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ABSTRACT

We explore four issues concerning annuitization options that retirees might use in the decumulation phase of an "individual accounts" retirement saving system. First, we investigate the operation of both real and nominal annuity individual annuity markets in the United Kingdom. The widespread availability of real annuities in the U.K. dispels the argument that private insurance markets could not, or would not, provide real annuities to retirees. Second, we consider the current structure of two inflation-linked insurance products available in the United States, only one of which proves to be a real annuity. Third, we evaluate the potential of assets such as stocks, bonds, and bills, to provide retiree protection from inflation. Because equity real returns have been high over the last seven decades, a retiree who received income linked to equity returns would have fared very well on average. Nevertheless we cast doubt on the "inflation insurance" aspect of equity, since this is mainly due to stocks' high average return, and not because stock returns move in tandem with inflation. Finally, we use a simulation model to assess potential retiree willingness to pay for real, nominal, and variable payout equity-linked annuities. For plausible degrees of risk aversion, inflation protection appears to have only modest value. People would be expected to value a variable payout equity-linked annuity more highly than a real annuity because the additional real returns associated with common stocks more than compensate for the volatility of prospective payouts. These finding are germane to concerns raised in connection with Social Security reform plans that include individual accounts.

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"It is better to have a permanent income than to be fascinating."
- Oscar Wilde, *The Model Millionaire: A Note of Admiration*

The current US Social Security system provides retirees with a real annuity during their retirement years. After a worker's Primary Insurance Amount has been determined at the point of retirement, the purchasing power of Social Security benefits remains fixed for the balance of the individual's life. This is accomplished by indexing retirement benefits to annual changes in the Consumer Price Index (CPI). Hence retirees are insulated from inflation risk, at least as long as their consumption bundle is not dissimilar to the bundle used to compute the CPI.

Several current reform plans propose to supplement, or partially replace, the existing defined-benefit Social Security system with mandatory individual defined contribution accounts (cf. Gramlich, 1996; Mitchell, Myers and Young, 1999; NASI, 1998). In most "individual account" plans, retirees would be required to purchase an annuity with all or part of their accumulated account balances. Yet the existing market for individual annuities in the United States is small, the expected present value of annuity payouts is typically below the purchase price of the annuity, and virtually all annuities currently available offer nominal rather than real payout streams. This has led some to argue that individual account plans would expose retirees to inflation risk that they do not currently face, in that they might purchase nominal annuities with their accumulated funds.

In this paper, we explore four issues concerning real annuities, nominal annuities, and the inflation risks faced by prospective retirees, all of which are relevant to the prospects for individual accounts under Social Security reform. We begin by describing the annuity market in the United Kingdom. Annuitants in the U.K. can select from a wide range of both real and nominal annuity products. The U.K. annuity market demonstrates the feasibility of offering real annuities in the private marketplace. Moreover, the current U.K. annuity market may indicate the direction in which the U.S. annuity market will evolve, since indexed bonds promising a fixed real return to investors have been available in Britain for nearly two decades. The availability of such bonds has made it possible for U.K. insurers to offer real annuity products without bearing inflation risk. Similar bonds have been available in the United States for only two years. Our evaluation of the U.K. annuity market includes an analysis of the relative prices of both real and nominal annuities, and we present estimates of how much a potential annuitant must pay to purchase the inflation insurance provided by a real annuity.

Next we turn to the annuity market in the United States and investigate the availability of real annuities in this country. In early 1997 the U.S. government introduced Treasury Inflation Protection Securities (TIPS) and since then, two products that might be described as "inflation indexed annuities" have come to market. One, offered by Irish Life Company of North America (ILONA), promises a constant purchasing power stream of benefits. Though this product offers buyers a real stream of annuity payouts, to date it has not been a commercial success. The second, offered by TIAA-CREF, is a variable payout annuity with payouts linked to returns on the CREF Index-Linked Bond Account. We describe the operation of the latter account in some detail, and explain why in practice the TIAA-CREF variable annuity proves not be an inflation-indexed annuity. Hence our analysis of these two products leads us to conclude that there are no commercially significant real annuities available in the U.S. annuity market at the present time.

We then go on to consider whether a retiree could use a portfolio of stocks or bonds to hedge long-term inflation risk, in lieu of a portfolio of indexed bonds. Specifically, we evaluate how much inflation risk annuitants would bear if, instead of purchasing nominal annuities, they purchased variable payout annuities with payouts linked to various asset portfolios. The potential inflation protection provided by alternative variable payout annuities is assessed using historical correlation patterns between inflation and nominal returns on stocks, bonds, and bills.

The final portion of the analysis explores the expected utility consequences of annuitizing retirement resources in alternative ways. A stylized model is used to calculate the expected lifetime utility of a retiree who could purchase a nominal annuity (thereby bearing inflation risk), a real annuity, and a variable-payout equity-linked annuity. We calibrate this model using available estimates of risk aversion, mortality risks, and the stochastic structure of real returns on corporate stocks. Our results suggest that for plausible values of risk aversion, retirees would not pay very much for the opportunity to purchase a real rather than a nominal annuity. This finding is sensitive, however, to assumptions regarding the stochastic process for inflation. Very high expected inflation rates, or very high levels of inflation variability, can lead to a different conclusion.

We also find that a variable payout annuity, with payouts linked to the returns on a portfolio of common stocks, is more attractive than a real annuity for consumers with modest risk aversion. This result rests on assumptions about the expected return on stocks relative to riskless assets and hence must be viewed with some caution, since there is substantial prospective uncertainty about expected stock returns. The finding nevertheless illustrates the potentially important role of variable payout annuities as devices for annuitizing assets from individual accounts.

The paper is divided into five sections. Section one presents findings on the real and nominal annuity markets in the United Kingdom; the next section describes two "inflation linked annuities" offered in the United States. Section three reports findings on the correlation between unexpected inflation and real returns on various financial assets and summarizes previous research on this relationship. This section also presents evidence on the *ex post* real payout streams that would have been paid to retirees had they purchased variable payout annuities at different dates over the last seventy years. The fourth section outlines our algorithm for evaluating the utility benefits of access to various types of annuity products. We report on the "wealth equivalent" of different annuitization options and link this work with the rapidly growing literature on lifetime portfolio allocation in the presence of financial market and inflation risk. In a brief concluding section we sketch directions for future work.

1. The Market for Real Annuities in the United Kingdom

We begin our analysis by describing the real annuity market in the United Kingdom, since these annuities provide important evidence on both the feasibility of providing real annuities through private insurers as well as the consumer costs of buying inflation insurance. We then calculate the expected present discounted value of payouts on real and nominal annuities currently available in the U.K.

1.1 The Current Structure of the U.K. Annuity Market

Annuities providing a constant real payout stream are widely available in the United Kingdom. This is partly due to the fact that government-issued indexed bonds have been available in the U.K. for nearly two decades. Insurance companies holding these bonds can hedge the price level risk that is associated with offering annuity payouts denominated in real rather than in nominal terms. Blake (1999) reports that insurers offering nominal annuities typically back them by holding nominal government bonds, while those offering real annuities hold indexed bonds.

The two segments of the individual annuity market in the United Kingdom are defined according to where funds used to purchase the annuity are accumulated. One market segment involves annuities purchased with tax-qualified retirement funds, while the other segment is focused on annuities purchased outside such plans. Qualified retirement plans in Britain include defined benefit occupational pension schemes and "personal pension plans" (PPPs). Most occupational plans are defined benefit plans, and the annuities that are paid out to their beneficiaries are not purchased in the individual annuity market. PPPs, available since 1988, are retirement saving plans that are broadly similar to Individual Retirement Accounts in the United States. (Prior to 1988, a similar type of plan was available to self-employed individuals.) Contributions to PPPs are tax-deductible, and income on the assets held in such plans is not taxed until the funds are withdrawn. Budd and Campbell (1998) report that in the early 1990s, roughly one quarter of U.K. workers participated in a personal pension plan. Personal pension plans are likely to account for most of the purchases of qualified annuities, since defined contribution plans constitute a minority of U.K. occupational pensions.

Those who reach retirement age with assets in a defined contribution occupational pension, or with assets in a personal pension plan, are legally required to annuitize at least part of their pension accumulations. For this reason, the U.K. market for annuities purchased with funds from qualified pension plans is known as the "compulsory annuity market." In recent years there has been some relaxation of the rules requiring annuitization. Currently, a retiree can withdraw up to one quarter of a personal pension plan accumulation as a lump sum distribution, and assets can be held in the PPP up to age 75 before they must be annuitized.

The U.K. annuity arena is also characterized by a second group of voluntarily purchased annuities, known as the "noncompulsory" market. In this second market segment, funds accumulated outside of qualified retirement plans are used to purchase annuity products.

As other analysts of the individual annuity market have emphasized, demographic characteristics and mortality prospects of annuity buyers in the compulsory and non-compulsory markets are likely to differ. The set of people that purchases annuities in a voluntary purchase market is likely to have better mortality prospects (i.e. a longer life expectancy) as compared to randomly selected individuals in the population. For this reason, workers with PPPs or covered by defined contribution occupational plans are probably not a random subset of the population; their longevity prospects are likely to be better than those of the population at large. Finkelstein and Poterba (1999) compare the U.K. compulsory and non-compulsory annuity markets and show that payouts as a fraction of premiums are somewhat lower in the non-compulsory market. But the extent of adverse selection among annuitants receiving employer pensions is anticipated to be smaller than among people buying individual annuities outside a retirement plan. Our analysis focuses on annuities offered in the “compulsory annuity” marketplace.

The compulsory annuitization requirement for Personal Pension Plans has created a substantial group of retirement-age individuals in the U.K. who must purchase an annuity. To service their needs, “annuity brokers” exist to help retirees obtain quotes on annuity products. We contacted several of these brokers for data on UK annuity prices and the terms of annuity contracts. Though we have not established precisely how much of the annuity market our sample firms cover, it does appear that we have identified most of the major annuity providers.

