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RESEARCH PAPER

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ABSTRACT

Both academic economists and financial professionals emphasize the value of annuities for households that need to manage risks during retirement. Yet, the types of annuity products that they consider, and the risks that those products help manage, are vastly different. We demonstrate how to incorporate features of realworld annuity products into economic models, with the goal of stimulating academic research, and we elucidate the economic consequences of realworld annuity products for financial professionals, with the goal of facilitating an appropriate match of product features to household needs.

A PRIMER ON ANNUITIES

What Economists and Financial Professionals Need to Know about Variable Annuities, Fixed Indexed Annuities, and Registered Index-Linked Annuities LEORA FRIEDBERG AND ANTHONY WEBB

INTRODUCTION

oth academic economists and financial professionals emphasize the value of annuities for households that need to manage risks during retirement. Yet the risks that each focuses on, and the types of annuity products that economists versus professionals consider to be the best way to manage those risks, are vastly different. Academic economists almost exclusively consider traditional income annuities as a tool to eliminate longevity risk, even though income annuities are quite rare in the real world. Financial professionals offer a range of products that have annuity or annuity-like components or options, combined with additional features that help households manage investment and, in some cases, long-term care cost risk. These complicated financial products may not be fully understood when financial professionals are offering advice to individuals who are considering purchasing them, and they are rarely analyzed by academic economists. Consequently, the goal of this primer is twofold: first, to incorporate the features of real-world annuity products into economic models, with the goal of stimulating academic research; and second, to elucidate the economic consequences of real-world annuity products for financial professionals, with the goal of facilitating an appropriate match of product features to household needs.

Academic economists are familiar with **income annuities**, in which households pay an irrevocable sum of money to an insurer in exchange for a lifetime income starting immediately or, less commonly, at some fixed future date.¹ Many economists have investigated the value of income annuities as a mechanism for managing longevity risk and have puzzled over the quite low holdings of such annuities in the real world. However, income annuities—whether they are the traditional variety where income commences immediately or the recently introduced deferred variety where income commences at some future date, normally when the retiree is at an

1. Bolded terms are defined in appendix C.

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advanced age-comprise only a small share of the annuity market.² The overwhelming majority of sales are of variable annuities (VAs), fixed index annuities (FIAs), and, of late, registered index-linked annuities (RILAs)which we collectively refer to as deferred annuities; all of these are investment products that offer the household protection against financial market losses along with the opportunity to purchase additional riders. The most notable rider will, for an additional fee, grant the option-but not the obligation-to receive a lifetime income commencing at a deferred date, with both the premium and the lifetime benefit partially contingent on asset returns. In other words, these products combine some protection from asset market volatility and other contingencies with the opportunity to initiate lifetime income at a later date; income would first be paid out of the account and later, if the account is exhausted, income would be supported by annuitization.

These deferred annuity products have received little attention from academic economists. Most of the limited academic research has focused on pricing the financial options embedded in their riders under risk-neutral terms (e.g., Milevsky and Salisbury 2006). Such pricing studies tell us little about the utility gains from these products as tools for managing post-retirement risks.³ The optimal strategy for a consumer seeking to maximize (and smooth) the lifetime utility of consumption is not necessarily a strategy that extracts the maximum liability from the issuer; in other words, the optimal hedging strategy (for the risk-neutral manufacturer) might not be the symmetric opposite of the optimal dynamic utilization strategy (for the risk-averse buyer) (Huang, Milevsky, and Salisbury 2014).⁴ Only a handful of studies investigate VAs and FIAs, much less RILAs, and even those few studies leave many important questions unanswered about the value of deferred annuities to households that are confronted with multiple risks (we single out longevity risk, rate-of-return risk, and long-term care cost risk) and incomplete markets (since some combinations of those risks remain uninsurable to typical households).

Because some helpful guides to the various annuity products are available (see, e.g., Pfau 2019), this primer seeks to explain not so much the annuity types themselves but rather the extent to which each type does or does not insure longevity, rate-of-return, and long-term care cost risks. To see why these explanations may be useful, consider the contrast between a traditional income annuity, which involves a one-time purchase decision, and the much more common guaranteed lifetime withdrawal benefit (GLWB) rider embedded in the contracts of VAs and FIAs. In return for an annual premium that depends on asset returns, GLWB riders allow purchasers to initiate a periodic lifetime income that also depends on asset returns as well as on commencement age; that income is first paid by withdrawals from the annuity account, and later by the insurer should the assets in the account become exhausted. It is not surprising, then, that exercising these options to maximize utility is a complex decision that differs in key respects for different annuity products. We suspect that most households lack the requisite financial skills to make optimal decisions and that they rely on financial professionals instead. Financial professionals have little in the way of academic literature available for reference, however. We will demonstrate why modeling option exercise and asset allocation strategies that maximize the value of the option are examples of the difficult questions that academic economists should investigate in future practitioner-relevant research.

The remainder of this paper is as follows. Section 1 provides an overview of the approach taken by academic economists to understanding annuities, which focuses on annuities' role in managing financial risk. Section 2 provides a taxonomy of annuity types, using standardized language. Section 3 demonstrates how each type of annuity can raise household welfare by insuring against longevity risk. Section 4 describes our simplified economic model and results, which illustrate how annuities may help in managing rate-of-return as well as longevity risk. We discuss long-term care cost risks as well. The paper ends with conclusions and summarizes directions for future research.

^{2.} In 2019 annuity sales totaled \$227.8 billion, of which \$98.3 billion were variable and \$129.5 billion were fixed. Of the former, only \$0.1 billion were income annuities (all immediate); of the latter, only \$11.9 billion were income annuities, \$10.2 billion were traditional immediate, and \$1.7 billion were deferred (Insured Retirement Institute 2020). Consequently, income annuities comprise around 5 percent of the market.

^{3.} Analogously, a study of auto insurance pricing, which is determined on risk-neutral grounds, tells us little about the value of auto insurance to risk-averse motorists facing the risk of otherwise unaffordable crash repairs.

^{4.} Holz, Kling, and Russ (2012) price the cost of the options to the insurer assuming probabilistic or deterministic policyholder behavior or behavior that maximizes that cost, but that does not assume behavior that maximizes the value to the household.

1. THE ACADEMIC ECONOMISTS' POINT OF VIEW: HOW ANNUITIES HELP HOUSEHOLDS MANAGE FINANCIAL RISKS

We focus on three risks that loom large for retired households:

- The risk of outliving their wealth if they live longer than expected (**longevity risk**)
- The risk of experiencing poorer-than-expected investment returns, or returns that do not cover increases in the cost of living (**rate-of-return risk**)
- The risk of higher-than-expected costs of long-term or other out-of-pocket health care (**long-term care cost risk**)

A very lengthy list of papers by economists have documented the magnitudes of these risks, as well as the highly imperfect insurance available to most households who are confronting these risks.⁵

1.1. HOW ECONOMISTS THINK ABOUT ANNUITIES

The simplest type of annuity—a traditional **fixed immediate income annuity**, or simply a traditional annuity or income annuity—provides full insurance from the date of purchase against both longevity risk and rateof-return risk.⁶ Yet fixed immediate income annuities comprise only a small share of the annuity market. In practice, most products termed "annuities" provide an option—but not a requirement—for households to convert their investment into a lifetime income and provide partial protection against rate-of-return risk while offering households upside potential should financial markets perform well. The common feature of all these annuities is that they reduce the risk of bad financial outcomes more generally, rather than reducing longevity risk exclusively or even primarily.

