Fixed Income for Retirement Saving: TIAA Traditional's Lessons on Quality, Duration, Risk, and Gradual Withdrawals

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Abstract. TIAA's Traditional Annuity has supported retirements for a century. It resembles a stable-value fund. We investigate the holdings supporting it, construct readily-available alternatives resembling those holdings, compare the returns of those alternatives to Traditional, and construct a new measure of risk to compare Traditional's risk to that of its alternatives in a more appropriate way than using short-term standard deviation of returns. Under this new measure of risk, which is appropriate for retirement investors, some alternatives exhibited second-degree stochastic dominance over Traditional using 1987–2015 data. However, Traditional may still be better choice for unsophisticated investors.

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JEL Codes: G11, J26, J32

The oldest "defined contribution" retirement vehicle in the US is run by the nonprofit Teachers' Insurance and Annuity Association ("TIAA") and called the TIAA Traditional annuity, established in 1918 to provide pensions for professors. TIAA Traditional ("Traditional" from now on) was the sole pre-tax retirement savings vehicle for many professors until the 1950's, when Social Security was extended to higher education and TIAA established the "College Retirement Equities Fund" for stocks, inventing the "variable annuity." Traditional remains important today, being the largest member of the class of investments that offer a guarantee of no loss of principal. Other members of this class are stable value funds and U.S. savings bonds. Investments in this class use "book value" accounting or do not directly own assets at all, whereas other fixed-income investments use "mark to market" accounting; the latter are said to be "marketable" and the others are not. One of the several ways in which guaranteed-principal class members differ from each other is in size: Traditional and the US federal government retirement system's "G Fund," which both have more than $200 billion in assets, and savings bonds, which are worth somewhat more than $150 billion, dwarf the fourth largest member of this class, which has less than $30 billion in assets. For comparison, among the universe of marketable fixed income investments, no bond mutual fund has more than $150 billion in assets except Vanguard's Total Bond Market/Total Bond Market II, and no bond ETF has more than $60 billion in assets. Traditional is backed by the claims-paying ability of TIAA, which is "one of only three insurance groups in the United States to currently hold the highest possible rating from three of the four leading insurance company rating agencies: A.M. Best, Fitch and Standard & Poor's and the second highest possible rating from Moody's Investors Service" (TIAA 2018b). TIAA prominently advertises that part of its portfolio comprises investments unavailable to retail investors: it is the largest global investor in agriculture, the "second largest grower of wine grapes by acreage in the United States," and the "third largest commercial real estate manager in the world."[1]

Given this extraordinarily long history and continuing importance in the marketplace, it is of interest to get a comprehensive view of what investments are responsible for Traditional's performance and what that performance has been. It is also useful to determine if there are any close substitutes for Traditional because most people cannot invest in it—retirement savers working

[1] TIAA (2018i). For TIAA's history, see Biggs (2010 p. 7) and Funding Universe (n.d.); for its current size, see State Universities Retirement System (2017). For the size of the G fund: Thrift Savings Plan (2018). For the amount of U.S. savings bonds outstanding: United States Treasury (2019). The size of other stable value funds: Barron's (2018). The size of bond mutual funds: MutualFunds.com (2018). Size of ETFs: ETFdb.com (2018).

outside the nonprofit and government sectors are ineligible to put money into Traditional unless an "eligible family member" of theirs can (TIAA 2014)—and because even people who can invest in it and desire an intermediate- or long-term fixed-income investment may hesitate to invest in it because of its very strict withdrawal requirements: "all withdrawals and transfers from the account must be paid in ten annual installments" (TIAA (2018b)), a process TIAA calls a "Transfer Payout Annuity" (TIAA 2018e). (Traditional actually comes in nine versions and a correspondingly complicated set of eligibility and withdrawal rules (see TIAA (2018a) and TIAA (2014)); we deal only with the "Retirement Annuity" ("RA") type, which is the variety which has the highest guaranteed minimum interest rate.)[2]

Assessing Traditional is unusually difficult for two reasons. The first is that the many sources of investment information for retail investors are of no avail because Traditional is subject to the reporting requirements for insurance companies not for mutual funds. The second is that the conventional metric for risk, monthly or annual standard deviation of returns, is inappropriate for Traditional because its withdrawal restrictions mean that investors cannot access the rewards of its gentle always-upward change in account value in at all the same way they could access the value of a mutual fund. Section 1 discusses how the difficulties of obtaining data were overcome. Section 2 develops appropriate benchmarks for Traditional; the benchmarks we chose are all mutual funds or ETFs, partially because many other members of the guaranteed-principal class share Traditional's drawbacks of having limited accessibility or limited availability of performance information, and partially because because our main interest is in studying the effect of the presence or absence of a principal guarantee. Section 3 assesses historical returns of Traditional and its benchmarks; and Section 4 develops a new measure of risk that is much more appropriate for comparing Traditional with mutual funds, then applies it to make an overall assessment of Traditional versus its benchmarks.

The new measure of riskiness leads to an overall assessment rather different from the decidedly-favorable assessments of Traditional arrived at by Goodman and Richardson (2014, e.g., their Table 2) and by Babbel et al. (2015). Tradi-

[2] A few of Traditional's other varieties share RA's guaranteed minimum interest rate and have less restrictive withdrawal requirements (GRA, GSRA, IRAs issued before 10/11/10, Keogh, and SRA), but the last four of those have lower 10-year returns as of 10/31/18 than RA, and although GRA has a return equal to RA's, its withdrawal restrictions almost as restrictive: its only alternative to withdrawal over ten annual installments is "lump-sum withdrawals... only within 120 days after termination of employment and are subject to a 2.5% surrender charge" (TIAA 2018c). (Ten-year returns from `https://www.tiaa.org/public/investment-performance?defaultview=faonly`.)

tional was still less volatile than its mutual-fund benchmarks, but not enough to compensate for its lower returns compared to some of those benchmarks, at least according a key criterion explained and used in Section 4, second-order stochastic dominance. Traditional would seem to be a fine choice for investors who would otherwise engage in panic selling at some point if they held close to one-half of their fixed-income investments in long-term bonds, but investors who could hold that amount of long-term bonds without panicking have alternatives to Traditional which, with similar bond quality and maturity, did better.

1. Obtaining Data

TIAA (2018b) writes that "TIAA Traditional is a guaranteed insurance contract and not an investment for Federal Securities Law purposes," and it is regulated as such. This is no doubt appropriate and in some ways beneficial but it means Traditional is not subject to the reporting requirements of the Investment Company Act of 1940. Because Traditional's returns do not come about as a transparent consequence of the returns of the assets it holds, but as a discretionary action taken by TIAA's Board of Directors, there is always going to be some lack of transparency in how Traditional's returns come about. In recent years TIAA has become somewhat more transparent about what those returns have been, if not about how they were decided. TIAA acknowledges now being subject to "competitive pressures derived from additional financial services providers. . . as they became available to core participants" in a time of "increased widespread use of the Internet. . . and thus, increased transparency of financial products and rates available to TIAA participants" (TIAA 2018f pp. 7, 8). Nevertheless its communications for the investing public still fall short in three key areas: reporting historical performance; providing competitive benchmarks; and reporting past performance fluctuations.

The investing public and investment advisors assess historical performance of mutual funds using 1-, 3-, 5-, and 10-year "average annual returns," which the Securities and Exchange Commission ("SEC") requires all companies to calculate in exactly the same standardized way.[3] Traditional is not subject to that regulation and does not provide those average annual return figures. More unfortunate is that TIAA *does* prominently provide for Traditional figures which it labels as "average annual returns" and "average annual total returns" but fine-

[3] 17 CFR 230.482, 'Advertising by an investment company as satisfying requirements of section 10,' (d) 'Performance data for non-money market funds,' (3) 'Average annual total return.' Available at `https://www.law.cornell.edu/cfr/text/17/230.482`. The mathematical details are specified in Item 26(b) p. 52 (PDF p. 62) of SEC Form N-1A (US SEC (2018)).

print footnotes reveal that those are not at all the industry-standard measures,[4] so they cannot be used to compare Traditional to other investment products, even to the other investment products offered by TIAA.

The investing public and investment advisors assess the performance of an investment company's management in part by comparing its performance to that of a suitable securities index, a "benchmark." Mutual fund companies are required by the SEC to choose such a benchmark and to publicly disclose how it performed.[5] TIAA is not required to provide such a benchmark for Traditional and it does not do so. Instead, it either provides an inappropriate benchmark—"A 10-year risk-free rate seems appropriate to use as a benchmark for the TIAA Traditional Annuity" they write (2018f), although Section 2 below will show that Traditional's portfolio is far from risk-free—or it implies there *is* no appropriate benchmark, writing "TIAA Traditional isn't structured exactly the same way as guaranteed annuities that other financial services firms may offer, so it's difficult to make a direct apples-to-apples comparison. Our rates are designed to be competitive, fair, sustainable and based on clear principles that participants can count on over the long term" (TIAA 2018a).

