over time. In a rising interest rate environment, interest rates credited to new contributions will tend to be higher than rates for older contributions, while in a falling rate environment the opposite tends to be true.

Figure 1 indicates how this process worked at TIAA for over 50 years. As interest rates rose during the 1970s, new money entering either the RA or the SRA would earn higher crediting rates—rising from 7.0% in 1970 to 12.0% in 1981. As interest rates declined from the early 1980s to around 2009, crediting rates floated downward for both new and old money, the latter in a complex manner reflecting the inflows from earlier periods.

In no period during this study has the TIAA RA or SRA crediting rate been less than its contractual minimum guaranteed rate of 3%. As allowed by the contract, the RCP's crediting rates did drop below 3% in 2012, 2013, and 2020.

Over the period from March 1, 1988 through February 28, 2021, the average crediting rate for the RA exceeded that for the SRA in the cohorts studied by approximately 0.6%. Over the period from June 1, 2006 (the introduction date for the RCP) and February 28, 2021, the average crediting rate for the RCP exceeded that for the SRA by approximately 0.2%. The RCP exhibited more variability in crediting rates than the SRA from June 2006 through February 2021, both dropping below and rising above the SRA's rate for the same period. Over the RCP's existence its average crediting rate fell in between the average crediting rates for the RA and SRA. While we do not have enough data for the RCP to conduct the rigorous analyses performed by cohorts for the RA and SRA in the following sections, the fact that the RCP's average crediting rate falls between those of the RA and the SRA allows one to deduce that its performance in a retirement savings portfolio would fall in between that of the RA and the SRA.

2.2 The data for the other asset classes: stocks, bonds, and T-Bills

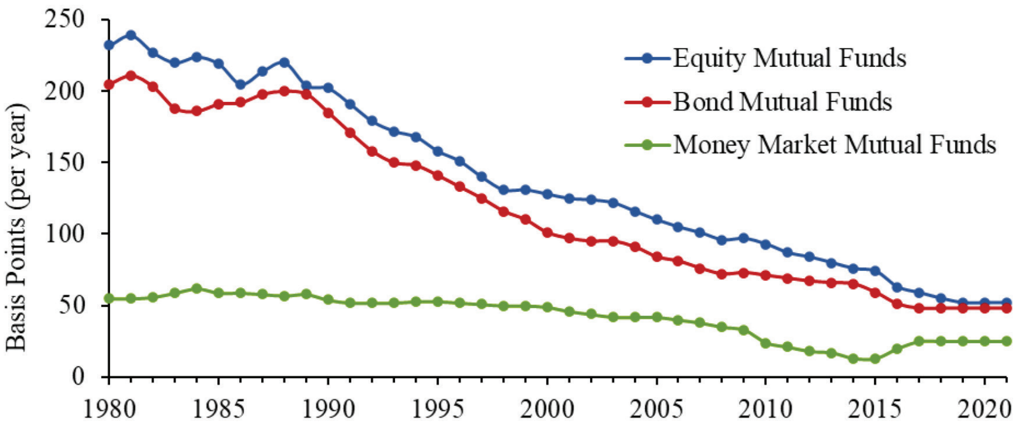
In addition to the TIAA annuities, this study uses data calculated from indexes reflecting the financial performance of broad asset classes. The asset classes and associated indexes used in this study are listed below.

- **Large US Stocks (LS).** This series corresponds to the S&P 500 Index.
- **Small US Stocks (SS).** This series includes about 1,700 stocks in the lower range of market capitalization. The data are from Directional Fund Advisors US Micro Cap Portfolio.
- **Long-Term US Corporate Bonds (LTCB).** The index for this series is the Citi USBIG Corp Index AAA/AA 10+ Year (High-Grade Bond Index).
- **Long-Term US Government Bonds (LTGB).** We use the Barclays 20+ Year Treasury Bond Fund index, available on Bloomberg from February 28, 1992 through the present. Returns for the period from March 1, 1970 through February 28, 1992 were obtained from Morningstar's Ibbotson SBBI 2014 Classic Yearbook as discussed in more detail in Appendix A.
- **Intermediate-Term Government/Credit (ITG/C)**. This series is the Barclays Intermediate US Government/ Credit Total Return Index, available on Bloomberg from March 1973 through February 2021. Prior to March 1973, SBBI data for the intermediate-term government bond series are used from March 1970 through February 1973 as discussed in more detail in Appendix A.
- **Money Market (MM).** For money market returns we use the ICE Bank of America Merrill Lynch US 3-Month Treasury Bill Index, available in Bloomberg from December 31, 1977 through February 2021. For the period before 1978 we splice this series with SBBI's money market returns as discussed in more detail in Appendix A.

Net Return Construction. The asset classes we consider as investment alternatives to the RA and the SRA are represented by index values and, as such, one cannot invest in them directly. We use average mutual fund fees and expenses, expressed as annual percentages, reported by the Investment Company Institute (ICI), to approximate the net returns that mutual funds benchmarked to these indexes would have obtained over the years covered by the different cohorts.

Data provided by ICI for average mutual fund fees and expenses are reported in their various research publications and date back to 1980. We assume that these fees and expense percentages for the years 1973 through 1979 are the same as for 1980 so that to the extent that average fees and expenses were higher during this period, the net returns we obtain on the affected asset classes are slightly overstated. As Figure 2 shows, average mutual fund fees and expenses began to decrease significantly in the late 1980s, driven mostly by the switch from load-funds to no-load mutual funds.

Figure 2. Average mutual fund fees & expenses – ICI



3. Summary statistics—A first look at relative performance

We first present a comparison of the average monthly return series for the different investment cohorts and corresponding sample periods. The sample periods for each studied investment cohort are shown in Table 1.

Table 1. Sample periods and number of monthly observations by cohort

Cohort	Sample period	No. of monthly observations	Years in sample
1970	Mar-1970 – Feb-2021	612	51
1973	Mar-1973 – Feb-2021	576	48
1975	Mar-1975 – Feb-2021	552	46
1980	Mar-1980 – Feb-2021	492	41
1985	Mar-1985 – Feb-2021	432	36
1990	Mar-1990 – Feb-2021	372	31
1995	Mar-1995 – Feb-2021	312	26
2000	Mar-2000 – Feb-2021	252	21
2005	Mar-2005 – Feb-2021	192	16
2010	Mar-2010 – Feb-2021	132	11

Note: The RA product is the only TIAA product in the 1970 cohort. Both the RA and SRA products are in the remaining cohorts.

Table 2 reports the monthly net return summary statistics for all asset classes studied by cohort. Figure 3 plots the arithmetic means of monthly net returns for all asset classes studied by cohort. The corresponding annual net return summary statistics are presented in Table A1 and Figure A7 in Appendix A.

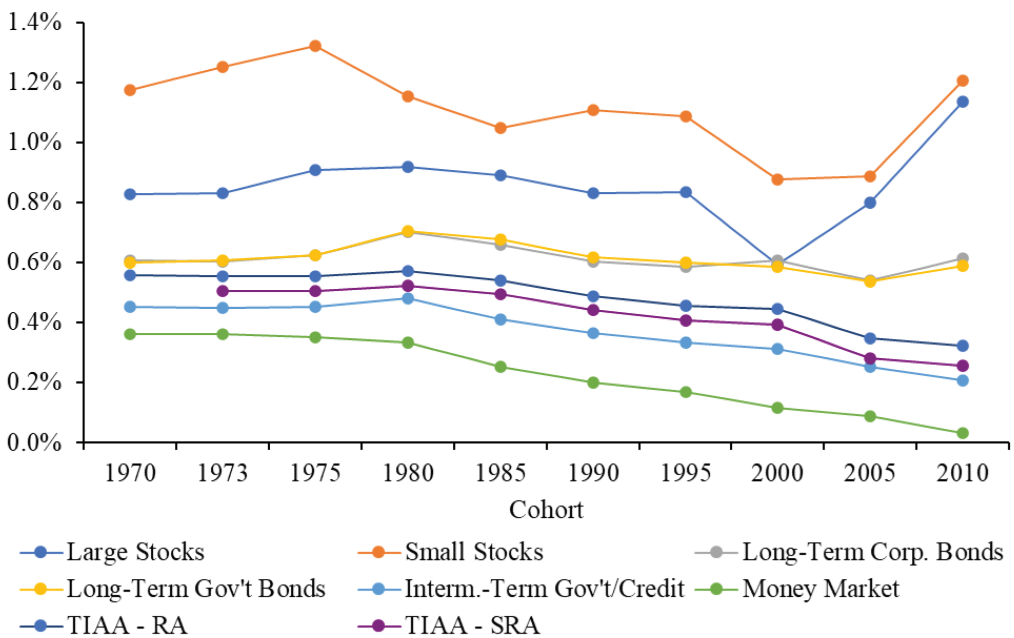
In Table 2 and Figure 3 we observe the sensitivity of large and small stock average returns to the sample period corresponding to cohorts we consider. Especially interesting is the large dip in large stock average returns for the 2000 cohort where the 2000 Dotcom Bubble burst and the 2007-8 Financial Crisis are overrepresented. These two events also had an effect on the small stock average returns for the 2000 and 2005 cohorts, mainly because small stocks lagged in performance compared to large stocks. This is especially evident for the periods since 2005 and 2010, where large stock average returns have been as close as ever observed to small stocks, without a noticeable increase in their volatility. We observe that both the RA and the SRA means are between those of the Long-Term Government Bond (which are very similar to the corresponding Long-Term Corporate Bond means) and the corresponding Intermediate-Term Government/Credit. As expected, the monthly average RA return is about 5 basis points higher than the monthly average SRA return for all cohorts considered.

The results presented in Table 2 and Figure 3 show that both TIAA's RA and SRA have outperformed intermediate-term bonds and money market instruments on a return basis, and with a significantly smaller volatility, across all investment cohorts considered. The results presented in Table 2 and Figure 3 form the basis for the examination of the RA and the SRA that we present in the following sections on mean-variance analysis with Sharpe and Sortino ratios, efficient frontier structures, optimal portfolio construction, and stochastic dominance results.

Table 2. Summary statistics for monthly net returns – all asset classes and cohorts

Cohort	1970	1973	1975	1980	1985	1990	1995	2000	2005	2010
Asset Class	Mar-1970 Feb-2021	Mar-1973 Feb-2021	Mar-1975 Feb-2021	Mar-1980 Feb-2021	Mar-1985 Feb-2021	Mar-1990 Feb-2021	Mar-1995 Feb-2021	Mar-2000 Feb-2021	Mar-2005 Feb-2021	Mar-2010 Feb-2021
	ARITHMETIC MEAN									
Large Stocks	0.83%	0.83%	0.91%	0.92%	0.89%	0.83%	0.83%	0.59%	0.80%	1.14%
Small Stocks	1.18%	1.25%	1.32%	1.16%	1.05%	1.11%	1.09%	0.88%	0.89%	1.21%
Long-Term Corp. Bonds	0.61%	0.60%	0.62%	0.70%	0.66%	0.60%	0.59%	0.61%	0.54%	0.61%
Long-Term Gov't Bonds	0.60%	0.61%	0.62%	0.71%	0.68%	0.62%	0.60%	0.59%	0.54%	0.59%
Interm-Term Gov't/Credit	0.45%	0.45%	0.45%	0.48%	0.41%	0.36%	0.33%	0.31%	0.25%	0.21%
Money Market	0.36%	0.36%	0.35%	0.33%	0.25%	0.20%	0.17%	0.11%	0.09%	0.03%
TIAA-RA	0.56%	0.56%	0.55%	0.57%	0.54%	0.49%	0.46%	0.44%	0.35%	0.32%
TIAA-SRA	N/A	0.51%	0.50%	0.52%	0.50%	0.44%	0.41%	0.39%	0.28%	0.26%
	GEOMETRIC MEAN									
Large Stocks	0.73%	0.73%	0.82%	0.82%	0.80%	0.74%	0.74%	0.50%	0.71%	1.06%
Small Stocks	0.98%	1.06%	1.14%	0.98%	0.87%	0.93%	0.90%	0.69%	0.71%	1.04%
Long-Term Corp. Bonds	0.57%	0.56%	0.59%	0.66%	0.63%	0.57%	0.55%	0.57%	0.50%	0.58%
Long-Term Gov't Bonds	0.54%	0.55%	0.57%	0.65%	0.62%	0.56%	0.54%	0.52%	0.47%	0.53%
Interm-Term Gov't/Credit	0.45%	0.44%	0.44%	0.47%	0.40%	0.36%	0.33%	0.31%	0.25%	0.21%
Money Market	0.36%	0.36%	0.35%	0.33%	0.25%	0.20%	0.17%	0.11%	0.09%	0.03%
TIAA-RA	0.56%	0.56%	0.55%	0.57%	0.54%	0.49%	0.46%	0.44%	0.35%	0.32%
TIAA-SRA	N/A	0.51%	0.50%	0.52%	0.50%	0.44%	0.41%	0.39%	0.28%	0.26%
	STANDARD DEVIATION									
Large Stocks	4.40%	4.44%	4.31%	4.36%	4.36%	4.22%	4.35%	4.37%	4.26%	4.04%
Small Stocks	6.20%	6.14%	5.95%	5.80%	5.82%	5.88%	6.13%	6.11%	5.95%	5.72%
Long-Term Corp. Bonds	2.76%	2.79%	2.78%	2.82%	2.55%	2.56%	2.69%	2.85%	2.96%	2.57%
Long-Term Gov't Bonds	3.30%	3.33%	3.37%	3.46%	3.29%	3.27%	3.43%	3.61%	3.76%	3.67%
Interm-Term Gov't/Credit	1.17%	1.16%	1.16%	1.14%	0.92%	0.86%	0.84%	0.84%	0.76%	0.65%
Money Market	0.30%	0.31%	0.31%	0.32%	0.22%	0.19%	0.18%	0.15%	0.14%	0.07%
TIAA-RA	0.14%	0.14%	0.14%	0.19%	0.18%	0.12%	0.11%	0.11%	0.03%	0.01%
TIAA-SRA	N/A	0.14%	0.15%	0.19%	0.19%	0.14%	0.12%	0.12%	0.03%	0.01%

Figure 3. Arithmetic means of monthly net returns – all cohorts



4. Mean-variance analysis as measured by Sharpe and Sortino ratios

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

Beginning as early as 1967, Arditti determined that investors considered measures of down-side risk beyond variance, and numerous additional studies along similar lines have continued to demonstrate that variance is an inadequate measure of either security or portfolio risk. However, if the distribution of market returns can be fully described by its first two moments, then restricting 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 that 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 RA and SRA to dominate other asset classes in terms of overall financial performance and thereby replace some asset classes in a retirement portfolio.

For our first examination of mean-variance analyses of the TIAA annuities in retirement saving portfolios, we turn to the Sharpe ratio commonly used in asset allocation and performance measurement.[9] The Sharpe ratio measures excess return per unit of risk according to the formula:

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

9 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).

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.[10] 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:

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

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 calculated Sharpe and Sortino ratios for monthly net return data are reported in Table 3. We make the following observations about the patterns observed in Table 3.

First, a systematic pattern we clearly observe is that the RA and SRA products have notably higher Sharpe and Sortino ratios than the alternative investment classes across all the cohorts we study. The Sharpe and Sortino ratios for the non-TIAA investment classes are no larger than 0.5. The lowest Sharpe ratio for the TIAA products is 0.92 (for the 1970 cohort) and this rises to 4.31 for the 2010 cohort. The lowest Sortino ratio is 4.36. In every cohort the Sharpe and Sortino ratios for the RA and SRA substantially exceed those calculated for the alternative investment classes. This is strong evidence in favor of the notably high return-to-risk ratio of the RA and SRA investments as well as their resilience over time.

10 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).

Table 3. Sharpe and Sortino ratios for monthly returns

	Large Stocks	Small Stocks	Long-Term Corporate Bonds	Long-Term Gov't Bonds	Intermediate-Term Gov't/ Credit Bonds	TIAA RA	TIAA SRA
	1970 COHORT						
Sharpe	0.11	0.13	0.09	0.07	0.08	0.92	Not available
Sortino	0.15	0.20	0.14	0.11	0.12	17.59	
	1973 COHORT						
Sharpe	0.11	0.14	0.09	0.07	0.08	0.89	0.65
Sortino	0.15	0.22	0.13	0.12	0.12	16.57	4.36
	1975 COHORT						
Sharpe	0.13	0.16	0.10	0.08	0.09	0.91	0.67
Sortino	0.19	0.24	0.15	0.13	0.14	20.49	5.01
	1980 COHORT						
Sharpe	0.13	0.14	0.13	0.11	0.14	1.25	0.97
Sortino	0.19	0.21	0.21	0.17	0.22	39.85	7.94
	1985 COHORT						
Sharpe	0.15	0.14	0.16	0.13	0.18	2.43	2.09
Sortino	0.21	0.20	0.26	0.21	0.28	Undefined	126.61
	1990 COHORT						
Sharpe	0.15	0.15	0.16	0.13	0.20	2.23	1.91
Sortino	0.22	0.23	0.25	0.20	0.31	Undefined	Undefined
	1995 COHORT						
Sharpe	0.15	0.15	0.16	0.13	0.20	2.40	2.01
Sortino	0.22	0.22	0.25	0.21	0.32	Undefined	Undefined
	2000 COHORT						
Sharpe	0.11	0.12	0.17	0.13	0.24	2.76	2.29
Sortino	0.16	0.18	0.28	0.21	0.39	Undefined	Undefined
	2005 COHORT						
Sharpe	0.17	0.13	0.15	0.12	0.22	2.11	1.47
Sortino	0.24	0.19	0.26	0.20	0.38	Undefined	Undefined
	2010 COHORT						
Sharpe	0.27	0.20	0.23	0.15	0.27	4.31	3.53
Sortino	0.45	0.32	0.39	0.28	0.49	Undefined	Undefined

Second, starting with the 1985 cohort, for the RA, and for all subsequent cohorts, for both the RA and the SRA, the Sortino ratio is not defined. The reason for this unusual result is that *not a single RA or SRA 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 (for the RA) and later.[11]

11 For the earlier cohorts, the notably high Sortino ratio calculated for the TIAA RA asset, relative to those calculated for the other investment classes, results from the fact that throughout the entire 612-month period for the 1970 cohort, the risk-free rate exceeded the TIAA RA return only for 61 months (or 10.0% of the number of monthly observations) and even then, by small amounts. For the 1973 cohort, this happened 61 out of 576 months, or 10.6% of the time. Hence, there were only a few small observations that factored into the denominator.

The Sharpe and Sortino ratios calculated for the SRA for the 1973, 1975, and 1980 cohorts are smaller than the corresponding ratios for the RA, but still significantly larger than those for the alternative asset classes. The lower SRA Sortino ratio is expected given the SRA's lower return pattern. When calculating the Sortino ratio for the SRA, there are 147 out of 576 months in the sample, or 25.5% of the time, where the risk-free rate exceeded the TIAA SRA return.

Third, when comparing the Sharpe and Sortino ratios across large and small stocks, long-term corporate and government bonds, and intermediate-term government/credit bonds, we note that small stocks generally enjoy larger Sharpe and Sortino ratios for the 1970, 1975, and 1980 cohorts. These are time periods long enough for small stock returns to overcome the bear market of 1973-1982 related to the energy crisis, the 2000-2002 Dotcom Bubble crash, the 2007-2009 Financial Crisis, and the short but pronounced dip in late February and March of 2020 caused by the shut-down of economic activity due to the Covid-19 pandemic. For the 1985 through the 2010 cohorts, however, the largest Sharpe and Sortino ratios generally correspond to intermediate-term government/credit and long-term corporate bonds.[12]

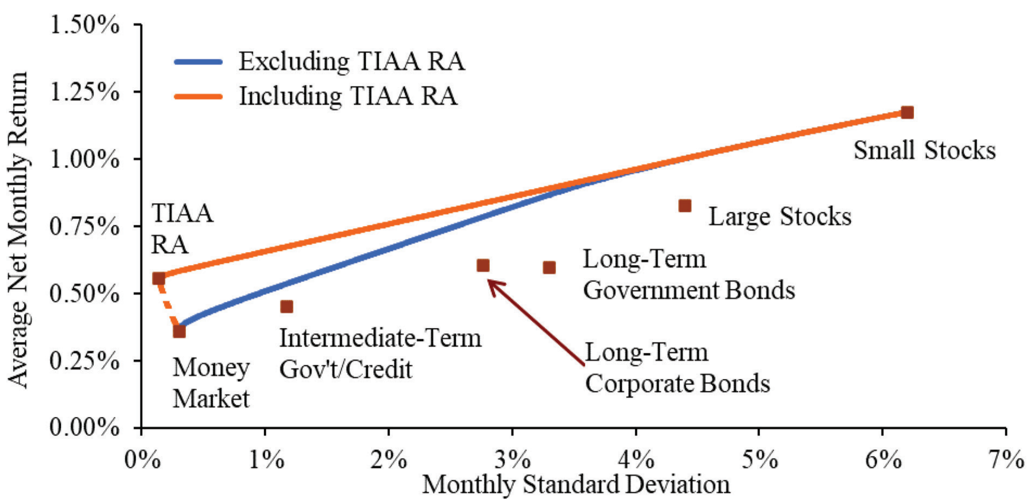
5. Mean-variance analysis: Efficient frontiers and optimal portfolios

In this section we present evidence that, when included in optimal mean-variance portfolios, the RA and SRA enhance the financial characteristics of the retirement savings portfolios during the accumulation phase. Indeed, the RA and SRA advantage for retirement savings 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/credit bonds, long-term corporate and government bonds, and even large stocks. In other words, optimal mean-variance portfolios always include RA and SRA 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.

5.1 The 1970 cohort—RA

When discussing summary statistics for net monthly return data in Table 2 and Figure 3 we observed that across all of the investment cohorts we consider RA and SRA returns exhibited both a higher mean return and lower volatility than either money market or intermediate-term government/credit bond returns. This feature can be seen in Figure 4 below, where we plot two efficient frontiers, one including all seven asset classes in our study and one that excludes RA returns for the 1970 investment cohort.

Figure 4. Efficient frontiers with and without the TIAA-RA – 1970 cohort



12 Appendix A presents an analysis of Sharpe and Sortino ratios for these same asset classes on an annual basis.

Figure 4 graphically displays the average net monthly returns and associated monthly standard deviations for the seven asset classes presented in Table 2 for the 1970 cohort. Average net monthly returns are presented on the vertical axis (starting at 0% and rising to 1.5% per month) and the associated calculated monthly standard deviations are presented on the horizontal axis (with volatility/risk increasing moving to the right). The average net monthly return and associated monthly standard deviation of each of the seven studied asset classes is mapped into this return/volatility space. The high return/high volatility small stock asset class is placed in the upper right of the graph. The low return/low volatility money market asset class is placed in the lower left of the graph. The blue line represents the efficient investment frontier when the RA is not present as an investment option. This efficient frontier represents the highest expected return possible for a given level of risk or, equivalently, the lowest risk possible for a given level of return from a portfolio constructed from the six non-annuity asset classes. The orange line allows for an investment in the RA. It is higher than the blue line meaning that a portfolio where investing in the RA is possible yields a higher return for a given level of risk than the portfolio without the RA.

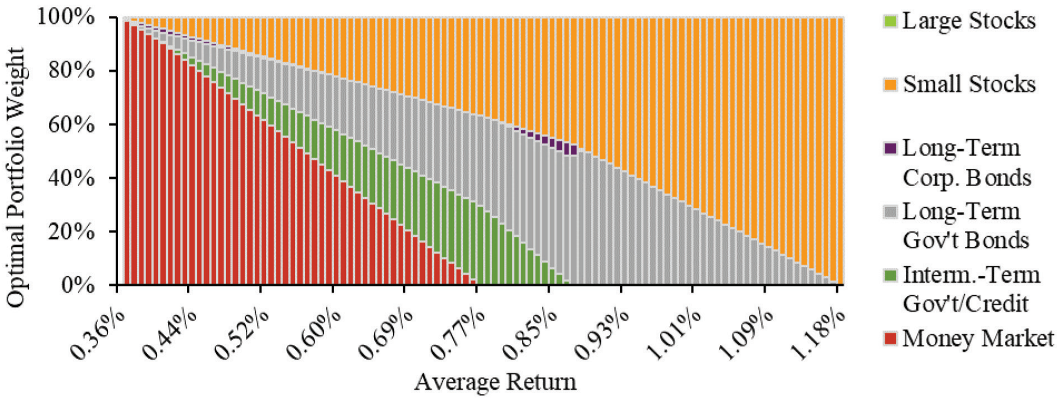
Adding the ability to invest in the RA in 1970 yields a return-risk profile that is better (higher return at the same risk or lower risk at the same return) than a portfolio that does not have the RA. This is because the RA has a higher return than the money market and intermediate bond classes and has a better return-risk profile than other fixed income classes. It is interesting to note the potentially large scope for improvement that inclusion of RA investments brings to an optimal mean-variance portfolio for more than two-thirds of the expected return range between money market and small stocks.

