Shortfall Risk, Asset Allocation, and Overfunding a Retirement Account

Danny Ervin
Salisbury University

Joe Smolira (contact author)
Belmont University
School of Business
1900 Belmont Boulevard
Nashville, TN 37221
Phone: 615.460.6463
Fax: 615.460.6487
joe.smoliraj@belmont.edu

08/18/2005

Keywords: Retirement planning, Portfolio choice

JEL Classification: G11 – Portfolio Choice

Shortfall Risk, Asset Allocation, and Overfunding a Retirement Account

Abstract

This study evaluates the success of the monthly deposit of funds into hypothetical retirement portfolios for the period January 1926 to December 2003. The results of the study indicate that, in general, portfolios with a higher equity portion had a greater likelihood of achieving the desired terminal value. We also find that monthly deposits based on the historical asset class returns generally do not have a high success rate. To achieve a high success rate, investors must overfund a retirement portfolio.

Shortfall Risk, Asset Allocation, and Overfunding a Retirement Account

Introduction

With the potential problems surrounding Social Security funding, and the decline of defined benefit retirement plans, more individuals are saving on their own for retirement. In fact, the U.S. Department of Labor expects 401k assets to top $3.3 trillion by 2006. With the increased individual participation in retirement plans, a critical question is: How much must an individual save in order to retire comfortably? While recent academic research has examined retirement withdrawals from a portfolio based on historical market returns, we know of no literature that has focused on savings results using historical market returns.

The decision of how much to save is critical to retirement spending. After retirement, most individuals have little earned income. It is often also difficult to re-enter the work force at a salary comparable to the salary earned before retirement. Obviously, an individual who saves more is better off, but saving too much is not optimal either since an individual is reducing current consumption.

The major risk faced by an individual saving for retirement is shortfall risk, that is, the risk of not having sufficient funds at retirement. This means the individual will have to delay retirement, or reduce spending in retirement, neither of which is a desirable outcome.

This study evaluates the success of various fund deposit amounts for different deposit periods and different portfolio compositions for the period 1926 to 2003. The portfolios examined in this study consist of U.S. large capitalization stocks, and U.S. long-term corporate bonds with various portfolio weights. The fund deposit amounts are

determined by historical asset performance, and the deposit periods are 20, 30, and 40-years.

In recent years, academic research has questioned the use of dollar-cost averaging. For example, Constantinides (1979) finds that dollar-cost averaging is not an optimal investing strategy. This line of research has focused on the mean-variance efficiency of dollar cost averaging, or the risk-return elements of dollar-cost averaging. Our research uses dollar-cost averaging implicitly since we estimate terminal values with equal monthly deposits. Dollar-cost averaging is still appropriate for our research for two reasons. First, we are concerned with shortfall risk, not total risk. Previous research on dollar-cost averaging focuses on standard deviation, the Sharpe ratio, the Sortino ratio, or the Upside Potential ratio as risk measures. Our research is focused on shortfall risk as it pertains to a retirement portfolio. Second, for most investors, dollar-cost averaging is the only viable method of saving. A typical investor does not have the luxury of deciding to invest a large lump sum or use dollar-cost averaging, but rather must invest a small amount in a systematic manner for their retirement. Thus, for most investors, whether or not dollar-cost averaging is mean-variance optimal is irrelevant since dollar-cost averaging is the only investment strategy available to them.

The remainder of the paper is organized in the following manner: the next section discusses the literature on withdrawals from a retirement portfolio and criticisms of dollar-cost averaging; the third section outlines our data and research methods; the fourth section discusses our results; and the fifth section adds our concluding remarks.

Literature Review

Most literature on terminal values of portfolios based on historical returns examines withdrawals from a portfolio. For example, Bierwirth (1994) examines fund withdrawals from a retirement portfolio consisting of 20 percent U.S. Treasury bills, 40 percent long-term government bonds, and 40 percent large capitalization common stocks. Using data from 1926 to 1992, his analysis focused on the historical dollar withdrawal amount an investor could make without invading principal assuming a 27-year retirement period. His results indicate the Depression-era was in fact favorable for withdrawals, generating some of the better income withdrawals. His results also show the importance of the timing of returns. A major determinant of whether a portfolio can support withdrawals is the rate of return early in the fund withdrawal period. If the returns are too low, or negative, early in the withdrawal period the portfolio value may fall to a level that makes it impossible to recover.

More recently, Cooley, Hubbard, and Walz (1999, 2001) examined the question of sustainable withdrawal rates. They find that a six to seven percent withdrawal rate appears sustainable for most periods if the portfolio is comprised of at least 50 percent equity. If the equity portfolio weight drops below 50 percent, the portfolio withdrawals do not consistently last for 15 years. Their findings also show the importance of a diversified portfolio in funding retirement withdrawals. For many withdrawal rates and periods, a portfolio of stocks and bonds has a greater likelihood of successfully funding retirement withdrawals compared to a portfolio consisting of only stocks or a portfolio consisting of only bonds.

The literature on withdrawals from a retirement portfolio implies that equal periodic withdrawals do not work well on withdrawal portfolios. With a historical average return of about 12 percent for large capitalization stocks, a portfolio comprised of large capitalization stocks will generally support withdrawals of about seven percent.

Literature on the effectiveness of dollar-cost averaging as an investment strategy is divided. Israelsen (1999) finds that dollar-cost averaging is a superior investment strategy for 19 of the 35 largest equity mutual funds. However, Leggio and Lien (2003), Thorley (1994), Rozeff (1994), and Williams and Bacon (1993) find that lump sum investing is a superior strategy. Abeysekera and Rosenbloom (2000) use a Monte Carlo simulation to analyze the performance of dollar-cost averaging and lump sum investments. They find that, in general, there is no definitive advantage of dollar-cost averaging over lump sum investing.