The investing public and investment advisors assess the riskiness of a mutual fund in part by investigating past performance fluctuations. The SEC requires mutual fund companies to provide a chart showing this information in a prominent place.[6] Such charts include year-by-year performance numbers to two decimal places. TIAA is not required to provide such a chart for Traditional and does not. It does provide a line graph (e.g., TIAA 2016c, 2017c, 2018f). That imparts much less precise information (unless laboriously examined in special ways, see below). Even worse, we will show that some of those graphs contradict each other, so they are unreliable.

The consequence is that while mutual fund companies are required to "clearly disclose the fundamental characteristics and investment risks of the Fund, using

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[4]They apply to "what an individual *making level monthly premiums* would have historically earned" (my emphasis). See e.g. `https://www.tiaa.org/public/investment-performance?defaultview=faonly`.

[5]From United States SEC (2018, Form N-1A): "Item 4. Risk/Return Summary: Investments, Risks, and Performance. Include the following information, in plain English under rule 421(d) under the Securities Act, in the order and subject matter indicated. . . . (b) Principal Risks of Investing in the Fund. (2) Risk/Return Bar Chart and Table. (iii). . . The table also should show the returns of an appropriate broad-based securities market index as defined in Instruction 5 to Item 27(b) (7) for the same periods" (p. 11, PDF p. 21).

[6]From US SEC (2018, Form N-1A): "Item 4 (b) (i) Include the bar chart and table required by paragraphs (b)(2)(ii) and (iii) of this section. Provide a brief explanation of how the information illustrates the variability of the Fund's returns (e.g., by stating that the information provides some indication of the risks of investing in the Fund by showing changes in the Fund's performance from year to year. . . " (p. 11, PDF p. 21).

concise, straightforward, and easy to understand language... [using] document design techniques that promote effective communication... for an average or typical investor who may not be sophisticated in legal or financial matters" (US SEC 2018 p. iii), TIAA does not do this for Traditional. In the following sections we provide the detailed analysis needed to fill that gap using sources not intended for the general public. Section 2 solves the benchmarking problem primarily using TIAA regulatory filings. Section 3 solves the performance data problems by using a TIAA-CREF Institute research report authored by Ph.D. researchers who were given access to in-house data, Babbel et al. (2015). For Section 4, the only way to obtain performance fluctuation data was by applying data extraction tools to 'reverse-engineer' Figure 1 of another TIAA-CREF Institute report whose authors had access to in-house data, Goodman and Richardson (2014), then combining those results with data obtained from the partially-erroneous line graphs described in the previous paragraph. TIAA is to be commended for sponsoring the research of Babbel et al. and of Goodman and Richardson.

2. Benchmarking: Matching the Duration and Quality of TIAA's General Account

While it is true that, as TIAA (2018a p. 6) says, "[Traditional's] participants do not invest in the TIAA general account portfolio" and the rate of interest "is determined at the discretion of TIAA's Board of Trustees" (op. cit. p. 5) rather than directly from the underlying holdings, TIAA's General Account's investments are what make Traditional possible and so are what someone trying to either benchmark or mimic Traditional using other instruments would want to imitate. TIAA invests in some long-term illiquid assets which are unavailable to a retail investor, and as of year-end 2016, only 63.31% of the General Account's investments were classified as "public fixed income," with the rest being various non-public instruments.[7] Nevertheless the primary characteristics of the General Account's portfolio, like any fixed-income portfolio, are its duration and credit quality, and they can be reproduced using retail investments. Ideally we

[7] TIAA (2017a, p. 1). The other investments were: "13.16% Private fixed income, 8.28% Commercial mortgage whole loan by investment type, 3.53% Real estate by investment type, 3.43% Natural resources, 2.60% Private equity funds and co-investments, 2.39% Operating subsidiaries, 1.58% Other investments, 1.72% Other subsidiary investments." The source of this data, a TIAA almost-two-hundred-page-long General Account Annual Statement, is TIAA (2016b)~~no longer available on TIAA's web site, but~~; the current version~~one~~ is (TIAA 2018j). Some information, such as the dollar value of TIAA's investment in wine grapes, cannot be found, at least not in a straightforward way, even in TIAA's Annual Statements' "Investment Schedule Detail" since the assets are held by subsidiaries (see `https://www.tiaa.org/public/about-tiaa/corporate-governance-leadership/document-library`).

would have a time series of several decades of General Account duration and quality, but the oldest source we have for its option-adjusted duration is year-end 2015, so we choose that as the single point in time to match. Its duration—the source makes clear that the duration is for all the ~~entire~~ General Account's fixed-income holdings, not just ~~for~~ its publicly-traded ~~securities~~bonds—was 7.59 (TIAA 2016a), which becomes our duration target.[8]

The 2015 quality target is more difficult to compute for three reasons. The first is that matching credit quality by blending several bond funds cannot be done directly using credit ratings such as "AAA," "AA," and "A" because there is no meaningful way in which the difference between the first rating and the second is the same as the difference between the second rating and the third. Instead we think of credit quality as being represented by expected average loss rates, whose mathematical combinations have straightforward interpretations. Moody's Investors Service (2011, Exhibit 23) gives the following average cumulative five-year loss rates: Aaa, 0.02%; Aa, 0.18%; A, 0.49%; Baa, 1.19%; Ba, 6.90%; B, 15.57%; Caa–C, 35.08% (we will use the latter for all bonds rated less than B, and for non-rated bonds). Our measure of credit quality will be one minus the five-year loss rate.

The second difficulty in computing the quality target is that before 2018, TIAA never revealed its quality breakdown in a form that was readily understandable by the public. It did however appear, for year-end 2015, in one of the forty-four boxes present on the one-hundred-fifty-sixth page of the 167-page regulatory filing called the 2015 General Account's Annual Statement (TIAA 2016b). Again, the data is for both TIAA's publicly traded bonds and for its private placements.[9]

[8] In comparison, "the Treasury securities used in the G Fund rate calculation have a weighted average maturity [not duration] of approximately 12 years" (Thrift Savings Plan 2018 p. 2), and the average duration over 2003–2017 for stable value plans was 2.92 years for individually managed accounts, 2.63 years for pooled funds, and 4.77 years for insurance company general and separate accounts (Stable Value Investment Association 2018). The General Account's characteristics do change somewhat from year to year. TIAA (2018f p. 8) mentions "increased duration matching used by General Account portfolio managers," and the bond quality breakdown in TIAA (2018h) shows a degradation in quality since 2015 (quality measure 0.9755 vs. 0.9874 according to the measure we introduce shortly, moving Figure 1's diamond leftwards to the right-hand edge of the letter "o" in "Account"). Confirming this, Exhibit 2 of Moody's (2018) shows a rather steady degradation in credit quality since 2013, which is the oldest data they report, and so does Fitch (2018 p. 10). Duration, on the other hand, has not changed much recently from the 7.59 figure of year-end 2015; one year later it was 7.65 (TIAA 2017a) and a year after that it was 7.68 (TIAA 2018h). For more on past changes see `http://discuss.morningstar.com/NewSocialize/forums/t/236456.aspx` and Greenough (1990).

[9] P. SI07 rows 9.1–9.6 column 7. Elsewhere on that page appear quality breakdowns separately for TIAA's publicly traded bonds and for its privately placed bonds.

bond category	in report	adjusted	1 − loss rate
US Govt.		21.4	1
NAIC 1	68.9	47.5	0.9982
NAIC 2	23.5	23.5	0.9881
NAIC 3	4.7	4.7	0.9310
NAIC 4	2.3	2.3	0.8443
NAIC 5	0.5	0.5	0.6492
NAIC 6	0.1	0.1	0.6492
total	100.0	100.0	
wtd. average			0.9874

Table 1. Distribution of average quality for the TIAA General Account.

The third difficulty in computing the quality target is that TIAA is required in its General Account Annual Statement to list the credit quality of investments not by Moody's or S&P/Fitch's letter categories but by the 1–6 numerical categories of the National Association of Insurance Commissioners' Securities Valuation Office (NAIC SVO). SVO Category 1 corresponds to Moody's "Aaa, Aa, or A," and SVO categories 2, 3, 4, 5, and 6 correspond to Moody's categories Baa, Ba, B, Caa, and "Ca, C" respectively.[10] Accordingly it is straightforward to assign loss rates to every SVO category except category 1; for it, we will assign the loss rate of Aa bonds, except for US government bonds, to which we assign a loss rate of zero.

Table 1 gives the remaining calculations to determine the quality of the General Account. The source for the NAIC breakdowns of Table 1's first column is TIAA (2016b p. SI07) as discussed above; adjusting for US Government holdings gives the second column.[11] The quality ratings for each row are in the last column; weighting the quality ratings by the previous column gives the average quality rating, 0.9874, which corresponds to a loss rate of $1 - .9874 = .0126$, very close to that of Baa ("BBB" for S&P). This duration and quality for General Account is illustrated in Figure 1.[12]

[10]National Association of Insurance Commissioners (2016); see also `https://en.wikipedia.org/wiki/Bond_credit_rating`. For each Moody category there is a corresponding category on the scale S&P and Fitch use: AAA, AA, A, BBB, BB, B, CCC, CC, and C. TIAA had begun to provide S&P/Fitch ratings in documents intended for the public by 2018 (TIAA 2018h), but not as of year-end 2016 (TIAA 2017a) or 2015 (TIAA 2016a).