Figure 4 does not show the full extent to which the RA contributes to an optimal portfolio since it says nothing about the relative allocations of wealth among RA investments and other investments at different points along the efficient frontier. The next two graphs show the asset class weights in optimal portfolios without the RA and with the RA for the 1970 cohort.

Figure 5 displays the optimal weights of each asset class for the efficient frontier presented in Figure 4. The vertical axis measures the weight of the asset class in an optimal portfolio. The horizontal axis displays the average monthly net return available for the 1970 cohort. At low average monthly net returns, the money market asset class (a low return/low risk choice) comprises most of the portfolio. As monthly net returns increase, higher returning/higher risk asset classes enter and eventually comprise the entirety of the portfolio. At the highest available monthly net return available for the 1970 cohort, the small stock asset class is the only holding. Consistent with the pattern exhibited in Figure 4 and received financial theory, higher monthly net average returns are associated with a higher volatility of those returns.

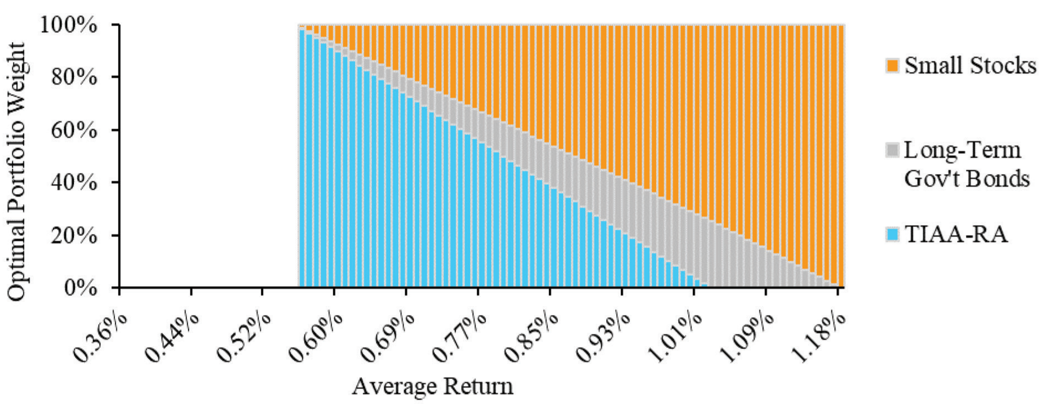
We note over the range of historical expected returns, all studied asset classes are part of possible efficient portfolios, although large stocks only show up in a very small proportion for the lowest monthly average return and long-term corporate bonds also have a small presence. Small stocks, long-term government bonds, money market, and, to a smaller extent, intermediate-term government/credit assets all participate in efficient portfolios in a larger proportion, depending on the risk-return level of the efficient portfolio.

Figure 5. Optimal weights excluding the TIAA-RA – 1970 cohort



In Figure 6, we introduce the TIAA RA into the mix of optimal portfolios, where we observe the extent to which the RA displaces every other asset class except small stocks and long-term government bonds. Adding the RA to the retirement portfolio completely eliminates any allocation to short- and intermediate-term fixed income assets—money market and the intermediate-term government/credit are not part of the retirement portfolio.

Figure 6. Optimal weights including the TIAA-RA – 1970 cohort



Figures 5 and 6 are intended to be compared to one another and this is the reason why the horizontal scale is the same in all cases. The gap in Figure 6 immediately to the right of the vertical axis shows the range of lower average returns that belong to the inefficient part of the frontier in Figure 4. Including the RA into the portfolio eliminates low returns available from other asset classes. This comparison also allows us to see the degree to which the RA replaces money market and long-term corporate bonds (entirely), and intermediate-term assets (significantly) in efficient portfolios.

5.2 The 1973 cohort—RA and SRA

Not surprisingly, the performance of the 1973 RA cohort is very similar to that of the 1970 RA cohort (compare Figure 4 with Figure 7). Figure 8 shows that the efficient frontier with the SRA included looks qualitatively similar to the efficient frontier with the RA included (Figures 4 and 7). The SRA, however, exhibits about 5 basis points per month (60 basis points per year) lower returns on the efficient frontier.

Figure 7. Efficient frontiers with and without the RA – 1973 cohort

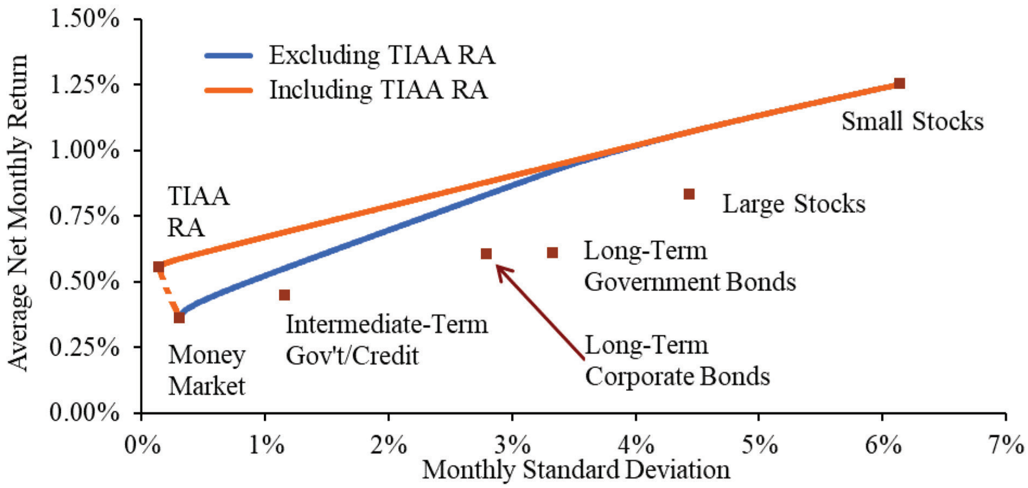
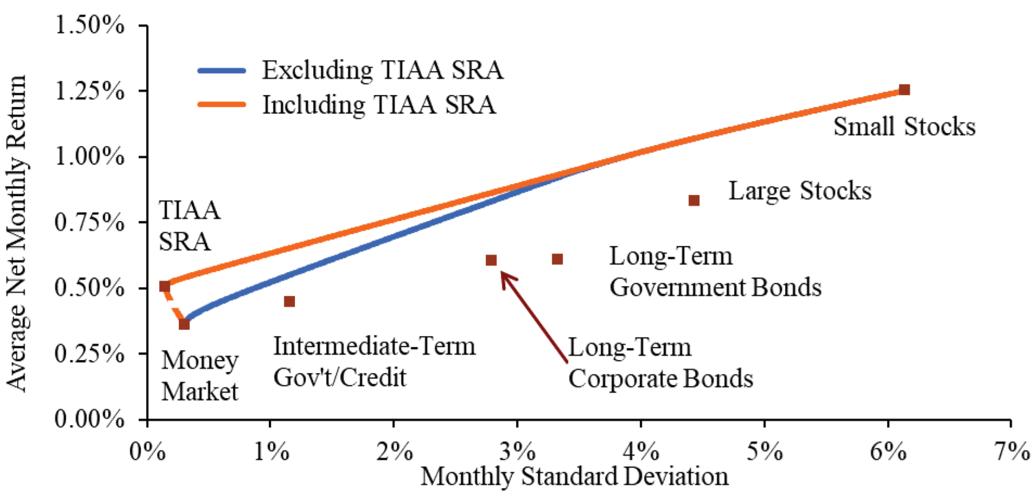


Figure 8. Efficient frontiers with and without the SRA – 1973 cohort



The optimal portfolio weights are depicted in Figure 9 (with neither the RA or SRA), Figure 10 (with the RA), and Figure 11 (with the SRA).

Figure 9. Optimal portfolio weights – Excluding the RA & SRA

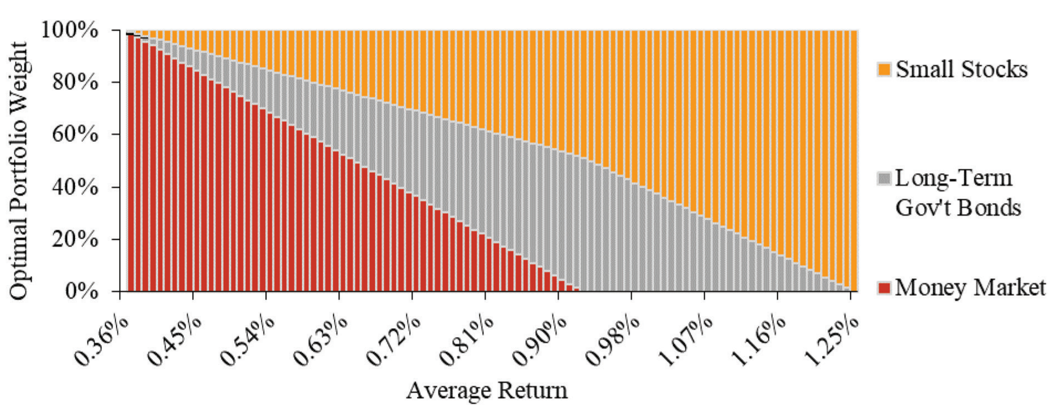


Figure 10. Optimal portfolio weights – Including the RA

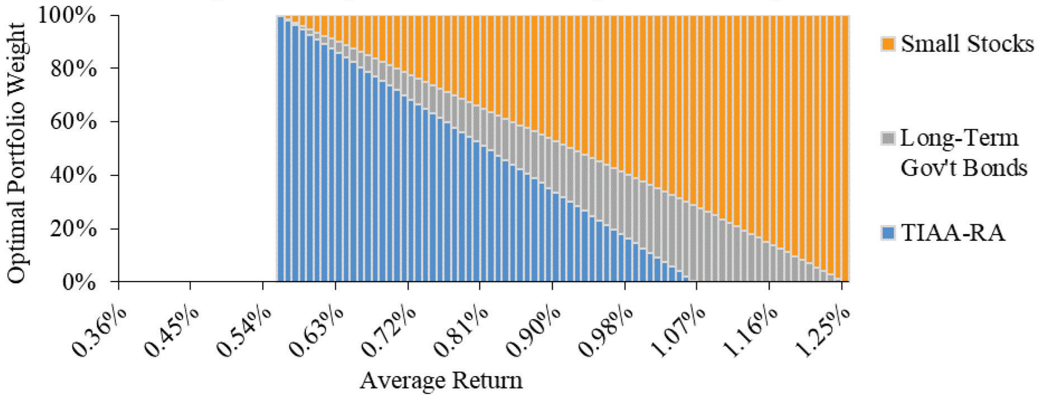
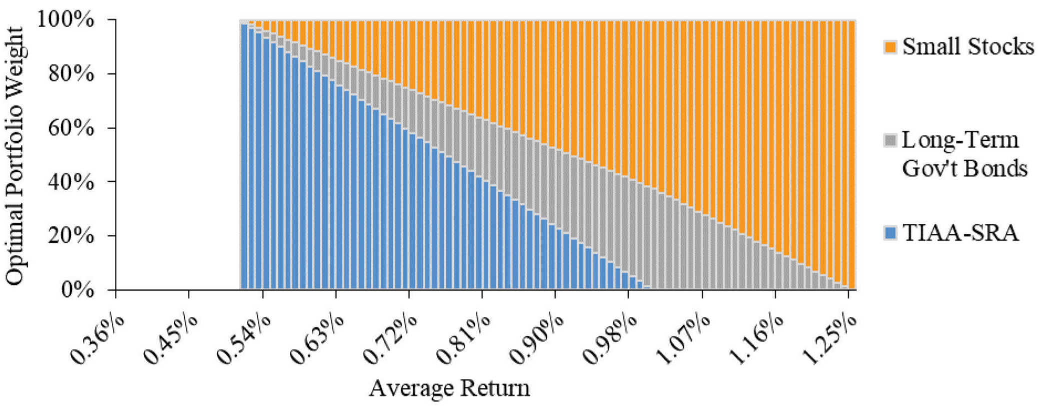


Figure 11. Optimal portfolio weights – Including the SRA



As we observed for the 1970 cohort (Figures 5 and 6), Figures 9 through 11 are intended to be compared to one another, and this is the reason why the horizontal scale is the same in all cases. The gaps in Figures 10 and 11 immediately to the right of the vertical axis show the range of lower average returns belonging to the inefficient part of the frontiers in Figures 8 and 9, respectively. This comparison allows us to see the degree to which the RA and SRA replace money market (entirely) and intermediate-term assets (significantly) in efficient portfolios.

5.3 The 1975 and subsequent cohorts

Efficient frontiers and associated optimal portfolio weights with and without the RA and SRA for the 1970 through 2010 cohorts are shown in Figures B1 through B32 in Appendix B. The graphs for the 1975 through 2010 cohorts in Appendix B repeat the approach presented in Figures 7 through 11 for the 1973 cohort to compare first the relative positions of the efficient frontiers with and without the RA and SRA and then to portray the optimal weight distributions across all alternative assets with and without the RA and the SRA. General patterns across the cohorts are consistent. Adding the RA or SRA to the retirement portfolio improves the position of the efficient frontier and replaces allocation to money market and intermediate-term fixed income in the optimal portfolios. The optimal portfolios over all cohorts consist of the RA or SRA along with long-term government bonds and equities (large and small capitalization) in various combination depending upon the average return realized.

It is interesting to observe in Appendix B the increasing curvature of the efficient frontier graphs for the more recent cohorts as capital market returns in later years become more determinant in the overall results. An illustration of the increasing curvature of the efficient frontier is to compare the 2010 cohort in Figures 12 and 13 below to the 1973 cohort in Figures 7 and 8 above. The return-risk position of the small stock asset class changed only marginally from the 1973 cohort to the 2010 cohort. The return-risk position of fixed income asset classes dropped notably in the 2010 cohort compared to the 1973 cohort. The increasing curvature, therefore, is partially due to the historically low interest rates in the later years as the return on the less risky fixed income asset classes (including the RA and the SRA) declined relative to risk. We also note, less obvious in the graphs, that this increasing curvature of the efficient frontier is a result of the increasingly negative correlation between small stocks and long-term government bonds as explained more fully in Appendix C.

In general, we note the ubiquitous dominance of the RA and the SRA in retirement portfolios to the exclusion of money market and intermediate-term government/credit investments. These results are consistent with what we have shown in the summary statistics section.

Figure 12. Efficient frontiers with and without the RA – 2010 cohort

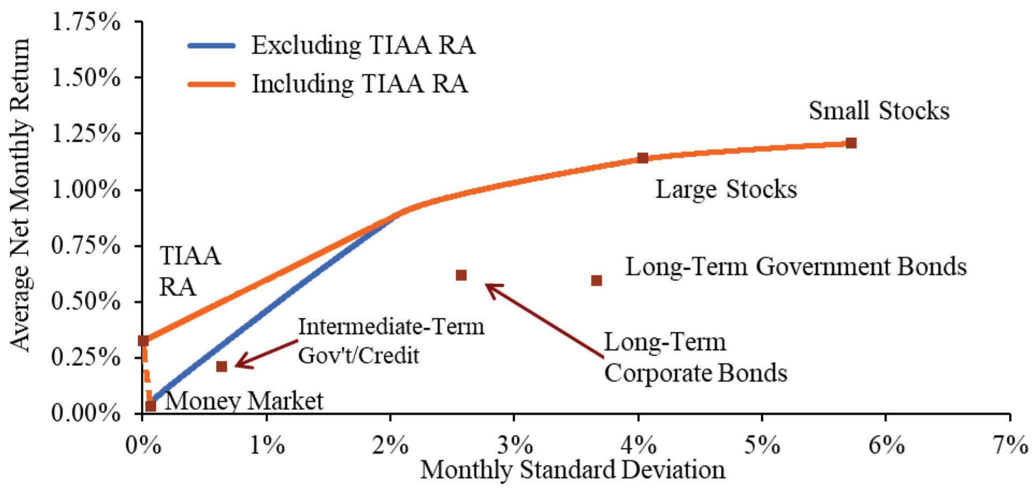


Figure 13. Efficient frontiers with and without the SRA – 2010 cohort

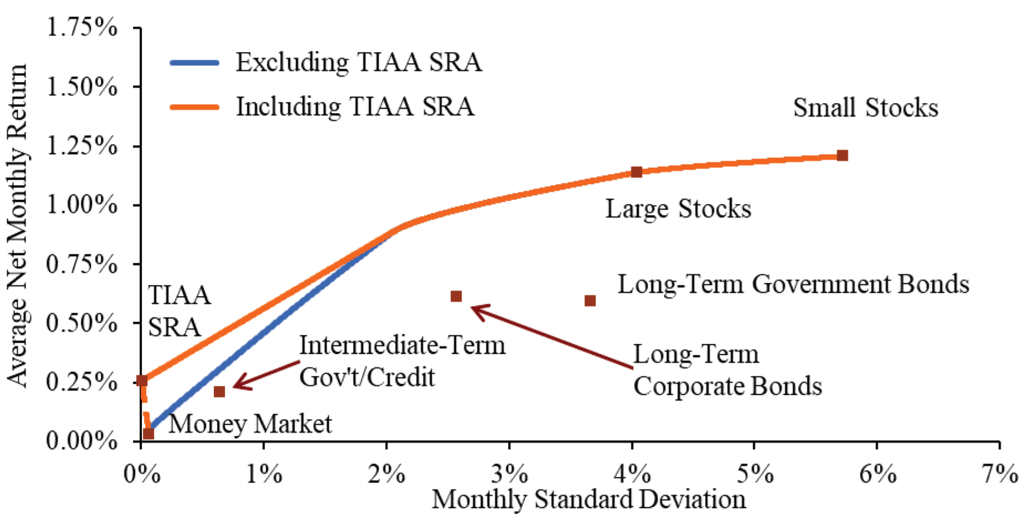
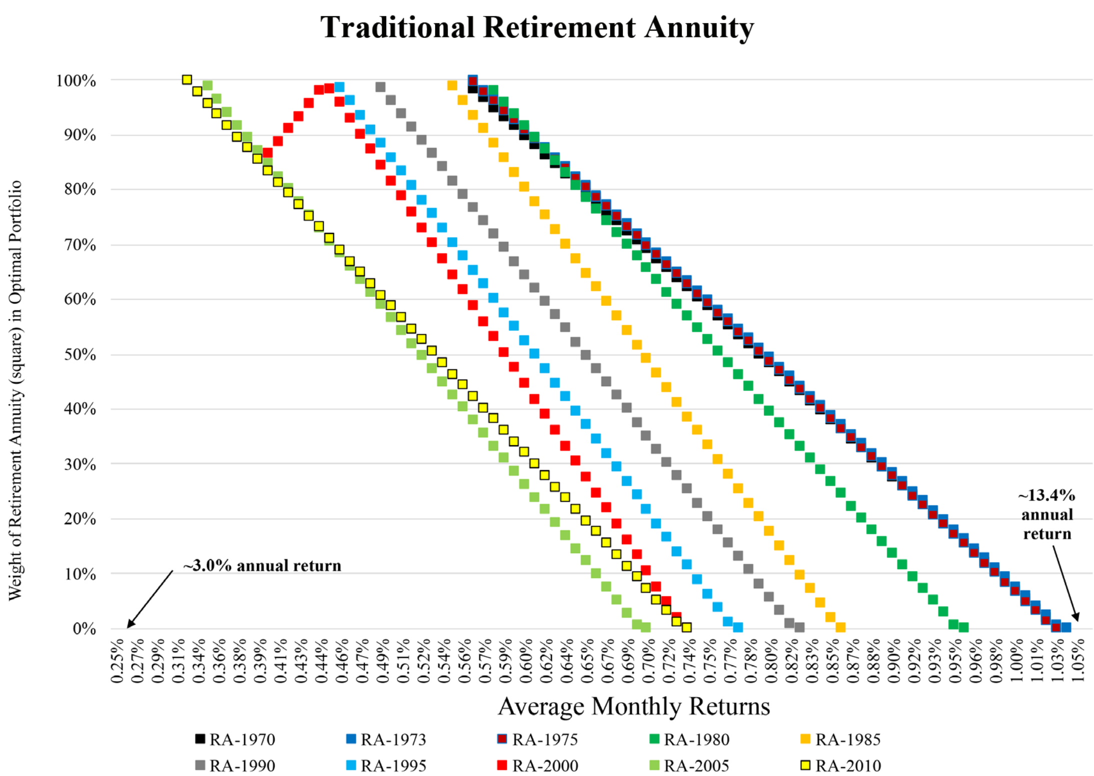
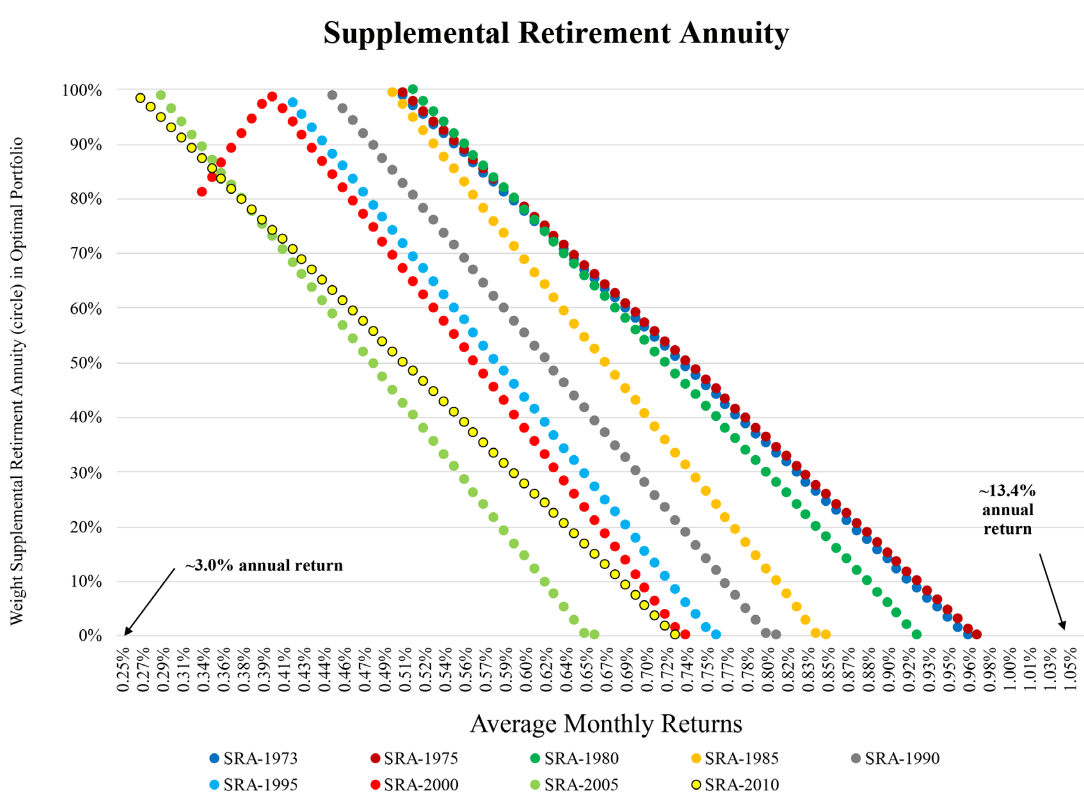


Figure 14 below summarizes across all studied cohorts the optimal portfolio weights for the RA (top panel) and SRA (bottom panel) in a retirement savings portfolio based on the efficient frontier results depicted above and in Appendix B. Each cohort is represented by a distinct color. There are several patterns in Figure 14 to discuss.

