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The asset allocation decision in retirement: lessons from dollar-cost averaging

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Abstract

How should a retiree allocate his wealth between stocks and bonds? We address this question by studying whether it would have been better to have consumed periodically from stocks than from bonds over the seven decades of U.S. financial markets beginning in 1926 and ending in 1995. We find that retirees would have consistently done better by investing in stocks as opposed to bonds. When we analyze dispersion in consumption around its mean we find that there are greater chances for low consumption from the bond portfolio and greater chances for high consumption from the stock portfolio. Thus, we challenge the conventional wisdom that one should move away from stocks and towards bonds as one ages. © 2000 Elsevier Science Inc. All rights reserved.

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1. Introduction

How should a retiree allocate his wealth between stocks and bonds? This asset allocation decision is of interest to all investors (Brinson, Hood & Beebower, 1986), but it is of particular significance to retirees, whose human capital is close to zero making it most difficult to handle adverse investment results (Posner, 1995). We address this question by

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studying whether it would have been better to have consumed periodically from stocks than from bonds over the seven decades of U.S. financial markets beginning in 1926 and ending in 1995.

Our study is different from other studies of stock and bond performance. The existing literature assumes either that money is periodically invested in financial assets (e.g., Butler & Domian, 1993) or that a set amount is invested in financial assets at the beginning of a time span with no additional infusions or withdrawals (Ibbotson & Sinquefield, 1989; Siegel, 1994). We look at performance from the perspective of an individual who is constantly "disinvesting" from financial assets. Our hypothesis is that it is better to consume from stocks than from bonds. We are led to this hypothesis by the literature on the fallacy of dollar-cost averaging (e.g., Constantinides, 1979; Knight & Mandell, 1993; Rozeff, 1994). Specifically, we argue that if dollar-cost averaging into stocks is suboptimal, then dollar-cost disinvesting from stocks ought to be sound; that is, because it is imprudent to gradually transfer one's wealth from cash to securities, it makes sense to gradually transfer one's wealth from securities to cash (for consumption).

In order to test this hypothesis, we begin with a representative retiree who has a life expectancy of N years after retirement. Without loss of generality, we assume that this retiree has wealth of $1 at the beginning of his retired life which is invested in a stock portfolio. Using monthly return data on the Center for Research in Security Prices' (CRSP) Value Weighted (VW) portfolio, we calculate the amount that this retiree could have spent every month from the dividends and capital gains for the N years, that is, if the retiree followed a dollar-cost disinvesting strategy, we calculate the equal monthly amount that the retiree could have consumed for N years. In order to be able to make comparisons between asset classes of different risks, we then repeat the procedure for a portfolio consisting solely of long-term Treasury bonds (safe class), an annuity based on the yield to maturity on a portfolio of long-term AAA- and Baa-rated corporate bonds and Treasury bonds (moderate risk class), and an annuity based on the yield to maturity on a portfolio consisting of only Baa-rated corporate bonds (moderately high risk class) and compare the magnitude of these consumption amounts to the stock portfolio based (risky class) amount.

We find that retirees would have consistently done better by investing in the stock portfolio as opposed to investing solely in T-bonds or in the broadly diversified bond portfolio or even the moderately risky bond portfolio. This result is particularly true as N gets larger—over longer periods of time stocks look better relative to T-bonds, the broadly diversified bond portfolio, and the moderately risky bond portfolio. We also examine the impact of inflation on consumption. Once we allow consumption to grow at the rate of inflation we find even stronger support for our result that disinvesting from stocks is better than from bonds.

We also analyze the likelihood, across different asset classes, of states in which consumption is extremely low or high due to extreme returns. We find that there are greater chances for low consumption from T-bonds and greater chances for high consumption from the stock portfolio, that is, there is more "downside risk" from T-bonds than from stocks and there is greater "upside potential" from stocks than from T-bonds. We also find that as the horizon increases, retirees are guaranteed a low consumption from T-bonds and, unless circumstances are exceptional, they are guaranteed better consumption from stocks.

In order to pinpoint these exceptional circumstances, we construct and analyze the best portfolio of stocks and T-bonds by calculating the optimal weights that should have been attached to stocks and bonds for every period in our study. We find that the frequency with which the optimal portfolio should have been 100% invested in stock is much greater than the frequency with which the optimal portfolio should have been 100% invested in bonds or in a mix of stocks and bonds. We also find a strong correlation between the occurrence of contractions in the economy and the optimality of the T-bond portfolio or the portfolio that has a mix of T-bonds and stocks.

This evidence goes against the conventional wisdom that more wealth should be allocated to bonds as one ages. One such rule of thumb is that the percentage of wealth invested in stocks should be equal to 100 minus the investor's age. For a 65-year old, this would mean no more than 35% of wealth should be invested in stocks. Our results indicate that such an allocation would be very costly to older investors in terms of their standard of living—yet, we are aware that many invest very little in stocks relative to bonds. We speculate that this may be related to the fact that the current cohort of elderly investors grew up during the Great Depression and World War II and may be extremely sensitive, perhaps overly so, to the risk associated with loss of wealth from stocks.

In the next section we summarize some of the studies that look at the asset allocation decision and present our hypotheses; in section 3 we describe our data and methods; in section 4 we present our results, and we conclude in section 5.