It therefore makes sense to view annuity products as offering selections from a menu, with more risk reduction in some dimensions that, if not adding to the price, can be traded off against less risk reduction in others. Thus, FIAs and RILAs provide explicit insurance against market downturns, VAs offer the option to purchase such insurance, and all three include options to secure insurance against longevity risk. Additional riders insure bequests in case an annuity owner dies shortly after purchasing the annuity; in the recent past, those riders have helped insure the cost of long-term care (Super and de Cervens 2022).

Academic economists have written many papers on the value of annuities to risk-averse households facing an uncertain lifespan.7 The academic focus has been almost exclusively on longevity insurance that most closely resembles income annuities, however-contracts in which the purchaser hands over an irrevocable lump sum in return for a lifetime income. Yet, even in those cases, academic economists sometimes ignore the deferred version of these income annuities,⁸ which allow a retiree to begin receiving fixed income at some future date. Economists almost always ignore the version that forgoes insurance against market downturns by instead offering an income linked to stock market returns.9 The focus by academic economists on immediate and deferred income annuities (DIAs) might reflect both unfamiliarity with other annuity types and a preference for tractability, or it might be the case that at least some lack of awareness and shunning of complexity extends to financial practitioners as well.

^{5.} Social insurance fills some but not all of these gaps. Notably, Social Security functions as an income annuity, and, for lower-wealth households, it might offer sufficient insurance against longevity risk and rate-of-return risk relative to the purchase of even actuarially fair annuities, were they even available. Furthermore, Medicaid pays for medical and long-term care costs of destitute households; again, lower-wealth households might not face a compelling case to purchase insurance for these risks (Dushi and Webb 2004). Our discussion, therefore, focuses—as do financial professionals—on middle- and upper-wealth households.

^{6.} Technically, the act of annuitization occurs when the purchaser irrevocably exchanges a lump sum for a lifetime income (Pfau 2019, 150). The income payments on an immediate annuity sometimes start immediately (i.e., an immediate annuity) or sometimes are deferred (i.e., an immediate deferred annuity). To avoid confusion and spell-check errors, we refer to what are technically immediate annuities as traditional annuities or income annuities if the lifetime income starts at the time of the purchase, and as deferred income annuities (DIAs) if the lifetime income starts at some future date. In the context of an immediate annuity, the term "fixed" means that the benefit amount is determined at the time of purchase.

^{7.} The origin of this literature is Yaari (1965), a paper that, as of September 4, 2021, had been cited 3,851 times.

^{8.} Gong and Webb (2010) analyze DIAs.

^{9.} As an example of a further complication, some immediate and deferred annuity contracts stipulate that the income payment will be made for a minimum period in the event of an early death. The income payments on these contracts are lower than on similar contracts without guarantees and might be a rational choice for households with a bequest motive that cannot be satisfied by setting aside a lump sum. We hypothesize that households with an irrational concern that an insurance company would benefit at their expense if they die soon after purchase might also find them attractive. We will not be studying the value of these guarantees.

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In contrast to the hundreds of papers studying income annuities (with many recent examples described in the Retirement Income Institute [RII] Insights series), we have identified only a handful of papers that study VAs and FIAs, and a recent paper on RILAs. Descriptive analyses include Brown and Poterba (2006), who provide summary information on ownership patterns of VAs at the time and who explore motives for ownership. Pfau (2019) provides an excellent taxonomy of the various annuity types, describing key features and typical benefits associated with each. We mention a few other helpful examples later on as well. Additional papers that made the first attempts to assess the value of VAs to households (and that we summarize in appendix B) typically make assumptions about the timing of exercise of the options embedded in the annuity, and so consequently understate the value of the annuity relative to a model in which the options are exercised optimally. Those models have not considered the choice among annuity types, so further research is needed to discern whether a VA is not only preferable to a drawdown on unannuitized wealth, but is also preferable to (say) an income annuity. In our illustrative analysis in subsection 4.1 we, indeed, make some of the same arbitrary assumptions, while placing the analysis in a household choice framework. Such an approach points the way forward to future research that can relax these assumptions, thus allowing a realistic analysis of the value of annuities to households facing different situations.

1.2. HOW ECONOMISTS SHOULD THINK ABOUT ANNUITIES

As we have noted, a very large majority of annuities purchased in the real world fail to mirror the simple, theoretically tractable version of annuities that almost all economics papers have considered. Real-world annuities can provide potentially valuable insurance against market downturns while permitting households to benefit from the equity premium historically available from investing in the stock market.¹⁰ For example, purchasers of FIAs or RILAs give up part of potential upside investment returns in exchange for full or partial protection of the contract value against market downturns. FIAs, RILAs, and VAs offer insurance against exhaustion of the contract value, whether as a result of poor investment returns or of outliving the assets, through the option to receive a lifetime income, starting either at the time of purchase or at some future date of the purchaser's choosing.¹¹

All these features need to be captured explicitly in economic models in some way or the other (i.e., in full detail, in simplified form, or assumed away) in order to gain a greater understanding of the value of annuities to households. To make progress, economists will need to use the gold standard of numerical optimization for calculating the value of annuities. In all but the simplest theoretical models these calculations are necessitated by the complexities of both the set of choices available to households and the economic setting in which they make their choices. At a minimum, following are the assumptions that researchers must take a stand on, whether explicitly or implicitly:¹²

What form household preferences take, including (but not necessarily limited to)

- how averse households are to an uneven stream of future consumption (their risk aversion) [We assume constant relative risk aversion preferences, considering a range of values of the coefficient of risk aversion.]
- whether households require a minimum level of consumption, which tends to matter when modeling pre-retirement saving or post-retirement longterm care costs [*We assume this away because we assume a sufficient level of Social Security benefits.*]
- how the household makes decisions and trades off consumption when both spouses are alive, versus when only one spouse survives, versus when both have died and bequests are made [We ignore household decision-making, focusing on a single male retiree, and we assume no utility from bequests.]
- how much the household discounts future consumption (their time preference rate) [*We assume 3 percent.*]

10. VAs offer access to variable insurance trusts, which resemble mutual funds. FIAs offer returns linked to financial market indices, which are backed by the claims-paying ability of the insurer.

11. We will defer additional discussion of nomenclature that touches further on the timing of annuitization until section 2.

12. We indicate the assumptions that we impose in our illustrative analysis later with italics in brackets.

Beliefs about the future of the household, including

- annual survival probabilities at all future ages [We use annuitant (and not population) life tables for an average man age 60 in 2021.]
- future health, which affects both the utility gained from future spending and the need for care [*We ignore this.*]
- the future cost of medical and long-term care [*We ignore this.*]

Investment and lifetime income options available to the household, including

- availability and pricing of annuity options [We assume a market-priced annuity and ignore equilibrium changes in pricing if the annuitant pool changes.]
- availability and pricing of other investment options [We assume investments in a stock- or bond-market index, considering a range of allocations among them.]

Income streams, assets, and insurance policies already held by the household, including

- Social Security [We assume the household receives a Social Security benefit.]
- Medicare [We ignore this, implicitly assuming that all medical spending is insured, which it is not.]
- housing [We ignore housing or other illiquid wealth.]
- debt [We ignore this.]
- long-term care insurance [We ignore this, since we ignore long-term care costs.]
- access to implicit insurance from a social safety net in case they become destitute [We assume this away because Social Security, the absence of long-term care costs, and the impossibility of borrowing keep retirees from becoming destitute.]