To focus the discussion we restrict our attention to nominal and inflation-linked single life annuity products. Here the term *nominal* is used to refer to values denominated in current pounds (or dollars), while *real* refers to inflation-corrected pounds or dollars. The analysis was conducted using nine insurance companies offering Retail Price Index (RPI)-linked single life annuity policies, and fourteen companies offering nominal single-life products.   (By comparison, there are nearly one hundred insurance companies offering individual annuity products in the United States, according to A.M. Best's surveys.)   We do not consider "graded" nominal annuity policies that offer a rising stream of nominal benefits over the life of the annuitant at a pre-specified nominal escalation rate. Graded annuities provide annuitants with a way of backloading the real value of payouts from their annuities, but they do not insure against inflation fluctuations as real annuities do. We focus our attention on policies that were available in late August, 1998, and we consider annuities with a £100,000 purchase price (premium).

Table 1 reports mean monthly payouts for both nominal and RPI-linked annuities for the firms in our sample. The first two columns show the sample average payout for each type of annuity. They indicate that the first-month payout on a real annuity is between 25 and 30 percent lower than the first-month payout on a nominal annuity. This reduction in initial benefits is sometimes cited as the reason some consumers shy away from indexed annuities. The data also indicate differences in the ratio of nominal to real annuity payouts across age groups (real annuities are priced more favorably with rising age), and between men and women (real annuities are priced more favorably for men). These presumably reflect mortality-related differences in the expected duration of payouts under different annuity contracts.

We also see substantial variation in the annuity benefits paid by the different insurers, as was previously found for the U.S. annuity market (Mitchell, Poterba, Warshawsky, and Brown, hereafter MPWB; 1999). The third and fourth columns of Table 1 report the coefficient of variation for monthly annuity payouts in both markets; here we see that the pricing of indexed annuities varies more than that of nominal annuities. For five of the six "products" defined by age and gender of buyer, the coefficient of variation is greater for the real than for the nominal annuity. This may be due to the fact that the effective duration of a real annuity is longer than that of a nominal annuity, so that the insurer's cost of providing a real annuity is more sensitive to future developments in mortality patterns. Explaining the observed price dispersion in annuity markets is an important task for future research.

1.2 Evaluating the "Money's Worth" of Nominal and Real Annuities

To evaluate the administrative and other costs associated with the individual annuities offered in the U.K. market, we compute the expected present discounted value (EPDV) of payouts for the average nominal and the average index-linked annuity. We compare this EPDV with the premium cost of the annuity to obtain a measure of the "money's worth" of the individual annuity. Similar measures are available for annuities offered in the United States; Warshawsky (1988) reports calculations for the period from 1920 to the early 1980s, MPWB (1999) examine data through 1995, and Poterba and Warshawsky (1998) offer results for mid-1998.

The formula used to calculate the EPDV of a *nominal* annuity with a monthly payout A_n, purchased by an individual of age b, is:

(1) $$V_b(A_n) = \sum_{j=1}^{12*(115-b)} \frac{A_n * P_j}{\prod_{k=1}^{j}(1+i_k)} .$$

We assume that no annuity buyer lives beyond age 115 and we truncate the annuity calculation after 12*(115-b) months. P_j denotes the probability that an individual of age b years at the time of the annuity purchase survives for at least j months after buying the annuity. The variable i_k denotes the one-month nominal interest rate k months after the annuity purchase.

For a *real* annuity, this expression must be modified to recognize that the amount of the payout is time-varying in nominal terms but fixed in real terms. The easiest way to handle this is to allow A_r to denote the real monthly payout, and to replace the nominal interest rates in the denominator of (1) with corresponding real interest rates. We use r_k to denote the one-month real interest rate k months after the annuity purchase. Such real interest rates can be constructed from the UK yield curve for index-linked Treasury securities. The expression that we evaluate to compute the EPDV of a real annuity is:

(2) $$V_b(A_r) = \sum_{j=1}^{12*(115-b)} \frac{A_r * P_j}{\prod_{k=1}^{j}(1+r_k)} .$$

We evaluate (1) and (2) using U.K. population projected survival probabilities compiled by H.M. Treasury. We use cohort mortality tables for those who reached age 60, 65, or 70 in 1998. We were not able to obtain mortality tables corresponding to the annuitant population. By using population mortality tables, we are in effect asking what the EPDV of the average annuity would be when viewed from the perspective of an average individual in the population. Of course, the average annuity buyer and the average person in the population may be different, to the extent that annuitants have longer life expectancies. Since a real annuity offers larger payouts near the end of life than a nominal annuity does, using a population rather than an annuitant mortality table overstates the effective cost of purchasing an inflation-indexed annuity relative to a nominal annuity.

Table 2 reports EPDV calculations for single life annuities for men and women of different ages in the compulsory U.K. annuity marketplace. Results for the average annuity payout are given as a simple average across the firms in our sample; we also provide the EPDV using average payouts for the three highest and three lowest annuity payout firms in our sample. The results show that the cost of buying an inflation-protected annuity in the United Kingdom is about five percent of the annuity premium. Also, the EPDV of a nominal annuity contract purchased in conjunction with a qualified retirement saving plan is five percent higher than that for a real annuity. While the EPDV for nominal annuities is approximately 90 percent of the premium cost, the analogous EPDV for real annuities averages roughly 85 percent. This difference in EPDVs might explain Diamond’s (1997) claim that most annuitants in the United Kingdom elect nominal rather than real annuities.

Some of the apparent “cost” of inflation protection may arise from adverse selection across the various types of annuities. That is, if annuitants who anticipate that they will live much longer than the average annuitant tend to purchase real annuities, then mortality rates for those who buy real annuities may be lower than those for nominal annuity buyers. Whether such mortality differences actually explain the payout differences between nominal and real annuities is not yet known.

These estimates of the U.K. expected present discounted value of nominal annuity payouts are somewhat higher than our estimates of EPDV for U.S. nominal annuity products around roughly the same date. For example, in 1998, the average EPDV on U.S. nominal annuity contracts available to 65-year-old men (using the population mortality table) was 84 percent for annuities purchased through qualified retirement saving plans (Poterba and Warshawsky, 1998). The lower U.S. payout may reflect cross-country differences in the degree of mortality selection, relative to the population as a whole, in the "qualified" (U.S.) and "compulsory" (U.K.) annuity markets.

Table 2 also suggests that there are systematic patterns in the money's worth values across age groups for both nominal and real annuities in the U.K. market. The EPDV declines as a function of the annuitant's age at the time the annuity is purchased. An explanation for this pattern may be that those who retire later tend to have lower mortality rates than those who retire earlier. Age at retirement and age at annuity purchase may be linked more closely in the market for compulsory retirement annuities than in the market for non-compulsory annuities. We suspect that many compulsory annuity buyers purchase their annuities when they retire, even though current U.K. rules do not require such purchases.

The results in Table 2 also suggest that for a retiree of given age/sex characteristics there is frequently a ten percent difference between the average annuity payout for the firms offering the highest payout annuities and the firms offering the lowest payouts. Such dispersion is consistent with earlier evidence suggesting substantial pricing differences in the U.S. market for nominal annuities (MPWB, 1999). This raises the question of how potential annuitants choose among the various annuity products. In the U.S. case, there is little evidence of strong correlation between factors such as the credit rating of the insurance company offering the annuity and the EPDV paid out (MPWB, 1999).

In sum, one lesson from the widespread availability of index-linked annuities the U.K. annuity market is that it is possible for private insurers to develop and offer real annuity products. This is surely easier in a nation with a well-developed market for index-linked bonds. A second lesson is that, based on nominal and real annuity pricing, the costs of obtaining inflation insurance are less than five percent of the purchase price of a nominal annuity.

2. Real Annuities in the United States: TIAA-CREF and ILONA

The U.S. individual annuity market differs from that in the U.K. in that virtually all annuity products are nominal annuities. Individuals can purchase a variety of products with a graded payout structure, so that the nominal value of their payouts (and, for low enough inflation rates, the real value of payouts) is expected to rise over time. There are only two annuity products that we are aware of that promise some degree of inflation protection. The first is the “Freedom CPI Indexed Income Annuity,” offered by the Irish Life Company of North America (ILONA), and the second is the “Inflation Linked Bond Account” annuity, offered by TIAA-CREF. In this section we describe how these products work, their current prices and payouts, and the degree to which they provide inflation protection for annuity buyers. We also note that since Treasury Inflation Protection Securities (TIPS) were introduced to the U.S. market only recently, additional insurers may offer real annuities as familiarity with these new assets grows. Insurance companies can hedge the inflation risk associated with these price level indexed annuity products by purchasing TIPS bonds.

2.1 The ILONA Real Annuity

Irish Life PLC, an international insurance firm headquartered in Dublin, Ireland, offers index-linked annuities in the United States through the Interstate Assurance Company, which is a division of Irish Life of North America (ILONA). Interstate is a well-regarded company: it had assets of $1.3 billion and it received a AA rating from Duff and Phelps, an A rating from A.M. Best and Company, and a AA- rating from Standard and Poors in 1996. The indexed annuity product from ILONA is the “Freedom CPI Indexed Income Annuity.” The annuity payout rises annually in step with the increase in the prior year’s CPI. Annuity benefits from the Freedom CPI Indexed Income Annuity are guaranteed to never decline in nominal terms, even if the CPI were to fall from year to year. The minimum purchase requirement for the ILONA annuity product is $10,000, and the maximum purchase is $1 million. The annuity is available to individuals between the ages of 65 and 85. There are various payout options, including simple life annuities, annuities that provide a fixed numbers of years of payouts for certain, and “refund annuities.” These annuity products are available both as individual and as joint and survivor annuities. Although ILONA offers this real annuity product in the US, the agent whom we contacted indicated that thus far no sales of these annuities have been recorded.

Data were obtained on the monthly payouts offered by ILONA's indexed and nominal single premium immediate annuities for men and women age 65, 70, and 75, assuming a premium of $1 million in each case. We also obtained data on joint-and-survivor annuities with 100 percent survivor benefits. Policies purchased in mid-1998 offered a monthly payout on a real annuity at the start of the annuity contract about 30 percent smaller than the payout on a nominal annuity issued to the same individual. Table 3 shows that for men at age 65, the ratio of real to nominal payouts is 69 percent. For women at 65, the ratio is 66 percent, potentially reflecting the longer life expectancy and therefore greater back-loading that occurs with a real rather than a nominal annuity for women rather than for men.