2. Literature review and hypotheses

In this section, we review some prior work on optimal asset allocation between stocks and bonds for retirees and the findings on dollar-cost averaging (DCA). It appears that little work has been done to address the former issue while substantial work has been done on the latter topic. We were able to find only two studies that looked squarely at the question of optimal allocation for retirees. Bengen (1994) finds, for a retiree who has a horizon of at least 30 years, that a 50–50 to a 75–25 stock-bond combination is optimal in retirement if the primary goal of the retiree is to not outlive his assets. In related literature, Jagannathan and Kocherlakota (1996) pose the question “Why should older people invest less in stocks than younger people?” They consider a number of alternative explanations and they conclude that the only plausible explanation is that the value of their human capital (which is considered riskless) decreases as they age so that they need to shift more financial wealth into risk less assets in order to reach their optimal portfolio. Although Siegel (1994) does not look at optimal asset allocation in retirement, he presents an impressive array of statistics, particularly in the first two chapters, to make the case that stocks are far superior to bonds in terms of risk and return, especially over long holding periods.

On the topic of DCA, Constantinides, (1979) shows that it is a sub optimal investment policy because it depends upon the composition (and not just size) of the investor's wealth while the optimal nonsequential policy is independent of the composition of the investor's wealth. Knight and Mandell (1993) demonstrate numerically that a risk averse investor would get lower utility under DCA versus a lump sum or an optimal rebalancing strategy.

Additionally, they provide empirical evidence that the utility of risk averse investors would have been lower in the 1962–92 period under DCA as opposed to a lump sum or optimal rebalancing strategy. In a similar vein, Rozeff (1994) analytically and empirically demonstrates the superiority of a lump sum strategy over DCA. Thus, there appears to be a consensus in the literature that DCA is inferior to a lump sum strategy of investing into stocks. In the face of all this research why does DCA persist? Statman (1995) offers four behavioral explanations for the resilience of DCA, although he provides no evidence on which is the most plausible explanation.

Our study is somewhat related to Bengen's because we want to study whether stocks are better in retirement than bonds. Our study is related to the DCA literature in the following respect: a retiree's objective is fundamentally different from an individual who is building assets during his earning life. A retiree is concerned with the amount of consumption that his assets will allow him. In order to consume he will disinvest periodically from his financial assets. We call this activity dollar-cost disinvesting and it is the reverse of DCA. Our main hypothesis is that dollar-cost disinvesting from stocks will lead to a higher magnitude of consumption than from bonds. This hypothesis follows from the DCA literature that consistently shows that DCA into stocks is sub optimal. Our second hypothesis is that dollar-cost disinvesting from stocks gets continuously better relative to bonds as the retirement horizon gets longer. Although we are unaware of studies that examine the suboptimality of DCA for longer versus shorter periods of time, our second hypothesis follows from the various studies such as Siegel's that show that stocks look better in comparison to bonds as the horizon gets longer.

Although our study is related to Bengen's, there are significant differences between the two. For instance, it is unclear whether optimal asset allocation in retirement should be considered only from the perspective of individuals who expect to spend at least 30 years in retirement. With no mandatory retirement age in the U.S. in most professions, it is entirely possible that people who choose to keep working longer may be looking at a shorter retirement horizon. Thus, we consider various retirement horizons ranging from 5 to 30 years. Additionally, Bengen focuses on the longevity of the portfolio, and particularly upon the impact of significant downturns in the market on longevity; we believe that the main objective of retirees is to enjoy the utility they derive from consumption so we focus on the magnitude of consumption that is possible under different asset allocations.

3. Data and methods

We present below a simple model that is used to arrive at the equal monthly consumption amount for different portfolios together with a description of our data sources. DCA assumes that a fixed dollar amount is moved from one type of financial asset (like cash) into another type (like stock) periodically. Conceptually, dollar-cost disinvesting is similar to DCA except that we reverse the process by moving a fixed dollar amount from a stock or bond portfolio into cash which is spent immediately on consumption of goods or services. As in the DCA papers, we use a month as a convenient unit of analysis for moving dollars between assets.

We also believe that a month is a convenient period for analyzing the dollar-cost disinvesting decision because most households use a month as a convenient period for budgeting.

We calculate the monthly equal consumption that could be possible for an individual who has W_0 of wealth invested in a portfolio of investments at the beginning of his retirement and starts to spend the money right away. We assume that all the money is spent by the end of the retirement period. For a two-month long retirement period we would solve for c the consumption amount in the expression $((W_0 - c)(1+r_1) - c)(1+r_2) - c = 0$, where r_t is the rate of return on a portfolio in month t. When we extend this formulation to N years we solve for c in

$$(\ldots((((W_0 - c)(1 + r_1) - c)(1 + r_2) - c)(1 + r_3) \ldots - c)(1 + r_{12N}) - c) = 0 \tag{1}$$

Eq. (1) is linear in one unknown and it has a unique solution for a given $W_{0.}$ This approach abstracts away the uncertainty in the rate of return because the consumption amount is based on *ex-post* returns. Our goal is to make some statements regarding optimal asset allocation for retirees based upon events that have already occurred, and thus our approach is no different from the approach adopted in the studies discussed in the previous section.