Figure 14. Summary of optimal portfolio weights





First, with one exception (the 2000 cohort discussed below), the optimal portfolio weights of the RA and the SRA uniformly decrease with higher associated monthly average net returns. This feature is expected and consistent with the role that the RA and SRA play in replacing the relatively lower risk and return money market and fixed income allocations in the optimal portfolios as portrayed above. To get higher average returns over the cohorts examined, optimal portfolios need to add more return and risk as found primarily in the equity asset classes.

Second, as the cohorts become more recent (going, for example, from 1970 to 2005) the average monthly net returns available with any specified RA or SRA allocation decline. This is another manifestation of the overall decline in yields since the 2008-9 Financial Crisis. The 2010 cohort modestly reverses this trend but, of course, that cohort embeds a relatively short history dominated by the historic bull market in equities coming out of the 2008-9 Financial Crisis.

Third, the average monthly return for any specified optimal weight of the RA/SRA is lower for the SRA than for the RA. (Compare the horizontal positions of the two panels in Figure 14. The SRA is shifted left from the RA.) This feature is entirely expected because the SRA either had a front-end load or a lower crediting rate than the RA to reflect its higher liquidity. Equivalently, for any specified average monthly return, the RA would have a higher allocation in the portfolio than the SRA. (Compare vertical positions of the two panels in Figure 14.) If an investor is willing to eschew the liquidity of the SRA in favor of including those funds into the RA, she or he can obtain a higher expected return for any specified expected risk, or a lower risk for any specified expected return. The difference is not large, but it is consistent and could be meaningful to many investors.

Finally, the 2000 cohort is the only one where the optimal allocation to the RA or SRA does not start at 100% and then decline uniformly. For the 2000 cohort, an allocation to money market funds instead of the RA or SRA was optimal at the lowest average expected monthly returns. This allocation to money market funds starts at just under 13% for the portfolio with the RA and 20% for the portfolio with the SRA, and then declines quickly. At their highest in the 2000 cohort, the both the RA and the SRA were allocated over 98% of the funds placed into an optimal mean-variance portfolio.

6. Stochastic dominance analysis

We next measure the comparative investment performance of the TIAA RA and SRA 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 accounting for all moments and other characteristics of the return distributions. It also provides a type of empirical investment analysis that does not depend upon 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).[13] While some of the residual limitations of stochastic dominance analysis have been overcome by an abundance of research dating from the 1970s to the present, there remain two:

1. Stochastic dominance methods provide no guidance into the construction of a portfolio from various individual securities, and
2. 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 degrees of stochastic dominance we characterize below refer to different aspects of investors' attitudes towards 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.

13 Appendix C presents additional details on stochastic dominance properties and methods as well as some other related results.

Second-degree stochastic dominance (SSD) requires that investors be risk averse (prefer less variability) and that the mean of the dominating distribution be no lower than the mean of the non-dominating distribution. This implies that a return distribution that stochastically dominates another in the second degree will be preferred by any risk-averse investor.

Stochastic dominance in the first and second degrees is particularly relevant because return distributions that exhibit dominance in either of these degrees ought to appeal to a very large fraction of investors. When one set of returns (ordered from lowest to highest) is never any lower and higher at a minimum of one point than a second set of returns, the first set of returns is always preferred by investors and stochastically dominates the second set in the first degree.

If two sets of returns have the same mean but one set has a smaller variance, the set with the smaller variance is preferred by investors and stochastically dominates the set with the higher variance in the second degree. A property of stochastic dominance is that a return distribution that stochastically dominates another one in a given degree also dominates in all higher degrees —e.g., if there exist first-degree stochastic dominance, then second-, third-, and fourth-degree dominance also exist. Because of the strong implications of first- and second-degree stochastic dominance, it is not common to observe these degrees of stochastic dominance in actual financial return distributions.

Table 4 below summarizes the results of the stochastic dominance analyses for the asset classes and cohorts studied. As Table 4 reports, the TIAA RA and SRA stochastically dominate, in either in the first or second degrees, the money market class for every cohort except 1970 and they also stochastically dominate the intermediate-term government/credit returns in all cohorts. The stochastic dominance results for TIAA's traditional RA are very similar to the results obtained in our earlier study when data are extended through February 2021. In addition, the long-term corporate bond asset class stochastically dominates (in the second or third degrees) long-term government bonds in the 1970, 1975, 2000, 2005, and 2010 cohorts and the large stock asset class in the 2000 cohort.

Table 4. Stochastic dominance results

Cohort	TIAA-RA Stochastically Dominates	TIAA-SRA Stochastically Dominates	LTCB Stochastically Dominates
1970	ITG/C bonds in the **2nd** and higher degrees	SRA Not Yet Available	LTGB in the **2nd** and higher degrees
1973	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	
1975	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	LTGB in the **2nd** and higher degrees
1980	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	
1985	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	
1990	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	
1995	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	
2000	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	LS in the **2nd** and higher degrees LTGB in the **2nd** and higher degrees
2005	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **2nd** and higher degrees ITG/C bonds in the **2nd** and higher degrees	LTGB in the **3rd** and higher degrees
2010	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	MM in the **1st** and higher degrees ITG/C bonds in the **2nd** and higher degrees	LTGB in the **2nd** and higher degrees

Note: When stochastic dominance obtains in a given degree it follows that it also obtains in any higher degree as well.

Table legend	Asset class
MM	Money Market (ICE Bank of America/Merrill US 3 Month Treasury Bill)
ITG/C	Intermediate-Term US Government/Credit (Barclays)
LTCB	Long-Term US Corporate Bonds (AAA/AA 10+ Year)
LTGB	Long-Term US Government Bonds (Barclays 20+ Year Treasury)
LS	Large Stocks (S&P 500)

A remarkable result in Table 4 is that the Supplemental Retirement Annuity stochastic dominance results are very similar to the RA across all cohorts. The minor exceptions are the 1995, 2000, and 2005 cohorts where first-degree dominance of the SRA over money market investments does not obtain.

The first- and second-degree stochastic dominance results for the RA and SRA in Table 4 can be illustrated in terms of the cumulative distribution function comparisons in Figures 15 through 18 for the 2000 cohort. Figures 15 and 16 illustrate the first-degree stochastic dominance of the RA and the second-degree stochastic dominance of the SRA, respectively, over the money market asset class for the 2000 cohort. The latter is an interesting case illustrating the strict requirements imposed by first-degree stochastic dominance. Visually, Figures 15 and 16 look very similar and yet Table 4 shows that the SRA does not dominate the money market asset. For the RA, its entire distribution (the blue line) is to the right of the distribution of the money market asset class returns. For the SRA, this is the case for all returns except for the largest observed in each distribution, which are 0.6161% for the SRA and 0.6198% for the money market. The failure of this one SRA return to be greater that the corresponding money market return is enough to prevent first-degree dominance of the SRA over the money market.

Figure 15. First-degree stochastic dominance of RA over money market, 2000 cohort

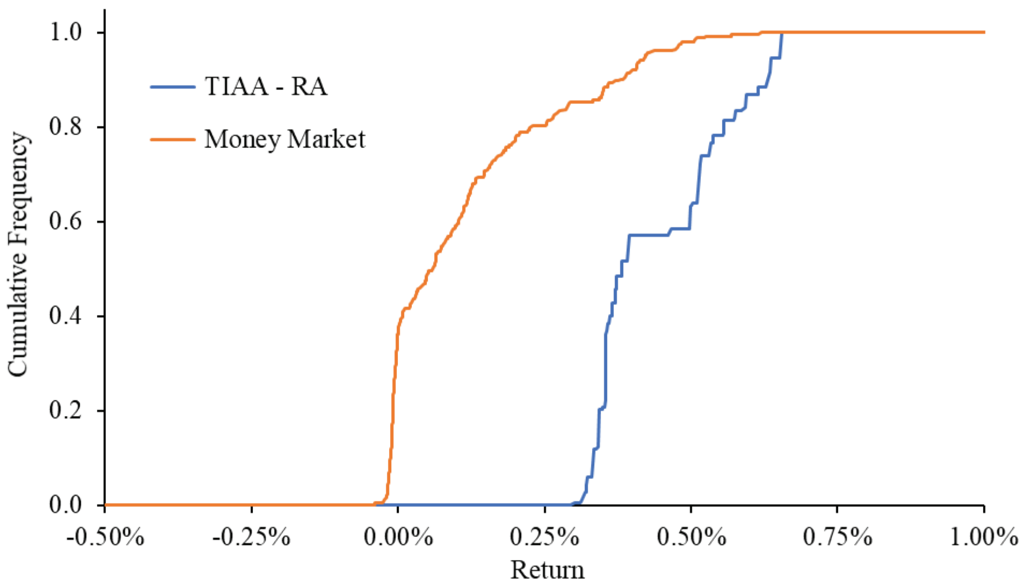


Figure 16. Second-degree stochastic dominance of SRA over money market, 2000 cohort

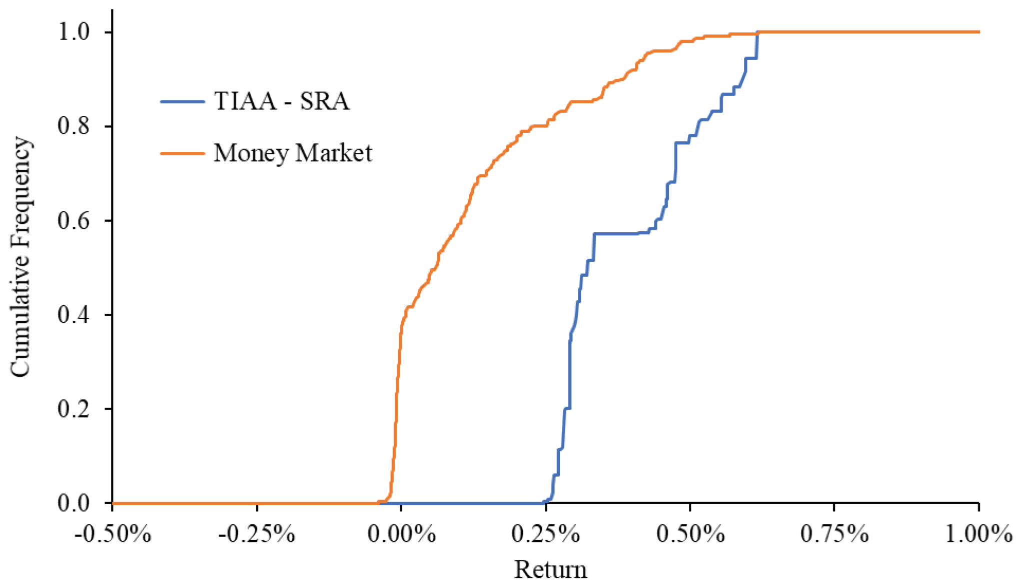


Figure 17. Second-degree stochastic dominance of RA over ITG/C, 2000 cohort

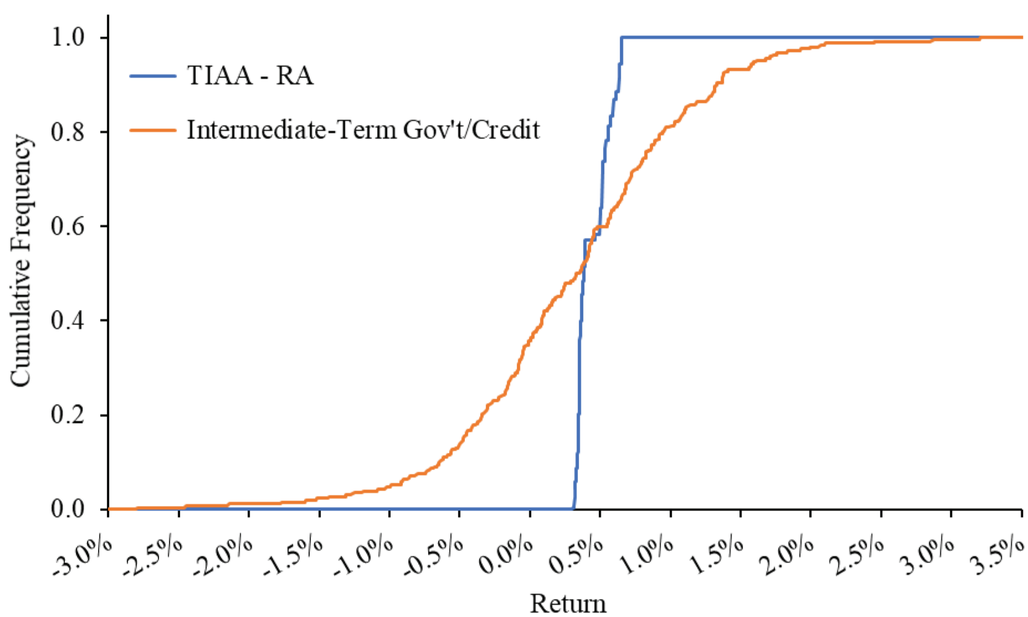
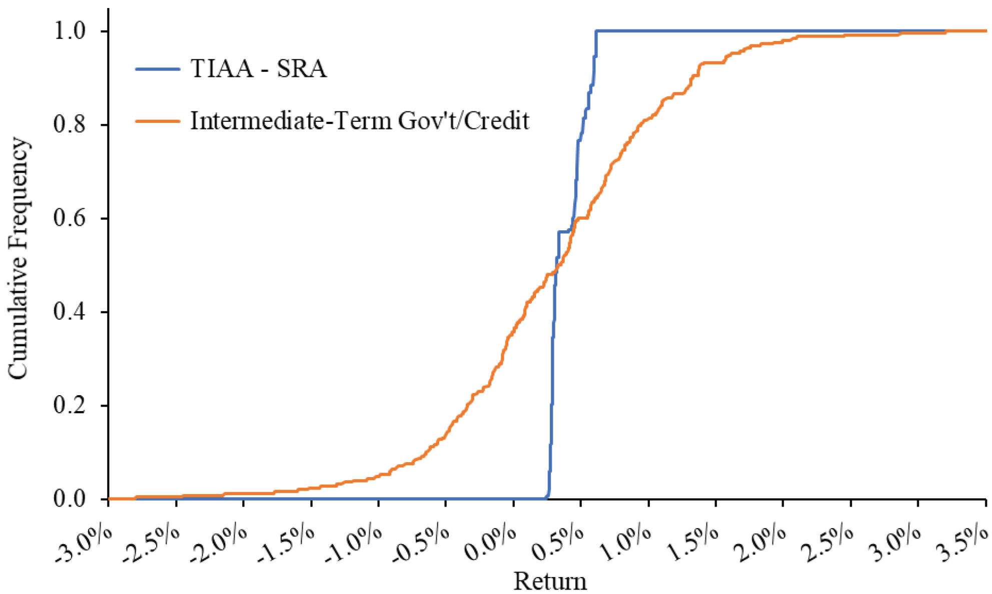


Figure 18. Second-degree stochastic dominance of SRA over ITG/C, 2000 cohort



Turning next to the second-degree stochastic dominance of the RA and SRA over intermediate-term government/credit assets, the difference in average crediting rates between the RA and the SRA is not an impediment: both the RA and the SRA dominate this alternative asset class for all the cohorts we study. Figures 17 and 18 illustrate this dominance for the 2000 cohort. Compared to the second-degree stochastic dominance illustrated in Figure 16, Figures 17 and 18 show a more typical illustration of second-degree stochastic dominance where the return distribution of the dominating asset (the RA or SRA) is enough to the right of the return distribution of the dominated asset (the intermediate-term government/credit) to represent more than half the probability mass required for second-degree stochastic dominance (that is, the area between the orange line and the blue line to the left of the point where they cross is greater than the area between the two lines to the right of this point).

7. Concluding remarks

The results presented in this paper confirmed and extended the analyses and conclusions in Babbel, Herce, and Meyer (2015). For the TIAA Traditional RA, the results in this report are entirely consistent with those obtained for the shorter sample period (through February 2014) in the 2015 study. More specifically, we demonstrated that replacing a typical allocation of some asset classes (e.g., fixed income) during the accumulation phase in a retirement savings program with the TIAA RA annuity yields improved financial performance (i.e., a better risk-return tradeoff) as measured by mean-variance, efficient/optimal portfolio, and stochastic dominance methods. This result holds across all previously analyzed cohorts, even adding more than seven years of recent capital market conditions, plus a new 2010 cohort. This, by itself, is a powerful result given the historically unprecedented capital market conditions experienced in the past decade—a period of extended low interest rates that limited the fixed income returns available to investors combined with a powerful rise in equity prices punctuated by periods of alarming volatility. The analyses presented above demonstrated that the ability of the TIAA RA to keep crediting rates above the 3% per year guaranteed minimum works to the substantial financial advantage of RA participants, as measured by mean-variance, efficient/optimal portfolio, and stochastic dominance approaches.

Extending the analysis to TIAA's SRA product, our results are qualitatively similar to those demonstrated for the RA despite the average 60 basis point reduction in annual crediting rates for the SRA compared to the RA. More specifically, replacing a typical allocation of some asset classes (e.g., fixed income) in a retirement savings program with the TIAA SRA annuity yields improved financial performance (i.e., a better risk-return tradeoff) as measured by mean-variance, efficient/optimal portfolio, and stochastic dominance methods. The approximately 60 basis point average annual reduction in crediting rates for the SRA compared to the RA is the cost TIAA charges the SRA for its liquidity – SRA participants can withdraw from the SRA and reallocate those funds elsewhere. Even with an average 60 basis points annual liquidity charge, the analyses above shows that allocating funds to the SRA instead of other fixed income assets improves the financial performance of a retirement saving program. If the liquidity is not needed, however, the participant would obtain a better result by placing those funds into the RA.

The mean-variance analyses, as measured by the widely used Sharpe and Sortino ratios, confirms the general risk-return advantage of the RA and SRA. Extending the mean-variance analyses to calculate efficient investment frontiers and optimal portfolio allocations demonstrated that both the RA and the SRA improved the risk-return profile and should replace allocations to other fixed income asset classes in retirement saving programs. Expanding beyond mean-variance considerations, the stochastic dominance analyses presented confirms the risk-return superiority of the RA and SRA over other fixed income alternatives. And, unlike most other examples of stochastic dominance of one asset class over another, in the case of RA and SRA this result holds across all cohorts examined—a remarkable result! Quantitatively, the lower SRA crediting rate does make a difference in the returns obtainable but allocating retirement savings to the SRA instead of other fixed income classes still improves the overall risk-return profile of the portfolio.

The research presented in this paper demonstrates that employees participating in TIAA retirement savings programs can simplify their investment decisions without sacrificing investment returns during the accumulation phase. Participating employees can contribute to TIAA annuities instead of money market and intermediate-term fixed income funds. The investment tradeoff is the lower liquidity of the TIAA annuities against a higher and more stable return. Given the characteristics of retirement portfolios, this is a tradeoff that many would make in favor of the TIAA annuities.

This study incorporates over fifty years of capital market conditions—March 1970 through February 2021. This period of time saw high inflation and interest rates followed by deflation and low interest rates as well as volatile equity prices. The cohort analyses in this study reveal at least two interesting phenomena related to the varying capital market conditions.

First, from 1970 through 2005, the risk-return relationship shifted generally downward along the return dimension. That is, the available return for any specified level of risk declined, especially at low to moderate risk levels. (See, especially, the efficient investment frontier figures depicted in Section 5 and Appendix B.) This is primarily the result of lower available interest rates in the years since 2008. Higher returns with commensurately higher risk coming from equity investments were still available but returns at lower levels of risk were distinctly lower because interest rates were lower.

Second, and perhaps more pertinent to the goals of this study, the general pattern of the allocation of investments in optimal portfolios exhibited a remarkable stability across cohorts. (See, especially, the optimal portfolio weight figures depicted in Section 5, especially Figure 14, and Appendix B.) In every cohort except 2000, the optimal portfolio allocation to the RA and the SRA was 100% at low levels of risk-return. Even in 2000, the optimal portfolio allocation to the RA and SRA was quite high and well over 95% at low levels of risk-return. As return criteria increased, the optimal amount allocated to the RA and SRA declined in a measured and understandable manner as higher returning and more risky equity investments increased in the portfolio. In addition, the optimal allocation to the SRA was always lower than the optimal allocation to the RA, reflecting the difference in crediting rates arising from liquidity options, and the optimal portfolio weight schedules were remarkably stable and close to each other. This is confirmation that the use of the RA and SRA in retirement saving portfolios is beneficial over a wide range of capital market conditions—all of those experienced in the past fifty years.

We did not conduct cohort analyses for the TIAA RCP product. Given its relatively recent arrival in TIAA's offerings we could only provide results for one or maybe two short-lived cohorts (i.e., 2010 and maybe 2006). Compared to the multiple cohorts examined for the RA and SRA, the information content of a one or two cohort analysis of the RCP would be low. Nevertheless, we highlight that the average crediting rates for the RCP have been lower than the crediting rates for the RA but higher than the crediting rates for the SRA since 2006, generally being closer to the lower SRA crediting rates. (The variability of the RCP crediting rates, while still low, is higher than the variability of the SRA crediting rates, however.) We contend, based on the experienced crediting rates for the RCP compared to the RA and, especially, the SRA, that the financial performance of the RCP in a retirement savings portfolio would be similar to that found for the SRA. In other words, replacing a typical allocation of some asset classes (e.g., fixed income) in a retirement savings program with the TIAA RCP annuity yields improved financial performance (i.e., a better risk-return tradeoff).

The concept of investment cohort that forms the basis for our analyses is not a satisfactory approach to evaluate the financial performance of the RA and the SRA in a retirement savings portfolio. The investment cohort approach does not come close to reflecting the actual pattern of retirement saving program contributions. Nevertheless, the results of the investment cohort approach are informative and suggest that the financial performance results of the TIAA annuities are very likely to be beneficial to retirement savings portfolios under more realistic contribution patterns. Additionally we note that the annual SRA return is, on average, approximately 60 basis points below that of the RA because the SRA has additional and more liquid features than the RA. The RCP has liquidity features more closely aligned with the SRA than the RA. The enhanced liquidity of the SRA and RCP would be better analyzed in a model where portfolio reallocation is considered, so that the SRA/RCP balances may be reassigned to other potential asset classes while the RA balances may not be reassigned. This analysis would allow us to consider the value of liquidity to better compare the performance of the SRA and the RA relative to other asset classes. These considerations will be the subject of future research.

Appendix A: Capital market data and supplemental descriptive statistics

Details on the data series replacing those used in the 2015 study

In our 2015 study the data used covered the period 1970 through 2013. For this original study we used the SBBI data set for the asset classes to compare to TIAA's Retirement Annuity (RA). In this new study the analyses run through February 2021. The SBBI database was discontinued in December 2015. Consequently, we need to replace and extend the SBBI data from the 2015 study as described in the first part of this Appendix. We turned to Bloomberg to obtain the replacement data, but that information did not always extend back to March 1970. Consequently, we need to use the original SBBI data for earlier periods. This appendix describes how we replaced the SBBI data with the Bloomberg data and, where needed, spliced the recent data from Bloomberg with the older data from SBBI. For large US stocks, small US stocks, and long-term US corporate bonds, we were able to determine that the Bloomberg and SBBI data coincide exactly for the overlap period.

Large US Stocks (LS). This series corresponds to the S&P 500 Index. We have verified that for the overlap period with SBBI, from December 1, 1986 through December 31, 2015, the monthly returns for both the SBBI data and the Bloomberg sources coincide exactly.

Small US Stocks (SS). The SBBI index for this series includes about 1,700 stocks in the lower range of market cap. The SBBI data are from Directional Fund Advisors US Micro Cap Portfolio. This return series can be obtained, from December 1, 1986 through the present, from Bloomberg. We have verified that for the overlap period with SBBI, from December 1, 1986 through December 31, 2015, the monthly returns coincide for both the SBBI data and the Bloomberg sources.