[11]US Government holdings are reported in p. SI05 column 6 row 1 of TIAA (2016b), and total NAIC category 1 holdings in p. SI07 column 6 row 1; dividing one by the other, 31.07% of category 1 holdings are US governments.

[12]Compared to Traditional's duration of 7.59 years and quality of BBB, the fixed-income positioning of "target date" mutual fund series offered by the three largest providers of them—in

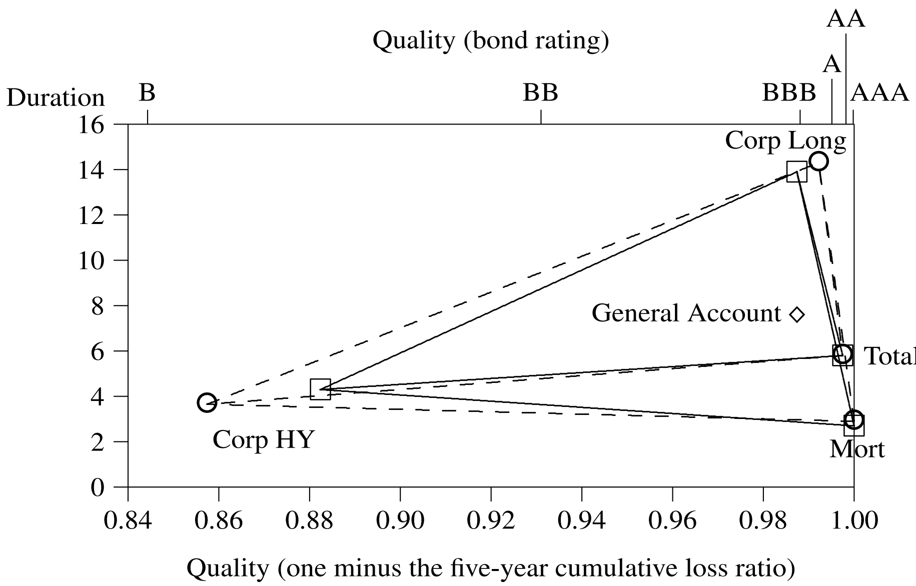

Figure 1. Quality versus duration in years for the General Account (diamond symbol), alternative mutual funds (squares, joined by solid lines), and alternative ETFs (open circles, joined by dashed lines). "Corp HY" stands for corporate high-yield, "Corp Long" for long-term corporates, "Mort" for government-guaranteed mortgages, and "Total" for the total bond market.

For benchmarking, we wish to find mutual fund or ETF alternatives which exactly match the General Account's quality and duration. In Figure 1, one of the alternatives will have to lie above the General Account and one will have to lie below it, and one of the alternatives will have to lie to the left of the General Account and one will have to lie to the right of it. This requires (in general) a minimum of three alternative instruments, so that the General Account lies within a triangle like the ones drawn in Figure 1. Many alternatives are available. We choose one set from mutual funds which have relatively stable portfolios and have a date of inception earlier than 1987 so that many years of performance data exists; we choose the other set from ETFs which are similar to the mutual funds and have the same sponsor, or, in one case where the sponsor offers no similar ETF, we choose the largest ETF in its class. The mutual funds were the "Investor" share classes of the following Vanguard funds, each listed together with its data source, which are annual reports issued near year-end 2015 and residing on the web site of the SEC: Long-term Investment Grade (Vanguard 2016b), High-Yield Corporate (ibid.), GNMA (Vanguard 2016c), and Total Bond Market Index (Vanguard 2016a). The ETFs were: the 'clone' of the Vanguard Total Bond Market Index Fund; Vanguard's Long-term Corporate Bond Index Fund (Vanguard 2016d); Vanguard's Mortgage-backed Securities Index Fund (ibid.); and the iShares iBoxx USD High Yield Corporate Bond ETF, "HYG" (Blackrock 2016), which is currently the largest ETF in the corporate high-yield category.[13] Table 2 shows the underlying data and the outcome of the calculations for quality; Figure 1's circles and squares illustrate the results.

Figure 1 shows that every 3-fund portfolio constructed to match the General Account from the list of alternatives of Table 2 will be composed of one 'Corp Long' asset, one 'Corp HY' asset, and either a 'Total' asset or a 'Mort' asset. We denote these 3-fund portfolios by '3t' or '3m,' short for "3 Total" and "3-Mortgage," if they use mutual funds, and by '3T' or 3M' respectively if they use ETFs. To construct, for example, 3m, one sets up the equations to match, respectively, the General Account's quality (0.9874) and duration (7.59 years),

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order from largest to smallest, Vanguard, Fidelity, and T. Rowe Price (McGrath 2018)—are as follows. Vanguard: duration from 5.7 to 6.6 years, quality AA or A; Fidelity, duration from 5.8 to 13.2 years, quality A to BB; T. Rowe Price, duration from 5.1 to 7.8 years, quality BBB to BB. (Sources: Morningstar Investment Research Center online database for Fidelity Freedom 2xxx and Income, Vanguard Target Retirement 2xxx and Income, and T. Rowe Price Retirement 2xxx. The latter's bond strategy will fluctuate over time (Acheson 2018) and the Fidelity Freedom funds use "active asset allocation" (McLaughlin and Dudley 2018).) Especially compared to Vanguard, Traditional's duration is longer and quality is lower. The implications of lower quality are straightforward; for the implications of longer duration see Section 4.

[13] Rank by "assets under management" ("AUM") in `https://www.etf.com/etfanalytics/etf-finder?asset_class=ac_Fixed+Income&focus=fo_High+Yield`.

Abbrev.	Long InvGr	GNMA	HY Corp	Total Bond	LngTrmCorp	Mtg-Bkd	CorpHY
mut. fnd. ticker	VWESX	VFIIX	VWEHX	VBMFX	(VLTCX)	(VMBSX)	
ETF ticker				BND	VCLT	VMBS	HYG
inception	7/9/1973	6/27/1980	12/27/1978	12/11/1986	11/19/2009	11/19/2009	4/4/2007
U.S. Govt.	5.5	100	2.9	62.6		100	
Aaa	4.2			6.0	2.7		
Aa	31.6			4.2	9.3		
A	49.4			12.4	40.0		
Baa	6.8		6.1	14.8	48.0		0.81
Ba			46.2				44.82
B			37.0				40.59
Caa, Ca, C			7.4				12.88
Not Rated	2.5		0.4				0.90
Duration	13.9	2.7	4.3	5.8	14.3	2.9	3.65
Quality	98.7423	100	88.2425	99.7544	99.2155	100	85.7439
govt.	4	0.9	2.9	42.9	0.1		
mort.		99.1		21.6		100	
other bond	96		97.1	35.5	99.9		100

Table 2. Alternative instruments. "Abbrev." is abbreviated name; ticker if a mutual fund exists (in parenthesis if the mutual fund is not used in this paper); ticker if an ETF exists; date of inception (of earliest share class, if more than one exists); distribution of quality; duration, in years; Quality, calculated as in Table 1; and distribution of types of bonds (defined later, in the paragraph after (1)).

imposes the condition that the weights on the alternative instruments sum to one, and then solves

$$
\begin{aligned}
0.9874\text{weight}_{\text{Long InvGr}} + 1 * \text{weight}_{\text{GNMA}} + 0.8824 * \text{weight}_{\text{HY Corp}} &= 0.9874 \\
13.9\text{weight}_{\text{Long InvGr}} + 2.7\text{weight}_{\text{GNMA}} + 4.3\text{weight}_{\text{HY Corp}} &= 7.59 \\
\text{weight}_{\text{Long InvGr}} + \text{weight}_{\text{GNMA}} + \text{weight}_{\text{HY Corp}} &= 1
\end{aligned}
$$

for the weights. These weights are listed in the first four rows of columns 3m and 3t of Table 3 and columns 3M and 3T of Table 4.

If one wanted to use an alternative portfolio of only two instruments it would not be possible to exactly match the quality and duration of the General Account; to come the closest, it is clear from Figure 1 that one would want to be on the lines which do not involve the corporate high-yield class (which is also the class that gets the smallest weight in 3m, 3t, 3M, and 3T). Call two-instrument portfolios 2m, 2t, 2M, and 2T. To calculate 2m, replace $\text{weight}_{\text{GNMA}}$ with $1 - \text{weight}_{\text{Long InvGr}}$ in the following definition of the "distances to the General Account" $dist_{dur}$ and $dist_{qual}$,

$$
\begin{aligned}
dist_{qual} &= 0.9874\text{weight}_{\text{Long InvGr}} + 1 * \text{weight}_{\text{GNMA}} - 0.9874 \\
dist_{dur} &= 13.9\text{weight}_{\text{Long InvGr}} + 2.7\text{weight}_{\text{GNMA}} - 7.59
\end{aligned}
$$

then choose $\text{weight}_{\text{Long InvGr}}$ to minimize the proportional distance measure

$$
\sqrt{\left(\frac{dist_{qual}}{0.9874}\right)^2 + \left(\frac{dist_{dur}}{7.59}\right)^2}. \tag{1}
$$

The result of this procedure is the portfolio listed as 2m in Tables 3 and 4; the portfolios 2t, 2M, and 2T were obtained in an analogous way.