Eq. (1) is used to estimate one consumption amount if a retiree's wealth is 100% invested in the CRSP VW portfolio and another consumption amount if a retiree's wealth is 100% invested in T-bonds. We obtain the monthly returns on the CRSP VW portfolio and the monthly holding period returns on an equally weighted T-bond portfolio from the CRSP tapes for January 1926 through December 1995. Clearly, this period was chosen for analysis due to the easy availability of data. However, because this period of 70 years (or 840 months) has seen extraordinary fluctuations in stock prices and movements in interest rates, results based on this period will be more robust than in periods of relative calm.

In addition to being able to invest their wealth in stocks and T-bonds, retirees have had the opportunity, for a number of decades, to invest in annuities (Poterba, 1997). If a retiree invests in a *certain annuity*, the invested wealth gets amortized at a fixed interest rate over a fixed number of years, while in a *life annuity* the invested wealth gets amortized at a fixed interest rate over the remaining life of the retiree. The interest rate that is used to amortize the investment is based on interest rates prevailing in the market at the time the annuity is bought, and even at a given time it can vary with the risk of the asset on which the annuity is based. We want to study whether such annuities outperform stock and T-bond based investments in retirement. Thus, we compare the performance of retirement assets based on monthly returns on the CRSP VW portfolio to a fixed annuity based on the holding period returns on a T-bond portfolio, an annuity based on the yield to maturity on a broadly diversified bond portfolio of medium risk, and an annuity based on the yield to maturity on a Baa-rated corporate bond portfolio of moderately high risk. The broadly diversified bond portfolio is created by assigning equal weights to a portfolio of AAA-rated corporate bonds, Baa-rated corporate bonds, and T-bonds. We amortize W_0 on a monthly basis over N years at the monthly yield to maturity prevailing on the first day of retirement.

One drawback of the above model is it does not account for inflation because the annuity remains fixed over the retirement period. We also separately allow for growth in the consumption amount at the rate of inflation in order to keep the retiree's standard of living constant. Thus, for the stock portfolio and the T-bond portfolio, we solve for c in the following expression which captures the essence of Eq. (1) and at the same time allows for inflation adjustments:

$$(. . . ((((W_0 - c)(1 + r_1) - c(1 + i_1))(1 + r_2) - c(1 + i_1)(1 + i_2))(1 + r_3). . .$$

$$- c \prod_{t=1}^{12N-1} (1 + i_t))(1 + r_{12N}) - c \prod_{t=1}^{12N} (1 + i_t) = 0 \quad (2)$$

where i_t is the rate of inflation at time t. We obtain the monthly CPI for all urban wage earners from the Bureau of Labor Statistics (1997) and we calculate the monthly rate of inflation based on this CPI. For the annuities we account for inflation by setting $r_t = r_1$ for all t=2,3,. . . . . ,12N in Eq. (2) because the annuities based on the yield to maturity on the broadly diversified bond portfolio and the annuity based on Baa-rated corporate bond portfolio depend solely on the interest rate at the commencement of the retirement period.

With the growing life expectancies in the U.S. during 1926 through 1995 and the changing dynamics of employment it is difficult to make statements regarding what the appropriate retirement horizon N should be. We address this issue by looking at six values for N ranging from 5 years, which is considered a short retirement, to 30 years, which is considered a long retirement, with 5-year increments. With 840 months of data at our disposal, there are 840–12N different periods of length 12N that could be analyzed. Even when N is set to its maximum value of 30 there are 480 possible unique periods of analysis. It is redundant to study periods beginning in month t and beginning in the vicinity of month t because the results are likely to be very similar. Thus, we impose the following constraints on the number of periods that are studied: (i) For each N at least 30 periods are studied, and (ii) for the sake of consistency the number of months between the beginning of one draw and the beginning of the next remains constant.

For an example that will clarify the above procedure, consider the retirement horizon of 5 years, when $N = 5$. If the first retirement period begins in January 1926, it will end in December 1930. If we allow the second retirement period to begin in March 1928 and end in February 1933 then the gap between the beginning of the first and the beginning of the second is 26 months. With this gap, we have a total of 31 retirement periods with the last beginning in January 1991 and ending in December 1995. If the gap were to be increased to 27 months or more then it is not possible to have at least 30 retirement periods within the 840 months of data that we have. If the gap is decreased, then we have too many retirement periods. We find that for every 5-year increment in N if the gap is decreased by two months then we are able to meet both of the above constraints. An additional benefit is that we uniformly end up having 31 retirement periods of analysis for all N with the first period always beginning in January 1926 and the last period always ending with December 1995.

Summary statistics for the returns in the data are presented in Table 1 . The average monthly return on the CRSP VW portfolio is 0.9606% while the standard deviation of its rate of return is 5.5%. Compared to the rates of return on the other portfolios, it appears that the CRSP VW has higher risk but also offers a higher rate of return. In the next section we turn our attention to the results.