Beliefs about the future of the economy, including beliefs about inflation and the risk and return characteristics of each asset class to which the household

is exposed or could be exposed [We make a range of assumptions about asset returns, while ignoring inflation.]

Marginal tax rates on annuity and non-annuity income [We ignore this.]¹³

Given assumptions about preferences, income and asset holdings, and expectations, the next task is to formulate the choice set. For example, in a model with stocks, bonds, and a FIA, the household has three decisions to make each period: (1) how much to consume, (2) how to allocate financial assets between stocks and bonds, and (3) how much to spend on annuity purchase; with all three decisions depending on wealth level.¹⁴ With more-complicated annuities, additional decisions are whether to purchase riders that confer an option to take a future action and whether to take that action in later periods. For example, a household considering a VA with a GLWB rider must decide how much to invest in the VA; how to invest the funds in the VA; and whether to purchase, and, if so, when to exercise the GLWB option within the VA.

To analyze the role of annuities, the researcher twice calculates the optimal drawdown strategy that finances consumption during retirement.¹⁵ The researcher calculates the optimal strategy (first assuming that annuities are available and then assuming they are unavailable), which yields **annuity-equivalent wealth**, the amount by which the household's wealth must be increased so that, from the vantage point of the start of retirement, the household is indifferent between (a) its original wealth plus access to the annuity market, and (b) increased wealth, but no access to the annuity market.¹⁶ When the household is better off not annuitizing, annuity equivalent wealth is zero.

The optimization problem is solved through backwards induction: in other words, the researcher calculates the optimal choice in the final period of the household's life, given all possible survival and investment return outcomes (unless there is a bequest motive, the optimal choice is to spend everything), and then works back pe-

13. Annuities can offer tax advantages to households that have financial assets in non-tax-deferred accounts and that anticipate lower marginal tax rates in retirement. Similarly, the taxable status of annuities can affect the optimal exercise of options in VAs (Moenig and Bauer 2016). The subject is complex and beyond the scope of our current analysis.

^{14.} Once a spouse is introduced, the researcher must further determine the amount that each spouse consumes while both are alive and the optimal amounts for surviving spouses to consume for each age of widowhood.

^{15.} The optimal strategy is one that maximizes the sum of each period's utility in each realization of mortality and investment returns, multiplied by the probability of occurrence and discounted by a rate of time preference.

^{16.} Households are indifferent between two choices when they have the same expected utility in both.

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riod by period to a starting point, often chosen as age 65. The researcher might even work back to younger ages in order to study the hedging of investment and labor market risk during the accumulation phase. In each period, the researcher calculates the optimal strategy in that period, assuming the household will then choose the optimal strategy in each subsequent period. The optimal decision will vary as circumstances evolve, so the researcher must solve for the optimal decision in each time period across a range of values of financial wealth, income, health, and survivor status of both spouses.

The numerical optimization techniques that are necessary to solve these complicated problems can easily become computationally infeasible, not to mention extraordinarily sensitive to seemingly innocuous assumptions.¹⁷ Thus, researchers consider a limited range of annuity purchase and asset allocation options and make other simplifying assumptions, which have gradually been relaxed over time as computing power has risen and the literature has developed. An early paper such as Mitchell and colleagues (1999), for example, studied single individuals rather than married households, assumed away investment risk, assumed that households faced a one-time decision at the start of retirement as to whether to annuitize all of their financial assets, and ignored bequest motives. A robust finding of those early studies was that most households (except the poorest, who rely on Social Security) would benefit from annuitizing at least part, and perhaps quite a lot, of their wealth. This finding stands in stark contrast with the low levels of annuity ownership observed among American households-leading to many attempts to explain the so-called **annuity puzzle**. Some argue that low levels of annuity ownership may be rational and that the literature omits important aspects of the wealth drawdown problem (Lockwood 2012; Pashchenko 2013). In fact, such low levels of annuity ownership might not be surprising, given the long list of assumptions enumerated earlier in this section. Nevertheless, other dynamic optimization papers continue to support a role for annuities, and further consensus has coalesced around a critical role for behavioral biases, in which the household either fails to maximize a consistent set of preferences, makes mistakes in doing so, or misapprehends the risks faced in doing so (Webb 2021a). The possible biases that could help explain observed choices are numerous (DellaVigna 2009; Stango and Zinman 2020) and further lengthen the long list of complications to the household optimization problem.

Even the latest studies, though, consider only a subset of both products and choices available to the household. As a result, excluded options may dominate choices that are allowed in any particular study. For example, a study of traditional income annuities might assume only fixed immediate income annuities, stocks, and bonds are available, leading households to optimally restrict their annuity purchases so they can benefit from the equity premium, whereas in reality they can obtain both longevity insurance and the equity premium by investing in **variable immediate income annuities**.¹⁸

We are aware of only two papers that pioneered the use of numerical optimization techniques to assess the utility of VAs: Horneff et al. (2015) and Steinorth and Mitchell (2015). As we discuss in appendix B, both papers make restrictive assumptions of the kind we have mentioned about the menu of investment and lifetime income options open to the household. Thus, they remain of limited use to practitioners who need to know, for example, factors affecting the choice between a smaller allocation to fixed immediate income annuities offering complete protection against longevity and rate-of-return risk with a larger allocation to a stock portfolio, versus a larger allocation to a variable immediate income annuity offering less-complete protection against investment risk and a smaller allocation to a stock portfolio. In other words, economists are a long way from offering practitioners a tool to download, plug in their client's preference parameters, and have the software calculate a personalized optimal annuity purchase, GLWB exercise date, asset allocation, and asset location strategy.

^{17.} Recent advances in the use of machine learning, which apply deep reinforcement learning to neural net approximations, might help researchers move beyond current state-space constraints in dynamic optimization problems. An example is the life-cycle portfolio model (though with annuities omitted, of course) of Duarte et al. (2021).

^{18.} It might be more efficient for households also to bear aggregate mortality risk, which is the risk of households, on average, living longer than expected (Maurer et al. 2013).

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The complexity of the optimization problem that we have outlined helps to explain why the academic literature considers simplified versions of annuities. Furthermore, if markets were complete, then investors could simply replicate any potential payout profile using other available assets (Moenig 2021b), obviating the necessity of understanding current annuity products. In our view, however, individual investors lack both the know-how to do this and the access to the same instruments with the same fee structure as insurers have; after all, insurers reportedly devote whole trading floors to hedging and managing VA risks (Chopra et al. 2009). Perhaps another reason for inattention by academic economists is that many of them lack awareness of how annuity products actually work; in that event, our primer next briefly describes the key features that real-world annuities offer, and then describes the types of risks that these features help households manage.

2. A TAXONOMY OF ANNUITY TYPES

A major difficulty faced by both academic economists and financial practitioners is the degree of product differentiation among annuities. We provide a brief taxonomy so that readers are clear about similarities, differences, and the technical terms used in this paper (with a glossary appearing in appendix C). This taxonomy draws heavily on the valuable study by Pfau (2019).