To determine the payouts relative to premium cost for these annuities, we again calculate the EPDV of annuity payouts for each of the ILONA policies quoted using a procedure similar to that described above. (Interest and mortality rates differ somewhat relative to the U.K. calculations). For discount factors in our EPDV calculations, we use the nominal yield curve for zero-coupon U.S. Treasury bonds. We start from the term structure of yields for zero-coupon Treasury "strips," and work out the pattern of monthly interest rates implied by these yields under the simple expectations theory of the term structure. Data on the zero-coupon yield curve are published each Thursday in the Wall Street Journal, and we use information from the beginning of June 1998. Because we do not know the precise date at which ILONA offered the annuities we are pricing, and in light of the absence of transactions in this annuity market, we select the June 1998 term structure as an approximate guide to discount rates in mid-1998. When evaluating the EPDV of the ILONA real annuity, we use the implied short-term real interest rates that can be derived from the term structure of real interest rates of Treasury Inflation Protection Securities; once again we use these rates from early June 1998.

With regard to survival patterns, we have access to two distinct mortality tables for the U.S. The first, developed by the Social Security Administration's Office of the Actuary and reported in Bell, Wade, and Goss (1992), applies to the entire population. We update this mortality table to reflect the prospective mortality rates of a 65-year old (or 70- or 75-year old) purchasing an annuity in 1998. For example, in estimating the money's worth of an annuity for a 65 year old in 1998, we use the projected mortality experience of the 1933 birth cohort. A second set of projected mortality rates corresponds to that relevant to current annuitants. MPWB (1999) develop an algorithm that combines information from the Annuity 2000 mortality table, described in Johansen (1996), the older 1983 Individual Annuitant Mortality table, and the projected rate of mortality improvement implicit in the difference between the Social Security Administration's cohort and period mortality tables for the population. This algorithm generates projected mortality rates for the set of annuitants purchasing annuity contracts in a given year. It is worth noting that the population and annuitant mortality rates differ. For instance, the 1995 annual mortality rate for annuitants age 65-75 was roughly half that for the general population (MPWB 1999). This mortality differential generates a substantially larger EPDV of annuity payouts using the annuitant versus the population mortality table.

Table 4 reports EPDV calculations for Irish Life real and nominal annuities. (All EPDV calculations use pretax annuity payouts and before-tax interest rates. MPWB (1999) show that pre-tax and post-tax EPDV calculations for U.S. nominal annuities yield similar results.). For nominal annuities and using the population mortality table, the expected present discounted value of payouts for men is approximately 85 cents per premium dollar and 89 cents for women. These values are slightly higher than the average EPDV values based on nominal annuities described in A.M. Best's annuity survey of June 1998 (Poterba and Warshawsky, 1998). Using the annuitant mortality table for nominal annuities, the EPDV proves to be worth a much larger share of premium value, approximately 98 cents per dollar for men and 97 cents for women.

We next turn to EPDV results for the ILONA real annuity computed using the real interest rates implicit in the TIPS yield curve, and we see that the value per dollar of premium is much lower than for the nominal annuity. For instance, a 65-year-old man purchasing a real annuity would expect an EPDV of 70 percent, versus 86 percent for the nominal annuity. At other ages a similar pattern applies: the money's worth for the real annuity products is typically 15-20 percent lower than that for nominal annuities. The fact that inflation protection adds more than 15 percent to the annuity's cost may explain the limited demand for this product in the U.S.

2.2 Annuities Linked to the CREF Index-Linked Bond Account (ILBA)

In May of 1997 the College Equities Retirement Fund (CREF) launched a new investment account, one that was intended to appeal to those who are saving for retirement as well as to retirees receiving annuity payouts. This product, called the CREF Inflation-Linked Bond Account (ILBA), followed from the federal government's decision to issue TIPS on January 29, 1997. TIAA-CREF indicated that its new inflation-linked account was expected to be useful for providing participants with "another investment option that can enhance portfolio diversification and mitigate the long-term impact of inflation on their retirement accumulations and benefits" (TIAA-CREF 1997a). The fund's goal was described as seeking "a long-term rate of return that outpaces inflation, through a portfolio of inflation-indexed bonds and other securities" (TIAA-CREF 1997b).

The CREF Inflation-Linked Bond Account has grown slowly since its inception. At the end of September 1998, the account had attracted investments of only $131 million, making it the smallest of all the retirement funds offered by TIAA-CREF. To place this amount in context, on the same date the CREF Stock fund held $96.9 billion (75 times as much as the ILBA), the TIAA Traditional Annuity fund held $94.3 billion, and all other TIAA-CREF retirement funds combined held about $25 billion. Most of the funds held in the ILBA are in the accounts of TIAA-CREF active participants, rather than retirees, and as such they are still accumulating rather than drawing down assets.

To describe the inflation protection that an annuity linked to the CREF ILBA provides, we need to provide some background both on the structure of this account, on the basic structure of *variable annuity* products, and on the specific operation of the CREF variable annuity.

The CREF Index-Linked Bond Account The ILBA "invests mainly in inflation-indexed bonds issued or guaranteed by the US government, or its agencies and instrumentalities, and in other inflation-indexed securities" with foreign securities capped at 25% of the assets (TIAA-CREF 1998a). At present the ILBA holds 98 percent of its assets in U.S. government inflation-linked securities and 2 percent short-term investments maturing in less than one year. In principle, the fund's asset allocation could become broader in the future, with corporate inflation-indexed securities and those issued by foreign governments potentially being included as well as money market instruments. Expenses total 31 basis points annually which is probably explained by the small size of the fund and the fact that it is a new account. This expense ratio is lower than many mutual and pension fund expense levels, but it is as high as other, more actively managed CREF accounts such as the Stock Account (31 basis points) and the Bond Market Account (29 basis points) **(**see www.tiaa-cref.org/expenses.html).

The ILBA has no sales, surrender, or premium charges. Participants may elect this account as one of several investment vehicles into which new retirement contributions may be made, and/or into which existing assets from other TIAA-CREF accounts may be transferred. As with other CREF accounts, the participant is limited to one transfer per business day in or out of the account during the accumulation phase. The ILBA may used as a vehicle for accumulating retirement assets, or it can be used to back the payment stream for a variable payout annuity. Most of our interest focuses on the second function.

The ILBA account is marked to market daily, meaning that asset values fluctuate and the account could lose money. For example, if real interest rates rose due to a decline in expected inflation, bond prices could fall. As the Fund Prospectus points out, in such an event the inflation-linked bond fund's "total return would then not actually track inflation every year" (TIAA-CREF 1998b). This is a key feature of the ILBA, and it means that the account <u>does not</u> effectively offer a real payout stream to annuitants who purchase variable payout annuities tied to the ILBA.

Real interest rate changes are not the only source of variation in ILBA returns. If the principal value of inflation-linked bonds changes in response to inflation shocks, perhaps because investors infer something about the future of real interest rates from inflation news, this would also affect the returns on the ILBA. Similarly, changes in the definition of the CPI might affect the ILBA return.

The ILBA return for 1998 were 3.48 percent. This made it the lowest earning fund of all the tax-qualified accounts offered by TIAA-CREF in 1998, as Table 5 illustrates. Daily returns on the ILBA can sometimes be negative.

<u>Variable Annuities: General Structure</u> An annuity with payouts that rise and fall with the value of the CREF ILBA fund is a special case of a variable payout annuity. The key distinction between a fixed

annuity (including a graded fixed annuity with a pre-specified set of changing nominal payouts over time) and a variable annuity is that the payouts on a variable annuity cannot be specified for certain at the beginning of the payout period. Rather, a variable annuity is defined by an initial payout amount, which we shall denote A(0), and an "updating rule" that relates the annuity payout in future periods to the previous payout and the intervening returns on the portfolio that backs the variable annuity.

To determine the initial nominal payout on a single-life variable annuity, per dollar of annuity purchase, the insurance company solves an equation like

$$1 = \sum_{j=1}^{T} \frac{A(0) * P_j}{(1+R)^j} \tag{3}$$

where R is the variable annuity's "Assumed Interest Rate" or the "Annuity Valuation Rate" as in Bodie and Pesando (1983). T is the maximum potential lifespan of the annuitant. This expression would require modification if there were a guarantee of some number of certain payments or some other additional structure imposed on the annuity payouts. This expression ignores expenses and other administrative costs associated with the sales of annuities or the operation of insurance companies.

The annuity updating rule depends on the return on the assets that back the annuity, which we denote by z_t, according to:

$$A(t+1) = A(t)*(1+z_t)/(1+R). \tag{4}$$

The frequency at which payouts are updated varies across annuity products, and there is no requirement that the payout be updated every time it is paid. (Thus, one might have an annuity with monthly payouts but quarterly updating.)

In designing a variable annuity, the assumed interest rate (R) is a key parameter. Assuming a high value of R will enable the insurance company to offer a large initial premium, but, for any underlying portfolio, the stream of future payouts will be more likely to decline as the assumed value of R rises. Equation (4) clearly indicates that an individual who purchases a variable annuity will receive payouts that fluctuate with the nominal value of the underlying portfolio.

Specific Provisions of the CREF ILBA-Backed Annuity. When a TIAA-CREF participant terminates employment, he or she can begin receiving retirement benefits. The participant then decides how to manage the payouts from accumulated retirement accounts. This includes deciding whether to annuitize the retirement assets, how much to annuitize, and whether to use an inflation-linked annuity, subject to the proviso that individual employers may restrict retirees' options. Benefits are payable monthly, though recipients may elect quarterly, semi-annual, and annual payouts as an alternative (TIAA-CREF 1998d). In addition, the participant can chose the form and duration of the payout pattern, subject to minimum distribution rules set by the IRS. If the participant chooses to annuitize part of his or her accumulation, there are a variety of potential annuity structures, including life annuities, 10- and 20-year certain payout annuities, and joint and survivor as well as single life products.

Under TIAA-CREF rules, a CREF participant electing an annuity must be no older than age 90 when he or she initially applies for the annuity. The applicant must select at least one of the annuity accounts initially for the drawdown phase, and thereafter, he or she may switch from one annuity account into another as often as once per quarter (TIAA-CREF 1998a). There are restrictions on shifting funds from TIAA to CREF: this must take place over a longer horizon. While the choice of annuity fund can be altered, the form of benefit payout cannot be changed once the annuity has been issued.