Most of the previous literature on dollar-cost averaging has found that dollar-cost averaging is not an optimal investment strategy. We do not focus on this question, but rather attempt to determine the portfolio deposits and weights that create a specific terminal value. This research is an attempt to determine the shortfall risk an investor faces with various investment portfolios and deposits.

Data and Analysis

We use monthly returns from January 1926 to December 2003. The returns used were gathered from Ibbotson's *Stocks, Bonds, Bills, and Inflation 2004 Yearbook*. The returns used in the construction of our portfolios were large capitalization stocks, long-term corporate bonds, and inflation.

We used these returns to construct portfolios to analyze retirement fund terminal values. The portfolios are composed of large capitalization stocks and long-term corporate bonds. We examine portfolios with equity weights of 100, 75, 50, 25, and 0 percent. The remainder of the portfolio is invested in the bond index.

While an individual should begin saving earlier rather than later for retirement, many individuals postpone retirement savings until later in life. To accommodate the different savings horizons of individuals, we examine savings periods of 20-, 30-, and 40-years. We use rolling periods in our testing. For example, the first 30-year period begins January 1926 and ends in December 1955. The next 30-year period begins February 1926 and ends in January 1956. With 78 years of data we get 697 rolling 20-year savings periods, 577 rolling 30-year periods, and 457 rolling 40-year savings periods. We have elected to begin the rolling withdrawal period in every month rather than at the beginning of every year to examine the timing factor in retirement withdrawals.

We have included the period prior to 1946, which includes the Great Depression and World War II economies. We feel three factors support the inclusion of these years. First, research on retirement fund withdrawals by Bierwirth (1994) indicates that, contrary to expectations, retirement withdrawals during this period are generally supported, and, in fact, provide some of the highest supportable withdrawal rates. We wish to examine whether this period supports long-term deposit accounts as well. Second, recent research (such as Siegel (2002)) has argued that the market risk premium during the most of the 1900s was historically too high. Including this data adds a relatively low market risk premium period to our study. Finally, ignoring part of the available data is a form of data mining. While it can be argued the 1926 to 1945 period should be ignored

because of the unique economy that is unlikely to be repeated, it can also be argued we should also exclude the bull market of the 1990s since it was also a very unique period that is unlikely to be repeated.

An important consideration in determining the terminal value of a savings portfolio is the dollar amount of the deposits into the portfolio. Table 1 shows the required monthly deposit necessary to achieve a $1 million terminal value for a large capitalization stock portfolio and a long-term corporate bond portfolio based upon the arithmetic and geometric returns of these asset classes over the entire period. For example, on a nominal basis, the arithmetic return of large capitalization stocks was 12.4 percent over the period, and the geometric return was 10.4 percent. Given these returns, an individual who deposited $74.87 per month over a 40-year period would have a $1 million terminal value based on the arithmetic return. A monthly deposit of $139.94 would be required based upon the geometric return. Similarly, the required monthly deposits into a long-term corporate bond portfolio would be $475.52 and $515.92. We used these calculations for each different deposit period to determine a lower and an upper bound for our examination of deposits. For example, based on the numbers given, we used a lower deposit amount of $100, an upper deposit amount of $500, and intervals of $100 for the 40-year deposit period. Where there was a larger difference between the upper and lower estimates, we used larger intervals.

<<INSERT TABLE 1 ABOUT HERE>>

We begin each savings period by making an initial deposit. Each month, the same dollar deposit is made. The portfolio is considered a success if the terminal value of the portfolio at the end of the savings period is greater than $1 million. We then calculate the

success rate as the number of successful portfolios divided by the number of portfolios with the same deposit length and asset weights.

We also account for the effects of inflation by examining a real terminal value of $1 million. The effects of inflation can greatly affect the necessary deposits. For example, based on Figure 1, a deposit into a 100 percent stock portfolio based on the nominal geometric return would be $1,250.05 for a 20-year deposit period. A deposit of $1,828.23 would be required based on the real geometric return.

When utilizing nominal returns, our method of analysis assumes an investor deposits an equal nominal dollar amount each month. This deposit pattern may not replicate the exact savings pattern for many investors since it requires larger initial deposits when the individual is younger. This may not be feasible for many investors since income at this stage of life is generally lower than the income level later in life. Utilizing real returns implicitly assumes a growth rate in deposits equal to the inflation rate. Thus, the real deposit pattern is similar to more investors' savings habits. Investors can and do have different growth rates in savings, but the analysis of every savings pattern is not possible here.

The terminal value of $1 million is arbitrarily chosen, and may be impossible for many investors to achieve, especially in real terms. For example, the per capita income in the United States during 2003 was approximately $38,000. Based on historical market performance, an individual who saves $425 a month in real terms for 40 years, or approximately 13 percent of her annual salary, will have a 58 probability of achieving a million dollar portfolio, assuming a 100 percent stock investment. To have the same probability of reaching a terminal value of $1 million with a 30 year savings horizon

would require a deposit equal to approximately 26 percent of her annual salary. However, the terminal value and savings amount will always have the same relationship. A savings amount of one-half of either example for the same savings period will result in the same probability of reaching a terminal value of $500,000.