Long-Term US Corporate Bonds (LTCB). The SBBI index for this series is the Citi USBIG Corp Index AAA/AA 10+ Yr (High-Grade Bond Index), which can also be found in Bloomberg. We have extended the SBBI data through the present using Bloomberg. We have verified that monthly returns for the Bloomberg series coincide with the corresponding SBBI returns for the period these two series overlap, January 31, 1980 through December 31, 2015.

For the remaining series, long-term government bonds, intermediate-term U.S. government/credit bonds, and 3-month U.S. Treasury bills, the SBBI data are based on individual bonds and bills to construct monthly returns. We replace these series with close substitutes starting with the first available date in Bloomberg through February 28, 2021, splicing the original source data onto the earliest years to obtain complete return series for these asset classes. The specifics are described below.

Long-Term US Government Bonds (LTGB). We use the Barclays 20+ Year Treasury Bond Fund index, available on Bloomberg from 2/28/1992 through the present. The monthly returns obtained from this series, over the overlap period with corresponding SBBI returns, February 28, 1992 to December 31, 2015, have a correlation coefficient of 98.6%, with an average difference of 1.9 basis points lower for the SBBI series. Figure A1 depicts the Barclays 20+ Year Treasury Bond fund returns against the SBBI Long-Term Government Bond returns for the overlapping period.

Figure A1. Barclays 20+ year Treasury Bond Fund returns v. SBBI's Long-Term Government Bonds returns (February 28, 1992 to December 31, 2015)

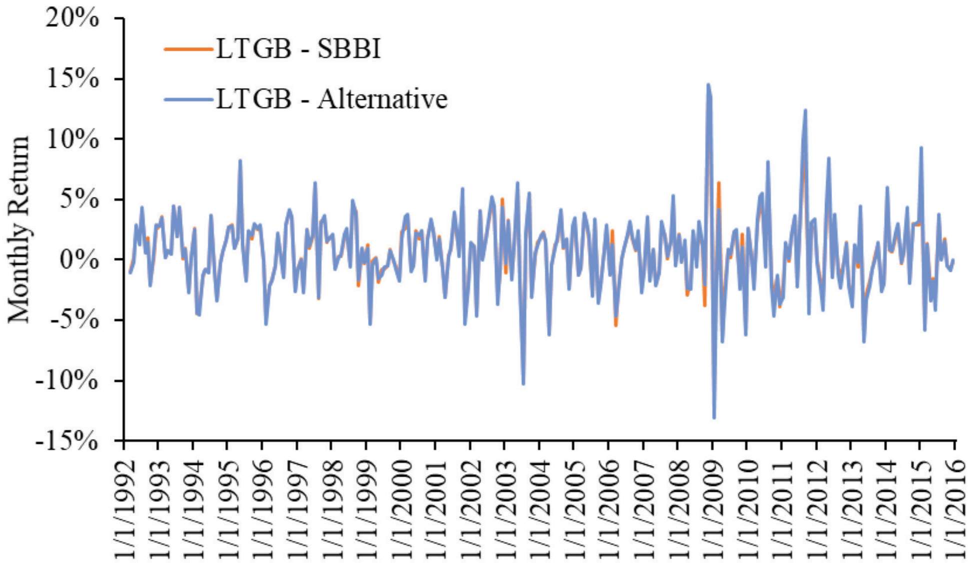
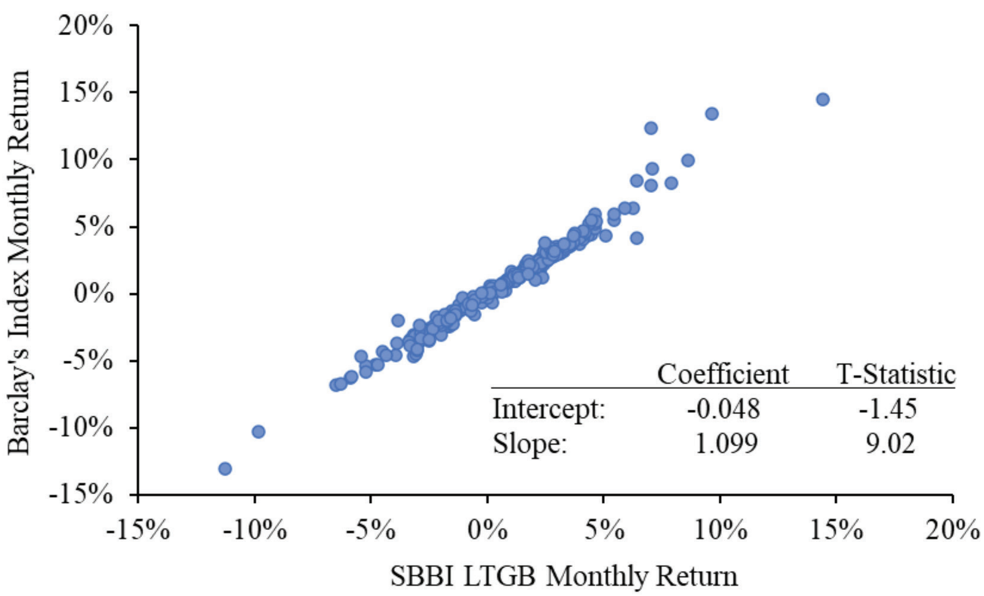


Figure A2 scatters the Barclays returns against the SBBI returns and shows the results of a bivariate regression. The return results are very similar.

Figure A2. Barclays 20+ year Treasury Bond Fund returns v. SBBI's Long-Term Government Bonds returns (February 28, 1992 to December 31, 2015)



Intermediate-Term US Government/Credit (ITG/C). This series is the Barclays Intermediate US Government/ Credit Total Return Index, available in Bloomberg from March 1973 through February 2021 Thus, the entire series of intermediate-term returns is composed of this series for all cohorts from the 1973 cohort on. Prior to March 1973, SBBI data for the intermediate-term government bond series are used from March 1970 through February 1973. The correlation between the two series for the overlap period is 94.9%, with an average difference of 0.2 basis points higher for the SBBI series, over the period February 1973 through December 2015. Figure A3 depicts the Intermediate-Term Government/ Credit bond returns against the SBBI Intermediate-Term Government Bond returns for the overlapping period.

Figure A3. Intermediate-Term Government/Credit bonds v. SBBI's Intermediate-Term Government Bond returns (February 1973 through December 2015)

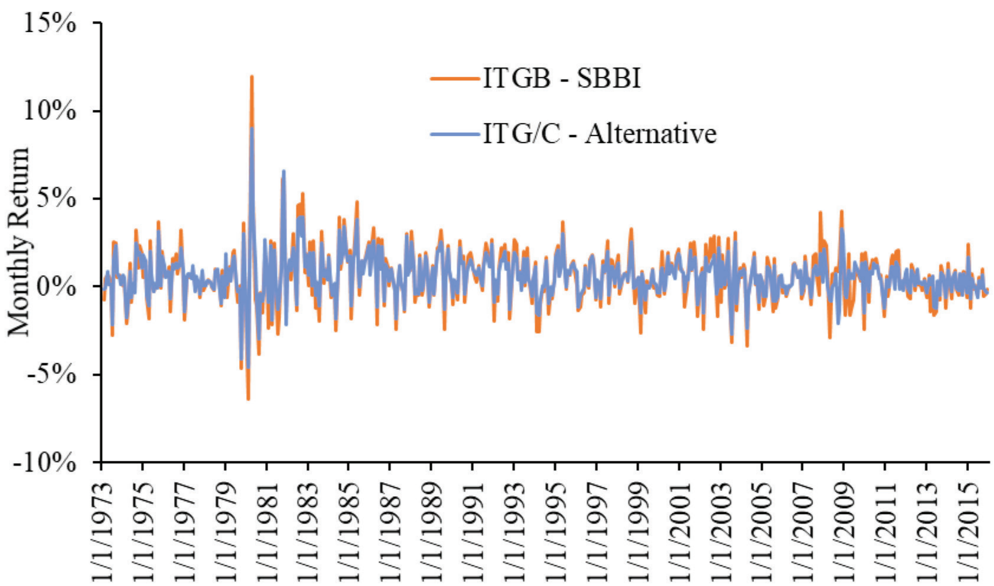
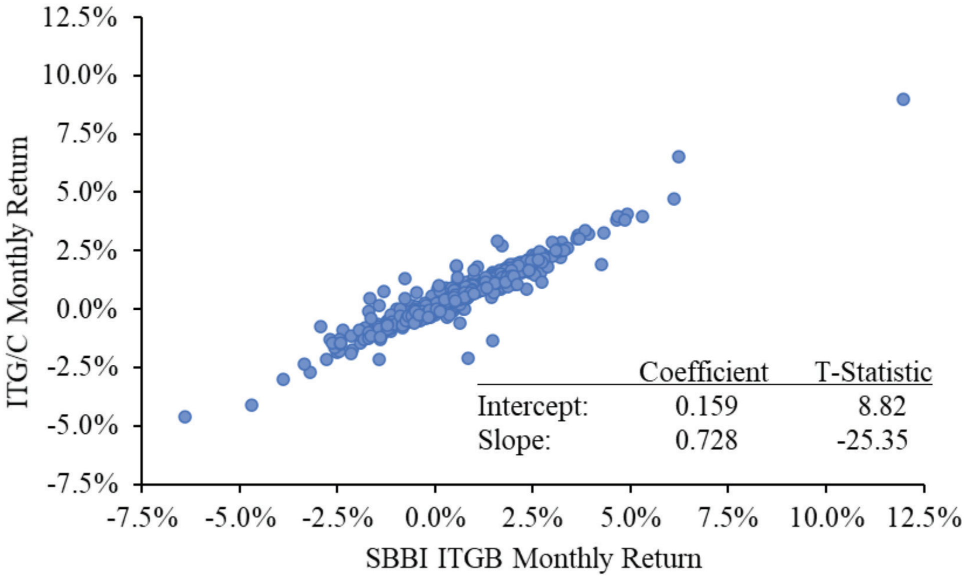


Figure A4 scatters the Intermediate-Term Government/ Credit bond returns against the SBBI Intermediate-Term Government Bond returns and shows the results of a bivariate regression. The return results are not as close as those observed for the long-term government bonds, but we view the return data obtained from Bloomberg on the index portfolio to be more representative of that asset class than the SBBI bond series.

Figure A4. Intermediate-Term Government/Credit bonds v. SBBI's Intermediate-Term Government Bond returns (February 1973 through December 2015)



Money Market (MM). For money market returns we use the ICE Bank of America Merrill Lynch US 3-Month Treasury Bill Index, available in Bloomberg from December 31, 1977. For the period before 1978 we splice this series with SBBI's money market returns. The correlation of monthly returns for these two series over the overlap period, January 1978 through December 2015, is 96.9% with an average difference of 3.5 basis points lower for the SBBI series. Figure A5 depicts the Bank of America Merrill Lynch US 3-Month Treasury Bill Index returns against the SBBI 3-Month Treasury Bill returns for the overlapping period.

Figure A5. Bank of America Merrill Lynch US 3-Month Treasury Bill Index v. SBBI's 3-M Treasury Bill returns (January 1978 through December 2015)

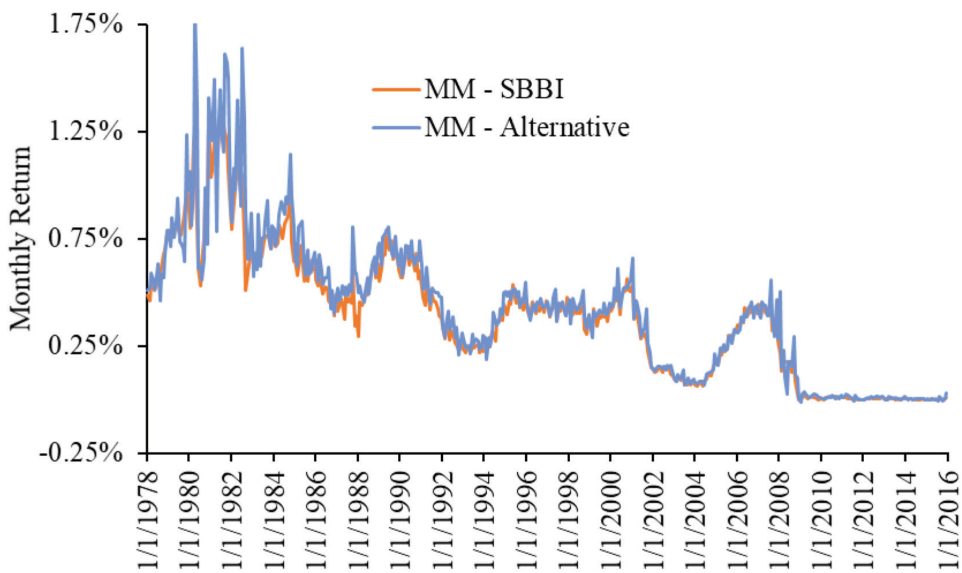
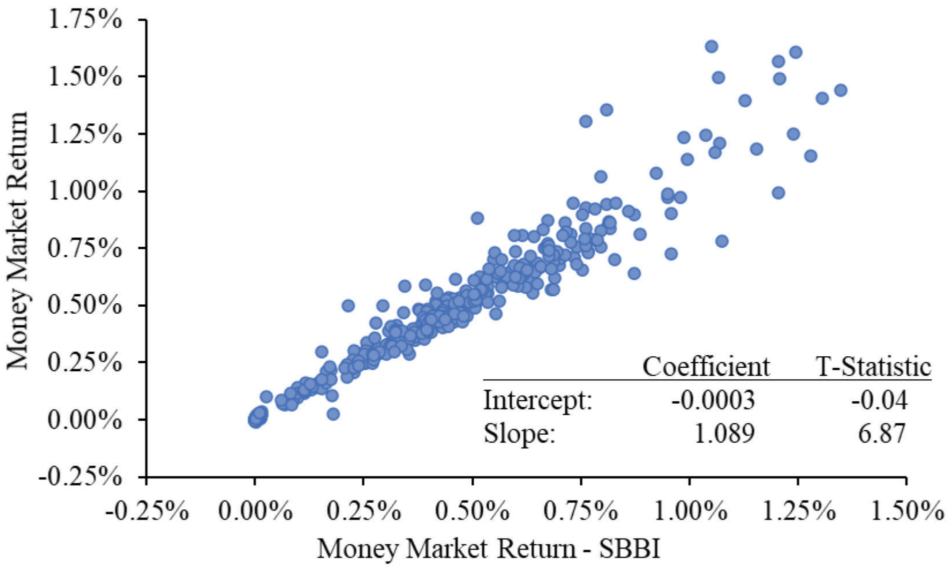


Figure A6 scatters the Bank of America Merrill Lynch US 3-Month Treasury Bill Index returns against the SBBI 3-Month Treasury Bill returns and shows the results of a bivariate regression. The return results are not as close as those observed for the long-term government bonds, but we view the return data obtained from Bloomberg on the index portfolio to be more representative of that asset class than the SBBI bond series.

Figure A6. Bank of America Merrill Lynch US 3-Month Treasury Bill Index v. SBBI's 3-M Treasury Bill returns (January 1978 through December 2015)



The scatter plots in Figures A2, A4, and A6, include summary statistics from a regression line of the alternative asset class on the corresponding SBBI series it replaces in this study. The null hypothesis for the intercept term is that this intercept term is zero and the null hypothesis for the slope term is that it equals one.

In all cases, the slope is statistically different from one. This slope term is to be interpreted as the volatility of the replacement series relative to that of the corresponding SBBI series. This regression is comparable to the regression of an individual stock return on an industry or a market index return as is done in the Capital Asset Pricing Model (CAPM) and so, the slope coefficients in the regressions in Figures A2, A4, and A6 can be interpreted as the beta coefficient in the CAPM. In particular, Figures A3 and A4 demonstrate the relatively smaller volatility of the alternative intermediate-term government/credit series compared to the SBBI intermediate-term government bond series.

In our opinion, the Bloomberg index data are more representative of the return performance in the asset classes than the SBBI data. If possible, we would have preferred to use the Bloomberg data everywhere, but we decided that splicing the earlier SBBI index data on to the existing Bloomberg data was the best approach to use all the available TIAA annuity crediting rates and maintain some level of comparability with the results in the original 2015 study.

Summary of additional annual data

Table A1 below reports the annual net return summary statistics for all asset classes and cohorts. It corresponds to the monthly net return summary statistics in the body of the study at Table 2.

Table A1. Summary statistics for annual net returns – all asset classes and cohorts

Cohort	1970	1973	1975	1980	1985	1990	1995	2000	2005	2010
Asset Class	Mar-1970 Feb-2021	Mar-1973 Feb-2021	Mar-1975 Feb-2021	Mar-1980 Feb-2021	Mar-1985 Feb-2021	Mar-1990 Feb-2021	Mar-1995 Feb-2021	Mar-2000 Feb-2021	Mar-2005 Feb-2021	Mar-2010 Feb-2021
	ARITHMETIC MEAN									
Large Stocks	10.53%	10.64%	11.68%	11.84%	11.55%	10.96%	11.26%	8.29%	10.95%	13.95%
Small Stocks	16.41%	16.41%	17.52%	15.40%	14.11%	15.26%	15.26%	12.38%	12.29%	14.75%
Long-Term Corp. Bonds	7.45%	7.45%	7.74%	8.69%	8.12%	7.31%	7.11%	7.31%	6.47%	7.55%
Long-Term Gov't Bonds	7.42%	7.42%	7.61%	8.62%	8.31%	7.41%	7.20%	6.96%	6.39%	7.31%
Interm-Term Gov't/Credit	5.55%	5.55%	5.59%	5.94%	5.05%	4.48%	4.07%	3.81%	3.10%	2.52%
Money Market	4.48%	4.48%	4.37%	4.13%	3.08%	2.46%	2.05%	1.39%	1.08%	0.39%
TIAA-RA	6.89%	6.89%	6.86%	7.10%	6.72%	6.00%	5.63%	5.48%	4.25%	3.96%
TIAA-SRA	N/A	6.26%	6.23%	6.46%	6.13%	5.44%	4.99%	4.81%	3.44%	3.12%
	GEOMETRIC MEAN									
Large Stocks	9.12%	9.15%	10.23%	10.32%	9.97%	9.26%	9.24%	6.11%	8.84%	13.44%
Small Stocks	13.50%	13.50%	14.60%	12.46%	11.02%	11.80%	11.32%	8.55%	8.85%	13.24%
Long-Term Corp. Bonds	6.99%	6.99%	7.27%	8.27%	7.77%	7.05%	6.82%	7.01%	6.14%	7.21%
Long-Term Gov't Bonds	6.84%	6.84%	7.02%	8.04%	7.76%	6.98%	6.72%	6.44%	5.76%	6.49%
Interm-Term Gov't/Credit	5.43%	5.43%	5.47%	5.82%	4.97%	4.42%	4.01%	3.76%	3.06%	2.49%
Money Market	4.41%	4.41%	4.30%	4.06%	3.05%	2.43%	2.02%	1.38%	1.06%	0.38%
TIAA-RA	6.88%	6.87%	6.84%	7.08%	6.69%	5.99%	5.62%	5.47%	4.25%	3.96%
TIAA-SRA	N/A	6.25%	6.21%	6.43%	6.11%	5.42%	4.98%	4.80%	3.44%	3.12%
	STANDARD DEVIATION									
Large Stocks	16.96%	17.48%	17.11%	17.55%	17.83%	18.55%	20.26%	21.11%	20.47%	11.06%
Small Stocks	26.29%	26.29%	26.29%	26.30%	27.05%	28.62%	30.67%	30.02%	27.60%	19.58%
Long-Term Corp. Bonds	10.33%	10.33%	10.45%	10.10%	9.02%	7.73%	8.05%	8.26%	8.96%	9.27%
Long-Term Gov't Bonds	11.62%	11.62%	11.80%	11.80%	11.44%	10.02%	10.60%	11.17%	12.33%	14.36%
Interm-Term Gov't/Credit	5.06%	5.06%	5.16%	5.19%	4.30%	3.65%	3.43%	3.49%	2.96%	2.60%
Money Market	3.72%	3.72%	3.76%	3.85%	2.66%	2.28%	2.12%	1.81%	1.63%	0.77%
TIAA-RA	1.76%	1.82%	1.85%	2.45%	2.33%	1.58%	1.38%	1.44%	0.40%	0.10%
TIAA-SRA	N/A	1.84%	1.88%	2.41%	2.38%	1.75%	1.49%	1.55%	0.39%	0.14%

Figure A7 below presents a graph of the average annual net returns for all studied asset classes for each cohort. It corresponds to Figure 3 depicting average monthly net returns for all studied asset classes for each cohort in the body of the study.

Geometric means are a more appropriate representation of the growth over time of an initial investment over a given holding period, since they do not include the asset return volatility component included in the arithmetic average and their sum is roughly equivalent to the cumulative growth rate of the investment over the same period. Figure A8 presents a chart of the geometric means for each studied asset class across all cohorts. We observe, both for monthly average returns in Table 2 and for annual average returns in Table A1, that the geometric means for the RA are on a par with those of long-term corporate and government bonds for the early cohorts—1970, 1973 and even 1975. The returns based on geometric averages can be observed in Figure A8 where we can see that the RA performed just as well as long-term corporate and government bonds for both the 1970 and the 1973 cohorts and that the SRA was not far behind it (for the 1973 cohort). In addition, both the RA and the SRA were well above the performance of intermediate-term bonds and money market. We also observe in Figure A8 the relative underperformance of large stocks compared to long-term bonds for the 2000 cohort and of the small company stocks for the 2005 and 2010 cohorts compared to the previous relation with large stocks.

Figure A7. Arithmetic means of annual net returns – all cohorts

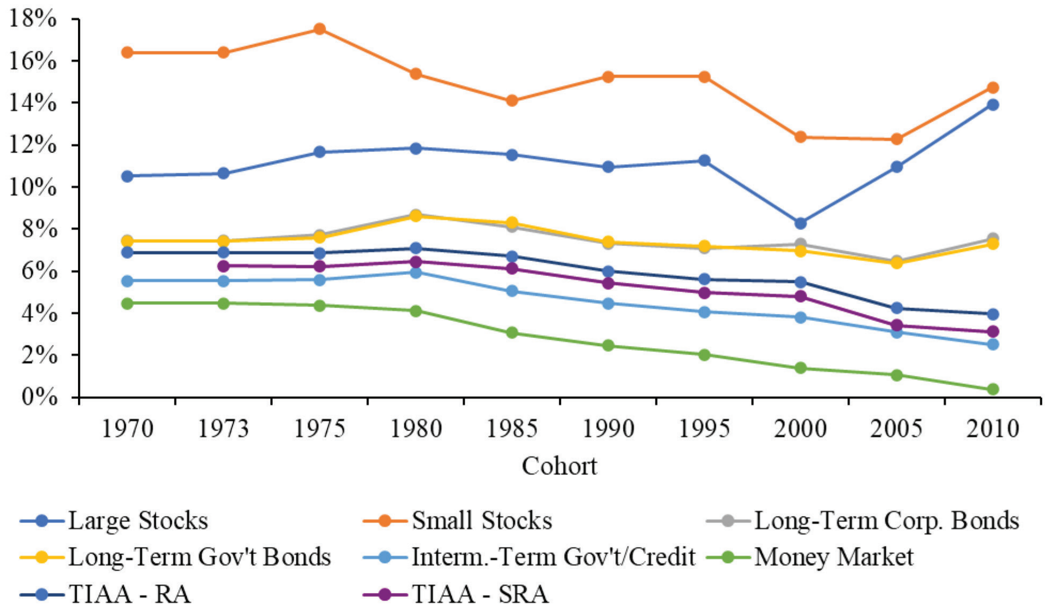
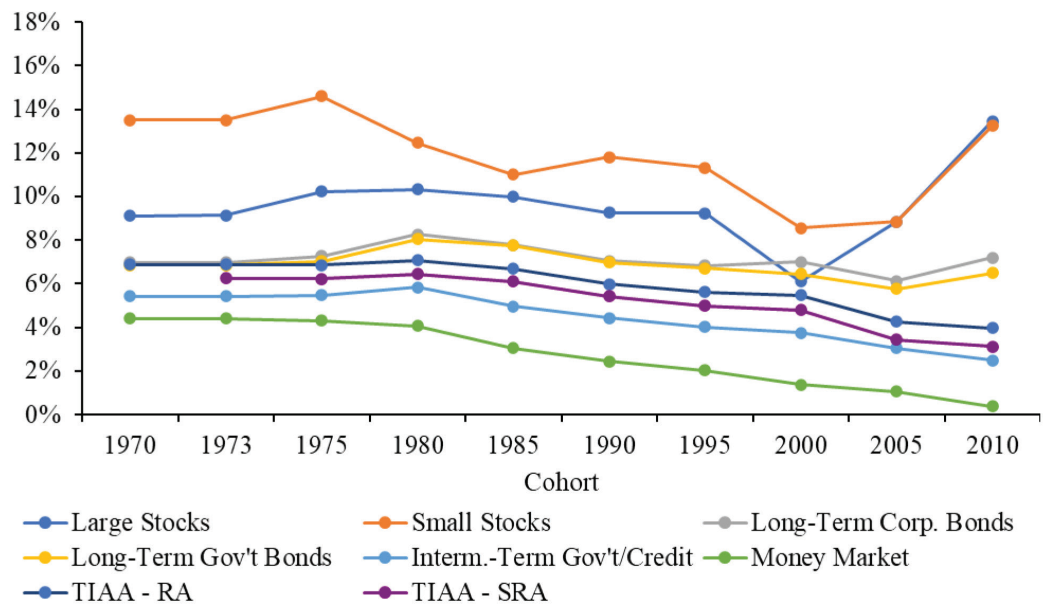


Figure A8. Geometric means of annual net returns – all cohorts



The 2000 cohort includes the Dotcom Bubble, the effects of the 2008 Financial Crisis, and the severe, if short-lived, drop in stocks towards the end of February of 2020. These downturns show in the relatively poor performance of large and small stocks, reflecting their riskiness in shorter periods. In particular, small stocks performed poorly during the recent downturn so that large stocks caught up with them in terms of average returns over the full period for the 2005 and 2010 cohorts, as shown in Figure A8.