We group annuities into four categories:

- 1. income annuities, both traditional income annuities and deferred income annuities (DIAs)
- 2. fixed index annuities (FIAs)
- 3. registered index-linked annuities (RILAs)
- 4. variable annuities (VAs)

The latter three products must contain an option to convert the account to a lifetime income, but these income annuity options are rarely exercised. Rather, they are frequently sold with a GLWB rider, among other possible riders; we focus on the GLWB rider instead of on the income annuity option. If the income annuity option is not exercised, then any remaining value of the asset after deducting GLWB payments becomes part of the estate upon death.

2.1. INCOME ANNUITIES

These are the annuities we have already described as the economists' typical subject of study: the purchaser (the annuitant) pays a lump sum in return for an income payable for life (or possibly for a specified period, through a **period certain annuity**). Once purchased, the contract has no surrender value, although annuities can be sold on the secondary market. Among the options that are available (and that some economists have studied) are these:

- The annuity could be on a single life (of one household member) or on joint lives (of a married couple).
- The annuity could offer a guarantee in the form of a partial refund of the premium in the event of early death. For example, a lifetime with ten-year period certain annuity would continue to make payments until ten years had elapsed since the date of purchase in the event of death during that period.
- The annuity could offer income payments that are level, increasing at a fixed rate, linked to the performance of an underlying mutual fund, or indexed to the Consumer Price Index.¹⁹
- The annuity could offer income that starts immediately (a traditional immediate income annuity) or at some future date (a DIA, sometimes referred to as an advanced life-deferred annuity).

2.2. FIXED INDEX ANNUITIES

FIAs pay annual interest equal to the return (excluding dividends) on some stock market index—for example, the S&P 500—subject to floors and ceilings.²⁰ A typical floor is 0 percent; if the floor is less than zero, the annuity is technically a **variable index annuity**. The guar-

^{19.} At the time of this writing, income annuities with payments linked to the Consumer Price Index have been withdrawn from the market, and income annuities with payments linked to the performance of an underlying mutual fund are extremely rare. The latter product has an assumed interest rate—typically in the range of 3–5 percent. If in a particular year the fund return exceeds the assumed interest rate, the income payment is increased. If the return falls short, the income payment is reduced.

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antee is paid for by the forfeit of some of the upside potential of the stock market. For example,

- the interest may be capped at some index return,
- the annuitant may receive only some percentage of the index return,
- · the crediting may be subject to some threshold, or
- all of the above.

FIAs are intended to be long-term investments with penalties for surrender during a surrender period, which is typically six to eight years, although the term over which returns are measured is typically only one year. The insurance company hedges its guarantees by investing most of the annuity premium in bonds to provide the floor amount, and the remainder in a call option, giving the company the right but not the obligation to buy the underlying index at some given price. Bond yields and option prices fluctuate, and insurance companies therefore do not pledge in advance what guarantees will be available after the expiry of the initial term.

2.3. REGISTERED INDEX-LINKED ANNUITIES

Insurance companies can offer upside potential only if they offer a guaranteed rate of return of less than the current interest rate, because they must give up some of the return they earn on their investments in bonds to purchase hedges against their obligations to policyholders, and the amount of upside potential VAs can offer has consequently been squeezed by the decline in interest rates.²¹ RILAs are able to offer households greater upside potential than FIAs do because the minimum return is less than zero. RILAs enable households to select a maximum amount of investment loss that they are willing to accept and a participation rate—the share of any loss that is borne by the household—customized to their appetite for risk.²² For example, with a \$100 investment a household might choose to bear 100 percent of a loss up to a 10 percent decline, or 50 percent up to a 20 percent decline.²³ The crediting period over which such losses are measured is typically one year but can be as long as six years. RILAs therefore give households protection against extreme market declines, such as occurred in 2007–9, in return for giving up some of the upside potential. For a fuller discussion, we refer to Moenig (2021a).

2.4. VARIABLE ANNUITIES

Purchasers of VAs invest in mutual funds (technically, they are variable insurance trusts) through subaccounts. A VA without a GLWB rider is, therefore, basically a mutual-fund type investment.²⁴ Whether a VA is preferable to a directly held portfolio of mutual funds will depend on the range of investment options available, the level of fees, and tax considerations.²⁵ Compared to FIAs, therefore, VAs offer both more upside and more downside rate-of-return risk.

2.5. GUARANTEED LIFETIME WITHDRAWAL BENEFITS AND SIMILAR RIDERS

FIAs, VAs, and some RILAs offer GLWBs in return for an additional fee that is agreed on in the initial contract. The annuitant has the option but not the obligation to take a lifetime income starting at any age. The income is funded by selling investments held within the annuity. If those investments are exhausted, so that the contract has zero value, subsequent benefits are met by the insurer, and fees cease to be paid; hence, the GLWB offers insurance against an unexpectedly long life, but with both fees and benefits that are uncertain at the

20. A key technical difference between FIAs, RILAs, and VAs is that VA premiums are held within purchaser subaccounts, whereas FIA and RILA premiums are paid into the insurance company's general account. In consequence, fees are explicit in VAs but are instead reflected in the level of guarantees in FIAs and RILAs.

^{21.} The situation is not quite as dire as might be inferred from current short-term interest rates since insurance companies are able to invest at longer maturities and at higher rates of return than households.

^{22.} Technically, RILAs are a type of VA because they expose the holder to the risk of loss.

^{23.} Some RILAs offer protection in the form of a buffer, so that the insurer bears X percent of losses between (say) 10 and 20 percent, but 0 percent thereafter. 24. Though every annuity, by definition, must include an annuitization option (Pfau 2019, 152), this option is rarely exercised. The GLWB defers the

annuitization process until the contract value is depleted, with income from subsequent income payments being supported by the insurer.

^{25.} VAs offer the possibility of tax deferral to ages at which the marginal tax rate could be lower. But income is taxed at ordinary income tax rates, not at the lower rates applicable to qualified dividends and long-term capital gains.

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outset of the contract, making GLWBs distinct from income annuities.

Rather than making a lump-sum payment, as is the case for an income annuity, the fee that GLWB holders pay for the option (continuing after it is exercised) is typically a percentage of benefit base or contract value, both of which are affected by investment returns.²⁶ The benefit amount is easier to project than the fee: it depends on the age at which the GLWB option is exercised, multiplied by the benefit base. Prior to recent interest rate declines, typical amounts were 4.5 percent of the benefit base at ages 60–64, 5 percent at ages 65–69, 5.5 percent at ages 70–79, and 6.5 percent at ages 80 and above. The benefit base equals the premium paid, plus increases based on the deferral period or contract value, so in some contracts it also depends on investment returns.

For example, a rider may provide that the base on which the guaranteed income is calculated increases at some simple or compound interest rate from the date of purchase to the date of exercise of the annuity option. If the annual increase is 5 percent and the annuity option on a hypothetical \$1 million annuity is exercised at age 61, one year after purchase, the \$45,000 income is increased by 5 percent to \$47,250. With some riders, the amount of the benefit base is stepped up if the high-water mark of the contract value exceeds the purchase price. With yet other riders, roll-ups are stacked on step-ups (see exhibit 1, reproduced from Pfau 2019).

Increases in the benefit base resulting from the contract value creating a new high-water mark will typically result in increases in annuities already in payment. To illustrate, consider a hypothetical \$1 million annuity purchased at age 60. By age 61, the contract value (premium plus investment returns minus fees) has increased to \$1.1 million and the benefit base has increased to \$1.1 million. The GLWB option is exercised, resulting in an income of \$49,500 a year (\$1.1 million times 4.5 percent). By age 62 the contract value has declined to \$900,000 due to fees, the \$49,500 withdrawal, and poor investment

26. The contract value is simply the market value of the assets in the account and will be influenced by investment withdrawals and past returns.