The calculation of the growth of the portfolio implicitly assumes portfolio rebalancing each month. We do not include rebalancing costs in our analysis. While transaction costs of rebalancing could have potentially been large in the past, current investors can rebalance at a very low cost by using no-load index mutual funds or exchange-traded funds (ETFs). Taxes on portfolio gains are not considered. If the portfolio is held in a tax-deferred vehicle such as an IRA or 401k, taxes on the gains can be ignored since they are not paid until withdrawal. The results of this paper also do not address the issue of taxable retirement plans and tax-deferred retirement plans. For a discussion of the tax issue in retirement savings accounts, see Poterba (2004).

Results

Table 2 presents the results for nominal deposits with 20-, 30-, and 40-year deposit periods. Examining the results for the 20-year deposit period, we find that the variability of the terminal value increases when more funds are invested in large capitalization stocks. As we would expect, a greater investment weight in large capitalization stocks also results in terminal values with a greater mean, median, minimum, and maximum.

More interesting is the percentage of portfolios that have a terminal value greater than $1 million. For example, based on the historical arithmetic (geometric) return of large capitalization stocks, a monthly deposit of $957.65 ($1,250.05) should result in a

terminal value of $1 million. However, a monthly deposit of $900 is successful 48 percent of the time for a portfolio fully invested in large capitalization stocks. A monthly deposit of $2,200 has a mean terminal value of about $2.5 million, and a success rate of 97 percent. A short-term deposit period appears to have a significant amount of shortfall risk.

Another finding in the 20-year deposit period is the benefits and costs of diversification. For example, a $2,200 monthly deposit has a success rate of 97 percent with a 100 percent equity portfolio, 85 percent with a 50/50 portfolio, and only a 33 percent success rate with a 100 percent bond portfolio. The introduction of equity greatly increases the success rate of a portfolio. The mean terminal value of these portfolios is $2.5 million, $1.6 million, and $1.0 million, respectively. While the success rate for a 50/50 portfolio is greater than the average success rates of the 100 percent equity and 100 percent bond portfolios, the mean terminal value is closer to the bond portfolio. This can occur because of greater skewness in the terminal values of the all equity portfolio, however, the median values show the same tendency, with median terminal values of $2.40 million, $1.36 million, and $800,000, respectively.

<<INSERT TABLE 2 ABOUT HERE>>

We should also note the low potential return for a 100 percent bond portfolio over this period. For example, a $2,200 monthly deposit into a 100 percent bond portfolio has a minimum terminal value of $578,343. The same deposit into an account earning no interest would have a terminal value of $528,000. Deposits into the bond portfolio over this 20-year period would have earned less than 10 percent interest over the entire period, or less than one-half percent per year in nominal terms.

Aside from the higher required monthly deposits, a portfolio consisting of 100 percent long-term bonds appears to be a poor choice for a retirement portfolio. In addition to the previously mentioned problem, the 100 percent bond portfolio does not appear to be successful very often. For example, the required monthly deposit into a 100 percent stock portfolio is $957.65 based on the arithmetic return. Yet, with a monthly deposit amount of $900, the portfolio is successful about 48 percent of the time. The required monthly deposit into a 100 percent bond portfolio is $2,114, yet a monthly deposit of $2,200 per month is successful only about 33 percent of the time. Thus, the bond portfolio has significant shortfall risk.

For the 30-year deposit periods, the monthly deposits of $800 and $1,000 had a 100 percent success rate if invested in only equities. A $400 monthly deposit, which is approximately the monthly deposit based on the geometric average return, only has a 70 percent success rate. Even so, the mean terminal value of this monthly deposit is about $1.5 million.

Again, a 100 percent bond portfolio performs poorly. A $1,000 monthly deposit has a success rate of about 38 percent. This is the approximate monthly deposit required by the geometric return. Perhaps more unexpected is that the mean terminal value of this deposit amount is only $991,504.

The 40-year deposit period shows the greatest success rates. A 100 percent stock portfolio had a 100 percent success rate for all monthly deposits greater than $200. A $100 monthly deposit exhibited less than stellar performance. Even though the mean terminal value was greater than $1 million, a $100 monthly deposit was successful only 36 percent of the time. With a 40-year deposit period, a monthly deposit of at least $200

per month has a high success rate even for 50 percent large capitalization stocks and 50 percent long-term bond portfolios.

Again, we find that deposits into a portfolio with a large bond weight perform poorly. Based on the arithmetic mean return, the required monthly deposit into a 100 percent bond portfolio is $475.52, yet a monthly deposit of $500 is successful only 39 percent of the time and has a mean terminal value of $929,942.

Figure 1 shows the percentage of portfolios reaching a specific terminal value with an $800 monthly deposit, 30-year deposit period, and a portfolio invested 75 percent in large capitalization stocks and 25 percent long-term bonds. This deposit specification has a 97 percent success rate, a mean terminal value of $2.15 million, and a median terminal value of $1.94 million. This graph shows a typical distribution of the terminal values of the portfolios, that is, the distribution is skewed. Even though the mean terminal value is $2.15 million, only about 32 percent of the portfolios have a terminal value greater than the mean, and only about 20 percent have a terminal value greater than $2.4 million.

<< INSERT FIGURE 1 ABOUT HERE>>

Figure 2 shows the terminal value of each portfolio with an $800 monthly deposit, 30-year deposit period, and a portfolio invested 75 percent in large capitalization stocks and 25 percent long-term bonds. The effects of the bull market of the 1990s and early 2000 are very evident. The portfolios with the highest terminal value all begin between 1969 and 1971. The ending dates for these portfolios would be in 1999 to 2001, at the height of the stock market. The worst performing portfolios began during the period 1944 to 1952.