Table 1
Summary statistics on monthly returns for portfolios

Portfolio	Mean	Standard deviation
S&P 500 index	0.9606%	5.50%
T-Bond holding period	0.435%	1.57%
Aaa, Baa, T-bond annuity	0.502%	3.05%
Baa bond annuity	0.588%	3.27%

4. Results

4.1. Main results

In Table 2 we report the results on dollar-cost disinvesting for various values of the retirement horizon, *N*, and for the portfolios that we have selected. For each *N* and for each portfolio we present the average monthly consumption amount, which we termed *c* in Eq. (1), for the 31 retirement periods that are included in the analysis. Thus, an individual with a retirement horizon of 5 years who invested $100 into the CRSP VW portfolio could have spent $2.19 every month immediately upon retiring till the end of 5 years. Instead, if he had opted to invest in a portfolio of T-bonds, he could have spent $1.89. We provide the *p*-value of the Wilcoxon sign rank statistic for the null hypothesis that the mean difference between the stock based consumption amount and the T-bond based consumption amount is zero in parentheses. Our analysis of whether the consumption numbers as well as the differences in consumption between different classes of assets are normally distributed or not suggests that normality cannot always be assumed. Thus, we resort to nonparametric test statistics which impose few distributional assumptions on the data for all our hypothesis tests (Conover, 1980). We also provide the number of periods out of 31 in which the stock based consumption was greater than T-bond based consumption below the *p*-value of the Wilcoxon sign rank statistic. Finally, the number that appears in brackets provides an indication of how much bigger (in percentage terms) the consumption based on the stock portfolio is compared to consumption based on the T-bond portfolio. Thus, the consumption based on the stock portfolio over 5 year horizons is significantly greater than the consumption based on T-bonds at the 1% level. Additionally, in 23 out of 31 five-year periods the stock based consumption was greater than T-bond based consumption. Based on the sign test with a probability of success equal to 50%, in a random sample of 31 draws, we would find 23 or more successes to occur less than 1% of the time. Finally, the stock portfolio allows 15.87% greater consumption per 100 dollars invested than the T-bond portfolio, that is, the difference of 30 cents between $2.19 and $1.89 is 15.87% of $1.89.

When stock based consumption is compared to T-bond based consumption over different horizons, a clear pattern emerges. Stock based consumption is always greater than T-bond based consumption regardless of the retirement horizon *N*. This difference is always statistically significant at the 1% level. The percentage economic difference increases monotonically with the length of the retirement horizon. To see this economic difference more clearly consider an individual who has accumulated $100,000 by retirement. If this money is

Table 2
Monthly consumption based on U.S. financial market history[a]

Horizon (years)	Stock	T-bonds	Annuity A	Annuity B
5	2.19%	1.89%	1.94%	1.98%
		(<0.01)	(<0.01)	(0.02)
		*23****	*23****	*22****
		[15.87%]	[12.89%]	[10.61%]
10	1.31%	1.06%	1.10%	1.16%
		(<0.001)	(<0.01)	(0.02)
		*24****	*22****	*21***
		[23.58%]	[19.09%]	[12.93%]
15	1.05%	.75%	.79%	.86%
		(<0.001)	(<0.001)	(0.01)
		*21***	*20***	*20***
		[40.00%]	[32.91%]	[22.09%]
20	.91%	.59%	.63%	.69%
		(<0.001)	(<0.001)	(<0.01)
		*24****	*24****	*21****
		[54.24%]	[44.44%]	[31.88%]
25	.86%	.49%	.54%	.59%
		(<0.001)	(<0.001)	(<0.001)
		*25****	*25****	*24****
		[75.51%]	[59.26%]	[45.76%]
30	.85%	.43%	.47%	.53%
		(<0.001)	(<0.001)	(<0.001)
		*29****	*26****	*26****
		[97.67%]	[80.85%]	[60.38%]

[a] Monthly consumption is the consumption at the beginning of every month for every dollar of wealth, with nothing left over at the end of retirement. The percentages are an average over 31 retirement periods of equal length depending on the retirement horizon, with the first period beginning in January 1926 and the last period ending in December 1995. The *p*-values of the Wilcoxon sign rank statistic for the null hypothesis that the T-bond and annuity portfolios provide consumption equal to the stock portfolio are presented in parentheses. Number of periods out of 31 in which consumption from the stock portfolio is greater than that from the other portfolios is presented in italics. In brackets is how much more consumption the stock portfolio yields as a percentage of the other portfolios.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

invested in the stock portfolio, with a five year horizon it translates into an additional $300 per month of consumption as opposed to the T-bond portfolio. For a 30 year horizon, the stock portfolio generates $420 more each month than the T-bond portfolio. Thus, our results unequivocally suggest that a stock based portfolio is better than a T-bond based portfolio.

When stocks are compared to an annuity based on the broadly diversified investment grade bond portfolio (Annuity A) we find similar results. Consumption based on the stock portfolio is statistically significantly greater for all horizons from 5 to 30 years. The statistical and economic differences also grow monotonically as the retirement horizon lengthens. We note that consumption based on Annuity A is greater than consumption based on the T-bond portfolio for all horizons, but only marginally so. We also compare consumption based on the stock portfolio to consumption based on the yield on Baa-rated corporate bonds (Annuity

Table 3
Monthly real consumption based on U.S. financial market history[a]

Horizon (years)	Stock	T-bonds	Annuity A	Annuity B
5	1.99%	1.73%	1.76%	1.81%
		(<0.01)	(<0.001)	(0.02)
		*23****	*23****	*22****
		[15.03%]	[13.07%]	[9.94%]
10	1.12%	.90%	.94%	.99%
		(<0.001)	(<0.001)	(0.02)
		*24****	*22***	*21***
		[24.44%]	[19.15%]	[13.13%]
15	.84%	.59%	.63%	.67%
		(<0.001)	(<0.001)	(<0.01)
		*25****	*22****	*20***
		[42.37%]	[33.33%]	[25.37%]
20	.71%	.43%	.47%	.51%
		(<0.001)	(<0.001)	(<0.001)
		*26****	*26****	*23****
		[65.12%]	[51.06%]	[39.22%]
25	.65%	.35%	.38%	.42%
		(<0.001)	(<0.001)	(<0.001)
		*28****	*27****	*25****
		[85.71%]	[71.05%]	[54.76%]
30	.64%	.29%	.31%	.36%
		(<0.001)	(<0.001)	(<0.001)
		*29****	*27****	*26****
		[120.69%]	[106.45%]	[77.78%]