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returns. The benefit base remains at \$1.1 million and the same income of \$49,500 is paid at age 62. By age 63 the contract value had increased to \$1.2 million (the investment returns exceeded fees and withdrawals by \$300,000). This established a new high-water mark for the benefit base, and the income is increased to \$54,000 (\$1.2 million times 4.5 percent).

The GLWB thus provides the household with a lifetime consumption floor, paid for by an annual fee defined as a percentage of typically either (a) the contract value or (b) the greater of the purchase price and the high-water mark. As a result, a higher-than-expected return raises the fees for the lifetime payments. At recent annuity rates, the minimum GLWB is somewhat less than the income obtainable on an immediate annuity-the purchaser sacrifices some income in return for liquidity, upside potential, and possible return on death if the asset has not been exhausted. Yet if an individual investor uses their entire stock of wealth to purchase the annuity with the GLWB rider, the income is considerably more (at 4.5 percent or more) than the 3 percent or so that Webb (2021b) estimates is the maximum amount a household could draw from unannuitized wealth while holding the risk of outliving its wealth at an acceptably low level. 27

3. HOW ANNUITIES PROTECT HOUSEHOLDS AGAINST LONGEVITY RISK

Recall our enumeration (in section 1) of the three major types of risks that retired households face—longevity, rate-of-return, and long-term care cost risks. Economists focus almost entirely on the role of annuities in insuring against longevity risk (a household's risk of outliving its wealth), even though financial professionals may emphasize a key role of annuities in reducing rate-of-return risk (with income annuities and deferred annuities having different properties in this regard). We begin with the economists' point of view by explaining the extent to which income annuities and the GLWB riders that feature in many FIAs and variable index annuities insure against longevity risk; we then incorporate rate-of-return risk. This discussion may be useful for both economists and financial professionals. While financial professionals are familiar with longevity risk in the context of annuity products, economists who study saving decisions for old age can contribute by clarifying how the mitigation of longevity risks interacts with other strategies that households consider outside of annuity settings. And, similarly, financial professionals may gain from understanding the standard analytical framework that economists use to study a wide range of financial decision-making by households.

3.1. WHY HOUSEHOLDS WANT TO MANAGE LONGEVITY RISK

We begin with the economics of managing longevity risk alone, which is simple enough that it requires relatively little math. Our discussion compares strategies to self-insure longevity risk versus holding various types of annuity products. Throughout, we maintain a critical assumption that is typical of virtually all economic models: households do not like uneven consumption streams, because it is more painful when consumption declines than it is enjoyable when consumption rises by the same amount. This makes households averse to risks to their future wealth, income, or spending needs, including the risk of outliving their savings and experiencing a decline in consumption. Meanwhile, we assume away all sources of risk other than an uncertain lifespan, so households do not value liquidity for any other self-insurance purpose.

This simple assumption is enough to deliver clear predictions about the value of self-insurance versus annuity purchase, given the availability and price of the latter.²⁸ In short, if annuities are unavailable, households should self-insure longevity risk, restricting current consumption early on so that money will be available if they live longer than expected, while perhaps accepting a declining level of consumption as they continue to survive. Some of this wealth will remain unconsumed in many households, generating what is sometimes called an accidental bequest.²⁹

28. In contrast, once we incorporate two kinds of risk in our later analysis, with one or both not fully insurable, we cannot obtain simple theoretical results about optimal strategies and will resort to Monte Carlo simulation to understand the value of particular rules-of-thumb strategies.

^{27.} The 3 percent in Webb (2021b) was inflation indexed. In contrast, the 4.5 percent is fixed in nominal terms.

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On the other hand, if offered an actuarially fair annuity, households should, under restrictive assumptions, fully insure their longevity risk, allowing a constant consumption level for the rest of their lives.³⁰ This scenario enables households to consume more because the money that would have passed as bequests is now available to be consumed. In the intermediate case, if annuities are available but actuarially unfair, the theory predicts a combination of partial annuitization and partial self-insurance: the more averse households are to uneven consumption across time, the more they will either restrict consumption if annuities are unavailable or pay extra (above an actuarially fair rate) to insure future consumption. Estimates of the actuarial unfairness of annuities are sensitive to assumptions regarding mortality and interest rates. Assuming corporate bond interest rates, annuities are actuarially unfair to individuals with population-average mortality, but much less actuarially unfair to not only those who actually buy annuities (whose mortality can be observed from individual annuitant mortality tables), but also to potential purchasers-those with annuitizable wealth (Dushi and Webb 2006).

In subsection 3.2 we explain the intuition for these results, and we discuss some practical situations where outcomes might diverge from these simple predictions about the benefits of annuitization.

3.2. INCOME ANNUITIES

A traditional income annuity is purchased in year t and pays out in year t + 1 onwards, whereas a DIA is purchased in year t and pays out in year t + k onwards. Yet it can be helpful for analytical purposes to think of an income annuity (including a DIA) as a series of **singleperiod annuities**, all purchased in year t, and paying out in year t + 1, t + 2 (or in year t + k for a DIA), and so on. This allows us to contrast the resulting consumption stream with what is enabled by purchasing a series of zero-coupon bonds that also pay out in year t + 1, t + 2, and so on.³¹ Both strategies insure against rate-ofreturn risk, which is why we can conveniently assume that risk away here, but both also leave differing exposure to longevity risk. Because the insurance company is able to reallocate money from those who die to those who survive, annuities provide households with future income more cheaply than households could achieve by self-insuring through the purchase of zero-coupon bonds. Because the probability of survival decreases with age, these so-called mortality credits increase.

To illustrate, we assume that both the insurance company and the household are able to earn the same investment returns of 3 percent after inflation.³² Following the zero-coupon bond strategy, an individual age 65 must invest \$54 to provide \$100 of consumption at age 85 (exhibit 2), should he survive to that age, which he has a 47 percent chance of doing. If he does not survive to age 85, the \$54 plus interest will be provided to his heirs. Following the annuitization strategy, and ignoring sales and expense loads, the individual could purchase a hypothetical annuity providing a single payment of \$100 at age 85 for \$26, just over half the cost of self-insuring; alternatively, if the insurance company's sales and expenses load was 10 percent, the cost would be \$29. Projecting to later ages, if the probability of survival to age 100 is only 5 percent, the annuity strategy would cost one-20th of what the self-insurance strategy would cost to finance consumption. This example demonstrates the magnitude of additional consumption at all ages made possible by an actuarially fair single-period annuity relative to self-insurance, while the annuity with a 10 percent expense load is less expensive than

^{29.} Theoretical models of annuitization assume that households know only whether their annual mortality risk equals, is better than, or is worse than the population average. Yet, the value of annuities depends on both the expected length of life and the risk of living longer than expected. Holding life expectancy constant, a reduction in uncertainty regarding the age of death reduces the insurance value of annuities. At the extreme, a household that knows its date of death with certainty will buy an annuity only if the date of death exceeds the household's break-even age. An emerging literature suggests that households may know, or think they know, something about their risk of living longer than expected (Post and Hanewald 2013). While financial professionals might be able to help households elicit information about their life expectancy or apply life tables, neither approach quantifies the risk of living longer than expected

^{30.} In fact, households will seek to equalize marginal utility, rather than consumption itself, across periods. One reason marginal utility and consumption might diverge is if the marginal utility of consumption varies with age or health status.