Finally, although duration and quality are the most important characteristics of a bond portfolio, the type of bond may also play a role in how a portfolio changes over time. For example, Treasuries could behave differently than GNMAs when interest rates change even considering the option-adjusted measure of duration which is now standard in the industry[14]; also, corporates' credit quality could change, while bonds backed by the US federal government have unchanging credit quality (in the opinion of most observers). Tables 2, 3, and 4 break bonds into three categories: governments (including foreign governments) non-mortgage; mortgage-backed securities and direct mortgage loans; and "other." The calculations underlying Table 3's breakdown for the General

[14] This difference could be captured by option-adjusted convexity.

		Gen.Acct.	Alternatives 3m	3t	2m	2t	4mt
1.	Long InvGr		43%	23%	44%	22%	34%
2.	GNMA		51%		56%		28%
3.	Total Bond			70%		78%	32%
4.	HY Corp		6%	7%			6%
5.	qual/dur dist.		0	0	0.72%	0.80%	0
6.	govt.	15%	2%	31%	2%	34%	16%
7.	mort.	34%	51%	15%	56%	17%	34%
8.	other bond	50%	47%	54%	42%	49%	50%
9.	bond type dist.		21%	25%	27%	26%	0.4%
10.	prop. distance		98%	116%	108%	132%	1%
11.	mean ret. '87–'17		6.84%	6.37%	6.78%	6.25%	6.62%
12.	stnd. dev. '87–'17		5.13%	4.79%	5.17%	4.79%	4.97%
13.	mean ret. '11–'17		5.15%	4.34%	4.97%	4.04%	4.77%
14.	stnd. dev. '11–'17		4.99%	4.05%	5.11%	4.07%	4.56%
		Trad.					
15.	ret. '87–'16	6.24%	6.86%	6.40%	6.81%	6.28%	6.65%
16.	DCA ret. 3/'85–12/'13	6.94%	7.19%		7.12%		
17.	DCA ret. 3/'90–12/'13	6.22%	6.68%	6.31%	6.60%	6.17%	6.50%
18.	DCA ret. 3/'95–12/'13	5.87%	6.28%	5.89%	6.21%	5.77%	6.10%
19.	DCA ret. 3/'00–12/'13	5.87%	5.99%	5.57%	5.92%	5.43%	5.79%
20.	DCA ret. 3/'05–12/'13	4.19%	5.32%	4.96%	5.20%	4.78%	5.15%
21.	avg. 9YrPRoR '87–'15	6.6%	7.26%	6.91%	7.25%	6.85%	7.10%
22.	stnd. dev.	1.3%	1.69%	1.63%	1.69%	1.61%	1.66%

Table 3. Mutual fund portfolios "close" to the General Account. Rows 1–4 use the abbreviated names of Table 2. Row 5, "distance" to the General Account according to (1). Rows 9 and 10, bond type distances as in (2) and (3). Rows 11–20: all returns are continuously-compounded annual means unadjusted for inflation. Rows 16–20: "DCA" is "dollar-cost-averaging"; for its temporal pattern, see text. Rows 21–22: "nine-year payout rate of returns" as defined in equations (4)–(7).

	3M	3T	2M	2T	4MT
LngTrmCorp	41%	23%	41%	21%	32%
Mtg-Bkd	53%		59%		26%
Total Bond		71%		79%	35%
CorpHY	7%	6%			6%
qual/dur dist.	0	0	0.95%	0.91%	0
govt.	0%	30%	0%	34%	15%
mort.	53%	15%	59%	17%	34%
other bond	47%	54%	41%	49%	51%
bond type dist.	24%	24%	31%	25%	0.3%
prop. distance	114%	112%	125%	130%	1%
mean ret. '11–'17	4.84%	4.21%	4.64%	3.95%	4.52%
stnd. dev. '11–'17	4.59%	4.09%	4.57%	4.03%	4.33%

Table 4. ETF portfolios "close" to the General Account; rows analogous to Table 3. Totals of rows 1–4 and 6–8 may differ from 100 due to rounding.

Account require careful parsing of another one of the General Account Annual Statement's many pages of tables so the details are relegated to a footnote.[15] The difference between the bond types of an alternative portfolio and the General Account's can be measured in either an absolute way, given in Table 3 Row 9—for example, for portfolio 3m

$$\sqrt{(15-2)^2 + (34-51)^2 + (50-47)^2} \tag{2}$$

—or in a relative way, given in Row 10, and for portfolio 3m by

$$\sqrt{\left(\tfrac{15-2}{15}\right)^2 + \left(\tfrac{34-51}{34}\right)^2 + \left(\tfrac{50-47}{50}\right)^2}\,. \tag{3}$$

According to these metrics, 3m's bond types are closer to Traditional's than 3t's, and both 2m and 2t are farther away than 3m and 3t. Similarly from Table 4, 3M and 3T's bond types resemble Traditional's more than 2M and 2T's, with 3T being very slightly closer than 3M.

[15] TIAA (2016b) p. SI01 (PDF p. 150) breaks all of the General Account's holdings into categories. First omit the following categories (listed with their p. SI01 line number and the portion of the total they represent): 3. Equity, 1.394%; 5. Real Estate, 0.825%; 6. Contract Loans, 0.678%; 7. Derivatives, 0.114%; 11. Other, 11.076%. This leaves 85.914% of assets. Out of these, place into the "govt." category: 1.1 US Treasuries, 6.770%; 1.2 US fed. govt. excl. mort., 1.394%; 1.3 non-US govt., 2.037%; 1.4 US muni, 2.474%; 10. cash, 0.579%. Place into the "mort." category: 1.5 MBS, 21.210%; 4. mortgage loans, 8.114%. Place into the "other" category: 2.1 other domestic, 33.709%; 2.2 other foreign, 9.234%; 2.3 affiliated, 0.393%. As a percentage of 85.914%, these three categories represent the portions given in the first column of Table 3.

Portfolio 4mt in Table 3 shows the solution to the problem of choosing a four-instrument mixture of portfolios 3m and 3t in order to minimize “bond type dist.” Portfolio 4MT in Table 4 shows the solution to the problem of choosing a four-instrument mixture of portfolios 3M and 3T in order to minimize “bond type dist.” Because portfolios 4mt and 4MT have four instruments, they can perfectly match the General Account’s quality and duration and come very close to matching its bond types.

3. Assessing Return

As shown in Table 3 Rows 11–14, and the corresponding rows of Table 4, the alternative instruments all share broadly similar historical returns. (All returns are logarithmic (“continuously-compounded”) unless stated otherwise; data source `portfoliovizualizer.com`.) They are also highly correlated with each other: the 1987–2017 correlations between annual returns of pairs of the alternative instruments in Table 3 range from 0.979 to 0.998, and the 2011–2017 correlations between annual returns of all pairs of the alternative instruments in Tables 3 and 4 range from 0.974 to 0.999.

Section 1 said that TIAA does not report industry-standard “average annual total return” for Traditional but there was an exception: TIAA (2017b) gave Traditional’s “average annualized return of a contribution made at the start of a 30-year career on 1/1/1986” as 6.44%. Row 15 of Table 3 converts this to a logarithmic return and compares it to the return of the alternative investments during that period. Traditional’s return was the lowest, but not by much. Risk will not be discussed until Section 4.[16]

A complication impeding any further comparisons of Traditional’s returns with those of its alternatives is that Traditional credits investors with interest according to accounting techniques completely different from other instruments. In Traditional, the earnings between, for example, March 2010 and March 2011, on a 3/1/10 balance of $1, depend on how long before 3/1/10 the $1 was invested in Traditional—the “vintage” of the dollar, in TIAA’s terminology. This means that different investors holding $1 in Traditional on 3/1/10 and making no transactions during the next year probably earned different returns: there

[16] Return figures for other members of the guaranteed-principal class are difficult to obtain, but Stable Value Investment Association (2018) gives the following average returns for 2003–2017 (all returns in this footnote have been converted to a continuously-compounded annual basis): 3.34%, individually managed accounts; 3.00%, pooled funds; and 3.80%, insurance company general and separate accounts. Returns for the G Fund are available for all but the first six months of this period from `https://www.tsp.gov/InvestmentFunds/FundPerformance/index.html`; they are 3.04%. For comparison, the return of the Vanguard Total Bond Market Fund (VBMFX) was 3.93% during 1/2003–12/2017 and 3.66% during 6/2003–12/2017 .

is no such thing as a unique "average annual total return for Year X" for Traditional. TIAA publicly reports current vintage-by-vintage crediting rates but not historical ones. It did however make a limited set of historical vintage-by-vintage crediting rates available to the authors of Babbel et al. (2015, see their footnote 14) so they could calculate actual returns to December 2013 for a few cohorts of investors. The first cohort of their investors whose experience we can compare to our alternative investments' performances invested $1 in Traditional on March 1 of the years 1985, 1990, 1995, 2000, and 2005. The second, third, fourth, and fifth cohorts invested their first dollars in 1990, 1995, 2000, and 2005, respectively, and invested their future $1 increments every five years thereafter, with the last investment occurring in March 2005. Table 3 Rows 16–20 report the findings of Babbel et al. (p. 8, converted to annual logarithmic returns) together with returns calculated for each of the alternative investments making exactly the same "dollar-cost-averaging" assumptions. Traditional's returns exceeded an alternative's in five instances (Row 17 2t, Row 18 2t, Row 19 2t, Row 19 3t, and Row 19 4mt) and fell short in the remaining seventeen, never exceeding 3m or 2m during any of these time periods.