In order to understand how CREF annuity payments are determined, it is necessary to define the "basic" annuity unit value. This is an amount set each March 31 by dividing an account's total funds in payment status by the actuarial present value of the future annuity benefits to be paid out, assuming a 4 percent nominal interest rate and mortality patterns characteristics of existing CREF annuitants. A unisex version of the mortality table for individual annuitants is used when the applicant first files for an annuity "set back for each complete year elapsed since 1986" (TIAA-CREF (1998d)). The same mortality table is applied to all TIAA-CREF annuity accounts, based on participant mortality experience. Mortality experience is adjusted every quarter.

A newly retired participant seeking to annuitize his retirement sum must have his own accumulation amount translated into an *initial annuity amount* (A(0)), determined by dividing his accumulation by the product of an annuity factor and the basic annuity unit value just described. The annuity factor reflects assumed survival probabilities based on the annuitant's age and an assumed effective Annual Interest Rate (AIR) of 4 percent nominal (TIAA-CREF 1998c).

The participant's initial annuity amount is then adjusted over the life of the annuity contract on either a monthly or an annual basis, depending on the participant's election. The adjustment will reflect the actual fund earnings on a 'total return' basis, relative to the assumed 4 percent AIR. Actual investment performance is used to update the annuity values as of May 1 for those electing to have their income change annually, or monthly for those electing monthly income changes. Because the investment returns on the underlying accounts affect annuity payouts, these TIAA-CREF annuities are variable payout annuities.

The Extent of Inflation Protection. It is evident that a variable payout annuity linked to the CREF-ILBA does not provide a guaranteed inflation product, since it is marked to market daily. Thus if the price drops, or if the unit value failed to rise with inflation, the participant's unit value would not be constant in real terms. More importantly, the CREF annuity may fail to keep up with inflation because of the way in which it is designed. When the first-year annuity payout is set, it assumes the 4 percent AIR mentioned above, which is the same rate used for other CREF annuities. In subsequent years, if the unit value of the account were to rise less than 4 percent, payouts would be reduced to reflect this lower valuation. For example, the total return (after expenses) on the ILBA account for 1998 was 3.48 percent. Since the AIR for the CREF annuity is 4 percent, an annuity in its second or later year payout phase would experience a decline in payout of 0.52 percent.

This adjustment to future payout levels does not necessarily correspond to the CPI inflation rate in 1998. In our example, if the annual inflation rate for 1998 were anything greater than one percent, the real value of annuity payouts for those holding ILBA-backed variable annuities would decline in 1999 and subsequent years. The only way a second or subsequent-year payout could be guaranteed not to decline in real terms would be if the real return on the account, i.e. on Treasury Inflation Protection Securities, always exceeded 4 percent. It does not at present.

The precise extent to which payouts on ILBA-backed variable annuities will vary in real terms in the future is an open question. If the prices of inflation-linked bonds are bid up during high-inflation periods, and real interest rates decline at such times, this will partly protect the ILBA account value. One relevant comparison for potential annuitants, however, may be between holding a CREF ILBA-backed variable annuity, and purchasing TIPS bonds directly. Two considerations are relevant to such a comparison. First, the TIPS bonds offer a more direct form of inflation protection, although they do not provide any risk-sharing with respect to mortality risk. Second, there are tax differences between the two investment strategies. TIPS would be taxable if they were not held in a qualified pension account, while the income from bonds held in the CREF ILBA-backed account is not taxed until the proceeds are withdrawn.

The CREF variable payout annuity linked to the ILBA would be more likely to deliver a future real payout stream if the AIR on this annuity were set equal to the real interest rate on long-term TIPS at the time when the annuity is purchased. In this case, the return on the bond portfolio would typically equal the AIR plus the annual inflation rate, leaving aside some of the risks of holding indexed bonds such as changes in the way the CPI is constructed. This would provide a mechanism for delivering something closer to a real annuity payout stream. One difficulty with this approach is that it would make it more difficult for annuitants to take advantage of some of the investment flexibilities currently provided by CREF. At present, all CREF annuities assume the same AIR, regardless of the assets that back them. This facilitates conversions from one annuity type to another.

To date, there has been very limited demand for CREF's ILBA-backed variable payout annuities. This lack of demand raises the perennial question of why retirees are not more concerned about inflation protection. One reason often given is "inflation illusion"; that is, people simply do not understand how inflation erodes purchasing power. Another reason may be that inflation-proof assets are new so that investors have not yet learned how to think about such assets. Hammond (1998) notes that inflation-linked bonds in other countries took some time to become popular after they were introduced: "After a flurry of initial interest, inflation bonds in those countries went through a period of quiescence -- low liquidity and little interest. Then, with some sort of trigger – renewed inflation or a strong commitment on the part of central government – the market picked up and people began to figure out what the bonds were good for. In the U.K. this process took about ten years." The United States today may be in the early stages of this process.

2.3 Conclusions About Real Annuities in the United States

Our analysis of the ILONA and TIAA-CREF experience suggests that there is currently no market for genuine real annuities in the United States. While ILONA offers a product that guarantees a real stream of payouts, no one has yet purchased this annuity. This may reflect the fact that the instrument's pricing requires relatively high rates of inflation to generate benefits with expected present discounted values similar to those of nominal annuities offered by ILONA and other insurers. The inflation-linked bond account offered by CREF has attracted investment funds since it became available in 1997, but the CREF variable annuities with payouts linked to returns on inflation indexed bonds does not guarantee its buyers a constant real payout stream. Although in practice it may come close to delivering a constant real payout, its performance will depend on the as yet uncertain price movements in the prices of Treasury Inflation Protecton Securities.

3. Asset Returns and Inflation: Another Route to Inflation Insurance

The last two sections focused on insurance contracts that explicitly provide a constant real income stream for retirees. In this section we consider the possibility of using variable payout annuities linked to assets other than indexed bonds as an alternative means of avoiding inflation risk. Such variable payout annuities can reduce the impact of inflation in two ways. First, they may offer higher average returns than the assets that are used in pricing real and nominal annuities. These returns may, of course, come at the price of greater payout variability. Second, it is possible that the returns on the assets that underlie the variable payout annuities may move in tandem with inflation. In this case a variable payout annuity could provide a form of inflation insurance.

To examine these arguments, we begin by summarizing the well-known historical real return performance of U.S. stocks, bonds, and Treasury bill investments. We do this by considering an individual who considers investing one dollar in cash, or in a portfolio of Treasury bills, long-term bonds, or corporate stock. We calculate the real value of an initial $1 investment after 5, 10, 20, and 30 years. We first perform this calculation in 1926, so that the 30-year return interval concludes in 1955. We then repeat the calculation in 1927, 1928, and all subsequent years in which we have enough data to calculate long-term returns. The last year for which we have return information is 1997, so we finish our five year calculations in 1993, our ten year calculations in 1988, and so on.

To summarize the results on the real value of each investment, we calculate both the average real value of each investment, averaged across all of the years with sufficient data. We also compute the standard deviation of this real return. The results of these calculations appear in Table 6. The underlying calculations have been done using actual returns on stocks, bills and, bonds over the 1926-1997 period. For the return after five (30) years, there are 66 (41) overlapping return intervals. The results in Table 6 show that holding cash worth $1 initially would have an average real value of only 49 cents after 20 years on average. In contrast, a $1 initial investment in bills or bonds would have increased in real value. For bills, the cumulative real return over 20 years was 1.3 percent, while for bonds, it was 16.1 percent. The last column of Table 6 shows comparable calculations for corporate stock. Here the real value of the investment after 20 years would have increased by a factor of 4.5. This implies that an investor who purchased an income stream tied to the total return on the U.S. stock market, such as an equity-linked variable annuity, would have the potential to receive a higher real income stream late in retirement than at the beginning of retirement. This stands in stark contrast to the declining real value of the payouts on a fixed nominal stream, such as a nominal annuity contract.

The substantial real return on U.S. equities suggests that one method of obtaining partial long-term protection against inflationary erosion of annuity payouts might be to purchase a portfolio of equities, and then to link annuity payouts to equity returns. In practice, however, variable annuity policies that offer payouts linked to equity returns do not guarantee real payouts that rise as steeply as Table 6 suggests. This is because the payouts on a variable annuity depend on the performance of the underlying assets relative to the Assumed Interest Rate (AIR) on the annuity product (R in equation (3)) as Bodie and Pesando (1983) explain in detail. Therefore the variable annuity payout for an equity-linked variable annuity can only rise over time if the equity portfolio returns more than the assumed value of R used in designing the annuity. Bodie and Pesando (1983) assume that R equals the historical average return on the assets that back the annuity, but in practice we have found that nominal R values of 3 or 4 percent per year are common in the current variable payout annuity market. This is true even for equity-backed annuities. One should note that if a variable payout annuity assumed R = 0, then the real payouts in Table 6 would in fact describe the experience of an annuitant, since the nominal payout recursion would become $A(t+1) = A(t)*(1+z_t)$.

The high average real return on equities implies that an investor holding U.S. stocks over the last seven decades would have experienced a rising real wealth profile. But to study whether this is because equities provide a good inflation hedge, we must explore the way U.S. equity returns covary with shocks to the inflation rate. If stocks generate positive returns when the inflation rate rises unexpectedly, then equities operate as an inflation hedge. The fact that U.S. equities have generated substantial positive returns over the period since 1926 does not provide any information on the correlation between inflation and stock returns.

We investigate the historical covariances between real U.S. stock returns, bond returns, and bill returns, and unexpected inflation shocks, over the 1926-1997, and 1947-1997, periods. If the real return on a particular asset category is not affected by unexpected inflation, then that asset can serve as a valuable inflation hedge. If the real return on the asset declines when inflation rises unexpectedly, however, then that asset does not provide an inflation hedge.