^{31.} A zero-coupon bond pays out at its date of maturity but does not make payments before then.

^{32.} In practice, insurance companies do not sell single-period annuities. It is possible to back out those companies' hypothetical sales and expense loads given assumed mortality and interest rates. Using data from 1985 to 1995, Mitchell et al. (1999) estimated sales and expense loads assuming annuity mortality and corporate bond yields of in excess of 10 percent. Loads appear to have narrowed since their research.



self-insurance from age 70 on, when the mortality credit becomes sufficiently large.

This exercise demonstrates that, faced with an actuarially fair annuity, the optimal strategy is to purchase a series of single-period annuities with payments starting immediately; in other words, the best strategy is to purchase a traditional income annuity. If, however, these hypothetical single-period annuities have an expense load, then households will tend to self-insure consumption at young ages-self-insuring for longer, the higher is the expense load and the lower the aversion to uneven consumption streams. In our example, the household is better off self-insuring consumption at ages 65-70 regardless of the household's preference parameters, at the cost of consuming slightly less at these ages than an actuarially fair annuity would allow. After age 70 the mortality credit exceeds the expense load and annuitization becomes more attractive than self-insurance. In other words, when annuity prices are worse than actuarially fair, it might be optimal to delay receipt of annuity income from time *t* to time t + k.

Nevertheless, the logic of mortality credits extends to the decision of whether to purchase a DIA at time t to commence at time t + k, or whether to delay purchase of single-period annuities until time t + k. The wealth of individuals who defer purchase and die between *t* and t + k is no longer available to the annuitant pool. The mortality credit for an annuity making a single payment at time t + k + 1 becomes, instead of $1/p_{t+k+1} - 1$ (the reciprocal of the probability of surviving to t + k + 1), $P_{t+k+1}/P_{t+k} - 1$ (the reciprocal of the probability of surviving to t + k + 1, conditional on having survived to t + k, minus 1 [one]), which is smaller. DIAs are thus a highly effective means of insuring consumption at advanced ages because the mortality credits are so high (Gong and Webb 2010), and because DIAs reduce risk by locking in annuity rates. Insurance companies may revise future annuity rates either upward or downward in light of changes in mortality, interest rates, or inflation. Currently available DIAs have one limitation: benefits are fixed in nominal terms, rendering them less appealing to individuals seeking inflation protection or exposure to the stock market.³³ While we omit further consideration of DIAs due to their unpopularity, we regard the

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lack of demand for these simple yet valuable products (Webb 2021a) as the most perplexing aspects of the annuity puzzle.

Another consideration that some households report as important is the desire to leave bequests (Ameriks et al. 2011). This may explain why some income annuities offer the converse of deferred annuities: rather than deferring receipt of income for some years before death, the insurer guarantees income for a certain number of years' premiums in the event of early death, through a life annuity with period certain. This type of annuity has the effect of eliminating mortality credits on the payments for those years, reducing the longer-term internal rate of return on the cash flows from the annuity. At least in theory, moreover, a household that wishes to safeguard a bequest has the alternative of purchasing a portfolio of bonds maturing on different dates with coupons and returns of principal matching the amounts it would otherwise receive from an annuity-spending the bonds if it lives or bequeathing the bonds if it does not. The annuity route has the merit of simplicity and could yield larger payouts if the insurance company can earn a higher return, net of expenses, than that available to the household. But, for some, the annuity route has the disadvantage that the amount of the bequest depends on the annuitant's age at death.

Alternatively, the appeal of a life annuity with period certain could rest on behavioral economic models that incorporate psychological motives or cognitive mistakes. Period certain payments in the event of premature death may overcome a psychological barrier to annuity purchase. Consistent with evidence found in Brown (2009), some individuals may view the purchase of an annuity as augmenting risk—of dying before getting paid (an especially unusual form of preferences in an economic model)—rather than reducing risk.³⁴

3.3. GUARANTEED LIFETIME WITHDRAWAL BENEFITS

FIAs and VAs, along with RILAs, often contain a GLWB rider. This rider guarantees a withdrawal for life—one that the insurer continues to pay even if the withdrawals exhaust the value of the underlying asset; unlike with an income annuity, though, the lifetime benefits are not certain upon purchase of the contract. Moreover, rather than exchanging a lump sum for a lifetime flow of income, the individual pays fees for the rider that are not certain upon purchase. This link to market returns— which could increase the GLWB payout as well as the value of the underlying asset, plus the return of the contract value on death—explains why GLWB riders provide a smaller guaranteed income than immediate annuities, as a percentage of the annuity purchase price.

It means, furthermore, that GLWB riders eliminate neither longevity risk until they are exercised, nor investment risk (which affects the fee) upon exercise. They cannot therefore be evaluated using the simple framework of the previous section, which weighs the actuarial fairness of the terms of the annuity against the cost of self-insurance. Nor can their value to households be determined by calculating the value of the financial option embedded in the rider, because option pricing techniques rest on an assumption of complete markets; that is, the assumption is that all combinations of uncertain outcomes should be insurable. Instead, economists need to use the same numerical optimization techniques that we discussed in 1.2, treating the decision of when to exercise the GLWB option as another household choice. This will allow researchers to understand the role of both realized and ongoing expected investment returns from the underlying annuity product (which affect the exercise date on the option) and initial expected returns (which determine affect the decision to purchase the option). For example, the confluence of two bad outcomes-bad investment returns and outliving assetstogether increase the value of exercising the GLWB op-

^{33.} Currently available immediate income annuities have the same limitation as DIAs, but the exposure to inflation risk with immediate income annuities is less significant because the income is payable in the near future. Other deferred annuity products perhaps reduce inflation risk through their link to stock market investments.

^{34.} While economists are accustomed to modeling bequests to heirs as effectively providing utility after death, it is difficult to incorporate disutility after death from not doing something one should have done, given knowledge only available after death, as this would call into question any number of other decisions during one's life.

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tion. Given the critical role of rate-of-return risk to this valuation, we therefore postpone a discussion of optimal decision-making related to GLWB riders until section 4.

4. INTRODUCING RATE-OF-RETURN RISK

Annuities of different types face quite different exposure to market rates of return. Therefore, the advantages of holding each kind cannot be fully understood, nor compared to self-insurance strategies, without incorporating both rate-of-return risk and longevity risk. This can help us understand situations in which deferred annuities, with or without GLWB riders, reduce exposure to both kinds of risk. To understand the resulting economics, we undertake two simulations:

1. Variable annuities simulation. We analyze the consequences of purchasing a VA with a GLWB rider depending on how risky a household's investments are, along with how much they consume. Our model in subsection 4.1 compares the probability of running out of money (and thus being in a position to benefit from the GLWB payment) for someone who either

- self-insures with a constant consumption path;
- self-insures with a constant consumption path, though allowing consumption to rise if investment returns are high (which mimics the payout from a GLWB rider); or
- purchases a VA and pays for a GLWB rider.

The results discussed in subsection 4.2 help us understand the extent to which GLWB riders insure against longevity risk in an environment with risky returns. The analysis demonstrates this by showing when purchase may be valuable, given the consequences of choosing particular consumption paths; while not optimal, those paths nevertheless resemble plausible rules of thumb that can guide retirees as they draw down their wealth.