[a] Monthly consumption is the consumption at the beginning of every month for every dollar of wealth, with nothing left over at the end of retirement. The percentages are an average over 31 retirement periods of equal length depending on the retirement horizon, with the first period beginning in January 1926 and the last period ending in December 1995. The *p*-values of the Wilcoxon sign rank statistic for the null hypothesis that the T-bond and annuity portfolios provide consumption equal to the stock portfolio are presented in parentheses. Number of periods out of 31 in which consumption from the stock portfolio is greater than that from the other portfolios is presented in italics. In brackets is how much more consumption the stock portfolio yields as a percentage of the other portfolios.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

B). Although consumption based on this annuity is superior to consumption based on Annuity A, it is statistically and economically dominated by the stock portfolio and the dominance is stronger for longer horizons. Thus, we find that stocks are better than T-bonds and are also better than annuities based on treasury and corporate bonds.

One very important concern for retirees is the effect of inflation on consumption. In Table 3 we present our results on the real consumption that the retiree can afford during retirement based on the solution to Eq. (2). Compared to the percentages appearing in Table 2, the consumption allowances appearing in Table 3 are smaller. However, we find that the dominance of the stock portfolio over the others is generally larger in economic terms while tests for differences in mean consumption based on stocks versus consumption based on

T-bonds, Annuity A, and Annuity B maintain their level of statistical significance. Thus, our main results are robust to inflation.

4.2. Transactions costs and taxes

The results presented in Tables 2 and 3 and our discussion in the preceding section, present a strong case for investing in a broadly diversified stock portfolio in lieu of T-bonds or annuities based on bonds, particularly for retirees with long horizons. In this section we provide a brief discussion of the impact of taxes and transactions costs on our conclusions.

Formal comparisons of transactions costs between stocks, bonds, and annuities have yet to appear in the literature. However, it has been recognized that transactions costs are driven by dealer inventory considerations, by liquidity of the traded asset, and by adverse selection in the market for the traded asset (Huang & Stoll, 1997). Mitchell, Poterba, and Warshawsky (1997, p. 2), find that a 65-year old purchaser of a life annuity can expect to pay 15% to 20% of their amortized wealth as a transaction cost. They also note that adverse selection is a significant problem in the market for annuities as *every* annuity buyer knows more about their own health than any annuity seller. In the bond and the stock markets, however, adverse selection is a problem only when dealers are trading with buyers and sellers who are better informed than they are. Because the *average* investor in the bond and stock markets is unlikely to possess inside information, and therefore, unlikely to be better informed than dealers, we believe that adverse selection is a smaller problem in the bond and stock markets relative to the annuity market. Additionally, the bond and stock markets are significantly more liquid than the market for annuities. Therefore, if transactions costs were to be factored into our analysis, our result that retirees should consider investing in stocks will be even stronger.

The analysis of how taxes will affect our results will depend on whether disinvesting is being done from a "qualified" pension account like a 401(k), a 403(b), or a deductible IRA or from outside such an account. Because contributions to a qualified account are tax-deductible, the withdrawals from such an account will be wholly taxable regardless of whether the funds are invested in stocks, bonds, or annuities. In this instance, taxes have no impact on our conclusions. However, if disinvesting is being implemented from outside such a qualified account, then stocks will generally impose less of a tax burden than bonds or annuities. In a broadly diversified stock portfolio like the CRSP VW portfolio or the S&P 500 Index, many companies pay no dividends. Therefore, a greater portion of the monthly cash flow received from disinvesting such a stock portfolio will come from capital gains relative to the cashflow from disinvesting a bond portfolio or an annuity based on corporate bonds. Because the statutory tax rate on capital gains is less than on ordinary income (for most people), disinvesting from a stock portfolio will impose a slightly lower tax burden as compared to disinvesting from bonds or from an annuity. Thus, from a tax perspective our results remain unchanged if disinvesting is being carried out from a qualified account, and our case for a retiree investing in a stock portfolio becomes stronger if disinvesting is being implemented from outside a qualified account.

4.3. Consumption risk

A common objection that is raised to the type of analysis that is presented in the preceding section, which focuses on average outcomes, is that it fails to account for the higher dispersion in consumption around the mean that accompanies investing in stock portfolios. For a retiree, this dispersion manifests itself in fluctuations in purchasing power, or in "consumption risk". Therefore, although on average the retiree might have high consumption from stocks, there will be some states where the stock-based consumption is extremely low. Such low consumption will be reflected in a low level of utility during that state. The standard expected utility maximization models suggest that on an *ex-ante* basis the retiree will try to balance his portfolio between risky and risk less assets so that expected marginal utility across the two classes is equal at the optimum (for a mathematical derivation of this idea see chapter 2 in Merton 1992, especially Eq. 2.4. The comparative statics of the optimum will then suggest how the optimum will change with respect to changes in the distribution of the risky portfolio—the standard conclusion is that the optimum portion of wealth invested in the risky asset decreases with increases in the risk of that asset.