The first step in our analysis involves estimating of a time series for "unexpected inflation." We do this by estimating fourth-order autoregessive models relating annual inflation (π_t) to its own lagged values, or to its own lagged values as well as those of nominal Treasury bill rates (i_t). The basic regression specification is either

(5a) $$\pi_t = \rho_0 + \rho_1*\pi_{t-1} + \rho_2*\pi_{t-2} + \rho_3*\pi_{t-3} + \rho_4*\pi_{t-4} + \phi_1*i_{t-1} + \phi_2*i_{t-2} + \phi_3*i_{t-3} + \phi_4*i_{t-4} + \varepsilon_{it}$$

or

(5b) $$\pi_t = \rho_0 + \rho_1*\pi_{t-1} + \rho_2*\pi_{t-2} + \rho_3*\pi_{t-3} + \rho_4*\pi_{t-4} + \varepsilon_{it} \quad .$$

We estimate each model for the 1926-1997 period and the 1947-1997 period.

Table 7 presents the findings from estimating (5a) and (5b). Two broad conclusions emerge from the table. First, there is a great deal of persistence in inflation. The sum of the four coefficients on lagged inflation for the 1926-1997 period is .773, while for the 1947-1997 period it is .732. There is somewhat greater inflation persistence in the early years of the sample than in the post-war period. We experimented with extending the length of the lag polynomial in (5a) and (5b). While the fourth-order inflation lag in both equations shows a coefficient that is statistically significantly different from zero, higher lagged values were never statistically significant.

Second, the incremental explanatory power of lagged Treasury bill yields is relatively small after we have controlled for lagged inflation. Bill rates have somewhat greater explanatory power in the postwar period than for the full sample period. Because most of the estimated coefficients on bill rates for both sample periods are statistically insignificant, however, we expect that the unexpected inflation series calculated from specifications (5a) and (5b) should perform similarly in our tests for the correlation between unexpected inflation and asset returns.

We estimate of unexpected inflation ($\pi_{u,t}$) by computing the residuals from either (5a) or (5b). (Strictly speaking, our estimates for each year use some future information, because the coefficients are estimated over the full sample period.) We then use the resulting time series of residuals as the explanatory variables in regression models in which real stock, bond, or bill returns are the dependent variables, as follows:

(6) $$r_{it} = \alpha + \lambda_i*\pi_{u,t} + \xi_{it}.$$

Table 8 shows the results of estimating these regression models. It reports the coefficient values for λ_i. The results provide no evidence to suggest that stocks or bonds have been inflation hedges during the last seventy years. For both of these asset categories, a one percentage point increase in the rate of unexpected inflation is associated with a decline of more than one percent in bond and in stock values. The estimated negative effects are larger, though somewhat less precisely estimated, for the 1947-1997 period than for the longer sample. As noted above, the two unexpected inflation series, one corresponding to a lagged-inflation-only predicting equation, the other corresponding to the augmented specification with lagged Treasury bill returns as well, produce very similar results when they are included on the right hand side of equation (6).

We also find evidence that unexpected inflation reduces real Treasury bill returns. The effect on these returns is more muted than that on bond and stock returns, and for both sample periods we find that a one percentage point increase in unexpected inflation reduces the real return on Treasury bills by less than one percentage point. Nevertheless, for both sample periods we reject the null hypothesis that real Treasury bill returns are unaffected by inflation surprises.

The finding that unexpected inflation covaries negatively with real asset returns is broadly consistent with previous research. For example, Barr and Campbell (1995) show that the real interest rate on U.K. indexed bonds appears to covary negatively with inflation. Evans (1998) surveys a number of other empirical papers, using data from several nations and various methodologies, all of which reach similar conclusions. Our findings for equities are consistent with Bodie (1976), who suggested that using equities to hedge inflation risk requires a short position in equities.

One question that some might raise about the results in Table 8 concerns our focus on one-year return horizons. It is possible that the high frequency covariation between unexpected inflation and asset returns differs from the lower-frequency correlation. Boudoukh and Richardson (1993) present some evidence for both the U.S. and the U.K. suggesting that the nominal return on corporate equities may move together with inflation at long horizons. To explore this issue, we repeated our analysis using real returns and inflation over five year intervals. We confined our analysis to the 1926-1997 sample period, and used an AR(2) model to construct an estimate of unexpected inflation. We focused on non-overlapping five year intervals, which provided twelve observations for estimating equation (6). The results are show in the last row of Table 8. They continue to show a negative correlation between real stock and bond returns and unexpected inflation. The only change relative to the previous findings is that unexpected inflation no longer has a negative effect on real Treasury bill returns.

Our empirical results therefore suggest that the inflation-hedging properties of equities and long-term bonds are limited. Nevertheless, over long horizons, equities have typically generated very substantial positive returns (Siegel, 1998). Favorable long-term equity returns can be explained by high real returns on equities, even if there is a negative high-frequency correlation between equity returns and unexpected inflation. A substantial body of research has tried to explain the high average return on equities in the United States during the last century as a function of the correlation between equity returns and various risk factors. This proves difficult, and the resulting empirical puzzle has become known as the "equity premium puzzle."

The weak high-frequency correlation between equity returns and inflation is a challenge to many traditional models of asset pricing, since equities represent claims on real assets that such hold their value in real terms. Prior studies offer explanations for the weak empirical correlation between inflation and equity returns have been suggested, including the interaction of inflation and corporate tax rules (Feldstein, 1980), and inflation illusion among equity investors (Modigliani and Cohn, 1979). We are not aware of any empirical evidence that provides clear guidance for choosing among these explanations.

4. Evaluating the Utility Gains From Access to Real Annuities

Previous sections considered the operation of markets for inflation-indexed annuities and the role of assets such as corporate stock in providing an inflation hedge for retirement investors. We have not yet considered how valuable inflation protection might be for a retiree seeking to annuitize his retirement resources. Hence, we next estimate a potential annuitant's "willingness to pay" (WTP) for real annuities, nominal annuities, and variable payout annuities with returns linked to common stock returns. We focus on equity-linked variable annuities because equities have historically earned higher expected returns than other assets. Our results in the last section showed that while bills offer some inflation protection, their expected return has historically been very small. Bonds offer limited inflation protection and substantially lower average returns, at least historically, than stocks.

The annuity valuation framework employed is closely related to that developed in Kotlikoff and Spivak (1981) and MPWB (1999). These two studies compared the utility gain that would accrue to an individual who initially had no access to annuity markets if that individual were to become able to purchase a nominal annuity. Brown (1999) provides some empirical evidence suggesting that this framework has some predictive value for explaining whether individuals plan to annuitize the balance they accumulate in a defined contribution plan. In this section, we compare the utility gains associated with access to different types of annuities, thereby providing insight into the potential value to retirees of real versus nominal annuities.

4.1 Analytical Framework For Evaluating "Annuity Wealth Equivalents"

Our basic algorithm estimates the utility gains accruing to someone with no annuity who is offered a fixed, nominal annuity on actuarially fair terms, a real annuity on fair terms, and a variable annuity backed by a portfolio of common stocks. To illustrate our procedure, we explain how we calculate an individual's willingness to pay for a fixed nominal annuity. We assume that this individual purchases such an annuity at age 65 and normalize age so that age 65 is "year zero." This individual receives an annuity payment in each year that he remains alive, and his optimal consumption path will be related to this payout. The annuity payout at age a (A_a) depends on wealth at the beginning of retirement (W_0) and the annual annuity payout per dollar of premium payment (θ): $A_a = \theta * W_0$. In the case of a fixed nominal annuity, the nominal value of A_a is independent of age. For simplicity, we do not consider the taxes paid on annuity payouts, or the taxes on the returns to non-annuity assets. MPWB (1999) note that findings with respect to the relative utility of different annuity schemes are not sensitive to the inclusion of tax rules.

To find the actuarially fair ratio of nominal annuity payouts to premium cost, θ, for a 65-year old male in 1995, we use the Social Security Administration's cohort life table for men born in 1930. We define actuarial fairness as equality of the premium cost and the expected present discounted value of annuity payouts. This definition ignores the potentially important role of administrative expenses that are incurred by the insurance company offering the annuity. As such, it is likely to overstate the actual payouts that would be available in an idealized annuity market. We find θ from the following equation:

(7) $$1 = \sum_{j=1}^{50} \frac{\theta * P_j}{((1+r)(1+\pi))^j}.$$

In this expression, P_j denotes the probability of a 65-year-old retiree remaining alive j years after retirement, r denotes the annual real interest rate and π is the annual inflation rate. We use years rather than months in this part of our annuity valuation and continue to assume that no one survives beyond age 115, so $P_{50} = 0$.

After finding the actuarially-fair payout value, we compute the expected discounted value of lifetime utility that would be associated with the consumption stream generated by this nominal annuity. To do this we assume that individuals have additively-separable utility functions of the following form:

(8) $$U = \sum_{j=1}^{50} P_j * \frac{\left(\left(\frac{C_j}{(1+\pi)^j}\right)^{1-\beta} - 1\right)}{(1-\beta)*(1+r)^j}.$$

For this functional form, the parameter β is the individual's coefficient of relative risk aversion. This parameter also determines the degree of intertemporal substitution in consumption. The nominal consumption flow (C_j) is deflated by the price index, $(1+\pi)^j$.

We consider a first case in which our 65-year-old uses all of his resources to purchase an annuity contract, and a second case in which he purchases an annuity with half of his resources. In the second case, we assume that the other half of the individual's resources are invested in a real annuity. This case can be thought of as describing the retiree's choice problem when he has both an individual account balance that can be annuitized, and also a substantial real retirement annuity like that offered by the current Social Security system.

We assume that the retiree has wealth at age 65 of W_0. In the case in which the retiree is considering annuitizing all of this wealth, we first find the optimal consumption path for someone who receives a nominal annuity of θW_0 per period and who has no non-annuitized wealth at age 65. For such an individual, the budget constraint at each age a is given by:

(9) $$W_{a+1} = (W_a + \theta W_0 - C_a)*[(1 + r)(1 + \pi)].$$

The individual also faces an initial condition on wealth after purchasing the annuity: $W_0 = 0$. It is possible that the retiree will save some of the payouts from the annuity contract, and thereby accumulate wealth, in the early years of retirement.

Equation (9) assumes that the investment opportunity set for the retiree consists of a nominal bond that offers a fixed real return r. This specification assumes that nominal interest rates rise point-for-point with inflation; our results in the last section call this assumption in to question. The utility gains from purchasing an annuity are likely to depend on the set of portfolio options that investors have *outside* their annuity contract. Campbell and Vicera (1998) present some evidence on the optimal structure of portfolios at different points in the lifecycle for investors who have access to nominal and real bonds. One natural avenue for further work is to link these two lines of research.