2. GLWB exercise simulation. Our model in subsection 4.3 analyzes the consequences for overall utility of when an individual investor exercises a GLWB option (which might optimally occur before they run out of wealth),

along with how much they invest in a VA. Our results in subsection 4.3 help us pinpoint the value of the GLWB rider as longevity insurance, given uncertain investment returns and a particular consumption path.

In subsection 4.5 we consider long-term care riders as an alternative to long-term care insurance. Finally, in subsection 4.6 we briefly consider RILAs and FIAs as distinct from VAs.

4.1. VARIABLE ANNUITIES SIMULATION: APPROACH

We build a formal dynamic model in order to evaluate the likelihood of exhausting household wealth, depending on consumption and investment decisions that households must consider when managing both longevity and rate-of-return risk. We carry forward the fundamental assumption that households dislike uneven consumption streams, and incorporate an extensive set of additional assumptions. Moreover, to simplify the task of comparing outcomes, we evaluate a limited set of strategies rather than determining optimal choices among a full range of alternatives. Of course, the task of future economic research is to relax the assumptions that we impose while solving for optimal behaviors.

Assumptions about Wealth Drawdown Strategies. Our drawdown strategies build, reluctantly, on the widely cited paper by Bengen (1994). Bengen argued that households consuming 4 percent of their initial wealth faced a small, and arguably acceptable, risk of outliving their wealth. We implement a modified version of this 4 percent rule, though in fact we regard the 4 percent rule-or any single-valued rule-as having the sole virtue of simplicity.35 The analysis underpinning the 4 percent rule is deeply flawed, and the rule is highly suboptimal (Webb 2021b) because it fails to respond to realized returns: If returns are better than expected, households should be allowed to increase consumption. Conversely, households should reduce consumption if exhaustion is imminent, whether that exhaustion is a result of poor returns or an unexpectedly long life. It is noteworthy that VAs enable households to do this very

^{35.} The analysis is based on only 37 overlapping completed 30-year periods, far too few to reach statistically valid conclusions. Bengen (1994) fills in return histories for incomplete 30-year periods using average returns, in effect assuming away risk.

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thing: to increase consumption if investment returns are better than expected, through the step-up benefit. Notwithstanding its flaws, though, the 4 percent rule is widely known and perhaps superior to strategies such as spending only interest and dividends.³⁶

To undertake this benchmarking analysis, we start our simulations at age 60 and consider four possible ages (ages 60, 65, 70, or 75) at which the household commences drawdown of wealth to support consumption or, if an individual holds an option, exercises the GLWB rider to enjoy the same consumption path.³⁷ We now introduce three drawdown strategies: ³⁸

1. Constant consumption rule: The individual consumes a fixed percentage of initial wealth, while paying mutual fund fees on assets. The drawdown rates are chosen to match the income that could be obtained before step-up under a VA GLWB rider (4.5 percent of wealth annually starting at age 60, 5.0 percent starting at age 65, 5.5 percent starting at age 70, and 6.0 percent starting at age 70.

2. Do-it-yourself, with step-up mimicking a GLWB rider: Drawdowns start at the same level as in strategy 1, but are increased in the event that the market value of the portfolio exceeds the initial amount invested (analogous to the VA step-up provision).

3. VA with a GLWB rider: Drawdowns are increased as in strategy 2 through exercise of a GLWB rider; the individual also pays VA fees and GLWB fees.

What is notable about strategy 3 is that, in the event that the household exhausts its wealth, it would still retain a lifetime income from its GLWB rider. In the other scenarios, consumption must drop to the floor provided by the Social Security benefit when wealth is exhausted (though higher consumption may be enabled at younger ages because individuals do not have to pay for the GLWB rider).

Assumptions about Portfolio Allocations and Investment Returns. For investment options, we will compare an all-bond portfolio and a portfolio allocated with 30 percent bonds and 70 percent stocks, the maximum risk allowed by typical VA contracts. While households that are more risk averse might be better off with a smaller stock allocation, we defer exploration of optimal investment allocation to future research. Furthermore, we incorporate fees and will assume either prospective returns or higher historic returns, as described in appendix A.³⁹ With historic returns on stocks having been so high, we are skeptical that they should be counted on in the future, so we view our adjustments for somewhat less-buoyant prospective returns as a better predictor of outcomes. Notably, we do not assume a worst-case scenario for prospective stock returns. We base our assumed returns on prospective price-earnings ratios, which historically have tended to be optimistic, and not on, say, the cyclically adjusted price-earnings ratio, which would depress prospective returns further.⁴⁰

36. An under-appreciated danger of following a strategy of spending interest and dividends only is that the need for income distorts the portfolio so that it fails to achieve an optimal trade-off between risk and return (Webb 2009).

^{37.} We assume that the benefit base (the dollar amount on which the income payments are calculated) is increased during deferral should the contract value hit a new high-water mark, but we do not assume any fixed minimum age-related increase. We ignore required minimum distribution rules because, while those rules require wealth to be withdrawn from individual retirement accounts, they do not require that retirees consume that withdrawn wealth.

^{38.} The analysis is for illustrative purposes only and we do not consider strategies in which a portion of wealth is invested in an annuity, even though these strategies likely dominate all-or-nothing strategies. Moreover, before the age at which drawdown commences, we treat individuals as working and consuming their pay, so no decisions about saving occur. (This, too, is indicative of a non-optimizing model, since an individual should optimally save or dissave at those earlier ages.)

^{39.} We treat bonds as a risky asset. Campbell and Viceira (2002) argue that, to a long-term investor, and ignoring default risk, bonds of appropriate durations are the true risk-free asset because coupons and redemptions can be matched to the household's consumption requirements. A household adopting this strategy could insure their consumption to very advanced ages and, for all practical purposes, could eliminate the risk of outliving their wealth. In practice, few households do this—they invest in a bond exchange-traded fund or a mutual fund. In contrast, insurance companies hedge their obligations to annuitants.

^{40.} The cyclically adjusted price-earnings ratio is designed to smooth out fluctuations in earnings resulting from the business cycle and is significantly higher than the 2021 projected price earnings ratio, implying lower earnings going forward (Shiller 2016).

Assumptions about Household Structure, Income, and Wealth. We consider the case of a single man with survival probabilities based on annuitant mortality tables. We assume \$1,800 a month in income from Social Security beginning at age 62 and \$300,000 in financial assets.⁴¹ We ignore taxes and assume a time discount factor of 3 percent.⁴²

Method. We use Monte Carlo simulations to determine the probability that assets are exhausted in each of the three possible drawdown strategies. We simulate the impact of each strategy on the household given thousands of possible draws of uncertain investment returns and survival from the assumed distributions.

4.2. VARIABLE ANNUITIES SIMULATION: RESULTS

We compare worst-case scenarios under various investment and step-up strategies for consumption. Therefore, we compute the probability of an individual exhausting their wealth before death, which would leave only Social Security benefits for consumption; the exception is the VA scenario, which provides lifetime income from the GLWB in exchange for paying premiums.⁴³ Exhibit 3 reports these probabilities depending on the consumption path and investment allocation choices. We emphasize that this does not constitute advice; in other words, households should not choose between options simply on the prospect of wealth exhaustion, since total lifetime utility varies with commencement age (so results across columns do not yield the same utility) and since the GLWB option ensures that income continues even after wealth is exhausted (so results across rows do not yield the same utility)

First, consider the impact of investment returns and investment strategies. Unsurprisingly, the probability of running out of wealth is sensitive to returns, with historic equity returns in our 70 percent equity—30 percent bond portfolios eliminating most risk—and therefore rendering deferred annuities and other structured investment products relatively poor investments. It is therefore instructive, not to mention prudent, to consider somewhat less-buoyant prospective returns.