Table A2 is an expansion of Table 3 in Section 4. Table A2 presents the Sharpe and Sortino ratios for all studied assets and cohorts for both monthly and annual returns. We observe that, as was the case with ratios based on monthly excess returns, the annual Sharpe and Sortino ratios for the RA and the SRA continue to be well above the corresponding ratios for the alternative asset classes.

Table A2. Sharpe and Sortino ratios for monthly and annual returns 1970 to 2010 cohorts

	Large Stocks	Small Stocks	Long-Term Corporate Bonds	Long-Term Gov't Bonds	Intermediate-Term Gov't/ Credit Bonds	TIAA RA	TIAA SRA
1970 COHORT	**MONTHLY RETURNS**						
Sharpe	0.11	0.13	0.09	0.07	0.08	0.92	Not available
Sortino	0.15	0.20	0.14	0.11	0.12	17.59	
	ANNUAL RETURNS						
Sharpe	0.18	0.21	0.15	0.13	0.13	0.95	Not available
Sortino	0.28	0.36	0.25	0.20	0.22	17.89	
1973 COHORT	**MONTHLY RETURNS**						
Sharpe	0.11	0.14	0.09	0.07	0.08	0.89	0.65
Sortino	0.15	0.22	0.13	0.12	0.12	16.57	4.36
	ANNUAL RETURNS						
Sharpe	0.34	0.45	0.28	0.23	0.24	0.98	0.70
Sortino	0.61	1.09	0.66	0.60	0.46	15.50	4.09
1975 COHORT	**MONTHLY RETURNS**						
Sharpe	0.13	0.16	0.10	0.08	0.09	0.91	0.67
Sortino	0.19	0.24	0.15	0.13	0.14	20.49	5.01
	ANNUAL RETURNS						
Sharpe	0.42	0.50	0.31	0.27	0.27	1.00	0.72
Sortino	0.76	1.23	0.76	0.66	0.52	19.02	4.69
1980 COHORT	**MONTHLY RETURNS**						
Sharpe	0.13	0.14	0.13	0.11	0.14	1.25	0.97
Sortino	0.19	0.21	0.21	0.17	0.22	39.85	7.94
	ANNUAL RETURNS						
Sharpe	0.43	0.42	0.46	0.39	0.46	1.48	1.12
Sortino	0.78	1.00	1.62	1.15	0.95	35.51	7.38
1985 COHORT	**MONTHLY RETURNS**						
Sharpe	0.15	0.14	0.16	0.13	0.18	2.43	2.09
Sortino	0.21	0.20	0.26	0.21	0.28	Undefined	126.61
	ANNUAL RETURNS						
Sharpe	0.47	0.40	0.57	0.47	0.56	2.72	2.36
Sortino	0.86	0.96	2.03	1.51	1.40	Undefined	156.09

Table A2. Sharpe and Sortino ratios for monthly and annual returns 1970 to 2010 cohorts (continued)

	Large Stocks	Small Stocks	Long-Term Corporate Bonds	Long-Term Gov't Bonds	Intermediate-Term Gov't/ Credit Bonds	TIAA RA	TIAA SRA
1990 COHORT	**MONTHLY RETURNS**						
Sharpe	0.15	0.15	0.16	0.13	0.20	2.23	1.91
Sortino	0.22	0.23	0.25	0.20	0.31	Undefined	Undefined
	ANNUAL RETURNS						
Sharpe	0.45	0.44	0.61	0.50	0.66	2.41	2.06
Sortino	0.83	1.08	2.05	1.48	1.78	Undefined	Undefined
1995 COHORT	**MONTHLY RETURNS**						
Sharpe	0.15	0.15	0.16	0.13	0.20	2.40	2.01
Sortino	0.22	0.22	0.25	0.21	0.32	Undefined	Undefined
	ANNUAL RETURNS						
Sharpe	0.45	0.43	0.61	0.49	0.68	2.58	2.17
Sortino	0.83	1.04	2.20	1.55	2.09	Undefined	Undefined
2000 COHORT	**MONTHLY RETURNS**						
Sharpe	0.11	0.12	0.17	0.13	0.24	2.76	2.29
Sortino	0.16	0.18	0.28	0.21	0.39	Undefined	Undefined
	ANNUAL RETURNS						
Sharpe	0.32	0.36	0.70	0.51	0.83	2.95	2.42
Sortino	0.57	0.83	3.41	1.69	3.49	Undefined	Undefined
2005 COHORT	**MONTHLY RETURNS**						
Sharpe	0.17	0.13	0.15	0.12	0.22	2.11	1.47
Sortino	0.24	0.19	0.26	0.20	0.38	Undefined	Undefined
	ANNUAL RETURNS						
Sharpe	0.47	0.40	0.58	0.43	0.72	2.20	1.51
Sortino	0.86	0.85	2.96	1.48	3.54	Undefined	N/A
2010 COHORT	**MONTHLY RETURNS**						
Sharpe	0.27	0.20	0.23	0.15	0.27	4.31	3.53
Sortino	0.45	0.32	0.39	0.28	0.49	Undefined	Undefined
	ANNUAL RETURNS						
Sharpe	1.20	0.72	0.79	0.49	0.90	4.61	3.82
Sortino	6.20	3.05	8.81	2.07	6.41	Undefined	Undefined

Aggregation from monthly to annual frequency when calculating Sharpe and Sortino ratios requires attention to serial correlation in the returns. A common time aggregation approach is multiplying the ratio based on monthly data by the factor $\sqrt{12}$.[14] 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 RA and the SRA returns which exhibit significant positive serial correlation.[15] Sharpe and Sortino ratios calculated with this time aggregation method would be higher than the true ratios. We avoid this problem in Table A2 by calculating the Sharpe and Sortino ratios for the RA and SRA based on the annual crediting rates, avoiding the need to aggregate those excess returns.

Our substantive calculations are based on monthly data. The annual data are presented only for convenience and commentary.

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

15 The first-order autocorrelation coefficients for the RA and SRA excess returns in the 1973 cohort are 79.2% and 81.4%. In contrast, excess returns for most alternative asset series exhibit little serial correlation. For example, the first-order autocorrelation coefficient for the large stocks excess return series for the 1973 cohort is 1.48%.

Appendix B: Optimal portfolio weights with and without TIAA's RA and SRA

Optimal portfolio weights for efficient portfolios, with and without TIAA's RA and SRA are shown in this appendix. Each page presents five graphs for each cohort (except 1970)—(1) efficient frontiers with and without the RA, (2) efficient frontiers with and without the SRA, (3) the optimal portfolio weights without the RA or SRA, (4) the optimal portfolio weights with the RA, and (5) the optimal portfolio weights with the SRA. In general we observe both the RA and the SRA taking over, and exceeding, the role of money market and intermediate-term bonds in efficient portfolios.

The graphs in Appendix B use the approach employed in Figures 7 through 11 for the 1973 cohort to compare optimal weight distributions across all alternative assets with and without the RA and the SRA. Our interest in showing efficient frontiers in this subsection is to observe their increasing curvature as the cohorts in our analysis have a more recent starting point as capital market returns in later years become more determinant in the overall results. The increasing curvature is partially due to the historically low interest rates in the later years. We will also see later that this increasing curvature of the efficient frontier is a result of the increasingly negative correlation between small stocks and long-term government bonds, a pattern that is also the reason why long-term government bonds appear in the optimal weight distributions. In general, we note the systematic dominance of the RA and the SRA in efficient portfolios to the exclusion of money market and intermediate-term government/credit investments. These results are consistent with what we have shown in the summary statistics section.

An interesting characteristic of the extended sample is the improved performance of large stocks relative to small stocks, as discussed in Section 3. This prominence of large stocks, however, is at the expense of small stocks in the distribution of optimal portfolio weights in the higher return, higher risk part of the range, but does not seem to affect the performance of the TIAA RA and SRA in the lower and moderate return-risk range.