We estimate the value of annuitization by solving for the representative consumer's optimal consumption path $\{C_a\}$ using stochastic dynamic programming, where the stochastic component of the problem arises from uncertainty regarding date of death. We then compute the value of the expected utility function (U*) for this consumption stream, and label this as the utility value associated with a nominal annuity contract. To calculate the willingness to pay for access to a nominal annuity market, we ask what amount of wealth at age 65 (W_{EQUIV}) the individual would need to reach utility level U* if he followed an optimal consumption path in the absence of a nominal annuity market.

The consumer's problem in this case is to maximize the utility function (8) now subject to the budget constraint and initial condition

(10a) $$W_{a+1} = (W_a - C_a)*[(1 + r)(1 + \pi)]$$

and

(10b) $W_{65} = W_{EQUIV}$.

The optimal consumption path in this case yields a value of the expected utility function $U^{**}(W_{EQUIV})$ that depends on W_{EQUIV}. We use a numerical search algorithm to find the value of W_{EQUIV} that yields $U^{**}(W_{EQUIV}) = U^*$, where U^* is the utility level associated with initial wealth holdings W_0. Since the longevity insurance provided by the annuity market makes the individual better off, $W_{EQUIV} > W_0$. The consumer requires more wealth to achieve a given retirement utility level when he does not have access to a nominal annuity market than when he does.

We summarize the willingness to pay calculation by computing a *wealth equivalent* measure defined as W_0/W_{EQUIV}. This is the ratio of the wealth required to achieve a given expected utility level with access to an annuity market, to the wealth required without such access. One minus this wealth equivalent can be thought of as the fraction of wealth that an individual without any annuitized wealth would be prepared to give up in order to purchase an actuarially fair nominal annuity.

The discussion generalizes immediately to the case of a real annuity or a variable-payout annuity. For an actuarially fair real annuity, we determine the annual payout per dollar of premium, θ', from the expression

(11) $$1 = \sum_{j=1}^{50} \frac{q'^{*} P_j}{(1+r)^j}.$$

This expression is analogous to (7), but the discount factor involves only real interest rates, and the numerator involves only real payouts. As in the discussion above, we find the optimal consumption profile for a consumer who purchases such an annuity, and we then find the wealth equivalent from access to a real annuity as opposed to no access.

We also consider the utility consequences of being able to purchase variable payout annuity products, in particular the case in which annuity payouts are indexed to an underlying portfolio of common stocks. To compute the actuarially fair payout on such variable annuities, we assume that a risk-neutral insurance company offers a variable annuity with an *initial* payout θ" determined by

(12) $$1 = \sum_{j=1}^{50} \frac{q''^{*} P_j}{(1+R)^j}.$$

In this expression, R is the AIR for the variable annuity product, which we discussed above. The payout in the first period of the annuity purchase is therefore

(13) $A_v(0) = \theta''^{*} W_0$.

The nominal payout on the variable annuity is determined in subsequent periods by the recursion

(14) $A_v(t+1) = A_v(t)^{*}(1+z)/(1+R)$

where z denotes the nominal return on the equity portfolio.

In considering the equity-linked variable annuity, it is essential to recognize that the initial payout on the annuity policy is increasing in the assumed AIR. The appeal of the equity-linked variable annuity arises from this higher initial payout stream, and from the higher average returns earned on the assets invested in the variable annuity.

4.2 Calibration of Wealth Equivalent Calculations

To carry out the wealth equivalent calculations described in the previous sub-section, we must calibrate the lifetime utility function, the survival probability distribution, and the distributions for inflation and real returns on the assets that might be held in portfolios backing variable payout annuities.

Risk Aversion. The parameter β in equation (8) represents the household's degree of risk aversion and its willingness to engage in intertemporal substitution in consumption. This risk aversion parameter is an important determinant of the gains from annuitization when the real value of annuity payouts in future periods is uncertain because of stochastic asset returns or stochastic inflation.

Most empirical studies that attempt to estimate a value of relative risk aversion from household consumption patterns find values close to unity, which corresponds to log utility (Laibson, Repetto, and Tobacman, 1998). Much higher levels of risk aversion are required, however, to rationalize the presence of the large premium of corporate equity returns over riskless bond returns in historical U.S. data (Mehra and Prescott, 1985). It is difficult to reconcile the empirical evidence of low risk aversion and the existence of the large historical equity premium. Recent work based on survey questions about household tolerance of risk, reported in Barsky, *et al.* (1997), also suggests values higher than 1. In light of this dispersion of findings, we present calculations using risk aversion coefficients of 1, 2, 5 and 10. In their related study of the utility gains from annuitization, Baxter and King (1999) consider an even wider range of risk aversion values, ranging from 2 to 25. We are inclined to place the most emphasis on our findings with risk aversion coefficients between 1 and 5, but we present findings using a value of ten to provide some insight on how the findings would change with much higher risk aversion values.

Survival Probabilities. The mortality process that we use in our analysis corresponds to the population mortality table supplied by the Social Security Administration. We use a cohort life table with projected future mortality rates, since we are interested in an annuity purchased by someone who is currently of retirement age. We use a 1930 birth cohort table to study a 65-year-old male, so our calculations effectively describe someone who was considering purchasing an annuity in 1995.

The Inflation Process. We use historical data from the period 1926-1995 to calibrate the stochastic process for inflation. The average value of inflation over this period is 3.2 percent per year. We assume that the inflation rate in each "year" takes one of five values: -1.5 percent, 1.7 percent, 3.6 percent, 9.0 percent, or 18.4 percent. The respective probabilities of these inflation outcomes are assumed to be .2, .3, .3, .188 and .012. These inflation values correspond approximately to the 10th, 35th, 65th, 90th, and 99th percentiles of the annual inflation distribution for the years 1926-1995, and they imply an average annual inflation rate of 3.2 percent. We have devoted special attention the upper tail of the inflation distribution to make sure that our analysis captures the possibility of a very high inflation period, since we might otherwise understate the value of a real annuity.

We consider two cases for the inflation process, corresponding to different assumptions about the degree of inflation persistence over time. The first case treats each annual inflation rate as an independent draw from our five-point distribution. This approach to modeling inflation tends to understate the long-run variance of the real value of fixed nominal payments, and thus serves as a lower bound on the impact of inflation. Our empirical findings in the last section demonstrate clearly that inflation is a highly persistent process from year to year.

In the second case, we allow for each inflation draw to persist for 10 years before another inflation rate is drawn. We use the same possible inflation rates and probabilities as in the case of annual i.i.d. inflation shocks, but after drawing an inflation rate, we assume that it repeats ten times before we draw another inflation rate. This case probably overstates the actual degree of inflation persistence and it should illustrate the value of inflation insurance in an economic environment that makes inflation a greater risk to long-term welfare than it actually is.

The value of avoiding the risk of uncertain inflation is obtained by comparing our "wealth equivalent" for access to an actuarially fair nominal annuity with that for an actuarially fair real annuity. Our measure is related to, but not equivalent to, Bodie's (1990) analysis of the value of inflation insurance as the cost of purchasing a call option on the Consumer Price Index. His approach generates the cost of *producing* an inflation indexed income stream, while our approach focuses on the *consumer valuation* of such an income stream.

Risky Asset Returns. Our analysis assumes that investors have access to riskless real returns of three percent per year (r = .03). While this return is higher than the average return on "riskless" Treasury bills over the 1926-1997 period, it is lower than current return on long-term TIPS. We think of TIPS as the riskless asset with respect to retirement saving, and therefore use a higher return than the historical real return on T-bills. We further assume that inflation raises the nominal return on this riskless asset so that the real return is unaffected by inflation. This is tantamount to assuming that the investor is holding an indexed real bond.

When we consider variable annuity products backed by portfolios of risky securities, we must specify both the mean return associated with these securities and the variability of returns around this mean. Higher mean returns on the portfolios that back variable payout annuities will make these products more attractive to potential annuitants, while greater risk will reduce their attractiveness.

We consider a variable payout annuity backed by a broad portfolio of common stocks. Table 9 presents historical information on real returns and the standard deviation of real returns for U.S. stocks, bills, and bonds over the 1926-1997 period. This table is another way of presenting the information in

Table 6 on real returns over different horizons. We assume throughout that the standard deviation of real returns on equities equals its historical average value of 20.9 percent per year. As in our earlier analysis of inflation, we use a discrete approximation to capture the distribution of real equity returns. In this case we use a four point distribution, with points corresponding to the 10th, 35th, 65th, and 90th percentiles of the equity return distribution, to approximate the distribution of equity returns. Real equity returns are modeled as independent across time. One drawback of this approach is that it does not capture the possibility of extremely negative or positive equity returns in a given year, nor does it capture possible serial correlation in returns over time, particularly any mean-reversion and resulting variance compression at long horizons.

We consider two different assumptions with regard to the mean real return on equities. First, we assume a 6 percent real return (i.e., a 3 percent premium over the indexed bond return). In this case, we assume an AIR of 9 percent for the variable annuity, following the approach of Bodie and Pesando (1983). This assumption about the equity premium is substantially smaller than the historical average differential between stock and bond returns, but it is designed to be conservative. Second, we consider a case with a 9 percent real return on equities, which translates to a 6 percent premium above the real bond. This is still a smaller equity premium than historical returns suggest, but it yields a real return on equities close to the historical average. The extent to which historical real returns on corporate stock provide guidance on prospective returns is an open issue (c.f. Campbell and Shiller, 1997, and Siegel, 1998).

4.3 Results on the Valuation of Real vs. Nominal Annuities

Table 10 reports our estimates of the wealth equivalents for real and nominal annuities. The first three columns report results for the case with no pre-annuitized wealth, when the potential annuitant places all of his wealth in an annuity. The second set of three columns explores what happens when the potential annuitant already holds half of his net worth in a real annuity such as Social Security. To interpret the results, first consider the case in which the potential annuitant has a logarithmic utility function (CRRA = 1). In this case the wealth equivalent is 0.666 for a fixed real annuity, 0.684 for a fixed nominal annuity in the presence of i.i.d. inflation, and 0.701 for a fixed nominal annuity in the presence of ten-year persistent inflation. These results imply that an individual would be indifferent between having $1 in non-annuitized wealth, having wealth of $0.666 that could be converted into a real annuity stream, and having wealth of $0.684 or $0.701 that could be converted into a fixed nominal annuity, depending on the inflation process. If we subtract these wealth equivalent estimates from one dollar, we obtain an estimate of the individual's willingness to pay for access to annuitization. A lower wealth equivalent implies that the annuity is more valuable to the individual.