The smallest terminal value was a portfolio which began in July 1952. The portfolio terminal value was about $890,000. The largest terminal value was for a portfolio that began in September 1970. This portfolio terminal value was about $5.5 million.

<< INSERT FIGURE 2 ABOUT HERE>>

Figure 2 also shows the importance of timing in a deposit portfolio. If timing were not a factor, we would expect the graph to be smooth and not exhibit sharp up and down spikes. The largest difference in the terminal values of two portfolios that began one month apart was November and December 1968. An investor who began in November 1968 would have had a terminal value of about $4.0 million, while an investor who began in December 1968 would have had a terminal value of about $4.4 million. While this difference is large, it is also important to realize that this is may not be of great importance to an investor. Presumably, the investor who began in November 1968 would still have had the investment portfolio in December 1998, 30 years and one month later.

Table 3 shows the results for deposits in real terms. The implication of our calculation method is that the investor increases the monthly deposit amount each month by the inflation rate. With the larger real deposit amounts, the terminal value of the portfolios is similar to the nominal results. Looking at the results for a 20-year deposit period, the mean terminal value of a $1,400 real monthly deposit into a 100 percent large capitalization stock portfolio is $981,170, and the success rate is 45 percent. A deposit of $1,800 into the same portfolio has a mean terminal value of $1.26 million, and a success rate of 58 percent. This result is important to the deposit amount for investors. The $1,400 deposit corresponds closely to the calculated monthly deposit based on the

historical real arithmetic return, and the $1,800 deposit corresponds to the real return. The implication is that an investor who deposits a monthly amount necessary to achieve a $1 million terminal value will on average achieve the desired result, yet there is still significant shortfall risk, in this case a 42 percent probability.

Again, we find a significant shortfall risk in portfolios with a greater portfolio percentage invested in bonds. Looking at the 40-year deposit period, based on the historical arithmetic (geometric) real return, and investor should deposit $1,054.38 ($1,105.79) each month to achieve a $1 million terminal value. The results for a $1,100 monthly deposit show a mean terminal value of only $738,153, and a success rate of 26 percent. This is a significant shortfall risk.

These results are contradictory with Israelsen (1999). The higher volatility large capitalization stocks produce better terminal results than the lower volatility long-term bonds in both the mean terminal value and the success rate. Previous research has argued that dollar-cost averaging performs better for low volatility assets. However, previous research has focused on traditional risk measures. Our focus on risk concerns shortfall risk. We conclude that dollar-cost averaging performs better on assets with higher volatility when shortfall risk is the risk focus.

Conclusions

Using monthly returns from January 1926 through December 2003, we examine the probability a monthly deposit of funds into a retirement portfolio will achieve a terminal value of $1 million. The asset classes we consider are U.S. large capitalization stocks and U.S. long-term corporate bonds. We analyze different portfolio weights with these asset classes and different savings periods.

When we examine the results based on the required monthly deposit based on the historical asset class return, several interesting results arise. First, as the weight of long-term corporate bonds increases, the probability of the portfolio reaching the desired terminal value decreases. Additionally, the mean terminal value of the portfolio is often below the desired terminal value. Second, the mean terminal portfolio value of an all equity portfolio generally meets the desired terminal value; however, the success rate in this situation is often poor. Our conclusion is that an investor should overfund a retirement portfolio no matter what the portfolio weight, and that the overfunding should increase as the investor increases the weight of bonds in the portfolio.

We also find there is significant evidence of the importance of timing the savings decision. For example, portfolios which begin in 1926-1940 or the early 1970s, two periods when the market performance was poor, perform well because of the high returns at the end of the savings period. In other words, poor current market performance should not deter an individual from retirement savings since the terminal value is dependent on the performance over the entire savings period.

Our results also indicate the importance of saving early. Even when making deposits suggested by the historical return, a 20-year deposit period exhibits significant shortfall risk. In other words, the longer the deposit period, the less the shortfall risk.

The fund deposit amount is ultimately a decision for the individual based on consumption and risk tolerance. This research improves our understanding of what deposit amount an individual can choose, and still have confidence they will have the desired terminal portfolio value. If the retirement fund is insufficient, an individual must either work longer or reduce consumption during retirement.

Table 1

Table 1 shows the historic arithmetic and geometric return of large capitalization stocks and long-term corporate bonds over the period January 1926 to December 2003. The dollar amounts are the equal monthly deposit amounts required to create a portfolio with a terminal value of $1 million based on the historical returns and the deposit period. The dollar amounts are calculated for both real and nominal returns.

Large Capitalization Stocks

	Nominal		Real	
	Arithmetic	Geometric	Arithmetic	Geometric
Years	12.4%	10.4%	9.3%	7.4%
20	$957.65	$1,250.05	$1,441.10	$1,828.23
30	$261.71	$406.05	$513.01	$757.13
40	$74.87	$139.94	$195.33	$340.26

Long-Term Corporate Bonds

	Nominal		Real	
	Arithmetic	Geometric	Arithmetic	Geometric
Years	6.2%	5.9%	3.1%	2.9%
20	$2,113.50	$2,190.07	$3,012.84	$3,079.38
30	$958.02	$1,014.70	$1,686.83	$1,745.63
40	$475.52	$515.92	$1,054.38	$1,105.79

Table 2

Table 2 presents the results for different monthly deposit amounts and different portfolio allocation percentages. The top row lists the monthly deposit amount. The numbers listed in the upper left hand corner are the portfolio weights for large capitalization stocks and long-term corporate bonds, respectively. The percentages listed are the percentage of portfolios with that portfolio allocation and deposit amount that have a terminal value of $1 million or more. All dollar amounts are in nominal terms.