Since Traditional is a guaranteed instrument, its investors are not exposed to mark-to-market accounting.[17] This mostly affects perception of risk, the topic of Section 4, but can affect interpretation of return as well. For example, TIAA (2018d) makes the claim that

> "Contributing to TIAA Traditional for many years has resulted in higher lifetime income payments because older contributions have built up more reserves which can translate to higher income payout rates.... Let's take a look at two participants each with $100,000 and both age 65. Jane transferred money into TIAA Traditional just prior to retiring and Harry contributed regularly for 30 years. Over [the next] 20 years, Jane received a total of $116,660 from her $100,000 annuity. As a long-time contributor Harry received 27% more, or $147,660 in cumulative income. There is no guarantee that the payments will be higher. Their contribution history made all the difference in their annual and cumulative lifetime income payments."

Assume that Jane and Harry had identical contribution histories, but Jane invested in bond mutual funds rather than in Traditional. Due to the generally-falling interest rates over the past 30 years, under these assumptions if Harry has

[17] The investors hold no assets, only a claim on TIAA, and so are not directly affected by accounting rules such as "fair value" or "amortized cost"/"historical cost."

$100,000 at retirement, Jane would have more than $100,000 at retirement, due to her bond funds' capital gains; Harry, having invested in Traditional, would only have $100,000 because Traditional's accounting methods do not acknowledge capital gains. So while it is true that TIAA will pay Harry a higher interest rate in retirement, Jane's lower interest rate will be paid on her higher initial balance, and the payments the two receive should be roughly the same. Harry's higher interest rates are being paid in lieu of his capital gains.[18]

Another claim made by TIAA is that (2018a):

> "...some contracts require that benefits are paid in installments over time and/or may impose surrender charges on certain withdrawals... These provisions are designed to allow the TIAA general account, which backs the guarantees and benefits under TIAA Traditional, to invest in long-term illiquid assets that often offer enhanced returns versus short-term, more liquid assets. Other contracts allow full freedom to withdraw and transfer out of TIAA Traditional but the trade-off for increased access has typically been lower interest crediting rates. TIAA has rewarded participants who save in contracts where benefits are paid in installments over time instead of in an immediate lump sum by crediting higher interest rates, typically 0.50% to 0.75% higher."

The "contracts where benefits are paid in installments over time instead of in an immediate lump sum" include the version of Traditional studied in this paper (cf. footnote 2, earlier). In contrast to what TIAA wrote, Table 3 shows no illiquidity premium for Traditional. If any such premium was generated by the illiquid investments enumerated in footnote 7, presumably it was absorbed by the increased expenses of managing those investments. Hence the 0.50% to 0.75% difference between what TIAA typically pays on its liquid and illiquid contracts should be thought of not as a premium for investing in the illiquid contracts but as a surcharge for investing in the liquid contracts—basically an in-house version of the fee paid to a wrap provider in a synthetic Guaranteed Investment Contract, who in return "agrees to maintain principal and accumulated interest on the synthetic asset at book value and guarantees the crediting rate for the period until the next rate reset" (Markland 2002, Question 8). It is

[18] In a sustained environment of rising interest rates TIAA may come around to embracing the above reasoning to explain to their long-tenured investors why their receipt of lower interest rates on their large holdings of older vintages than newcomers receive on new money is actually not unfair: the newcomers suffered bond fund capital losses before bringing their money to Traditional, while Traditional protected the long-tenured investors from such losses. See also Goodman and Richardson (2014 p. 6).

similar to paying a premium to buy put options on bond ETFs, establishing a "protective put" (a "married put") position.

4. Risk and Overall Evaluation

It is completely unsurprising that securities such as mutual funds and ETFs which are marked to market show much higher fluctuations in value compared to Traditional, whose value never falls. Other investments which appear to never fall in value include those which are allowed to use amortized cost accounting, such as retail money market funds. Babbel et al. (op. cit., Table 3.1) report standard deviations of monthly annually-compounded returns for the 1985 cohort as 0.18% for Traditional, compared to 2.56% for long-term corporate bonds, 3.01% for long-term government bonds, 1.34% for intermediate-term government bonds, and 0.20% for money market instruments. The corresponding Sharpe ratios show Traditional in an obviously favorable light (ibid. Tables 5.1–5.3), as do graphs such as Figure 2 taken in part from Goodman and Richardson (op. cit.), which contrast the smooth, always-positive returns of Traditional with the large positive and negative returns of an intermediate-term bond fund and with the wild gyrations of a long-term bond fund, which can lose more than 5% of its value in a single month. The conclusion of these past authors is that Traditional has very much less risk than marked-to-market bond mutual funds.

However, the economic value of $3 held in a mutual fund on, say, 1/1/2020 is completely different than the economic value of $3 held in Traditional on that date. Holding $3 in a mutual fund on 1/1/2020 means one can buy a loaf of bread a few days after 1/1/2020. Holding $3 in Traditional on 1/1/2020 means one can buy a loaf of bread a few days after 1/1/2029 (because of the withdrawal restrictions). These are not the same thing at all. The only economic meaning of such-and-such a "paper" balance in TIAA Traditional is as a signal of how much, via a payout annuity, one may be able to get in ten payments spread out over the next nine years. Stripped of this context, as in Figure 2, balances in Traditional are meaningless, and *a fortiori* fluctuations in balances in Traditional are meaningless. The point is not that Traditional's withdrawal restrictions are bad—they may save people from behavioral errors—but that Traditional's withdrawal restrictions should not be ignored in analyzing its historical performance.

If one invested in Traditional in order to get a payout annuity, the economically-relevant question of risk involves measuring how the proceeds of payout annuities have fluctuated over time. We have the data to answer this. If instead

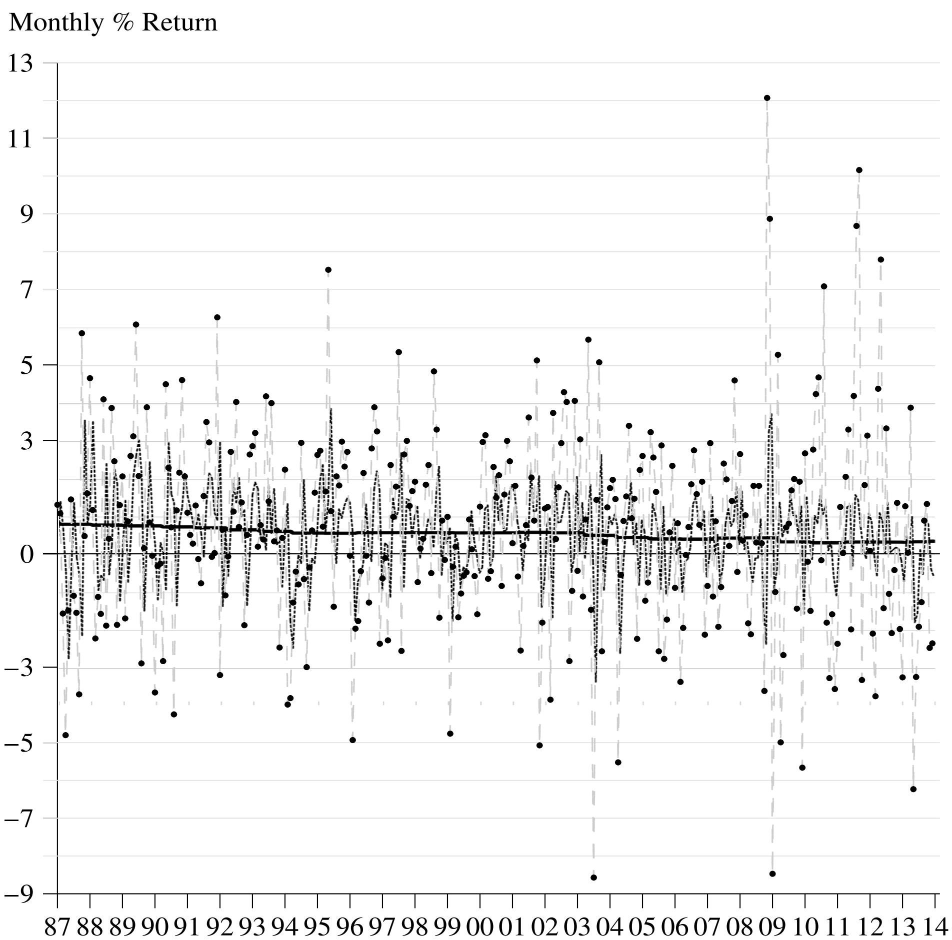

Figure 2. Monthly returns (using monthly compounding), 1987–2013. Solid: Traditional (average over vintages). Dotted: Barclays Aggregate Bond Index (duration approximately 6 years; benchmark for the Vanguard Total Bond Market Index Fund). Gray dashes with black dots: Vanguard Long-term Treasury Fund (VUSTX, duration approximately 17 years). Solid and dotted lines cut from Figure 2 of Goodman and Richardson (2014).