For a real annuity, the wealth equivalent is monotonically decreasing with the level of risk aversion. When the CRRA coefficient is 10, for example, the wealth equivalent falls to 0.499, meaning that an individual is indifferent between $1 of non-annuitized wealth and $0.499 in wealth that can be invested in a real annuity. For fixed nominal annuities in the presence of uncertain inflation, this monotonic relationship between the wealth equivalent and the level of risk aversion does not hold. This is because there are two effects of risk aversion that work on opposite directions. The first is that higher risk aversion leads one to value an annuitized payout more highly because the annuity eliminates the risk of outliving one's resources. This is the only effect present when examining real annuity products. The second factor, which works in the opposite direction, is that more risk averse individuals have greater dislike for the uncertainty introduced into the real annuity stream by stochastic inflation. Increased variability in the real value of the annuity flows reduced utility, and this effect is larger for those with the highest degree of risk aversion.

At low levels of risk aversion, the first effect dominates, and the wealth equivalent is decreasing with risk aversion. For example, moving from CRRA=1 to CRRA=2, the wealth equivalent decreases from 0.684 to 0.640 in the i.i.d. inflation case, and from 0.701 to 0.675 in the persistent inflation case. However, as risk aversion increases further, the second effect becomes stronger, and the wealth equivalents begin to rise as we increase risk aversion.

The wealth equivalents described above provide information on the amount that individuals would pay to purchase annuities, assuming that they have no pre-existing annuity coverage. The difference between the wealth equivalent values for real and nominal annuities provides information on what a potential annuitant would pay to obtain a real rather than a nominal annuity. For example, to achieve a given utility target in a world with peristent inflation, a consumer with logarithmic utility (CRRA=1) would require 3.5 percent more wealth (= .701 - .666) if he were only able to purchase a nominal annuity than if he were able to purchase a real annuity. At higher risk aversion levels the additional wealth required if only nominal annuities are available rises even further. When CRRA=5 and inflation persists, the potential annuitant requires 19 percent more wealth in the nominal annuity case than in the real annuity case.

The results are attenuated when we consider the annuitization decision of an individual who already holds a substantial amount of his wealth in a pre-existing real annuity. Such a potential annuitant would be prepared to give up a smaller fraction of his non-annuitized wealth to obtain annuity protection for that wealth than would someone without a pre-existing annuity. For example, a consumer with a risk aversion coefficient of unity will give up only about 25 percent of his wealth to obtain a real annuity in this case, compared with roughly 33 percent if he did not have a pre-existing real annuity. The presence of a pre-existing real annuity offers the potential annuitant some insurance against very low consumption values. This accounts for the diminished value of an additional privately-purchased annuity.

When the annuity option is a nominal annuity, rather than a real annuity, the effect of having a pre-existing real annuity is more complex. When inflation draws are independent across years, the results are similar to those for real annuities: the willingness to pay for annuitization declines when there is a pre-existing real annuity. When we allow for a persistent inflation process, however, along with very high values of risk aversion, the results change. For example, when CRRA=5 or 10, the willingness to pay for a nominal annuity is <u>higher</u> when the potential annuitant has pre-annuitized wealth than when he does not. This is because we have assumed that the pre-existing annuity is a fixed real annuity, which provides insurance against the annuitant ever experiencing very low values of real income and therefore consumption. Thus the utility cost of having high and persistent inflation erode the value of a nominal annuity is reduced, and the potential annuitant's willingness to purchase a nominal annuity rises.

4.4 Results on the Valuation of Variable Annuities

Table 11 reports our findings for the case of equity-linked variable-payout annuities. We assume that the AIR for such annuities corresponds to the average real equity return that is built in to our calculations. Once again we report two panels, corresponding to different degrees of pre-existing annuitization. The first column reports results when the average return on equities exceeds that on bonds by 3 percent, so the real return to equities averages 6 percent. For an individual with logarithmic utility and in this return environment, an equity-linked variable payout annuity generates a higher utility level than a real annuity. The wealth equivalent for the variable annuity, 0.602, is *lower* than that for the real annuity in Table 10 (0.666).

The lower panel of Table 11 reports the ratio of the wealth equivalent with an equity-linked variable annuity to the wealth equivalent with a real annuity. When these entries are less than one, a potential annuitant would require less wealth to attain a given utility level if he had access to an equity-linked variable annuity than if he had access to a fixed real annuity. The first entry in this panel, 0.903, is the ratio of 0.602 (from Table 11, row one, column one) and 0.666 (Table 10, row one, column two).

The valuation of an equity-linked variable annuity is sensitive to the potential annuitant's risk aversion. As the coefficient of relative risk aversion rises from 1 to 2 to 5, with an expected equity return of 6 percent, the wealth equivalent of an equity-linked variable annuity rises from 0.602, to 0.632, to 0.846. The same pattern is evident when we allow a higher real return on equities. For three of the six combinations of risk aversion and the real equity return that we considered, a potential annuitant who was preparing to annuitize all of his wealth would prefer the variable to the real annuity. For five of the six combinations, this outcome also emerges in the case with a pre-existing real annuity.

These findings suggest that for plausible risk aversion and rate of return assumptions, potential annuitants would prefer to purchase variable annuities with payouts linked to equity returns, rather than to purchase real annuities offering constant purchasing power throughout the annuity period. Even when the expected real return on stocks is only three percent, the extra return afforded by the variable annuity more than compensates potential annuitants for the inflation risk that they bear. This is particularly evident when the annuitant is already endowed with a real annuity that represents a substantial share of net wealth, because in that case the risk of very low consumption as a result of adverse variable annuity returns is mitigated. These results may be driven in part by our restriction of the menu of assets that investors can hold <u>outside</u> the variable annuity. In particular, we do not allow investments in corporate stock except through the variable annuity channel. We note below that analyzing the demand for variable annuities in a more complete model of individual financial behavior is a key topic for further research.

5. Conclusions and Further Directions

We have provided new evidence on the functioning of existing real annuity markets, and on the potential role of nominal, real, and variable payout annuities in providing income security to retirees. Three conclusions emerge from the analysis.

First, private insurers can and do offer real annuities to potential annuitants. Although at present there virtually no U.S. market for real annuity products, in the United Kingdom indexed government bonds have been available for nearly two decades and there, indexed annuities are widely available. From the standpoint of an annuity purchaser, the cost of purchasing a real rather than a nominal annuity in the United Kingdom is at most five percent of the annuity principal.

Second, real returns on a broad-based portfolio of U.S. stocks have historically outpaced inflation by a substantial margin. While extrapolating from historical returns must be done with caution, the past returns suggest that there may be benefits for retirees from investing part of their annuity wealth in a variable annuity product with returns linked to the returns on corporate stocks. Nevertheless, our analysis of the covariation between unexpected inflation and equity returns suggests that the appeal of an equity-linked variable annuity is primarily the result of the equity premium, and not the result of a strong positive correlation between inflation shocks and equity returns. At least at high frequencies, U.S. equities do not appear to offer a strong inflation hedge.

Third, we find that consumers would be prepared to pay a modest additional amount for the opportunity to purchase a real rather than a nominal annuity. This conclusion flows from a stylized model of individual annuity demand for inflation-indexed annuites. Consumers also value access to variable-payout equity-linked annuities, although their demand for such products is quite sensitive to their degree of risk aversion. For moderately risk averse consumers, with coefficients of relative risk aversion of two or less, willingness to pay for an equity-linked variable annuity may be greater than the willingness to pay for a real annuity. This finding obtains even when we assume that the average annual real return on equities is only 300 basis points higher than the real return on riskless bonds.

These findings bear on two concerns that are raised in connection with Social Security reform plans that include individual accounts. One is that insurers might not be able bring to market products providing inflation and longevity protection. Our evidence suggests that this is, in fact, not a concern in the two countries that we have examined. Both have government-issued inflation-indexed bonds that can be used to back the issuance of privately-sold inflation-indexed annuities.

A second concern is that, given a choice, retirees might use their individual account funds to purchase nominal rather than inflation-indexed annuities. This is perceived as a problem to the extent that it exposes retirees to the risk of consumption losses in old age. Our model suggests that the expected utility losses associated with purchase of a nominal rather than a real annuity are modest. It also implies that consumer demand for inflation-linked annuities in an individual accounts system would be positive, although the extent to which our stylized model describes actual consumer behavior is an open issue. The demand for real annuities is greatest among the most risk averse consumers. It is also increasing in the degree of persistence of inflation shocks. When inflation is serially independent, willingness to pay for the real annuity is lower than when inflation is highly persistent. This is because, conditional on the average inflation rate, the risk of experiencing high and persistent inflation poses a greater threat to real retirement consumption than the risk of a shorter-lived period of high inflation.

The demand for real annuities also tends to be lower for households with a substantial endowment of annuitized wealth. This would include any remaining real defined benefit promises offered to retirees under a restructured Social Security system. We estimate that the wealth equivalent of a real annuity is about 5-8% less for the consumer holding half his wealth in Social Security, as compared to one having no real annuity at all. Older Americans currently hold close to half their retirement wealth in real Social Security annuities (Moore and Mitchell 1998), which may explain why U.S. retirees appear reticent to demand real annuity protection with the remainder of their wealth.

Our examination of the interplay between annuity choice, inflation protection, and portfolio risks raises a number of issues that could productively be explored in future work. One pertains to the use of more complex annuity products than the ones considered here. One type of annuity not considered in detail here is the “graded nominal payout product” discussed by Biggs (1969) and King (1995). While graded policies do not offer inflation protection *per se*, they do provide annuitants with an opportunity to back-load their real annuity payouts. Willingness-to-pay for graded policies, relative to that for fixed nominal or real annuities, would be straightforward to explore in our framework.