	20 years				
	$900	$1,225	$1,550	$1,875	$2,200
100/0	48.49%	64.42%	78.62%	88.24%	97.42%
Mean	$1,045,120	$1,422,524	$1,799,929	$2,177,333	$2,554,737
Median	$981,359	$1,335,739	$1,690,119	$2,044,498	$2,398,878
Std. Dev.	$513,684	$699,181	$884,677	$1,070,174	$1,255,671
Min	$323,252	$439,982	$556,712	$673,442	$790,172
Max	$2,783,559	$3,788,733	$4,793,907	$5,799,081	$6,804,255
75/25	21.81%	53.52%	68.01%	84.22%	94.12%
Mean	$819,379	$1,115,266	$1,411,153	$1,707,040	$2,002,927
Median	$770,053	$1,048,128	$1,326,202	$1,604,277	$1,882,352
Std. Dev.	$361,444	$491,965	$622,487	$753,008	$883,530
Min	$310,271	$422,313	$534,355	$646,397	$758,439
Max	$2,071,484	$2,819,520	$3,567,555	$4,315,591	$5,063,627
50/50	14.78%	28.84%	43.62%	70.01%	85.08%
Mean	$654,345	$890,637	$1,126,928	$1,363,219	$1,599,511
Median	$558,355	$759,983	$961,611	$1,163,239	$1,364,867
Std. Dev.	$275,336	$374,763	$474,190	$573,617	$673,045
Min	$296,350	$403,366	$510,381	$617,397	$724,412
Max	$1,532,441	$2,085,823	$2,639,204	$3,192,586	$3,745,967
25/75	2.30%	23.82%	31.13%	32.57%	44.76%
Mean	$524,785	$714,290	$903,796	$1,093,301	$1,282,807
Median	$404,252	$550,231	$696,211	$842,191	$988,170
Std. Dev.	$220,552	$300,196	$379,840	$459,484	$539,128
Min	$282,127	$384,006	$485,886	$587,765	$689,644
Max	$1,118,144	$1,521,918	$1,925,693	$2,329,467	$2,733,241
0/100	0.00%	8.18%	28.55%	31.42%	33.14%
Mean	$422,459	$575,013	$727,568	$880,122	$1,032,677
Median	$329,681	$448,732	$567,783	$686,834	$805,886
Std. Dev.	$182,897	$248,943	$314,989	$381,035	$447,081
Min	$236,595	$322,032	$407,469	$492,906	$578,343
Max	$810,971	$1,103,822	$1,396,673	$1,689,524	$1,982,374

Table 2 (continued)

30 Years

	$200	$400	$600	$800	$1,000
100/0	15.60%	69.84%	96.88%	100.00%	100.00%
Mean	$757,947	$1,515,895	$2,273,842	$3,031,789	$3,789,737
Median	$694,360	$1,388,720	$2,083,080	$2,777,440	$3,471,800
Std. Dev.	$379,809	$759,617	$1,139,426	$1,519,235	$1,899,043
Min	$274,687	$549,374	$824,061	$1,098,748	$1,373,435
Max	$2,068,345	$4,136,689	$6,205,034	$8,273,378	$10,341,723
75/25	8.49%	45.41%	76.26%	97.40%	100.00%
Mean	$537,646	$1,075,292	$1,612,939	$2,150,585	$2,688,231
Median	$486,037	$972,073	$1,458,110	$1,944,146	$2,430,183
Std. Dev.	$264,937	$529,874	$794,811	$1,059,748	$1,324,685
Min	$222,520	$445,040	$667,560	$890,079	$1,112,599
Max	$1,382,183	$2,764,367	$4,146,550	$5,528,734	$6,910,917
50/50	0.00%	20.97%	39.69%	73.48%	94.11%
Mean	$382,929	$765,859	$1,148,788	$1,531,718	$1,914,647
Median	$314,957	$629,913	$944,870	$1,259,827	$1,574,783
Std. Dev.	$193,883	$387,767	$581,650	$775,534	$969,417
Min	$172,137	$344,273	$516,410	$688,546	$860,683
Max	$935,275	$1,870,550	$2,805,824	$3,741,099	$4,676,374
25/75	0.00%	13.69%	28.77%	37.61%	41.42%
Mean	$274,421	$548,842	$823,262	$1,097,683	$1,372,104
Median	$189,403	$378,805	$568,208	$757,610	$947,013
Std. Dev.	$146,081	$292,162	$438,243	$584,324	$730,405
Min	$127,341	$254,681	$382,022	$509,362	$636,703
Max	$630,069	$1,260,139	$1,890,208	$2,520,278	$3,150,347
0/100	0.00%	0.00%	21.32%	31.02%	37.78%
Mean	$198,301	$396,602	$594,902	$793,203	$991,504
Median	$135,415	$270,831	$406,246	$541,661	$677,076
Std. Dev.	$111,255	$222,511	$333,766	$445,021	$556,277
Min	$88,291	$176,582	$264,872	$353,163	$441,454
Max	$442,612	$885,224	$1,327,836	$1,770,448	$2,213,060

Table 2 (continued)