In order to address this objection, we present in Fig. 1 the frequency plots for the 31 inflation-adjusted consumption amounts that were calculated on the basis of Eq. (2). The frequency plots capture succinctly the magnitude of consumption, but more vitally, they capture the dispersion of the magnitude around the mean, and most importantly, the likelihood of extreme consumption outcomes. Thus, our response to the above objection is based on empirical evidence on the likelihood of low consumption states from stocks versus other portfolios. In the frequency plots, the magnitudes and frequencies of consumption for the CRSP VW portfolio, the T-bond based investment, and the best or optimal portfolio allocated between stocks and T-bonds are shown in different shades. The optimal portfolio is derived by calculating a, the portion of wealth invested in the CRSP VW portfolio and (1-a) invested in T-bonds that would have maximized a retiree's consumption during a particular sub period of our analysis. We use a computer program to find this a for every sub period. Our program begins with $a=1.0$ and calculates the consumption possible then decreases a by 0.05, then repeats the procedure till $a=0.0$. The optimal a is the one that maximizes consumption. We will discuss below the composition of the optimal portfolio once we make some inferences based on the frequency plots. We present in Fig. 1 three frequency plots, one corresponding to each of the 10-, 20-, and 30-year horizons. The 5-, 15-, and 25-year plots add little to the conclusions that we come to below, and therefore we choose to leave them out of the analysis.

In order to make the interpretation of the frequency plots easier, it may be helpful to examine one such plot in some detail. By looking at the left hand side of the frequency plot for the 10-year horizon the following statements can be made: A retiree with a 10-year horizon would have consumed 0.72% or less of his wealth every month only once out of the 31 periods of data that are analyzed, if the retiree had invested in the optimal stock-bond portfolio. Had this retiree invested in the CRSP VW portfolio, he would have consumed 0.72% or less of his wealth three out of 31 times, and with T-bonds this number would have been five out of 31 times. The next three bars that appear in the frequency plot suggest the following: This retiree would have consumed 0.93% of his wealth every month in seven out

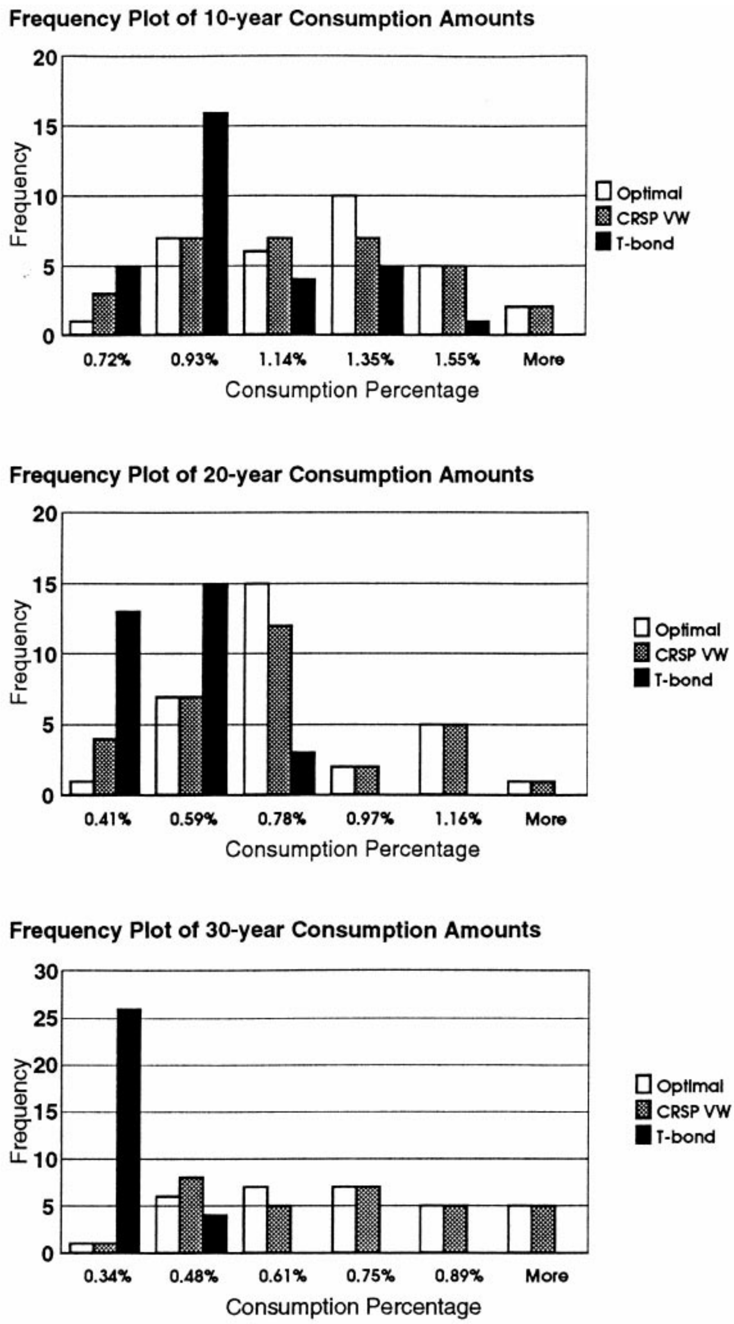

Fig. 1. Frequency plot of consumption amounts.

of the 31 periods, with the optimal stock-bond portfolio or the CRSP VW portfolio. However, with the T-bond portfolio this number rises to 16 out of 31 times.