one invested in Traditional in order to get a life annuity, the economically-relevant question of risk would involve measuring how the life-annuity payments have fluctuated. Studying that would require data on Traditional's life-annuity payments by year and cohort, and similar data for the life-annuity payments of the appropriate alternative instruments, which would be not mutual funds but single-premium immediate annuities ("SPIAs") from insurance companies. There is some publicly-available data on this but not enough to do a complete analysis. We are therefore only going to analyze the nine-year payout annuity. If Traditional turns out to be inferior for nine-year payout annuities to the set of mutual funds identified in Section 2, that will only be a judgment for the accumulation stage—Traditional could still be the best choice once the annuitization stage has come, and at retirement it is possible to switch from accumulating with mutual funds to annuitizing Traditional, as discussed in the second-to-last example in Section 3. If TIAA and other annuity issuers ever made the data available, it would be interesting to study the choice at retirement between annuitizing Traditional and an SPIA because SPIA payments are known in advance while Traditional payments are not, Traditional being a "participating" policy and TIAA being a nonprofit which returns 'profits' to policyholders.[19]

We now need to calculate how much Traditional, and each of its alternatives, could have paid out in ten increments over nine years leaving a zero balance at the end; then study how that number fluctuates over time. We have exact data to do this for the alternative mutual fund investments. For Traditional, Babbel et al. give, though only in graphical form, exact, vintage-by-vintage, month-by-month returns, but only for the five cohorts listed in Rows 16–20 of Table 3 and for some older cohorts whose dates precede our mutual fund data. It is not possible to construct returns for other cohorts with the data available to Babbel. Since we would like to have more than five data points in order to study fluctuations and risk, instead of Babbel's return series for Traditional we will use year-by-year return figures averaged over vintages. The only sources we have are graphs, not tables of numbers: Figure 1 of Goodman and Richardson (2014), supplemented for 2014–2017 by Exhibit 1 on p. 3 of TIAA (2016c, 2017c, and 2018f). Because there are serious errors in some of TIAA's exhibits the data extraction procedure is nontrivial and is described in detail in the Appendix.

[19] The issue is how to conceptualize the risk of market fluctuations, not of credit risk, which TIAA ~~always~~has disclose~~s~~d appropriately, though it does not explicitly state that since an investment in Traditional is merely a claim on TIAA's General Fund, rather than symbolizing ownership of underlying assets, a bankruptcy by TIAA could cause its policyholders to permanently lose money, unlike the bankruptcy of a mutual fund company but similarly to the bankruptcy of the sponsor of an "exchange-traded note" ("ETN").

Denoting the constant annual withdrawal amount which would have been possible by w, the balance at date t by x_t, the logarithmic (continuously-compounded) rate of return in the period leading up to date t by r_{t-1}, and assuming the initial balance to be \$10,000, we have

$$
\begin{aligned}
x_1 &= 10{,}000 - w \\
x_t &= e^{r_{t-1}}\, x_{t-1} - w \quad \text{for } 2 \le t \le 10 \text{ and} \\
x_{10} &= 0\,.
\end{aligned} \tag{4}
$$

Using a root-solving algorithm this can be solved for w. For example, setting the rates of return equal to Traditional's guaranteed 3% minimum (2.9559% logarithmic) results in $w = \$1138.16$.[20]

This w would be easier to interpret if it could be associated with a percentage "rate of return," but simply dividing w by the initial \$10,000 balance would not do that because it would include return *of* as well as *on* capital (just like the payouts from a "10 year period certain immediate annuity" partially include return of the original investment). To associate w with a true "rate of return," let w^* be the now-known w which solves (4) and find the constant r in (6) which makes (7) true given (5) and (6):

$$y_1 = 10{,}000 - w^* \tag{5}$$

$$y_t = e^{r}\, y_{t-1} - w^* \quad \text{for } 2 \le t \le 10 \text{ and} \tag{6}$$

$$y_{10} = 0\,. \tag{7}$$

For example, substituting $w^* = 1138.16$ into this system leads (again using a root-solving routine) to $r = 2.9559\%$ (annually-compounded 3%). The "r" which comes from (5)–(7) is interpreted as the constant rate of return which could have been paid during that nine-year payout period. Call it "the nine-year payout rate of return," "9YrPRoR." The values of r for Traditional and for Table 3's alternative assets are graphed in Figure 3. For comparison, the values of r for one-month Treasury bills (`portfoliovisualizer.com`'s "cash") and for the Total Bond Market Fund are also graphed in Figure 3. Both those investments had shorter duration than Traditional, so in an era of falling yields, it is understandable that they performed more poorly than Traditional and its alternatives. The alternatives' means and standard deviations of 9YrPRoR are reported in Rows 21 and 22 of Table 3 and illustrated in Figure 4.

[20](a) Note that if any x_{t-1} fell below zero then the first term on the right-hand side of $x_t = e^{r_{t-1}}\, x_{t-1} - w$ would be negative, so x_t would be negative, so all future x's would be negative and it would be impossible to achieve $x_{10} = 0$. (b) Traditional's guaranteed rate actually falls to 2.5% during a Transfer Payout Annuity. (c) There is actually an analytical solution to (4): $w = 10{,}000\, e^{\sum_{t=1}^{9} r_t} \big/ \left(1 + \sum_{t=1}^{9} e^{\sum_{i=t}^{9} r_i}\right)$. However the solution to (5)–(7) below is one of the roots of a ninth-degree polynomial so it is not analytical.

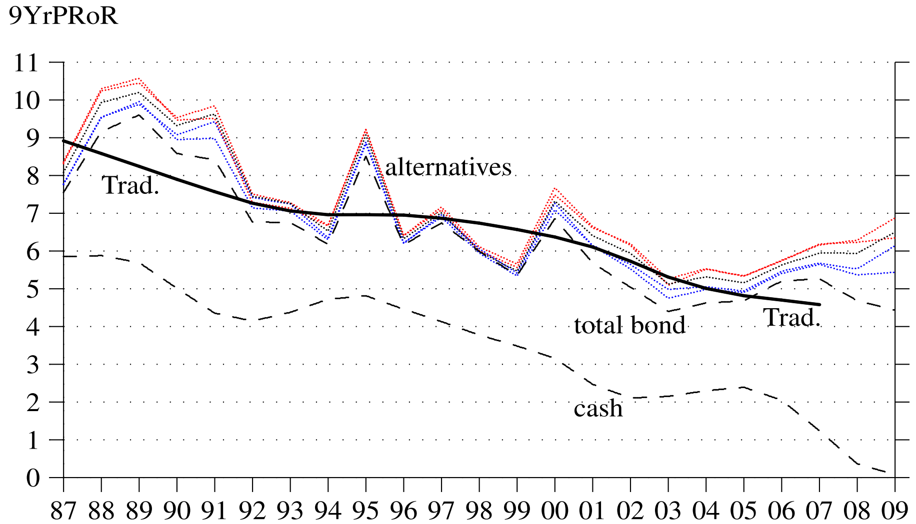

Figure 3. The nine-year payout rate of return beginning in the indicated year for: the alternative instruments in Table 3, dotted lines; Traditional, the thick solid line; "total bond market," the upper dashed line; and "cash," lower dashed line. The alternatives: red, 3m and 2m; blue, 3t and 2t; black, 4mt. Data 1987–2017 (1987–2015 for Traditional).

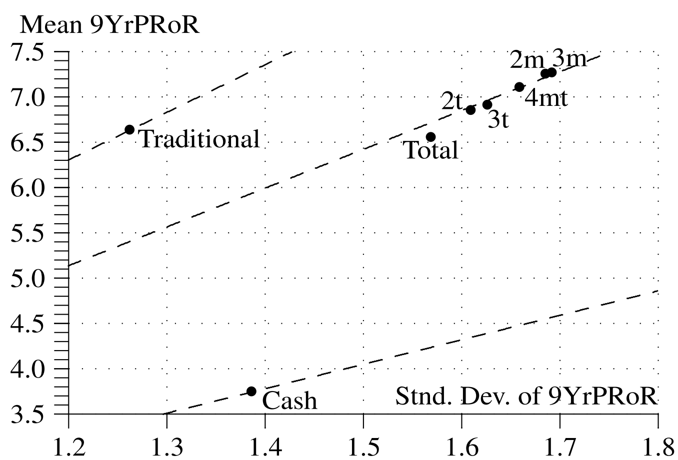

Figure 4. Mean and standard deviation for the nine-year payout rates of return shown in Figure 3, 1987–2015 data only. The dashed line through Cash has a "mean divided by standard deviation ratio," or slope, of 2.7; the dashed line through 4mt has a slope of 4.3; and the dashed line through Traditional has a slope of 5.3.