40 years

	$100	$200	$300	$400	$500
100/0	36.11%	100.00%	100.00%	100.00%	100.00%
Mean	$1,023,393	$2,046,786	$3,070,179	$4,093,573	$5,116,966
Median	$916,767	$1,833,533	$2,750,300	$3,667,066	$4,583,833
Std. Dev.	$389,691	$779,381	$1,169,072	$1,558,763	$1,948,454
Min	$536,995	$1,073,989	$1,610,984	$2,147,978	$2,684,973
Max	$2,367,460	$4,734,920	$7,102,380	$9,469,840	$11,837,299
75/25	15.32%	67.40%	99.78%	100.00%	100.00%
Mean	$667,991	$1,335,982	$2,003,974	$2,671,965	$3,339,956
Median	$584,544	$1,169,088	$1,753,632	$2,338,177	$2,922,721
Std. Dev.	$288,271	$576,542	$864,813	$1,153,084	$1,441,355
Min	$326,552	$653,104	$979,657	$1,306,209	$1,632,761
Max	$1,509,306	$3,018,612	$4,527,917	$6,037,223	$7,546,529
50/50	0.00%	30.42%	48.80%	85.12%	99.78%
Mean	$434,387	$868,773	$1,303,160	$1,737,547	$2,171,933
Median	$325,920	$651,841	$977,761	$1,303,681	$1,629,602
Std. Dev.	$213,153	$426,306	$639,460	$852,613	$1,065,766
Min	$197,345	$394,689	$592,034	$789,379	$986,724
Max	$953,739	$1,907,477	$2,861,216	$3,814,954	$4,768,693
25/75	0.00%	16.19%	32.82%	47.05%	49.02%
Mean	$283,084	$566,167	$849,251	$1,132,335	$1,415,419
Median	$190,785	$381,570	$572,355	$763,139	$953,924
Std. Dev.	$153,963	$307,926	$461,889	$615,852	$769,815
Min	$118,742	$237,483	$356,225	$474,966	$593,708
Max	$608,520	$1,217,040	$1,825,560	$2,434,081	$3,042,601
0/100	0.00%	0.00%	13.35%	31.95%	38.51%
Mean	$185,988	$371,977	$557,965	$743,953	$929,942
Median	$127,632	$255,263	$382,895	$510,527	$638,159
Std. Dev.	$108,035	$216,071	$324,106	$432,141	$540,176
Min	$71,339	$142,678	$214,018	$285,357	$356,696
Max	$431,474	$862,948	$1,294,422	$1,725,896	$2,157,370

Table 3

Table 3 presents the results for different monthly deposit amounts and different portfolio allocation percentages. The top row lists the monthly deposit amount. The numbers listed in the upper left hand corner are the portfolio weights for large capitalization stocks and long-term corporate bonds, respectively. The percentages listed are the percentage of portfolios with that portfolio allocation and deposit amount that have a terminal value of $1 million or more. All dollar amounts are in real terms.

	20 years				
	$1,400	$1,800	$2,200	$2,600	$3,000
100/0	45.48%	57.96%	71.45%	76.18%	81.64%
Mean	$982,170	$1,262,790	$1,543,411	$1,824,031	$2,104,651
Median	$852,072	$1,095,521	$1,338,970	$1,582,419	$1,825,868
Std. Dev.	$516,444	$663,999	$811,554	$959,110	$1,106,665
Min	$292,153	$375,626	$459,098	$542,571	$626,043
Max	$2,731,055	$3,511,357	$4,291,658	$5,071,960	$5,852,262
75/25	18.94%	47.35%	58.39%	73.03%	79.91%
Mean	$783,111	$1,006,857	$1,230,603	$1,454,349	$1,678,095
Median	$733,453	$943,011	$1,152,570	$1,362,128	$1,571,686
Std. Dev.	$363,273	$467,066	$570,858	$674,651	$778,443
Min	$275,764	$354,553	$433,343	$512,132	$590,922
Max	$2,012,038	$2,586,906	$3,161,774	$3,736,642	$4,311,510
50/50	9.90%	21.09%	37.88%	57.53%	72.45%
Mean	$629,364	$809,182	$989,001	$1,168,819	$1,348,637
Median	$596,420	$766,826	$937,232	$1,107,638	$1,278,044
Std. Dev.	$265,538	$341,406	$417,274	$493,142	$569,010
Min	$242,872	$312,264	$381,656	$451,048	$520,440
Max	$1,503,792	$1,933,447	$2,363,102	$2,792,757	$3,222,411
25/75	1.72%	16.07%	21.81%	29.41%	40.89%
Mean	$509,514	$655,090	$800,665	$946,241	$1,091,816
Median	$434,251	$558,322	$682,394	$806,466	$930,537
Std. Dev.	$203,429	$261,551	$319,673	$377,796	$435,918
Min	$208,148	$267,618	$327,089	$386,560	$446,031
Max	$1,110,527	$1,427,820	$1,745,114	$2,062,407	$2,379,701
0/100	0.00%	1.15%	18.65%	23.39%	30.56%
Mean	$415,355	$534,028	$652,701	$771,373	$890,046
Median	$339,656	$436,700	$533,745	$630,789	$727,833
Std. Dev.	$163,109	$209,711	$256,314	$302,916	$349,519
Min	$176,732	$227,227	$277,722	$328,217	$378,712
Max	$811,743	$1,043,670	$1,275,596	$1,507,523	$1,739,449

Table 3 (continued)