A more difficult issue for future research concerns the set of portfolio options available to the individuals considering annuitization, and the extent to which such households have access to assets other than riskless bonds. One reason we find that investors would be willing to pay for equity-linked annuities is that our models assume investors can access the equity market only by using variable annuities. For some low-income and low-net-worth households accumulating retirement resources in an individual accounts system, it may be realistic to assume that they do not hold stock in any other way. For higher net worth households with greater financial sophistication, this assumption is less appropriate. Extending the current analysis to allow for a richer portfolio structure on the part of potential annuitants is an important direction for further work.

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Table 1: Summary Statistics on Nominal and Real Annuities Available in the Compulsory Annuity Market in the United Kingdom, 1998

Annuity Buyer Characteristics	Average Monthly Payout For a £100,000 Annuity		Coefficient of Variation for Annuity Prices	
	Nominal	Real	Nominal	Real
Man, 60 Years Old	666.20	476.35	4.26	6.09
Man, 65 Years Old	754.80	563.20	3.36	6.29
Man, 70 Years Old	872.94	679.50	2.88	6.31
Woman, 60 Years Old	602.99	416.81	5.34	5.02
Woman, 65 Years Old	666.88	482.70	4.27	4.49
Woman, 70 Years Old	760.50	575.06	3.65	4.48

Source: Authors' calculations based on data provided by U.K. annuity brokers. Reference date is August 21, 1998. Sample consists of fourteen large insurance companies that provide annuites. Data were provided by Annuity Direct, Ltd. All annuity products analyzed in this table offer a five year guarantee period.

Table 2: Expected Present Discounted Value of Annuity Payouts for Nominal and Real Annuities Available in the Compulsory Annuity Market, United Kingdom, August 1998

Characteristics of Annuitant	Nominal Annuity			Inflation-Indexed Annuity		
	Average Payout	Highest Three	Lowest Three	Average Payout	Highest Three	Lowest Three
Male, Aged 60	0.921	0.953	0.873	0.867	0.916	0.808
Male, Aged 65	0.908	0.936	0.868	0.854	0.898	0.797
Male, Aged 70	0.889	0.917	0.853	0.836	0.881	0.783
Female, Aged 60	0.928	0.966	0.861	0.876	0.924	0.832
Female, Aged 65	0.907	0.942	0.857	0.857	0.892	0.812
Female, Aged 70	0.886	0.920	0.841	0.836	0.869	0.790

Source: Authors' calculations as described in the text. Sample consists of fourteen companies with data provided by Annuity Direct, Ltd. See notes to Table 1.

Table 3: Monthly Annuity Payouts on Single Premium Annuity Products Offered by ILONA in the United States Market, 1998

Annuitant Age and Product	Male, Single Life Annuity	Female, Single Life Annuity	Joint and Survivor Annuity with Full Survivor Benefits
Age 65, Unindexed	$7452	$6720	$6068
Age 65, Indexed	5149	4432	3849
Age 70, Unindexed	8520	7543	6663
Age 70, Indexed	6262	5332	4549
Age 75, Unindexed	10075	8825	7594
Age 75, Indexed	7833	6643	5552

Note: All payouts correspond to an initial purchase of $1 million. Data were provided by Irish Life of North America (ILONA). See text for further details.

Table 4: Expected Present Discounted Value of Annuity Payouts, Freedom Inflation Indexed Annuities Offered by ILONA, 1998

	Male Annuitant, Age 65	Male Annuitant, Age 75	Female Annuitant, Age 65	Female Annuitant, Age 75
Calculations Using Population Mortality Table				
Nominal Annuity	0.864	0.830	0.889	0.887
Real Annuity	0.702	0.720	0.708	0.762
Calculations Using Annuitant Mortality Table				
Nominal Annuity	0.987	0.984	0.966	0.967
Real Annuity	0.822	0.872	0.782	0.841

Notes: Each entry shows the expected present discounted value of annuity payouts using the algorithm described in the text. See notes to Table 3.

Table 5: Total Return, January 1 1998-December 31 1998, By TIAA-CREF Account

CREF Accounts:	
Inflation-Linked Bond Account	3.48
Growth Account	32.89
Stock Account	22.94
Equity Index Account	24.12
Social Choice Account	18.61
Global Equities Account	18.58
Bond Market	8.60
Money Market	5.45
TIAA Accounts	
Traditional Annuity	6.71
Real Estate Account	8.07
Personal Annuity Stock Index Account	23.84

Source: www.tiaa-cref.org, various pages.

Table 6: Real Value of a One Dollar Investment after Various Periods, 1926-1997 Average

Value After N Years:	Cash (No Investment Return)	Investment Portfolio		
		Treasury Bills	Treasury Bonds	Corporate Stock
5 Years	0.864 (0.150)	1.036 (0.163)	1.128 (0.315)	1.477 (0.517)
10 Years	0.729 (0.205)	1.047 (0.245)	1.233 (0.561)	2.214 (1.071)
20 Years	0.490 (0.160)	1.013 (0.285)	1.161 (0.560)	4.569 (2.941)
30 Years	0.356 (0.129)	1.033 (0.324)	1.112 (0.478)	8.679 (4.728)

Notes: Each entry shows the mean value of a one dollar initial investment, in real terms, and the (standard error) of this value. Calculations are based on authors' computations using actual realizations of inflation, bill, bond, and stock returns over the 1926-1997 period, as reported in Ibbotson Associates (1998).

Table 7: Estimates of the Inflation Process for the United States, 1930-1997

Explanatory Variable	Lagged Inflation Only, 1930-1997	Lagged Inflation & Bills, 1930-1997	Lagged Inflation Only, 1947-1997	Lagged Inflation & Bills, 1947-1997
Constant	0.008 (0.005)	0.010 (0.006)	0.009 (0.006)	0.005 (0.006)
Inflation (t-1)	0.706 (0.113)	0.666 (0.124)	0.647 (0.100)	0.566 (0.106)
Inflation (t-2)	-0.146 (0.142)	-0.086 (0.148)	-0.161 (0.119)	-0.127 (0.120)
Inflation (t-3)	-0.223 (0.142)	-0.208 (0.146)	-0.056 (0.118)	-0.066 (0.119)
Inflation (t-4)	0.436 (0.112)	0.447 (0.119)	0.302 (0.099)	0.280 (0.103)
Bill Yield (t-1)		0.370 (0.340)		0.549 (0.241)
Bill Yield (t-2)		-0.694 (0.470)		-0.677 (0.328)
Bill Yield (t-3)		0.129 (0.483)		0.218 (0.338)
Bill Yield (t-4)		0.108 (0.338)		0.053 (0.234)
Adjusted R2	0.507	0.500	0.544	0.571

Source: Authors' calculations using data from Ibbotson Associates (1998).

Table 8: Unexpected Inflation and Real Asset Returns, United States, 1926-1997

Inflation Process	1930-1997 Sample			1947-1997 Sample		
	Bills	Bonds	Stocks	Bills	Bonds	Stocks
Bills and Inflation	-0.827 (0.137)	-1.702 (0.389)	-1.582 (0.804)	-0.580 (0.174)	-3.442 (0.650)	-4.326 (1.077)
Inflation Only	-0.864 (0.128)	-1.672 (0.378)	-1.560 (0.783)	-0.387 (0.170)	-2.515 (0.664)	-4.271 (0.975)
5-Year Nonover-lapping Returns, Inflation Only	0.191 (0.437)	-1.522 (0.657)	-1.969 (0.670)			

Note: Each entry corresponds to the coefficient λ_i in the regression equation

$$R_{it} = \alpha + \lambda_i * \pi_{u,t} + \varepsilon_{it}$$

where R_{it} denotes the real return on asset I in period t and $\pi_{u,t}$ denotes the unexpected inflation rate. Estimates are based on authors' analysis of data in Ibbotson Associates (1998), as described in the text.

Table 9: Mean Real Returns, and Standard Deviations of Real Returns, 1926-1997

	1926-1997		1947-1997	
	Mean Real Return	Standard Deviation	Mean Real Return	Standard Deviation
Treasury Bills	0.73%	4.17%	0.87	2.64
Long-Term Treasury Bonds	2.57	10.53	2.01	11.13
Equities	9.66	20.46	9.93	16.95

Source: Authors' tabulations using data from Ibbotson Associates (1998).

Table 10: Wealth Equivalents, Real and Nominal Annuities

Coefficient of Relative Risk Aversion	Individual with No Pre-Existing Annuity Wealth			Individual With Half of Initial Wealth in Pre-Existing Real Annuity		
	Real Annuity	Nominal Annuity: i.i.d. inflation	Nominal Annuity: Persistent Inflation	Real Annuity	Nominal Annuity: i.i.d. inflation	Nominal Annuity: Persistent Inflation
1	0.666	0.684	0.701	0.752	0.762	0.770
2	0.606	0.640	0.675	0.694	0.713	0.729
5	0.539	0.615	0.732	0.616	0.660	0.699
10	0.499	0.629	0.936	0.551	0.634	0.735

Source: Authors' calculations. The wealth equivalent for the nominal annuity is calculated under the assumption that inflation takes one of five possible values, roughly capturing the distribution of inflation outcomes over the 1926-1997 period. Inflation shocks are independent across periods in the i.i.d. case, and persist for a full 10-year period in the persistent inflation case. See text for further discussion.

Table 11: Wealth Equivalents, Equity-Linked Variable Annuity Products

Coefficient of Relative Risk Aversion	No Pre-Existing Annuities		Pre-Existing Annuity Equal to Half of Initial Wealth	
	Real Stock Return 6%	Real Stock Return 9%	Real Stock Return 6%	Real Stock Return 9%
Wealth Equivalent Value:				
1	0.602	0.481	0.633	0.504
2	0.632	0.502	0.622	0.497
5	0.846	0.643	0.663	0.532
10	1.211	0.869	0.766	0.611
Wealth Equivalent Ratio, Variable Annuity/Real Annuity				
1	0.904	0.722	0.842	0.670
2	1.043	0.828	0.896	0.716
5	1.570	1.193	1.076	0.863
10	2.427	1.741	1.390	1.109

Source: Authors' calculations, as described in the text. The calculations in the bottom panel show the ratio of the wealth equivalent from the upper panel to the analogous wealth equivalent from holding a real annuity with an assumed real return of 3 percent. The underlying wealth equivalents for the real annuity case are shown in Table 10, columns 1 and 4.