TIAA guarantees that Traditional's earnings will never be less than 3% (recall from the introduction and footnote 2 that the term "Traditional" in this paper only refers to the "RA" version of Traditional). Figure 3 shows that, from 1987 to 2017, someone using any of Table 3's alternative instruments (but not cash) could have made the same guarantee in regards to withdrawing the money over nine years. Over those years, the smallest minimum 9YrPRoR for any of the alternative instruments was 4.75%; for Traditional, it was 4.6%. This confirms TIAA's statement (2013, p. 6) that "while the 3% guarantee rate exists as a term within the TIAA Traditional Annuity contract, the term does not appear to provide any meaningful value to owners of the contract. . . ."

Table 3 Rows 21–22 confirm the impression from Figure 3 that Traditional generally had lower 9YrPRoR and lower standard deviation of 9YrPRoR. The ETF's of Table 4 are too new to make this type of calculation, but they are likely to behave similarly to the mutual funds of Table 3.

We conclude that TIAA did more smoothing than could have been done via a mutual fund over nine years, but the difference was not nearly as much as suggested by Figure 2. Traditional usually returned somewhat less than the alternatives.[21]

Because in Figure 4 cash's average 9YRPRoR was so much lower than Traditional's and cash's standard deviation was so much higher, cash was not part of the figure's efficient frontier, and it is not surprising that blending any of Traditional's alternatives with cash in proportions to equal Traditional's return gives a standard deviation which is much larger than Traditional's (1.5 or more).

The dashed lines in Figure 4 represent combinations with the same ratio of return to standard deviation. This ratio differs from the Sharpe Ratio only in that the numerator of the Sharpe Ratio is return minus the risk-free rate of return, and in this dynamic context, no risk-free asset seems to exist—cash certainly was not risk-free (fluctuation-free). If one used this Sharpe-Ratio-like criterion, Figure 4 shows that Traditional would be the best asset, cash would be the worst, and the others would all be about the same.

Babbel et al. (op. cit., Section 6) rightly point out that measuring risk by standard deviation has drawbacks when returns are not normally distributed. The Sharpe Ratio measures risk by standard deviation. Its drawbacks are dramatically illustrated by a simple example. Any investor would prefer a fair coin paying \$1.20 (above the risk-free rate) on tails and \$1.50 on heads to a second fair coin paying \$0.90 on tails and \$1.10 on heads, but the first coin has a lower Sharpe Ratio than the second ($1.35/.212 = 6.4$ for the first, $1/.141 = 7.1$ for

[21] Perhaps TIAA's smoothing was possible because the roughly one-third of its assets which are not publicly traded may be infrequently priced.

the second).[22] Even though the second coin pays less in all states of the world, its lower volatility makes its Sharpe Ratio higher than the first coin's. In other words, the Sharpe Ratio can make low-volatility, low-return assets look deceptively good, and this could be a problem in judging Traditional because Figure 3 shows that Traditional is lower-volatility, usually-lower-return than its alternatives. Therefore, instead of concluding from the Sharpe-Ratio-like dashed lines of Figure 4 that Traditional is the best asset—a conclusion that does not seem obvious from Figure 3—we now follow Babbel et al. by investigating how to rank the assets using stochastic dominance.

If one investment F exhibits "first-degree stochastic dominance" ("FDSD") over another investment G then for *any* fixed return $\bar{r}$, the probability that the realized return r is greater than $\bar{r}$ is larger under F than under G. The cumulative distribution function for F lies everywhere under (or, to the right—to larger r's) of G's. FDSD is quite strong: all expected-utility-maximizing investors, regardless of other characteristics of their utility functions, will prefer F over G if F exhibits FDSD over G.[23] Figure 3 (data through 2015) can be analyzed in terms of FDSD. For the rest of this paragraph interpret "dominate" and "rank" in the sense of FDSD. Cash was dominated by everything else, and Total was dominated by 3m, 2m, 4mt, 3t, and 2t (despite the fact that Total does not look terrible in Figure 4), but these comparisons are not very interesting because they simply illustrate that falling yields favor longer-duration instruments over shorter-duration ones. Accordingly, for the rest of this paragraph, ignore cash and Total. As the capital letters in Table 5 show, Traditional cannot be ranked against any of the remaining instruments. On the other hand, some rankings are possible: 3m dominated 4mt, 3t, and 2t; 2m dominated 3t and 2t; and 4mt dominated 3t (and would have dominated 2t except for one data point). So the only instruments that were not dominated by any other instrument were Traditional, 3m, and 2m.

Second-degree stochastic dominance ("SDSD") has the property that if F exhibits SDSD over G then all *risk-averse* expected-utility-maximizing investors

[22] See also Hodges (1998 p. 2 Table 1, "Sharpe Ratio Paradox"). Another example "where using the Sharpe ratio leads to irrational behavior" is given in Klar and Müller (2017 Example 10 pp. 8–9).

[23] Despite FDSD's strength it can be criticized. Numerous observations of non-expected-utility-maximizing behavior can be found in behavioral economics research. Also, FDSD of F over G does not necessarily imply FDSD of "F mixed with another asset H" over "G mixed with the same amount of H." If we drop the requirement of being expected-utility maximizers, then "all investors preferring more return to less return," regardless of other characteristics of their utility functions, will prefer F over G if F exhibits "statewise dominance" over G; "statewise dominance" implies but is not implied by FDSD (see e.g. `https://en.wikipedia.org/wiki/Stochastic_dominance`).

	3m	2m	4mt	3t	2t	Trad.
3m	.		N	N	N	n
2m		.		N	N	n
4mt	Y		.	N	n	n
3t	Y	Y	Y	.	n	
2t	Y	Y	y	y	.	
Trad.	y	y	y			.

Table 5. "Y" if the column portfolio exhibited first-degree stochastic dominance over the row portfolio; "N" if the row exhibited FDSD over the column; "y" if the column did not exhibit FDSD over the row but did exhibit second-degree stochastic dominance over it; "n" if the row did not exhibit FDSD over the column but did exhibit SDSD over it; and blank if neither the column nor the row dominated the other either in the sense of FDSD or in the sense of SDSD. (Such a table has to be skew-symmetric.) Frequencies from Figure 3, 1987–2015 data.

will prefer F over G. FDSD implies SDSD but not conversely. Distribution F exhibits SDSD over G if the area under the cumulative distribution function of F (measured beginning at the left edge of the CDF) is less than the corresponding area under the CDF of G everywhere except when both become one. For example, in Figure 5, the area under Traditional's CDF from 4 (or from zero) to 5.5 is obviously greater than the area under 3m's CDF from 4 to 5.5 because 3m's CDF is below Traditional's from 4 to 5.5. It is less obvious that the area under Traditional's CDF from 4 to 8 is greater than the area under 3m's CDF from 4 to 8, but calculation shows that to be true, even though 3m's CDF rises above Traditional's on an interval around 6.5. Calculations further show that the area under Traditional's CDF from 4 to any number is greater than the area under 3m's CDF from 4 to that number, so 3m exhibits second-order stochastic dominance over Traditional in Figure 5. (3m does not exhibit first-order stochastic dominance over Traditional because 3m's CDF is not always below Traditional's.) The lower-case letters in Table 5 show the results of testing for SDSD using the discrete-random-variable definitions and techniques of Courtault et al. (2006). Traditional was SDS-Dominated by 3m, 2m, and 4mt. Contrary to the flawed, Sharpe-Ratio-like conclusion of Figure 4, Traditional would not have been the best asset for risk-averse expected utility maximizers. The only instruments that were not dominated in either first- or second-degree by any other instrument were 3m and 2m.

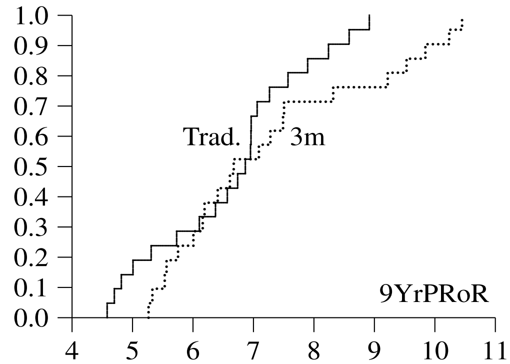

Figure 5. Cumulative distribution functions for Traditional (solid) and 3m (dotted). Frequencies from Figure 3, 1987–2015 data.

Conclusion

U.S. law permits insurance companies to publicly disclose much less information about the performance of some of their investment products than is required of mutual fund companies, but by combining several sources of information including some ad hoc TIAA research reports we have been able to compare TIAA Traditional's performance to that of appropriate benchmarks constructed from retail mutual funds by targeting a duration of almost 8 years, an average quality of BBB, and mortgages as about a third of holdings. Some investors may have preferred Traditional's performance to those of its alternatives in the 1987–2015 period studied, but risk-averse expected-utility-maximizing consumers withdrawing funds over nine years would have preferred several of the mutual-fund alternatives over Traditional had they known the probability distributions in advance.