30 Years

	$500	$825	$1,150	$1,475	$1,800
100/0	37.61%	60.66%	77.64%	89.95%	98.27%
Mean	$842,693	$1,390,443	$1,938,193	$2,485,943	$3,033,693
Median	$826,222	$1,363,266	$1,900,310	$2,437,354	$2,974,399
Std. Dev.	$429,262	$708,283	$987,303	$1,266,324	$1,545,344
Min	$233,223	$384,818	$536,413	$688,008	$839,603
Max	$2,074,067	$3,422,210	$4,770,354	$6,118,497	$7,466,641
75/25	10.40%	45.06%	66.72%	81.28%	89.60%
Mean	$601,802	$992,974	$1,384,145	$1,775,316	$2,166,488
Median	$570,600	$941,490	$1,312,380	$1,683,269	$2,054,159
Std. Dev.	$280,423	$462,699	$644,974	$827,249	$1,009,524
Min	$195,109	$321,930	$448,751	$575,572	$702,392
Max	$1,412,798	$2,331,117	$3,249,436	$4,167,755	$5,086,073
50/50	0.00%	14.73%	40.55%	68.63%	78.34%
Mean	$434,450	$716,842	$999,234	$1,281,626	$1,564,019
Median	$410,998	$678,147	$945,295	$1,212,444	$1,479,593
Std. Dev.	$193,600	$319,440	$445,280	$571,120	$696,960
Min	$158,549	$261,606	$364,664	$467,721	$570,778
Max	$968,043	$1,597,271	$2,226,499	$2,855,727	$3,484,955
25/75	0.00%	10.75%	18.20%	26.52%	48.01%
Mean	$318,092	$524,852	$731,612	$938,372	$1,145,132
Median	$276,484	$456,199	$635,914	$815,628	$995,343
Std. Dev.	$141,196	$232,973	$324,750	$416,528	$508,305
Min	$121,394	$200,301	$279,207	$358,114	$437,020
Max	$684,630	$1,129,640	$1,574,650	$2,019,659	$2,464,669
0/100	0.00%	0.00%	7.63%	21.49%	27.38%
Mean	$236,893	$390,873	$544,853	$698,834	$852,814
Median	$181,736	$299,864	$417,992	$536,120	$654,248
Std. Dev.	$107,196	$176,873	$246,551	$316,228	$385,905
Min	$93,376	$154,070	$214,765	$275,459	$336,153
Max	$537,119	$886,246	$1,235,373	$1,584,500	$1,933,627

Table 3 (continued)

40 years

	$200	$425	$650	$875	$1,100
100/0	8.75%	57.77%	98.25%	100.00%	100.00%
Mean	$618,416	$1,314,134	$2,009,852	$2,705,570	$3,401,288
Median	$488,922	$1,038,960	$1,588,998	$2,139,036	$2,689,074
Std. Dev.	$259,184	$550,766	$842,347	$1,133,929	$1,425,511
Min	$268,370	$570,286	$872,202	$1,174,118	$1,476,034
Max	$1,328,907	$2,823,927	$4,318,948	$5,813,968	$7,308,989
75/25	0.00%	29.32%	67.40%	91.25%	99.56%
Mean	$414,301	$880,390	$1,346,478	$1,812,567	$2,278,656
Median	$369,371	$784,914	$1,200,457	$1,616,000	$2,031,542
Std. Dev.	$171,514	$364,467	$557,421	$750,374	$943,327
Min	$173,951	$369,645	$565,340	$761,034	$956,728
Max	$871,029	$1,850,937	$2,830,844	$3,810,752	$4,790,659
50/50	0.00%	13.79%	27.79%	63.24%	75.71%
Mean	$279,655	$594,267	$908,879	$1,223,491	$1,538,103
Median	$252,949	$537,516	$822,083	$1,106,651	$1,391,218
Std. Dev.	$120,425	$255,904	$391,382	$526,861	$662,340
Min	$113,079	$240,293	$367,506	$494,720	$621,934
Max	$571,294	$1,213,999	$1,856,705	$2,499,410	$3,142,115
25/75	0.00%	0.00%	16.19%	27.35%	40.04%
Mean	$191,642	$407,239	$622,835	$838,432	$1,054,029
Median	$168,369	$357,784	$547,199	$736,613	$926,028
Min	$71,630	$152,213	$232,796	$313,380	$393,963
Max	$395,287	$839,986	$1,284,684	$1,729,382	$2,174,081
0/100	0.00%	0.00%	0.00%	11.60%	26.48%
Mean	$134,210	$285,196	$436,181	$587,167	$738,153
Median	$106,072	$225,404	$344,735	$464,067	$583,398
Std. Dev.	$63,225	$134,354	$205,482	$276,611	$347,739
Min	$47,701	$101,364	$155,027	$208,690	$262,353
Max	$296,335	$629,711	$963,088	$1,296,464	$1,629,841

Figure 1

Figure 1 shows the percentage of portfolios reaching a specific terminal value with an $800 monthly deposit, 30-year deposit period, and a portfolio invested 75 percent in large capitalization stocks and 25 percent long-term bonds. The terminal portfolio value is shown in nominal terms.