Figure B1. Efficient frontiers with and without the TIAA-RA – 1970 cohort

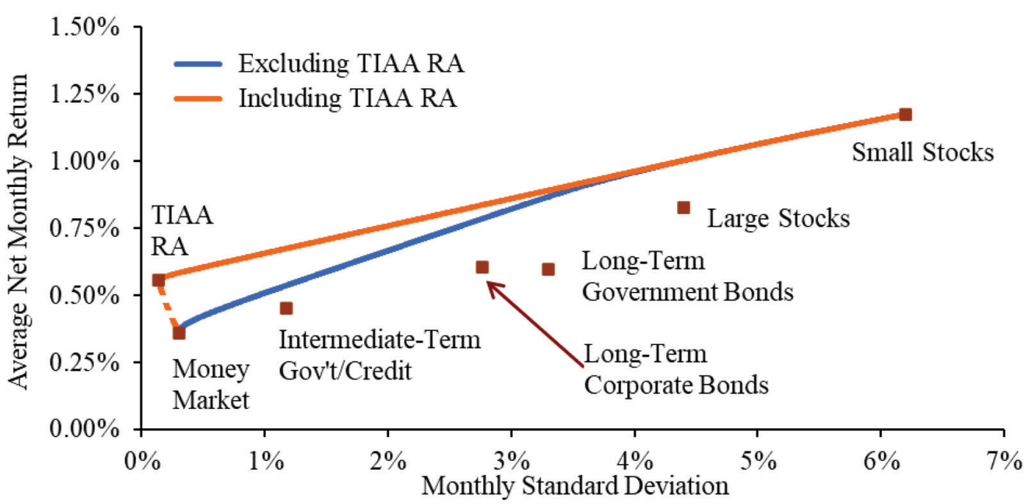


Figure B2. Optimal weights excluding the TIAA-RA – 1970 cohort

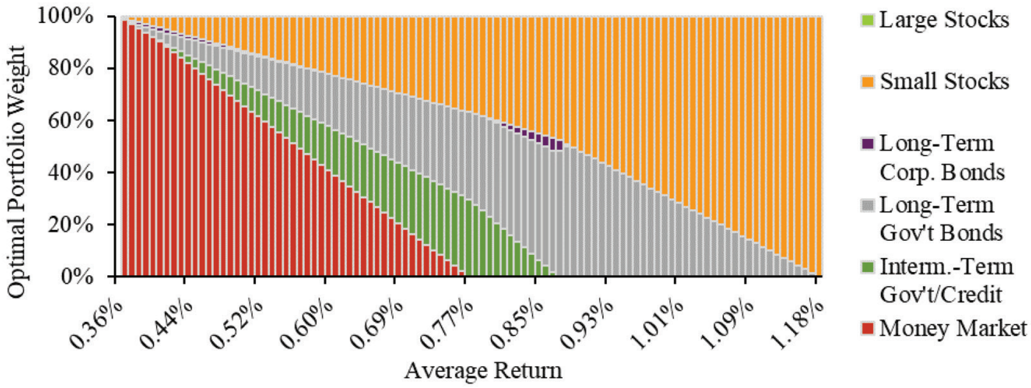


Figure B3. Optimal weights including the TIAA-RA – 1970 cohort

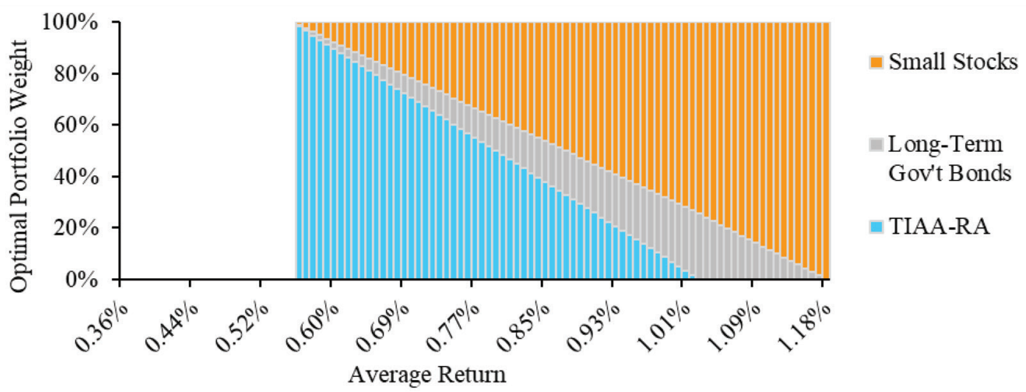


Figure B4. Efficient frontier with and without the RA – 1973 cohort

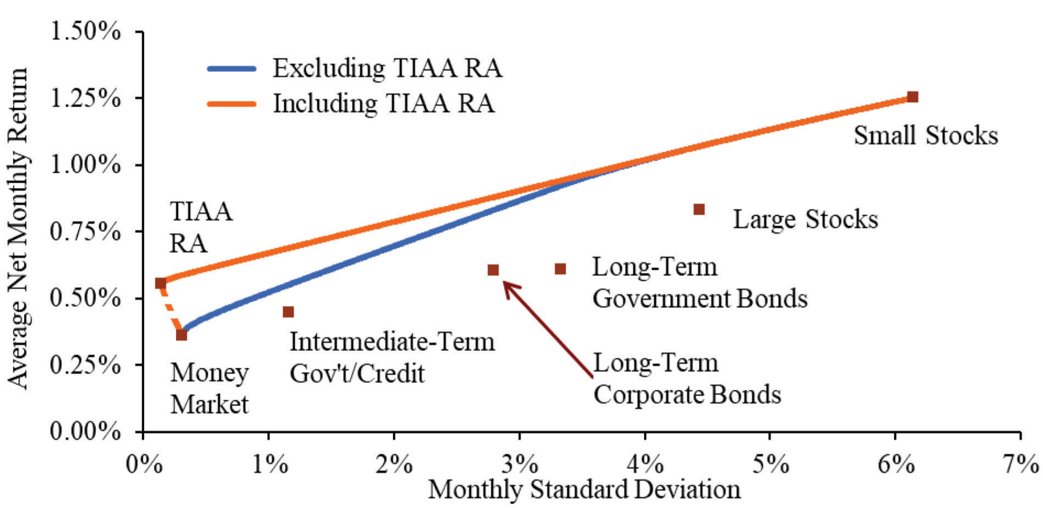


Figure B5. Efficient frontiers with and without the SRA – 1973 cohort

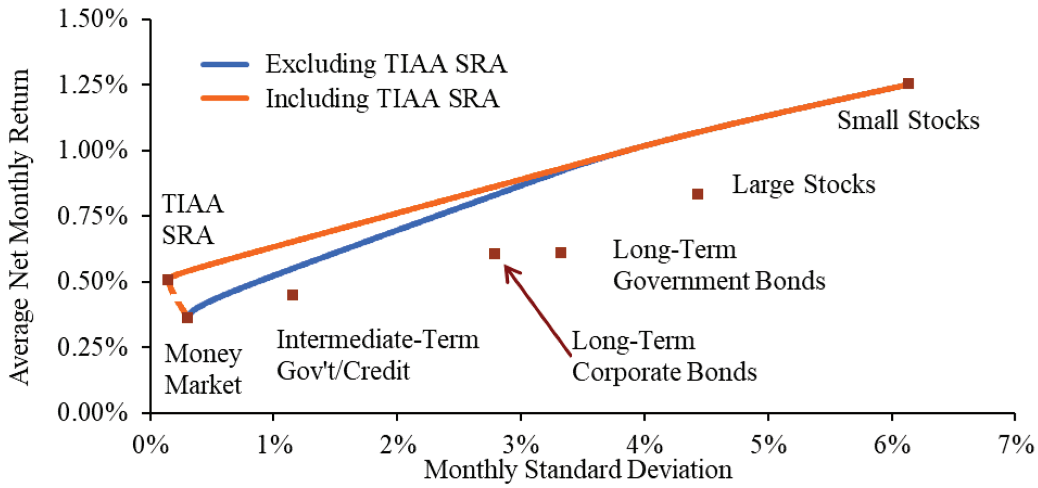


Figure B6. Optimal portfolio weights – 1973 cohort excluding the RA & SRA

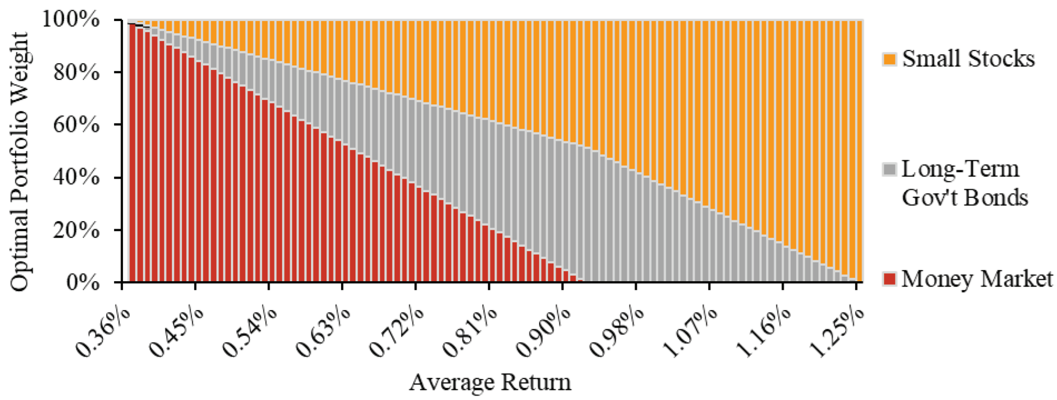


Figure B7. Optimal portfolio weights – Including the RA

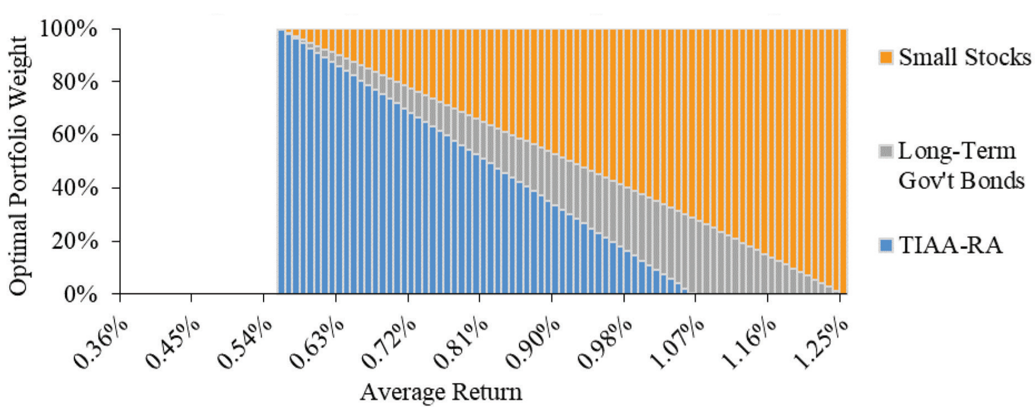


Figure B8. Optimal portfolio weights – Including the SRA

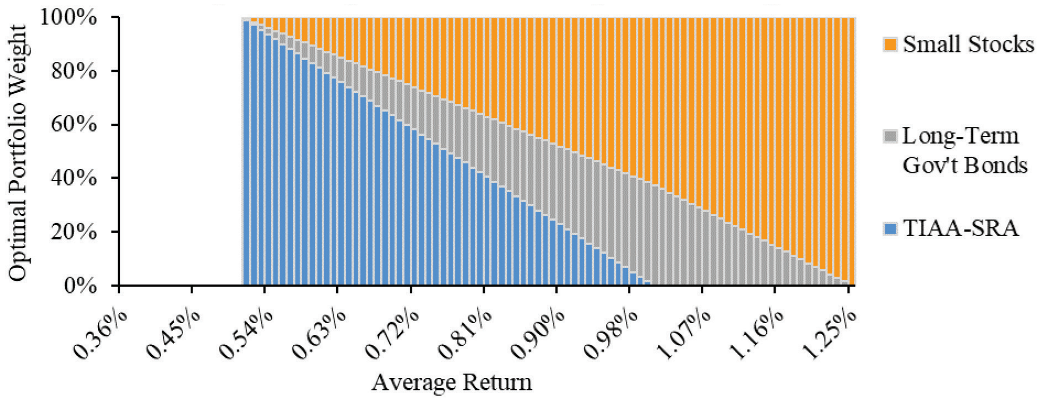


Figure B9. Efficient frontiers with and without the RA – 1975 cohort

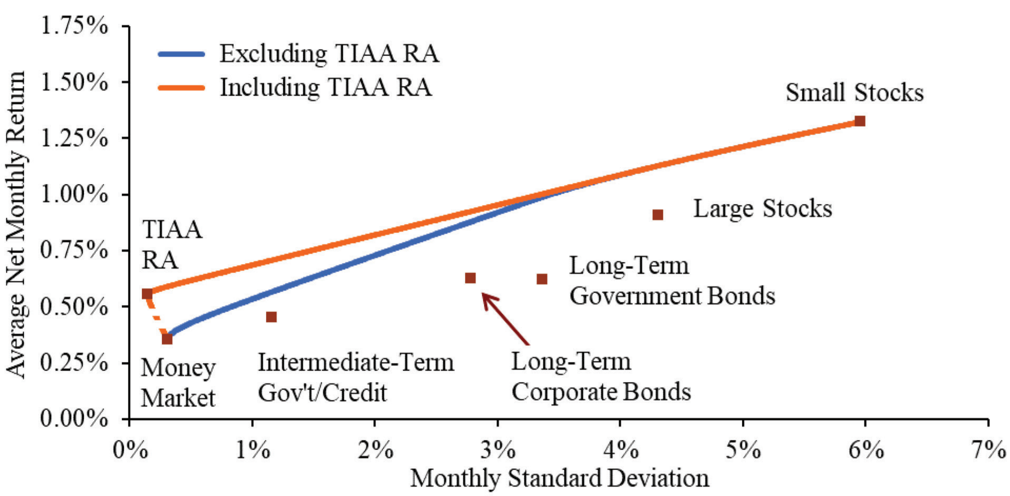


Figure B10. Efficient frontiers with and without the SRA – 1975 cohort

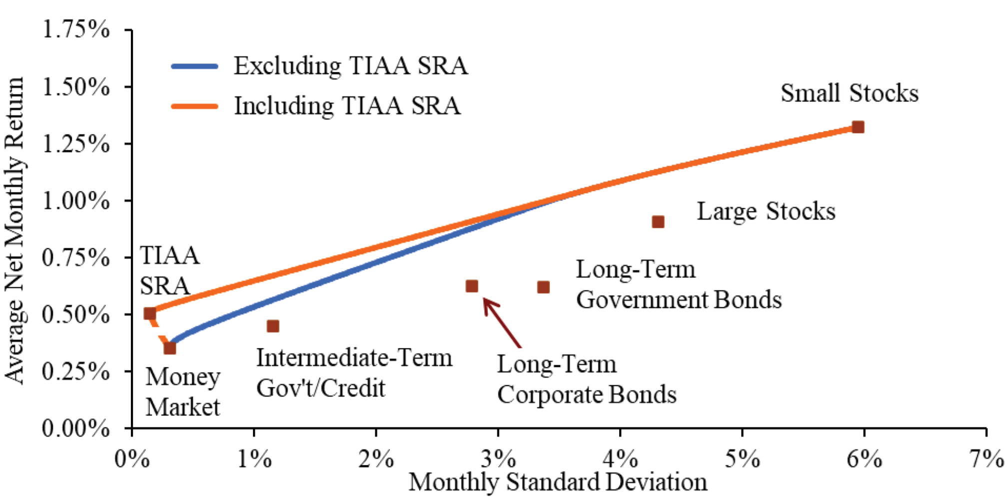


Figure B11. Optimal portfolio weights – 1975 cohort

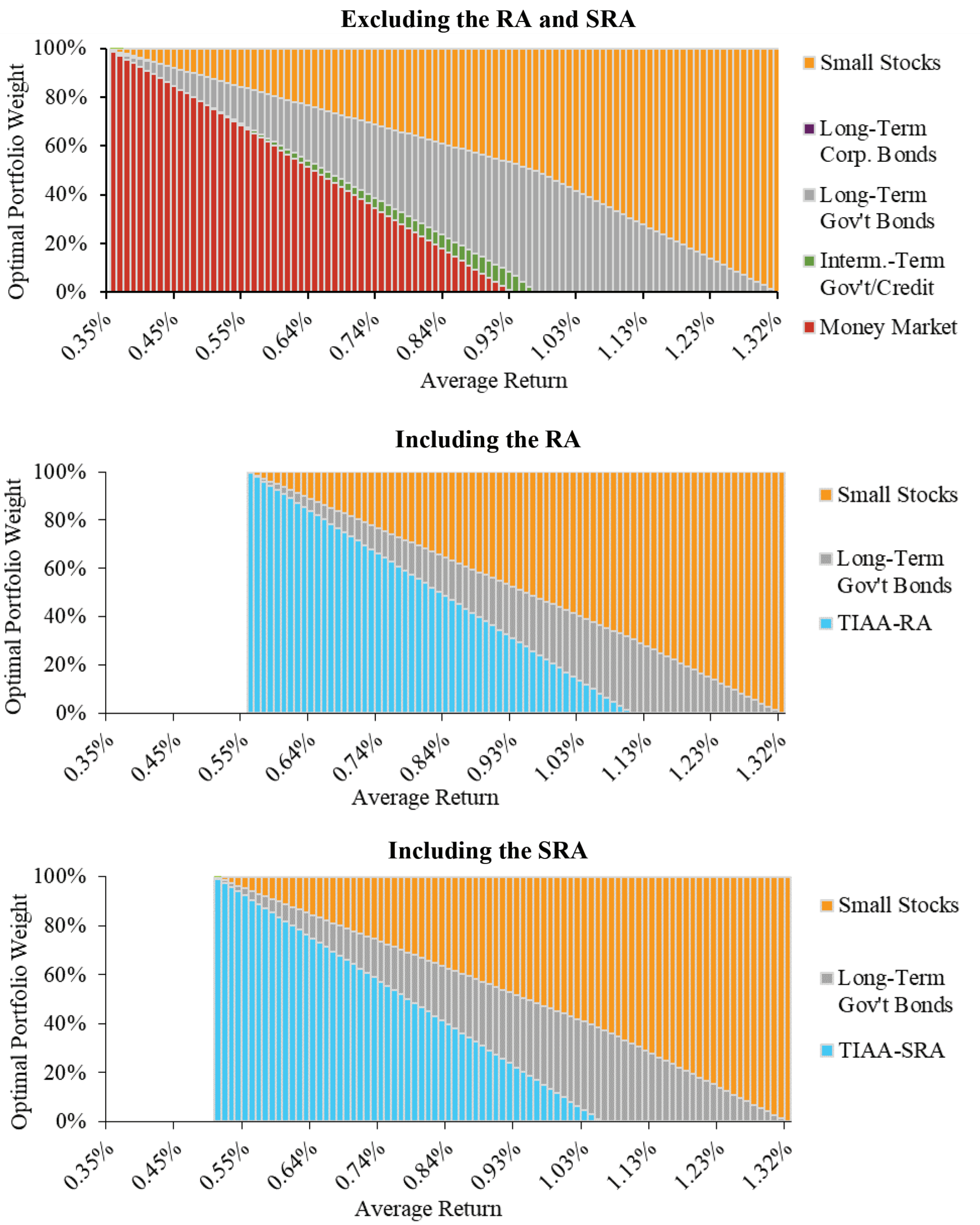


Figure B12. Efficient frontiers with and without the RA – 1980 cohort

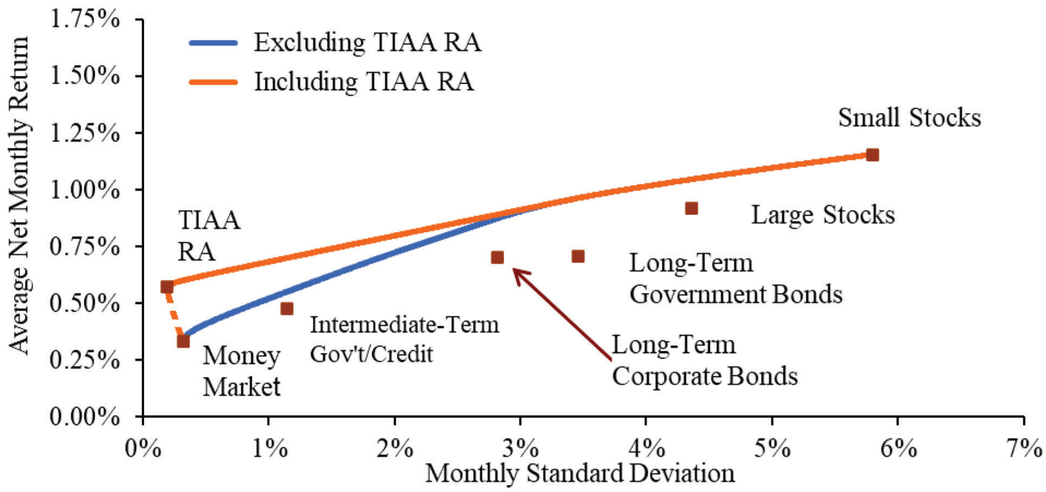


Figure B13. Efficient frontiers with and without the SRA – 1980 cohort

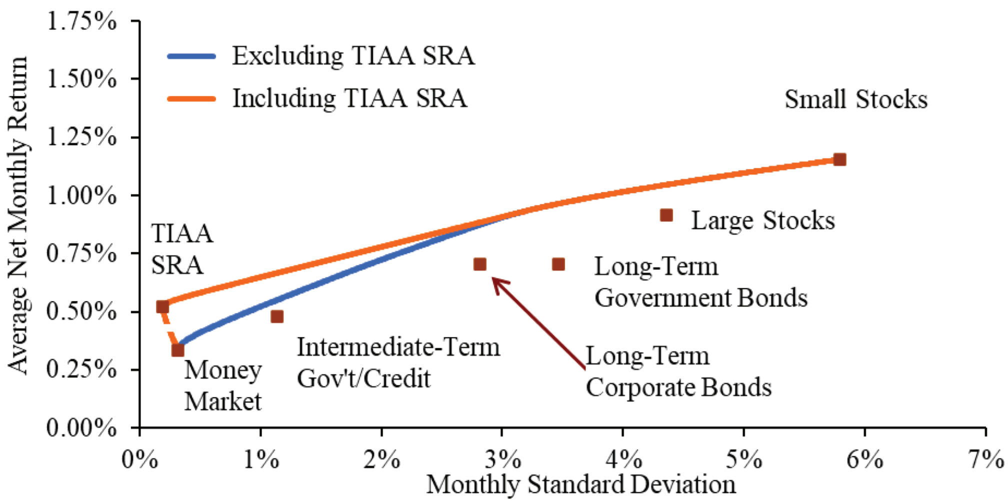