If 0.72% and 0.93% are considered to be low consumption, then it appears that the *frequency of low consumption for the optimal portfolio and the stock portfolio is smaller* than for the T-bond portfolio. Thus, although there appears to be more dispersion of consumption around its mean for the optimal and stock portfolios, there is more downside risk in the T-bond portfolio than in the other two portfolios. This is a new and very important finding that, to our knowledge, has not appeared anywhere in the literature.

Similarly, by analyzing the right hand side of the frequency plot, we find that frequency of high consumption (1.35%, 1.55%, and greater than 1.55%) is always greater for the optimal and the stock portfolios relative to the T-bond portfolio. In the extreme, the frequency of consuming more than 1.55% of wealth every month is zero for T-bonds while it is two for both the optimal and the stock portfolios. We conclude on the basis of the frequency plot that there is more upside potential in the stock and the optimal portfolios than the T-bond portfolio.

This pattern gets stronger as the investment horizon gets longer. As the horizon increases from 10 to 20 to 30 years the frequency of low consumption from T-bonds increases while the frequency of low consumption from the CRSP VW portfolio and the optimal portfolio decreases. At the 30-year horizon, the frequency plot shows that a retiree who invested in a T-bond portfolio would have been able to spend 0.48% *or less* of his starting wealth every month with no uncertainty while a retiree who invested in the CRSP VW portfolio or the optimal portfolio would have been able to consume 0.48% *or more* of his wealth with virtually no uncertainty. In fact, in only one period he is able to consume less than 0.48% of his wealth. Thus, the little dispersion in consumption around its mean for the T-bond portfolio means that a retiree is practically guaranteed a low standard of living (relative to the stock based or optimal portfolios) while for the CRSP VW or optimal portfolios low consumption occurs infrequently and high consumption always occurs more frequently than for the T-bond portfolio. We conclude from this analysis that as the horizon gets longer retirees would be well advised to invest in stocks over T-bonds.

The “good” thing about the little dispersion in consumption based on the T-bond portfolio is that it is easy for the retiree to determine what portion of his wealth he should consume while with the large dispersion in consumption based on the CRSP VW or optimal portfolios it is difficult to come to any general conclusions what consumption should be. However, this is really not a problem because the retiree cannot possibly go wrong by consuming 0.48% of his wealth from the CRSP VW or optimal portfolios knowing that he can spend more if the market turns out to be favorable while recognizing that there is virtually no risk that he will outlive his wealth over the 30-year horizon. Finally, we would like to point out that most retirees in the U.S. are eligible for Social Security payments. These payments are like interest payments from a relatively safe bond (Clements, 1999). For retirees who are eligible for Social Security payments, the monthly consumption that we calculate is in addition to the floor consumption that the Social Security payments will allow them. This fact should mitigate, to a great extent, any remaining doubts that stocks offer the best consumption possibilities for retirees.

Table 4
Composition and timing of the optimal portfolio

Panel A: Summary statistics on composition of optimal portfolio.

Horizon (years)	Number of periods out of 31 in which optimal portfolio has		
	100% stock optimum	100% T-bond optimum	An interior optimum
5	22	7	2
10	21	4	6
15	21	1	9
20	21	1	9
25	25	0	6
30	25	0	6

Panel B: Correlation between business contractions and composition of optimal portfolio.

Horizon (years)	100% stock optimum	100% T-bond optimum	An interior optimum
5	−0.07**	0.15***	−0.02
10	−0.19***	0.14***	0.19***
15	−0.05	0.12***	0.05
20	−0.09***	0.12***	0.09***
25	−0.12***	—	0.13***
30	−0.14***	—	0.14***

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

4.4. Composition and timing of optimal portfolio

We now turn our attention to the composition of the optimal portfolio. In Panel A of Table 4 we present summary statistics on the frequency with which the optimal portfolio is 100% invested in the CRSP VW portfolio versus 100% invested in the T-bond portfolio versus a combination of stocks and T-bonds (an interior optimum). One obvious conclusion that we can make is that there are significantly more periods in which the optimal portfolio is 100% invested in stocks versus being 100% invested in T-bonds or a combination of stocks and T-bonds. Another conclusion that can be made is that the number of periods in which the optimal portfolio is invested in stocks increases with the retirement horizon. This increase is generally at the expense of the number of periods in which the optimal portfolio is 100% invested in T-bonds.