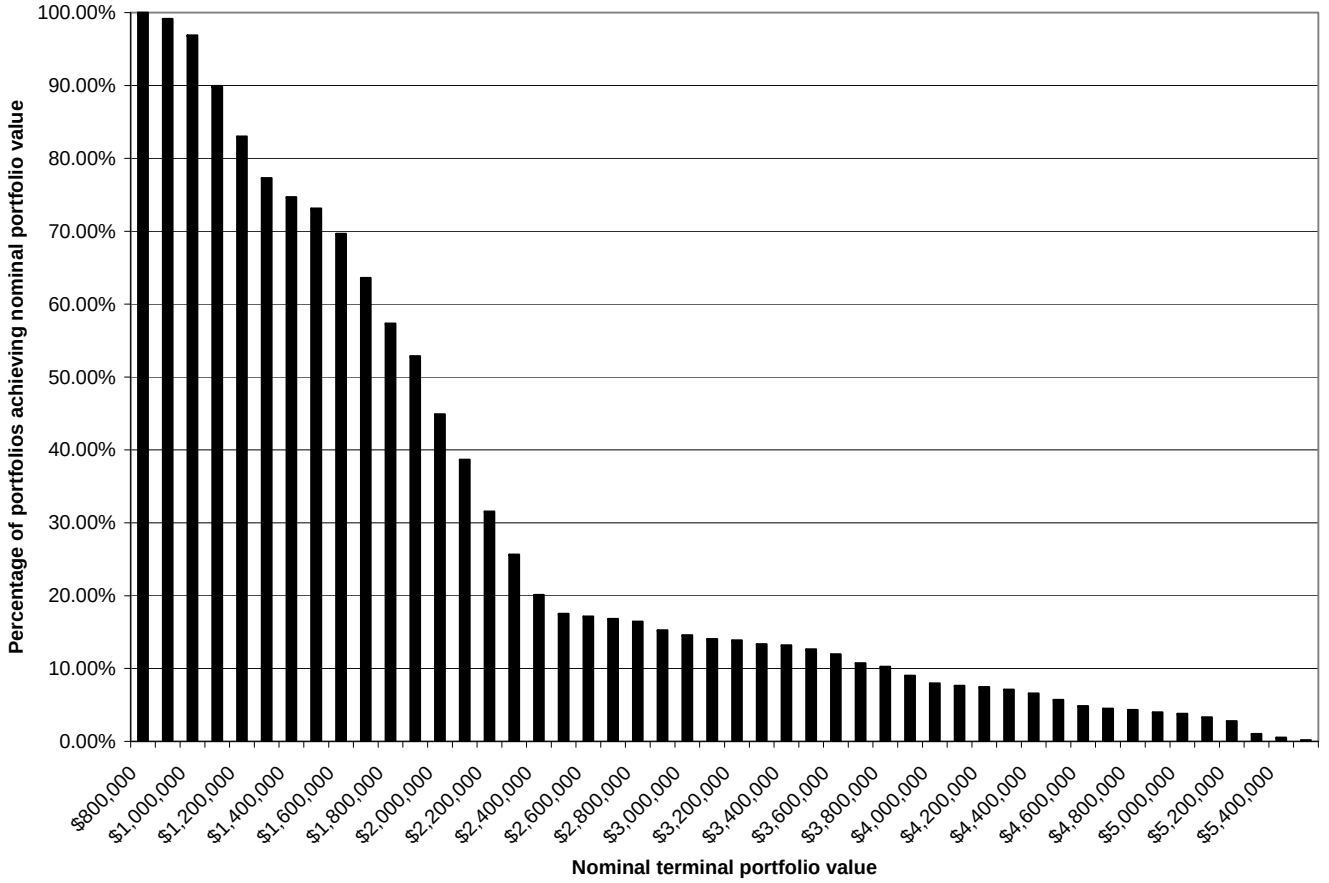

Figure 2

Figure 2 shows the terminal value of each portfolio with an $800 monthly deposit, 30-year deposit period, and a portfolio invested 75 percent in large capitalization stocks and 25 percent long-term bonds. The horizontal axis is the beginning month for deposits. The terminal portfolio value is shown in nominal terms.

Bibliography

Abeysekera, Sarath P., and E.S. Rosenbloom. 2000. “A Simulation Model for Deciding Between Lump-Sum and Dollar-Cost Averaging.” *Journal of Financial Planning* 13 (6): 86-96.

Bierwirth, Larry. 1994. “Investing for Retirement: Using the Past to Model the Future.” *Journal of Financial Planning* 7 (1): 14-25.

Constantinides, G. M. 1979. "A Note on the Suboptimality of Dollar-Cost Averaging as an Investment Policy." *Journal of Financial and Quantitative Analysis* 14: 443-450.

Cooley, Philip L., Carl M. Hubbard, and Daniel T. Walz. 1999. “Sustainable Withdrawal Rates From Your Retirement Portfolio.” *Financial Counseling and Planning* 10 (1), 39-47.

Cooley, Philip L., Carl M. Hubbard, and Daniel T. Walz. 2001 “Withdrawing Money from Your Retirement Portfolio Without Going Broke.” *Journal of Retirement Planning* 4(4), 35-42.

Ibbotson Associates. 2004. *Stocks, Bonds, Bills, and Inflation Yearbook.* Ibbotson Associates. Chicago, IL.

Israelson, Craig L. 1999. “Lumps Sums Take Their Lumps: Contrary to popular opinion, lump-sum investing doesn’t always result in superior returns over dollar-cost averaging.” *Financial Planning*. January: 51-56.

Leggio, Karyl B., and Donald Lien. 2003 “An Empirical Examination of the Effectiveness of Dollar-Cost Averaging Using Downside Risk Performance Measures.” *Journal of Economics and Finance* 27 (2): 211-223.

Rozeff, Michael S. 1994. “Lump-Sum Investing versus Dollar-Averaging.” *Journal of Portfolio Management*. 20 (2): 45-50.

Poterba, James M. 2004. “Valuing Assets in Retirement Savings Accounts.” *National Tax Journal*. 57 (2): 489-512.

Siegel, Jeremy J. 2002. *Stocks for the Long-Run.* McGraw-Hill. New York, NY.

Thorley, S. 1994. "The Fallacy of Dollar Cost Averaging." *Financial Practice and Education* 4: 138-143.

Williams, Richard E., and Peter W. Bacon. 1993. “Lump sum beats dollar-cost averaging.” *Journal of Financial Planning*. 6 (2): 64