Figure B14. Optimal portfolio weights – 1980 cohort

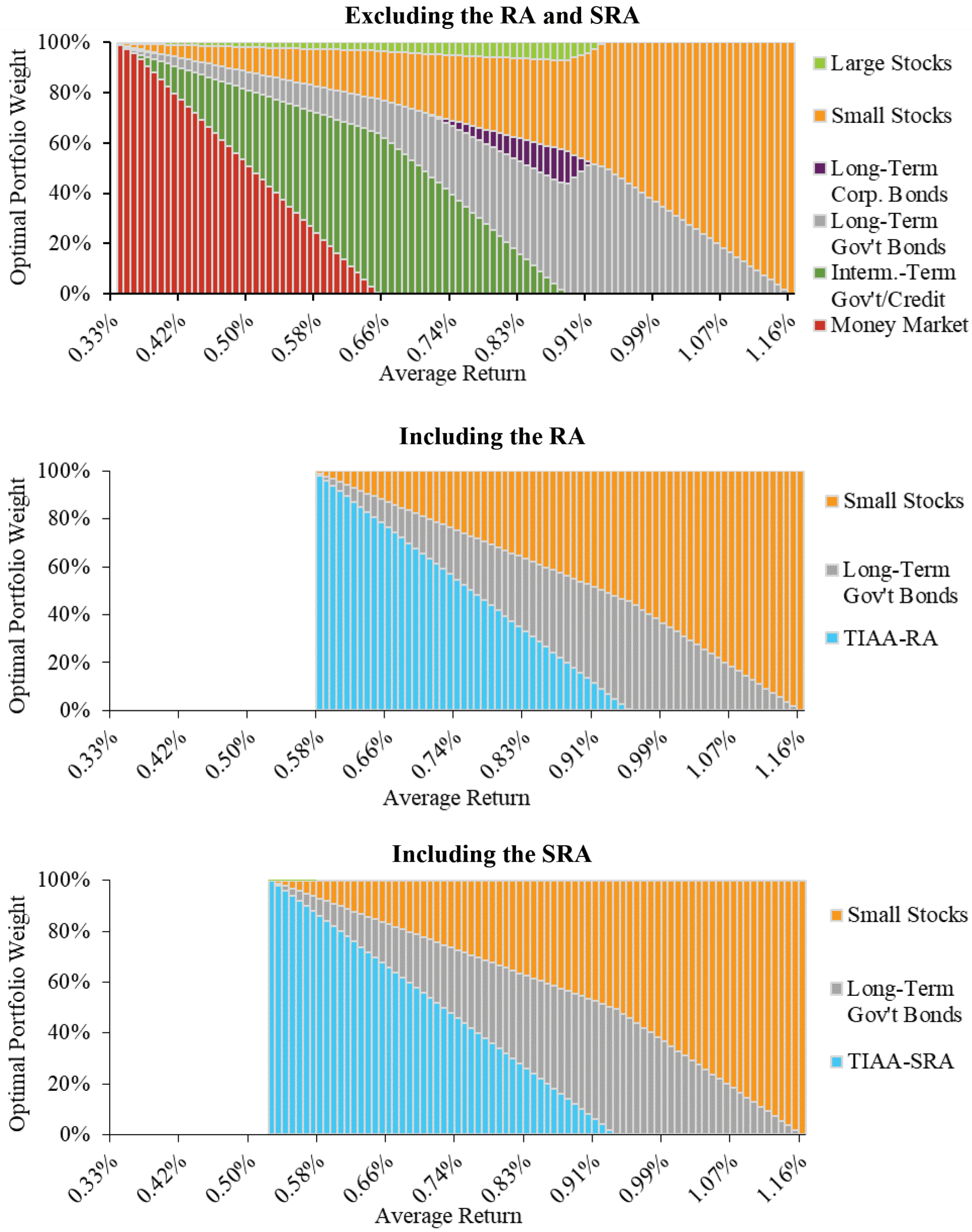


Figure B15. Efficient frontiers with and without the RA – 1985 cohort

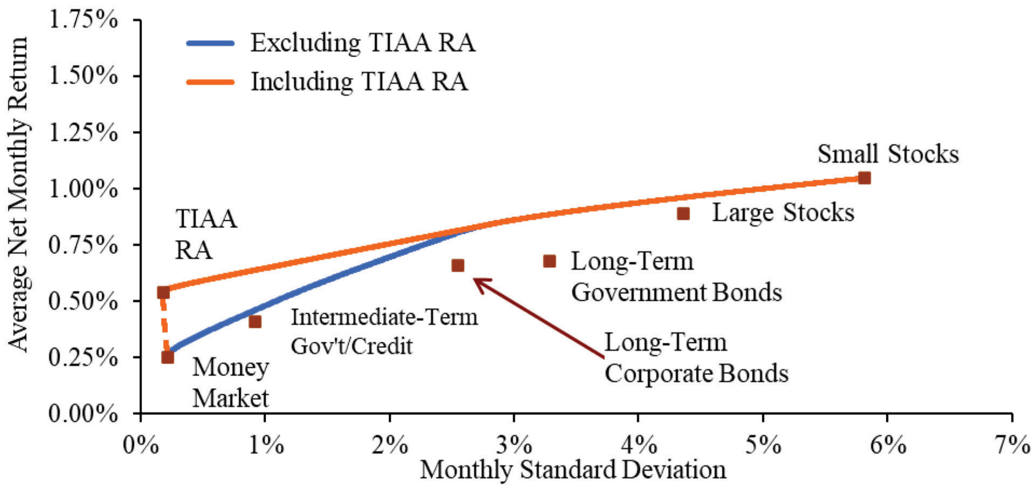


Figure B16. Efficient frontiers with and without the SRA – 1985 cohort

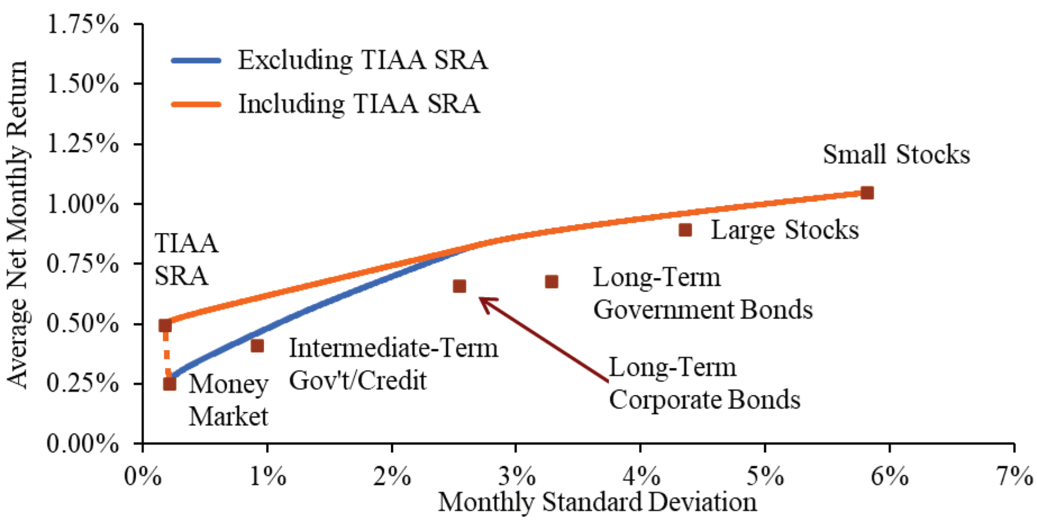


Figure B17. Optimal portfolio weights – 1985 cohort

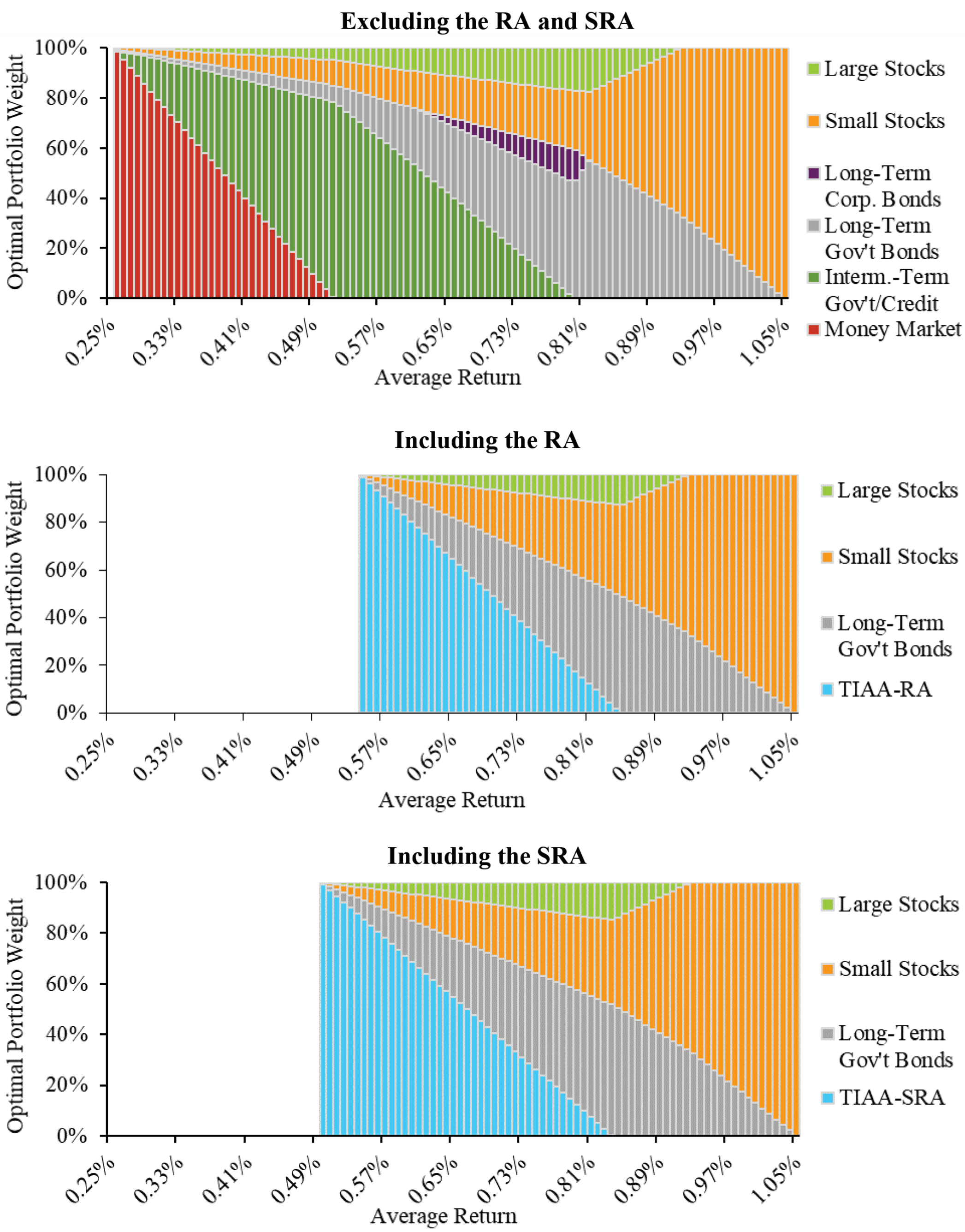


Figure B18. Efficient frontiers with and without the RA – 1990 cohort

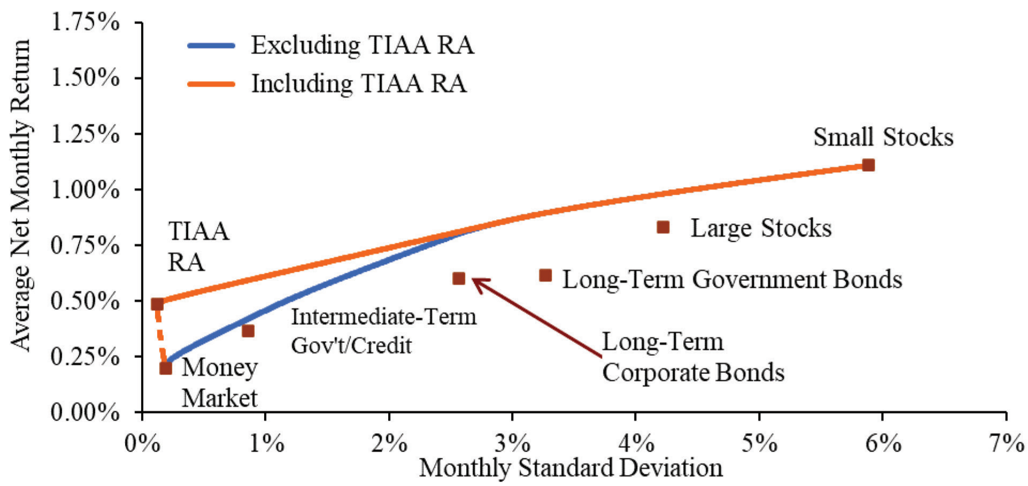


Figure B19. Efficient frontiers with and without the SRA – 1990 cohort

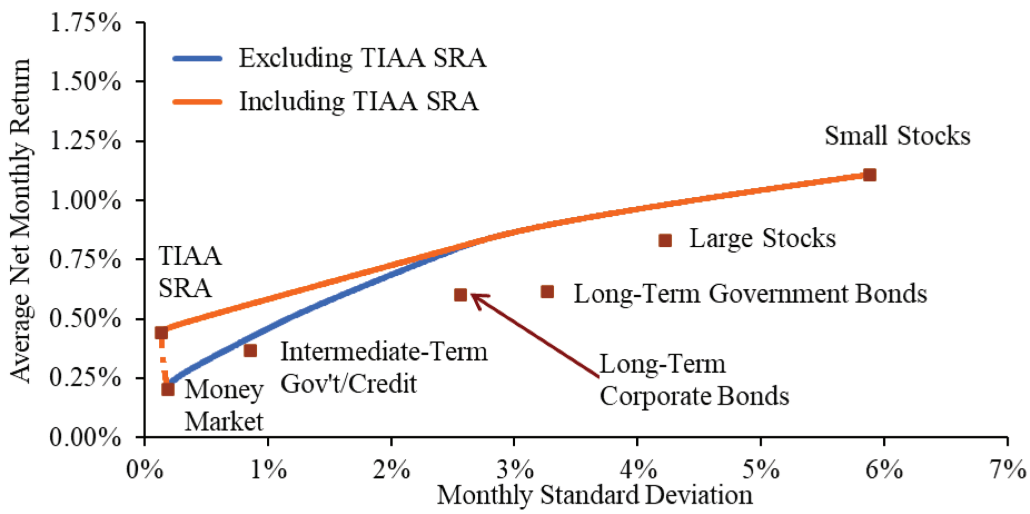


Figure B20. Optimal portfolio weights – 1990 cohort

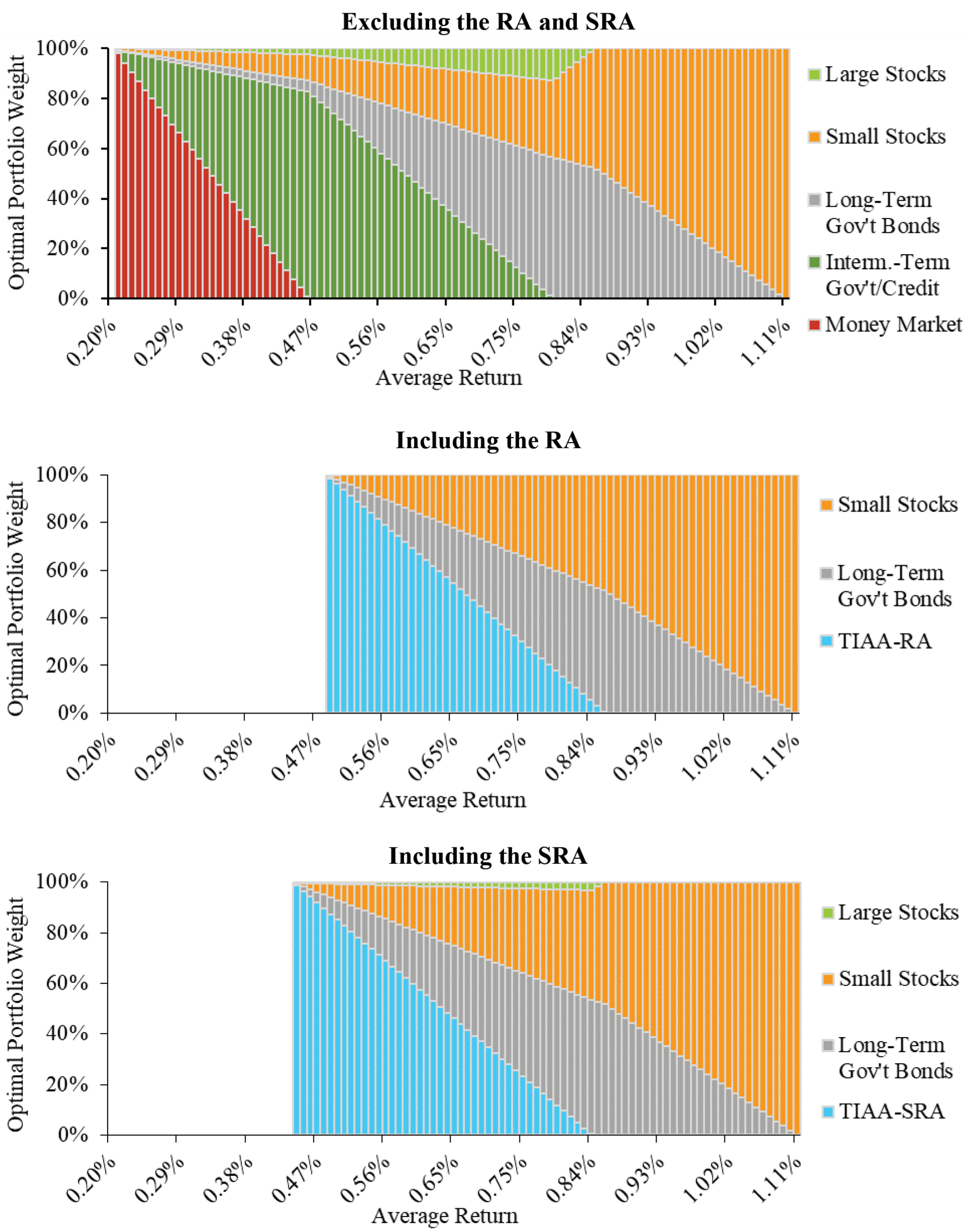


Figure B21. Efficient frontiers with and without the RA – 1995 cohort

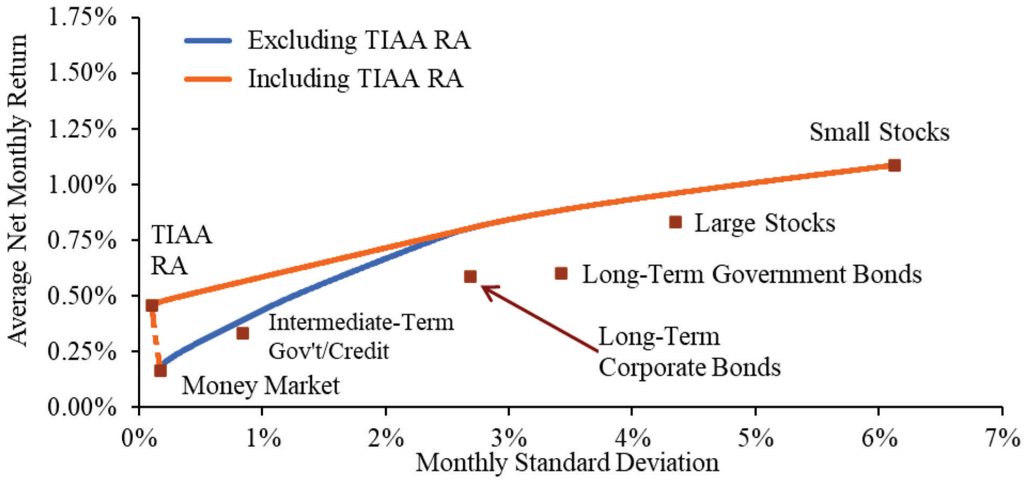


Figure B22. Efficient frontiers with and without the SRA – 1995 cohort

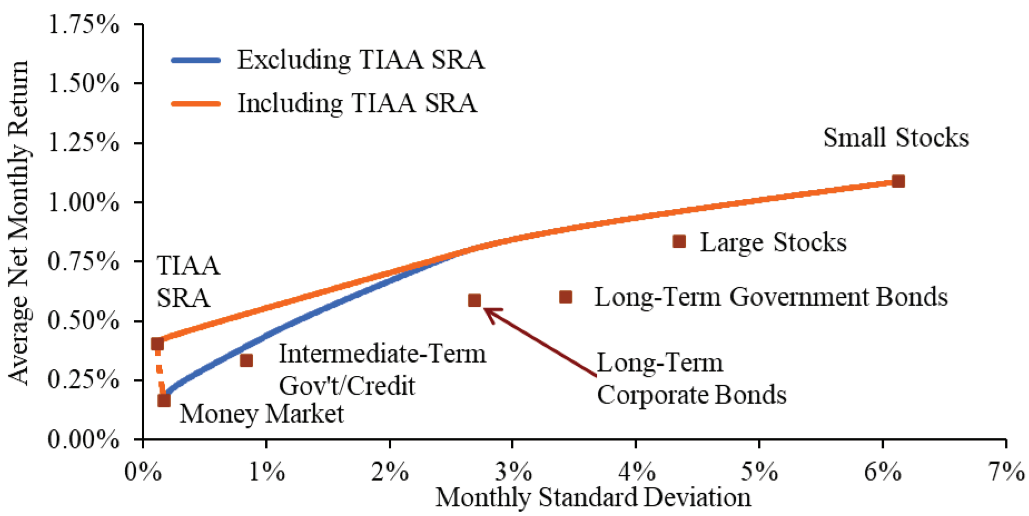
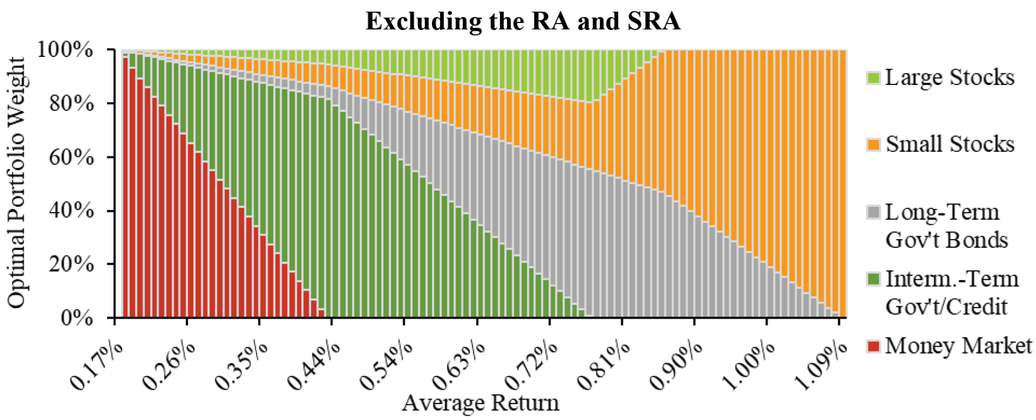
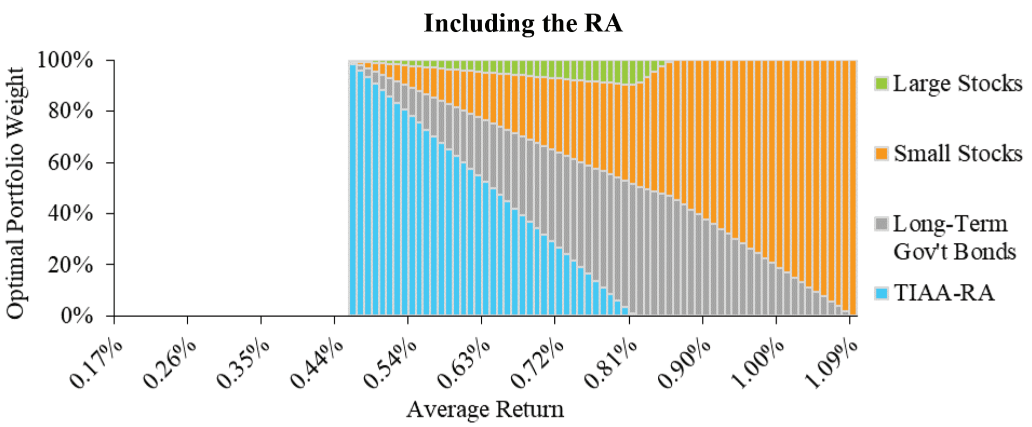


Figure B23. Optimal portfolio weights – 1995 cohort





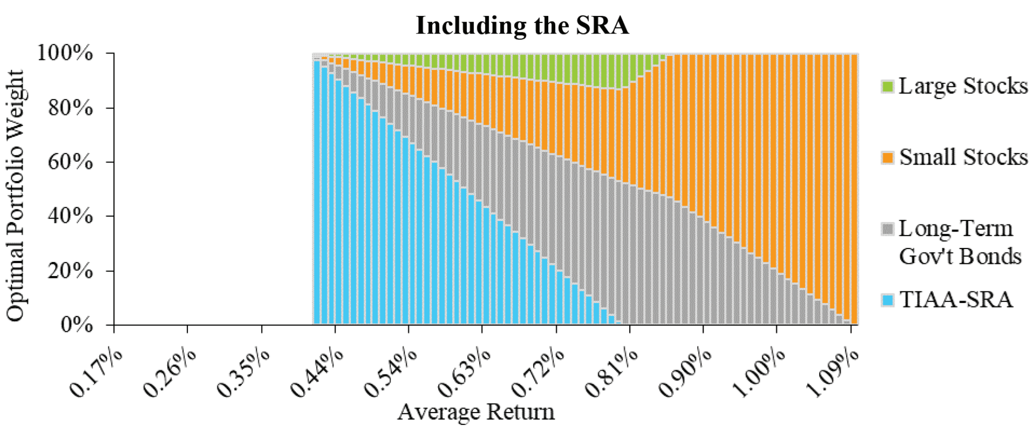


Figure B24. Efficient frontiers with and without the RA – 2000 cohort

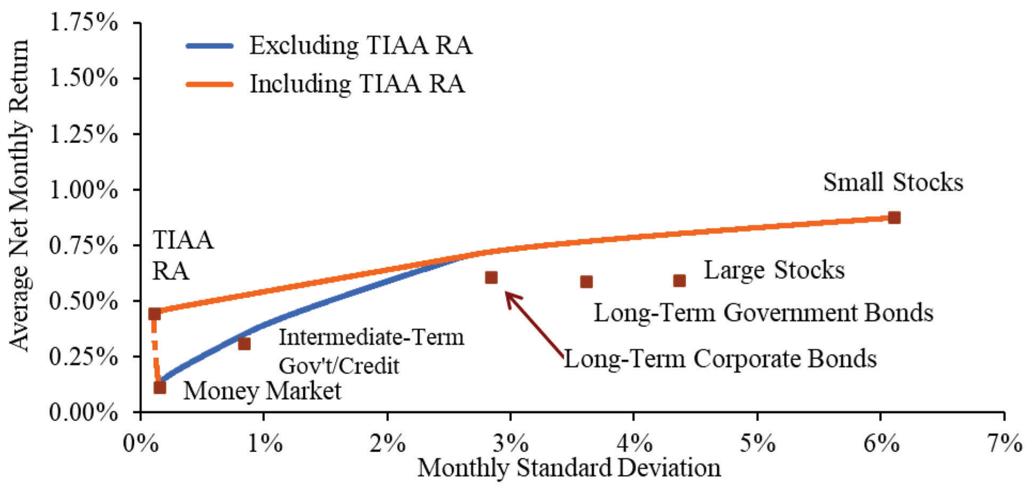


Figure B25. Efficient frontiers with and without the SRA – 2000 cohort

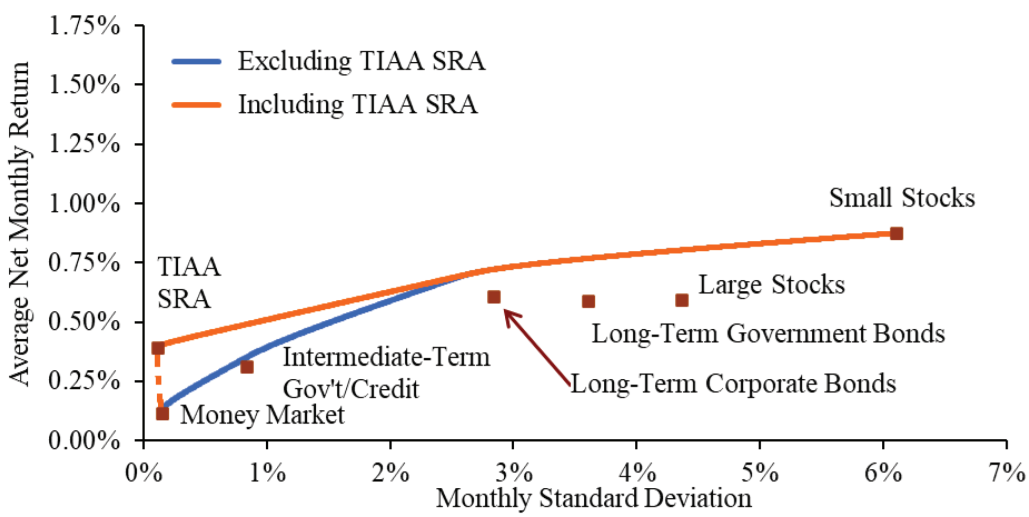
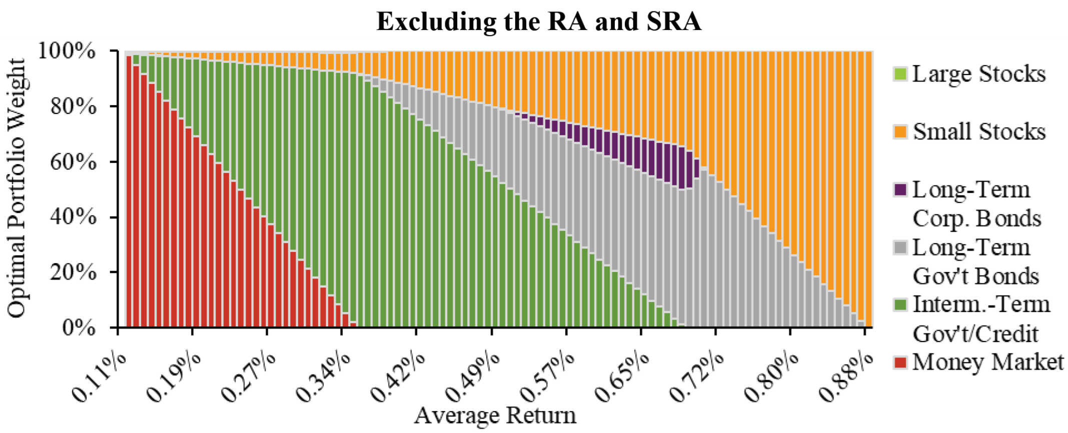
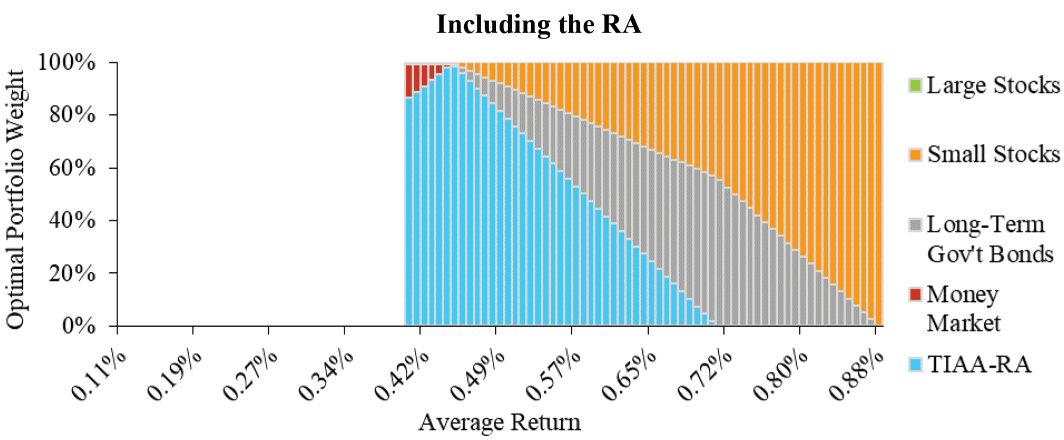