We can gain some additional insights into the retirement asset allocation decision by studying the correlation between the stage of the business cycle and the optimality of stocks versus T-bonds versus a combination of stocks and T-bonds. We obtain U.S. business cycle data for 1926 to 1995 from the National Bureau of Economic Research (NBER). For every month in which the economy expanded, we set the dummy variable CONTRACT to zero and when the economy contracted we set it to 1. Additionally, for every month in which a 100%

Table 5
Monthly consumption based on U.S. financial market history with randomized returns[a]

Horizon (years)	Stock	T-bonds	Annuity A	Annuity B
5	2.08%	1.87%	1.93%	2.00%
		(0.016)	(0.065)	(0.225)
10	1.19%	1.02%	1.14%	1.18%
		(0.013)	(0.200)	(0.327)
15	1.20%	0.77%	0.78%	0.86%
		(<0.001)	(<0.001)	(<0.001)
20	0.98%	0.67%	0.72%	0.81%
		(<0.001)	(<).001)	(0.008)
25	0.93%	0.60%	0.66%	0.67%
		(0.039)	(0.027)	(0.048)
30	0.81%	0.54%	0.57%	0.71%
		(<0.001)	(<0.001)	(0.016)

[a] Monthly consumption is the consumption at the beginning of every month for every dollar of wealth, with nothing left over at the end of retirement. The percentages are an average over 31 retirement periods of equal length depending on the retirement horizon. The returns are drawn randomly (with replacement) from a set that contains actual monthly returns based on the history of U.S. financial markets. The *p*-values of the Wilcoxon sign rank statistic for the null hypothesis that the T-bond and annuity portfolios provide consumption equal to the stock portfolio are presented in parentheses.

stock portfolio was optimal, we set the dummy variable STOCKS to 1, and to zero otherwise. Likewise, for every month in which the 100% T-bond portfolio was optimal, we set the dummy variable T-BONDS to 1, and to zero otherwise, and for every month in which a mix of stocks and T-bonds and stocks was optimal, we set the dummy variable INTERIOR to 1, and to zero otherwise. In Panel B of Table 4, we present the correlation coefficients of CONTRACT with STOCKS, T-BONDS, and INTERIOR. We find that the correlation coefficient between CONTRACT and STOCKS is negative and statistically significant for all horizons except 15 years. For the horizons for which a correlation coefficient between CONTRACT and T-BONDS can be calculated, we find it to be positive and statistically significant. The correlation coefficient between CONTRACT and INTERIOR is, with one exception, positive and statistically significant. When it is negative, it is statistically insignificant. Based on these correlation coefficients, we conclude that a 100% stock portfolio is optimal during economic expansions. When the economy contracts, either T-bonds or a mix of T-bonds and stocks are optimal.

McNees (1987), however, demonstrates that it is difficult to predict *ex-ante* when the economy will next contract. In order to determine whether our main results are robust to the unpredictability of business cycles, we run one final test. We use each of the 840 monthly returns for stocks, T-bonds, and the two annuities to calculate monthly consumption, but instead of using them in the chronological sequence that they appear in our tests reported in Table 2, we mix them up by drawing a random sequence of 840 returns, with replacement, from the set of returns that are at our disposal. The monthly consumption percentages based on the random sequence of returns and calculated from Eq. (1) appear in Table 5 together with the *p*-value of the Wilcoxon sign rank test statistic. Before we turn our attention to a discussion of the results we would like to place a note of caution here: there probably are linkages between the stock market, the T-bond market, and the market for annuities that are not fully understood currently. By randomizing the returns data, we ignore the linkages that might have existed between the different returns data that we have at our disposal.

We find that the stock portfolio based consumption is consistently greater than consumption based on other portfolios. However, our results are not as strong statistically as the results reported in Table 2. In particular, at horizons of 5 and 10 years, the consumption based on Annuity B is statistically virtually indistinguishable from stock based consumption. At the 10-year horizon, consumption based on Annuity A is also statistically virtually indistinguishable from stock based consumption. Apart from these two statistically insignificant results, the rest of the results that appear in the table are all statistically significant but in some cases not as significant as their counterparts in Table 2. However, based on the results that appear in Table 5 we conclude that our main result that at long horizons retirees are better off by being in stocks is robust to the unpredictability of recessions.

5. Conclusions

We study the history of U.S. financial markets from the perspective of a retiree because the voluminous literature on U.S. financial market history and on optimal asset allocation largely ignores the retiree's asset allocation decision. We assume that retirees are primarily interested in maximizing their consumption stream. Therefore, we calculate and compare the magnitude of consumption that would have been possible under various asset classes for various retirement horizons.

We find that consumption based on a stock portfolio has been much higher compared to consumption based on a portfolio composed of T-bonds, or annuities based on the yield on a broadly diversified portfolio of investment-grade bonds or even moderately risky bonds. This statistical and economic dominance of stocks over bonds increases as we increase the time horizon for investment. When we compare the real consumption that is possible across different asset classes we find that stocks perform even better. We also find that the likelihood of low consumption is higher with T-bonds and this likelihood increases with the time horizon, while the likelihood of high consumption is higher with stocks and this likelihood also increases with the time horizon.

Interestingly, the few cases in which other than a 100% investment in stock was superior, seem to cluster in periods when the economy contracted. Thus, we conclude that unless the economy is beset by an economic contraction, a retiree will be better off with a 100% allocation of wealth to stocks. However, we recognize that *ex-ante* the ability of any individual to predict the onset of an economic contraction is low. Therefore, we provide additional evidence on monthly consumption when returns are drawn randomly from the set of monthly returns that we have. Our results based on randomized returns are qualitatively consistent with our other results, but statistically they are not quite as significant, particularly at short horizons. Thus, our study provides strong evidence that individuals should seriously consider remaining in stocks even after retirement, particularly at long retirement horizons, due to the larger size of the stock based consumption amounts as opposed to fixed-income security based consumption.

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