The caveat that withdrawals take place gradually "over nine years" poses obstacles to implementing the alternatives. Panicky selling of long-term bonds in the face of a short-term market decline can actually be optimal behavior in a world of asymmetric knowledge and information, where less-informed investors could rationally interpret the decline as a signal that long bonds are an inappropriate investment for them, or that their investment provider is not acting in the investor's best interests. Only if investors understand how long-term bonds work and hold an appropriate duration will they be able to view capital losses when interest rates rise with equanimity, and will be able to distinguish between normal market fluctuations and adverse changes due to a failure of an investment firm to act in the investor's best interests. No education is necessary for Traditional's investors to avoid hasty selling because they are not permitted to do it, and that very lack of permission enables Traditional to use smoothing accounting methods which calm investors so they are quite unlikely to panic in the first place.

To summarize, then, Traditional's main advantages are that it is run by a non-profit; it uses a good investment strategy which has stood the test of time and is subject to strict insurance company regulations; and it prohibits hasty selling, which is often a behavioral mistake. Its disadvantages are that it lagged in performance compared to the particular benchmarks we identified, and that, not being subject to the Investment Company Act of 1940, we have found instances in which TIAA could definitely improve the accuracy, transparency and forthrightness with which it communicated to its customers the features and performance of Traditional and the composition of its General Account. The more an investor with an 8-year-duration bond portfolio is likely to hastily sell some of it when interest rates rise, or never to invest in such a long-duration portfolio in the first place, the better an investment in Traditional would be.

A final aspect to consider is that Traditional's crediting rate on each of the many vintages a customer will own is administratively and thus opaquely set, so Traditional's future performance will be as good as its past only if TIAA's expenses and ethical commitments to its customers do not deteriorate. In this regard, evidence from other TIAA products is worth considering. In the late 1990's TIAA was well-regarded for the low expenses charged by its CREF funds (PR Newswire 1998), but now, charges such as 0.215%, 0.265%, and 0.470% for different employer sizes of retirement plans for the CREF U.S. "Equity Index Account," including 12b-1 "distribution expense" fees of up to 0.13% (TIAA 2019), compared to Vanguard's charge of 0.040% for a similar product (VTSAX) and Fidelity's charge of 0.015% (FSKAX), raise questions about whether the ethos of TIAA has changed since the years when much of the data examined in this paper was generated. TIAA's very minor legal troubles with the SEC (Weil and Lublin 2004; U.S. District Court S.D.N.Y. 2017) have not helped assuage these doubts. On the other hand TIAA sends representatives to many customers' workplaces for face-to-face meetings, and TIAA makes it easy for retirees to annuitize their wealth, so the higher expenses may be worth it. Overall, the less sophisticated an investor is about investments, the better Traditional would have been. Less sophisticated investors are however least likely to be able to detect any deterioration in TIAA's ethos going forward, so there are many opposing factors to weigh before making a recommendation.

APPENDIX

The two publicly-available sources of year-by-year Traditional crediting rates, albeit averaged over vintages, are Fig. 1 of Goodman and Richardson (2014) and Exhibit 1 in an annually-updated series of “white papers” from TIAA entitled “TIAA Traditional Annuity: Adding Safety and Stability to Retirement Portfolios” (TIAA 2016c, 2017c, 2018f). Figure 6 superimposes the Goodman and Richardson graph onto the 2016, 2017, and 2018 editions of the white papers’ graphs, which claim to show data ending in, respectively, 2015, 2016, and 2017. These claims are, as explained below, mutually inconsistent, so more steps are needed before extracting this data.

Using CPI information from the Federal Reserve Bank of St. Louis’s “FRED” database, we can establish a known-correct horizontal (time) axis for Goodman and Richardson’s graph, and using 10-year constant-maturity Treasury information from FRED we can establish a known-correct time axis for the graphs from the three white papers.[24] All the graphs have horizontal grid lines with which to establish a known-correct vertical (crediting rate) axis.

There are no anomalies for 2013 and earlier. The “5” in the graph denotes the right-most extent of the lines taken from the white paper for 2015; similarly with “3” from Goodman and Richardson (op. cit.) and “6” and “7” from the other two white papers. The white paper for 2015 illustrates data through the end of 2016 when superimposed and carefully aligned to the time axis; therefore it cannot have been drawn correctly because that data was unknown when the graph was constructed in September of 2016. So we will not use the graph of the white paper for 2015. The white paper for 2016 illustrates data to 2014 when superimposed and aligned to the time axis. Its claim that it shows data through 2016 is thus a mistake, but that alone may not be a reason to throw out its data. However its green “10-year constant maturity Treasury” line in 2016 (the lower “6” in the graph) strongly diverges from the green line’s path as agreed by FRED and by the white papers for 2015 and 2017. This throws additional doubt on the white paper for 2016 and we rule out using its data. The only mistake in the white paper for 2017 seems to be that although it claims to depict data through 2017, it actually only depicts data through 2015. So we chose that white paper to provide data for the next step, together with Goodman and Richardson’s paper.

The next step was converting the return data from graphical to numerical form using “Web Plot Digitizer.[25]” The time axis for Goodman and Richardson’s graph was set by assuming their crediting rate line began in 1964 and ended in 2013 (rather than using their horizontal axis, which gave somewhat less exact results). The time coordinate for the 2018 white paper—data purportedly through the end of 2017—was set by assuming its crediting rate line began in 1987 and ended in *2015,* as explained above. The agreement between the extracted data from these two sources was 10 basis points, which is relatively poor, for 2013; this is reflected in Figure 6 in the slight divergence of the black and blue lines near the number “3.” However for 1987–2012, agreement stayed within the range of +3.2 to −4.8 basis points, which is good enough

[24] For CPI: Bureau of Labor Statistics of the USA (2018) showing “percent change from a year ago,” seasonally adjusted, frequency: annual, aggregation method: average. For the 10-year Treasury: Board of Governors of the Federal Reserve System of the USA (2018), showing “percent, not seasonally adjusted,” frequency: annual, aggregation method: average. Both via `https://fred.stlouisfed.org`.

[25] `https://automeris.io/WebPlotDigitizer/`

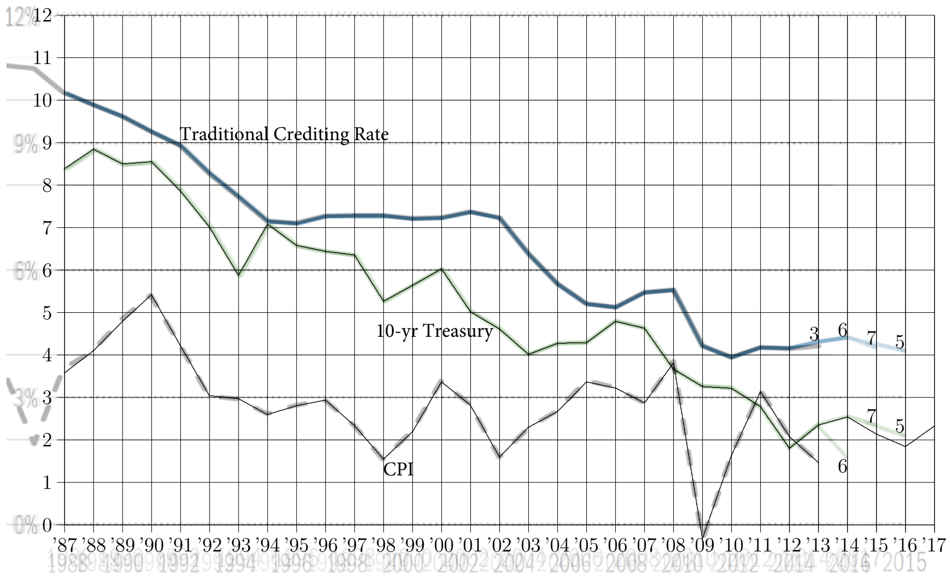

Figure 6. Superimposed, scaled, and aligned semi-transparent versions of graphs from Goodman and Richardson (2014) (in black, solid for the Traditional crediting rate and dashed for the Consumer Price Index year-over-year percent change), and from TIAA white papers for data ending in 2015, 2016, and 2017 described in the text (blue for Traditional crediting rate, green for the 10-year Treasury). Single-digit labels indicate the claimed last year of the data, "3" for 2013, "6" for 2016, and so forth. If the graphs were consistent with each other these digits would be increasing from left to right and their horizontal axes would match. Also, for calibration purposes, superimposed in solid thin black lines: the exact 10-year constant-maturity Treasury rates and exact Consumer Price Index year-over-year percent change, both from the FRED database. These determine the known-correct horizontal axis for time. Many of these lines cannot easily be distinguished from each other because they need to be placed directly on top of each other in order to calibrate the four graphs.

accuracy for our purposes. The data finally used was the average of the two data sources for 1987 to 2012, and for 2013 to 2015 was the white paper's.[26]

[26]For each year from 1987 to 2015, the resulting crediting rate used for Traditional in the analysis of Section 4 was: 10.19, 9.89, 9.61, 9.26, 8.92, 8.30, 7.72, 7.16, 7.10, 7.27, 7.27, 7.27, 7.21, 7.22, 7.37, 7.23, 6.37, 5.68, 5.20, 5.12, 5.48, 5.50, 4.24, 3.94, 4.18, 4.15, 4.31, 4.40, 4.18.

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