Figure B26. Optimal portfolio weights – 2000 cohort





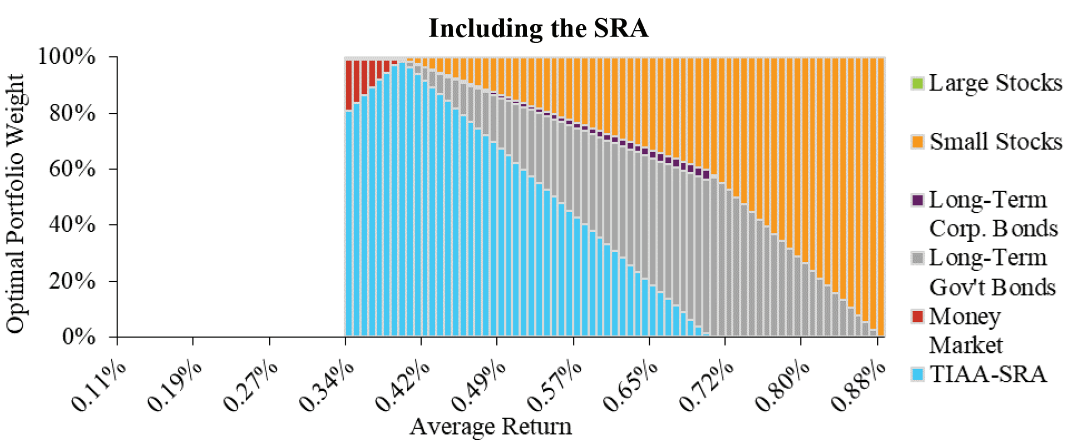


Figure B27. Efficient frontiers with and without the RA – 2005 cohort

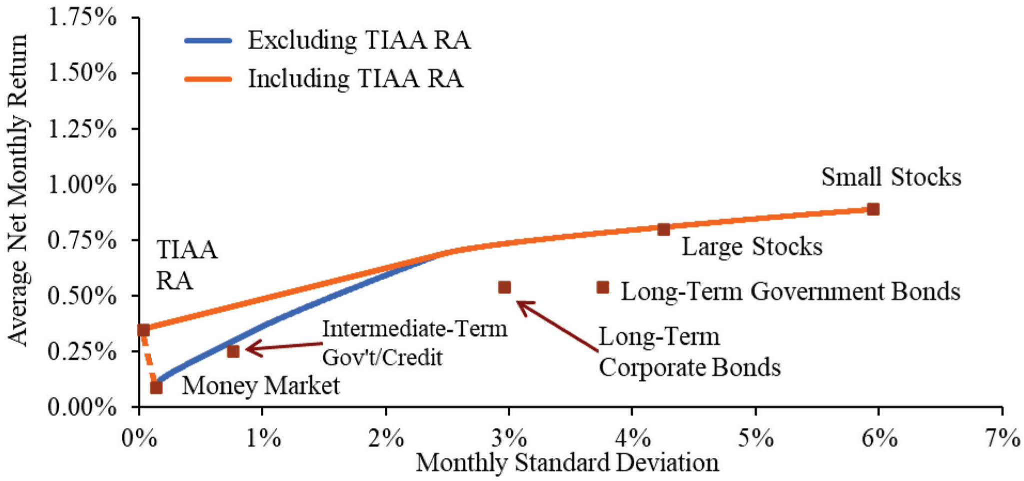


Figure B28. Efficient frontiers with and without the SRA – 2005 cohort

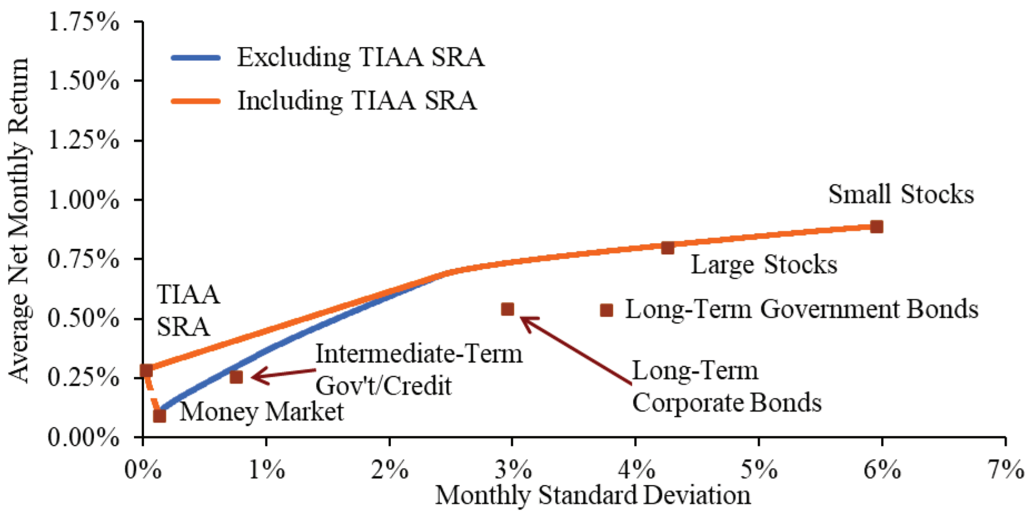


Figure B29. Optimal portfolio weights – 2005 cohort

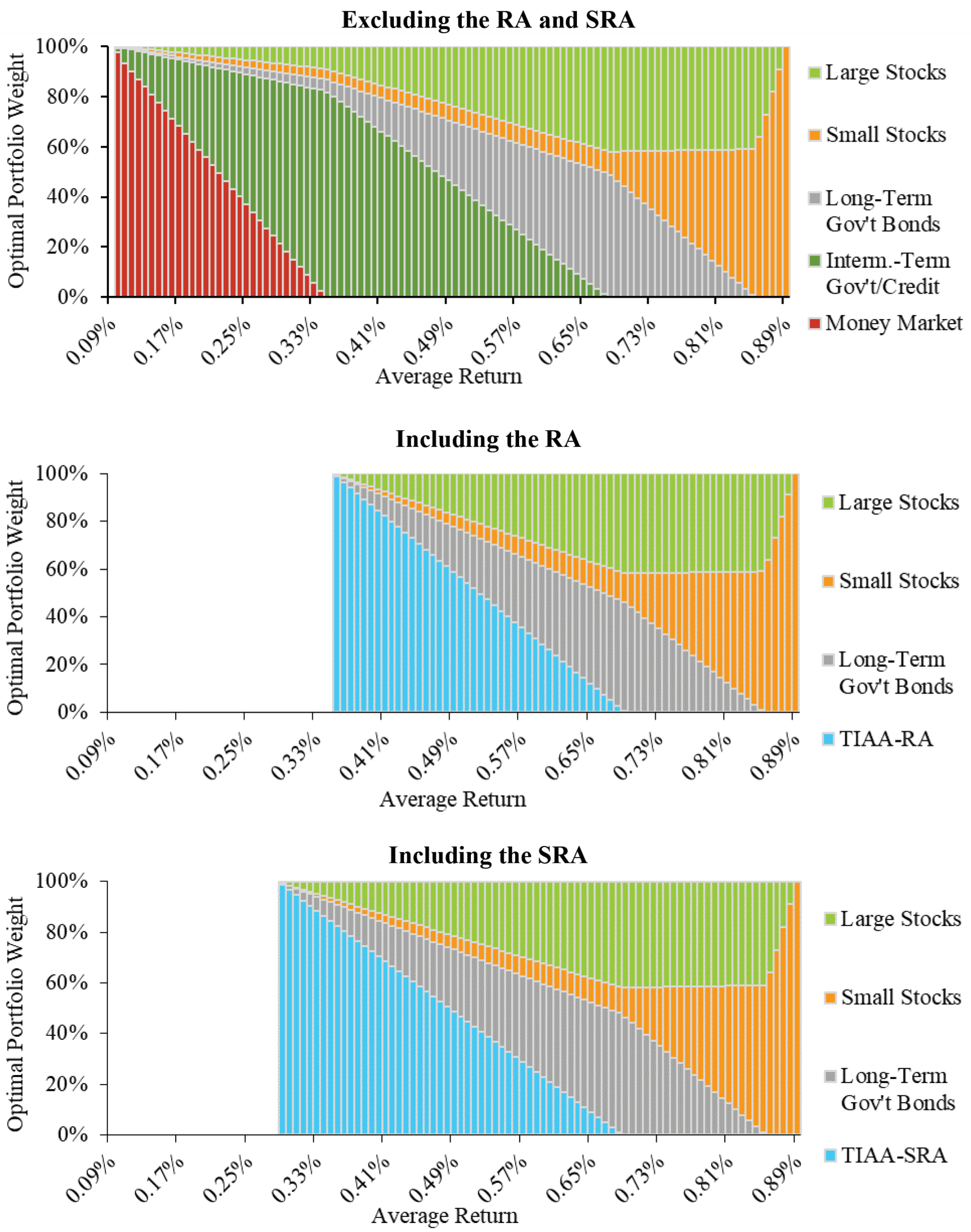


Figure B30. Efficient frontiers with and without the RA – 2010 cohort

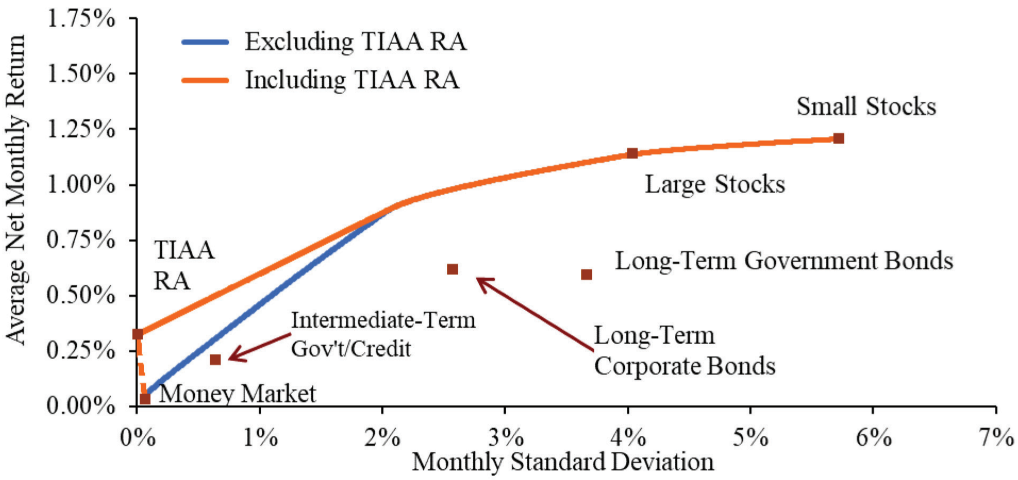


Figure B31. Efficient frontiers with and without the SRA – 2010 cohort

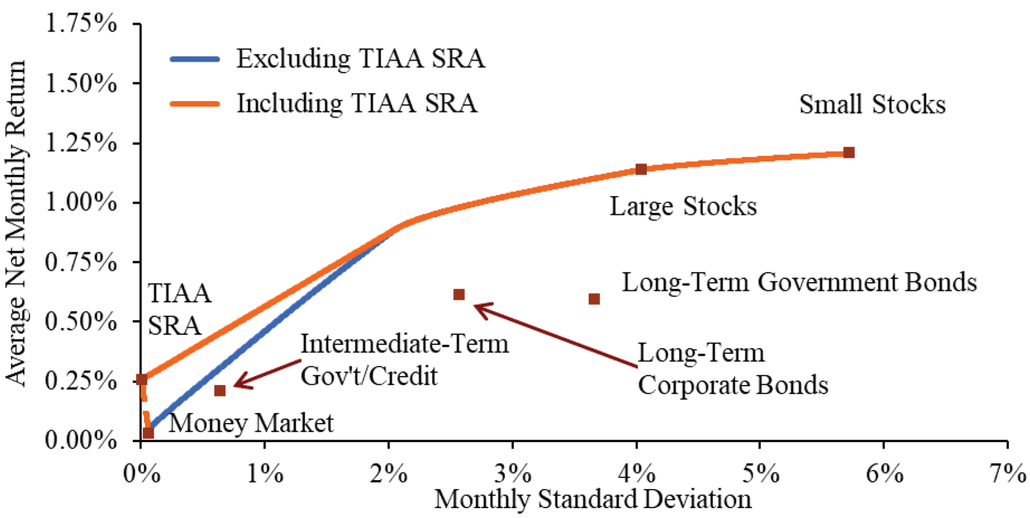
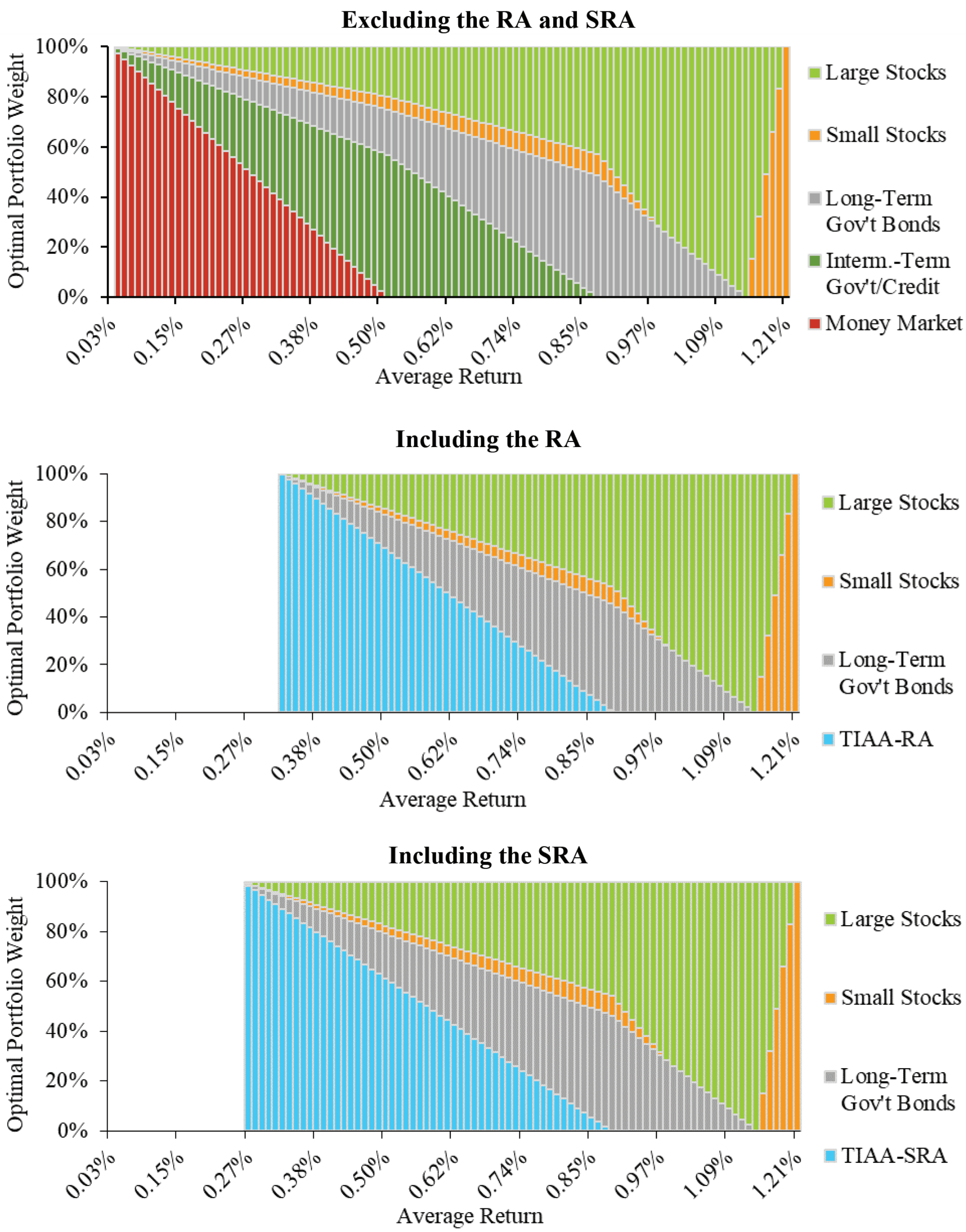


Figure B32. Optimal portfolio weights – 2010 cohort



Appendix C: Additional stochastic dominance explanation and results

This appendix first presents some additional explanatory detail regarding the stochastic dominance method and then some additional results arising from the analysis using the asset net return information over the cohorts.

Additional technical details on stochastic dominance

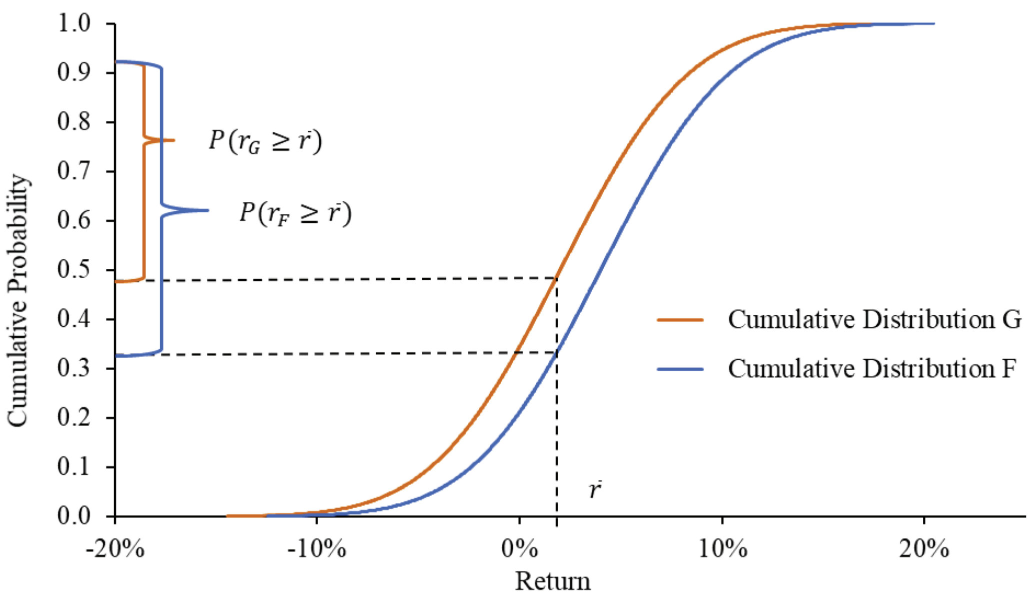
Formally, we say that distribution F stochastically dominates distribution G in the first degree if and only if,

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

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 C1 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 and to the right of the CDF of the dominated one so that Expression (3) obtains always.

Figure C1. First-degree stochastic dominance

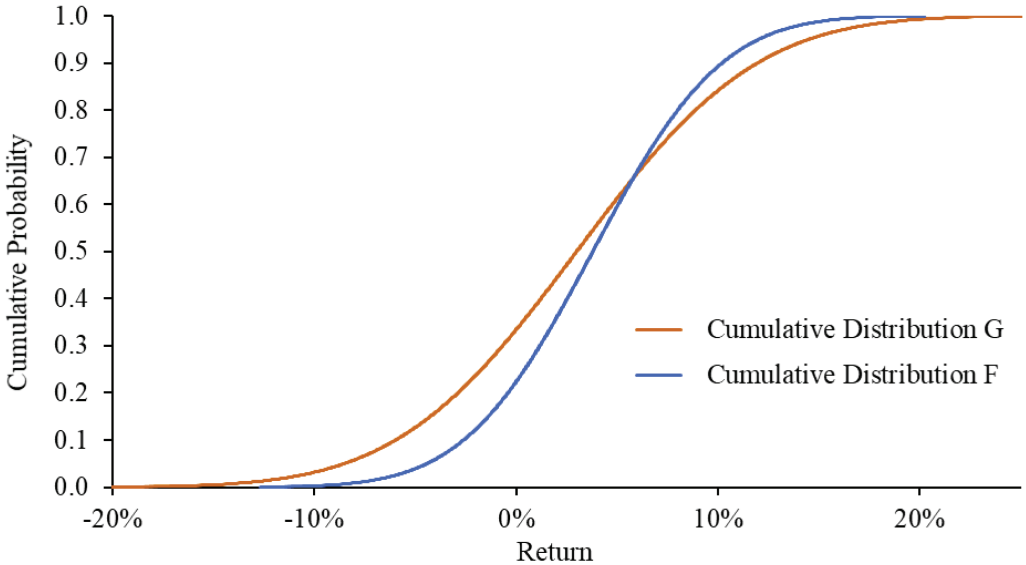


Second-degree stochastic dominance (SSD) requires investors to prefer lower variance when the dominating distribution has a mean that is at least as high as the non-dominating distribution. This implies that a return distribution that stochastically dominates another in the second degree will be preferred by risk-averse investors.

Figure C2 illustrates the conditions for return distribution F to dominate return distribution G in the second degree:

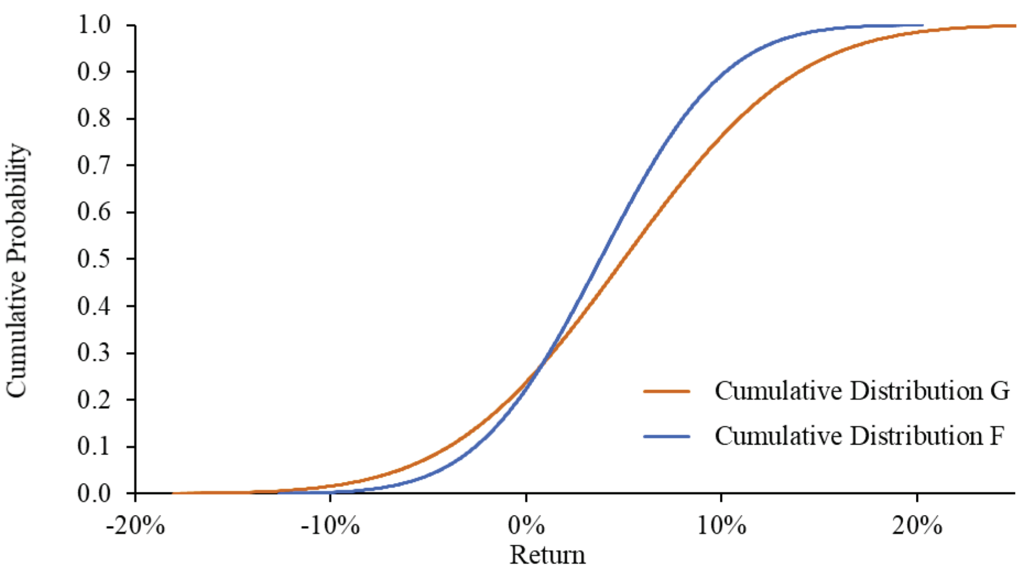
1. The distribution F is above the distribution G for part of the range of returns,
2. G starts at a lower return than F, and
3. The area where the CDF of F is above the CDF of G is smaller than the area where the CDF of G is above the CDF of F.

Figure C2. Second-degree stochastic dominance



Unless all these conditions are met, second-degree stochastic dominance does not obtain. Figure C3 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.

Figure C3. Absence of second-degree stochastic dominance



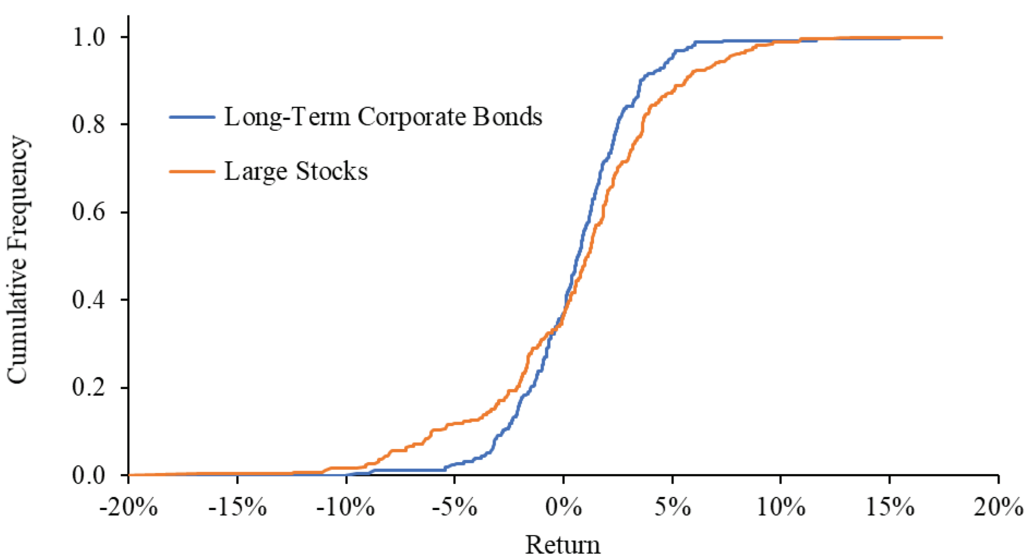
The development of third-degree stochastic dominance (TSD) was motivated by a long-observed preference among some investors for positively skewed (i.e., asymmetric) returns. A subset of the class of investors who prefer returns exhibiting third-degree stochastic dominance are those whose preferences are characterized by decreasing absolute risk aversion. Such investors are willing to pay less for insuring against a given sized risk, on average, 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.[16]

Additional observations on stochastic dominance results for alternative asset classes

An interesting result is the second-degree stochastic dominance of large corporate bonds over large stocks (represented by net returns on the S&P 500 index) for the 2000 cohort. (Illustrated in Figure C4.) This is not surprising, however, since the period spanned by the 2000 cohort includes the Dotcom Bubble of 2000 and the 2008 Financial Crisis. As Table 2 and Figure 3 in the body of the study show, the average net monthly return for the March 1, 2000 through February 28, 2021 cohort for large stocks was slightly smaller than the corresponding one for long-term corporate bonds (0.59% v. 0.61%), with a significantly larger standard deviation (4.37% v. 2.85%). The same relationships can be observed at the annual level in Table A1 and Figure A7 in Appendix A. For any other cohort, large stocks have a larger average net return than long-term corporate bonds and are never stochastically dominated by the latter.

Figure C4. Second-degree stochastic dominance for LTCB over LS, 2000 cohort

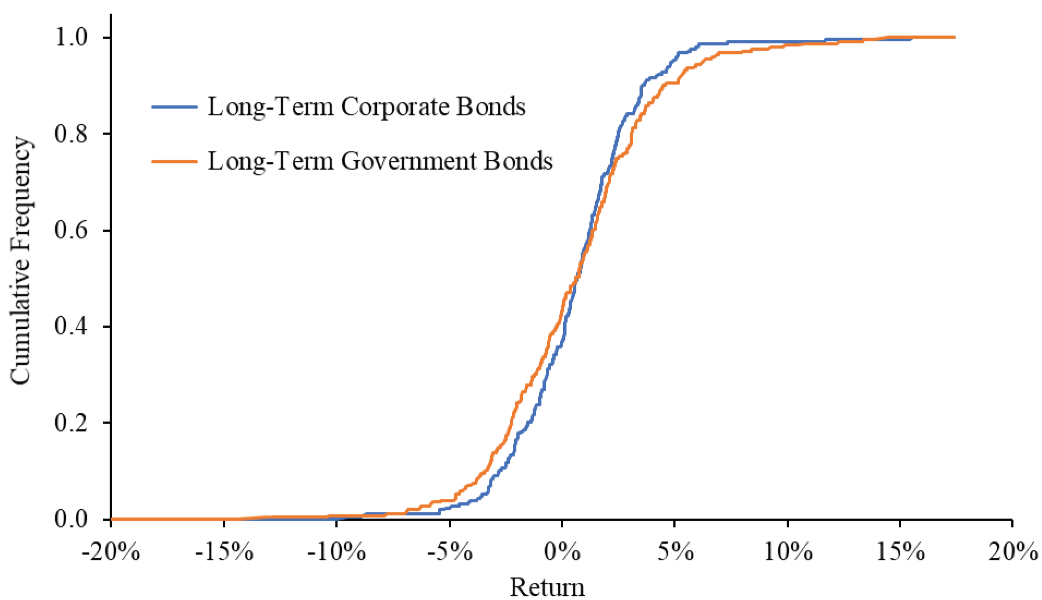


16 See the detailed exposition in Levy (2006) for a complete characterization of the necessary and sufficient conditions for SD. In this study, we have investigated stochastic dominance up to the fourth degree.

Interestingly, there are several cohorts where long-term corporate bonds stochastically dominate long-term government bonds, namely for the 1970, 1975, 2000 and 2010 cohorts. This result can be glimpsed in Tables 2 and 3 for summary statistics, where we note that long-term corporate bonds have slightly larger average returns than long-term government bonds and illustrated in Figure C5 below.

Despite this dominance, our mean-variance analysis reveals that long-term corporate bonds barely represent a significant share in optimal portfolios. The answer to this apparent paradox lies in that the mean-variance analysis relies on the covariance structure of all the investment classes and, as it turns out, for almost all the historical periods we consider, small stocks have had a negative and increasing covariance with long-term government bonds. It is these two classes that constitute the largest optimal weights for the upper ranges of the risk and return dimensions, whether the RA or the SRA are included or not, as we have shown in Section 4 above. This negative correlation is the reason that efficient mean-variance portfolios contain larger optimal shares of long-term government bonds while, at the same time, long-term corporate bonds stochastically dominate long-term government bonds in five of the ten cohorts we study. Table C1 reports correlation coefficients between small stocks and long-term government bonds and between small stocks and long-term corporate bonds.

Figure C5. Second-degree stochastic dominance – LTCB over LTGB, 2000 cohort



In Table C1, we observe that only the correlation coefficient between small stocks and long-term corporate bonds for the 2010 cohort is negatively significant while all but one of the correlation coefficients between small stocks and long-term government bonds are significantly negative. Indeed, the later our cohorts start, the more strongly negative become the correlations between small stocks and long-term bonds. This fact explains the more pronounced curvature that the efficient frontiers take on as the cohorts have a more recent starting point. It also explains why long-term government bonds are so prominent in optimal portfolios across all cohorts, despite long-term corporate bonds having a better performance when considered in isolation and stochastically dominating (in the second or third degrees) long-term government bonds for five out of the ten cohorts we consider.

Table C1. Correlation coefficients between small stocks and long-term corporate and government bonds

		SS-LTCB		SS-LTGB	
Cohort	Obs.	Coefficient	t-Stat	Coefficient	t-Stat
1970	612	0.13	3.31	-0.05	1.35
1973	576	0.11	2.67	-0.08	1.95
1975	552	0.09	2.16	-0.10	2.27
1980	492	0.07	1.55	-0.13	2.97
1985	432	0.03	0.58	-0.21	4.44
1990	372	0.02	0.40	-0.26	5.17
1995	312	-0.01	0.13	-0.31	5.72
2000	252	-0.01	0.12	-0.35	5.97
2005	192	0.00	0.05	-0.39	5.90
2010	132	-0.16	1.84	-0.55	7.59

Note: The t-statistic has an approximate standard normal distribution. The 90% critical values for one-tailed and two-tailed tests are 1.282 and 1.645, respectively. The 95% critical values for one-tailed and two-tailed tests are 1.645 and 1.960, respectively..

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