Next, consider an individual who begins drawing down wealth at age 60, with a portfolio allocated 70 percent to stocks, 30 percent to bonds. Assuming prospective returns, the risk of outliving wealth is high: it is 28.1 percent without step-up (when consumption is maintained as a constant fraction of initial wealth), 44.5 percent with increases in wealth drawdown equal to those provided by a VA step-up, and 75.5 percent with VA stepup along with GLWB fees.⁴⁴ This assumption highlights the importance of protected income when someone is exposed to both rate-of-return risk and longevity risk together (though, as we have noted, the assumption does not pin down what type of protected income product is optimal). Although paying the GLWB premium increases the likelihood of needing protected income, the risk remains considerable without the premiums, with an almost one-half probability of destitution (which seems higher than many would want to bear) for what is otherwise the same consumption path before destitution as the VA with GLWB rider provides. Notably, an all-bond portfolio increases the risks to 58.6 percent, 65.1 percent, and 86.3 percent. Although the all-bond portfolio has a lower variance of returns than the riskier portfolio, this is insufficient to compensate for the lower expected return.

^{41.} The Social Security benefit not only adds realism but also ensures bad investment returns can never result in destitution and negative infinity utility. Because most annuities are issued in nominal terms, we assume income is fixed in nominal terms so that its real value is eroded by inflation, whereas Bengen (1994) assumes a constant real income. Our assumption, yielding declining real consumption over time, is consistent with optimal consumption flows under some restrictive assumptions: if the rate of interest equals the rate of time preference, rate-of-return risk is absent, and the marginal utility of consumption is age-invariant, households who do not annuitize will prefer greater consumption earlier in retirement when they are more likely to be alive to enjoy it. For example, if households exhibit constant relative risk aversion, the optimal annual percentage decline in consumption will equal the inverse of the coefficient of risk aversion, multiplied by the annual mortality risk.

^{42.} As noted earlier, we ignore taxes in our analysis although some financial professionals might consider tax deferral to be a major advantage of holding annuities. The implicit assumption that justifies this is that annuities and all other assets in these simulations are held in tax-deferred accounts.

^{43.} Naturally, a household that is at increasing risk of outliving its wealth, by virtue of some combination of unexpectedly long life and unexpectedly poor investment returns, should cut its consumption before this actually happens; this consumption reduction is what an optimizing model would deliver. The probabilities that we report nevertheless benchmark the degree to which each strategy exposes the household to this unpleasant contingency.

^{44.} As a rough approximation, about half of the difference between the probability of exhaustion when the individual does not purchase an annuity but instead steps up withdrawals following favorable investment returns, versus purchasing a VA and paying GLWB fees, is due to the higher fees on annuities than on similar unannuitized investments. The other half is the result of GLWB fees.

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	WITHDRAWAL RATE AND COMMENCEMENT AGE			
	4.5% Start at 60	5.0% Start at 65	5.5% Start at 70	6.0% Start at 75
PROSPECTIVE RETURNS				
a. Constant consumption rule (consume Social Security if wealth is exhausted)				
100% bond	58.6%	56.3%	48.4%	29.7%
70% stock, 30% bond	28.1%	28.8%	25.7%	16.7%
b. Do-it-yourself step-up: Step up if assets exceed portfolio high-water mark (consume Social Security if wealth is exhausted)				
100% bond	65.1%	60.7%	52.1%	32.3%
70% stock, 30% bond	44.5%	42.1%	36.3%	22.8%
c. VA and GLWB rider: Step up if assets exceed high-water mark + VA fees + GLWB fees (consume Social Security and GLWB if wealth is exhausted)				
100% bond	86.3%	82.4%	75.1%	58.4%
70% stock, 30% bond	75.5%	71.4%	62.4%	45.6%
HISTORIC RETURNS				
a. Constant consumption rule (consume Social Security if wealth is exhausted)				
100% bond	6.5%	9.0%	9.3%	4.1%
70% stock, 30% bond	2.6%	3.6%	3.9%	2.5%
b. Do-it-yourself step-up: Step up if assets exceed portfolio high-water mark (consume Social Security if wealth is exhausted)				
100% bond	11.7%	14.1%	13.5%	5.8%
70% stock, 30% bond	7.6%	8.5%	8.7%	4.5%
c. VA and GLWB rider: Step up if assets exceed high-water mark + VA fees + GLWB fees: (consume Social Security and GLWB if wealth is exhausted)				
100% bond	61.5%	59.0%	51.5%	31.9%
70% stock, 30% bond	35.4%	34.6%	30.9%	18.2%

EXHIBIT 3. Probability of Exhausting Wealth

Source: Authors' calculations.

Note: See appendix A for further details.

Furthermore, the probability of an individual outliving their wealth decreases as they delay the commencement of drawdown or exercise of the GLWB option. The decrease that is gained—by postponing withdrawals and leaving funds to accumulate—more than offsets the larger monthly withdrawals that we assume upon delay—though only a quite substantial delay in exercise until age 75 reduces the risks uniformly to under one-third. Of course, in this scenario, a fully optimizing model would indicate that the individual should invest only part of their wealth in a VA, while drawing down non-annuity wealth during the period between retirement and the date of GLWB exercise.

In contrast, when we assume historic returns, individuals investing in a portfolio of 30 percent bonds and 70 percent stocks face only a small risk of outliving wealth when following constant drawdown strategies, consistent with Bengen (1994). The risk is 2.6 percent if they start drawing down at age 60, while it is a still modest 6.5 percent if they invest entirely in bonds. The risk of outliving wealth increases if the individual consumes more when hitting a high-water mark in their asset returns. Yet, at 7.6 percent, the risk remains somewhat low if the individual invests partly in stocks, while the risk becomes moderate if the individual invests in a bond portfolio instead. The only scenarios in which the individual faces a substantial risk of outliving wealth, given high historic returns, is by also paying GLWB fees, where the risk increases to above 30 percent in most cases; in that case, of course, the GLWB will provide an income flow until death. In this particular (and, we argue, unusual) scenario, therefore, the GLWB rider fees are high enough to significantly increase the probability of needing a GLWB payout and to significantly reduce the expected value of assets passing on at death. Thus, less-risk-averse households with a strong bequest motive that relied on historical data (erroneously in our view) might decide not to purchase a GLWB rider.

4.3. GUARANTEED LIFETIME WITHDRAWAL BENEFIT EXERCISE SIMULATION: APPROACH

The analysis so far shows that VAs can mitigate longevity and rate-of-return risk, but it does not tell us whether the insurance is worth the GLWB fee. Although an immediate income annuity might also mitigate such risks, figuring out the utility of a GLWB rider is more difficult because the rider's value depends on choices the household makes after purchase, such as how to invest the assets within the VA and when to exercise the GLWB option. To further complicate matters, those decisions must be made jointly with the decision of how to invest assets held outside the annuity.

As detailed in subsection 2.4, the income offered by a GLWB rider depends on either the initial investment or current market value as well as on the age of exercise. Assets in the annuity are gradually liquidated to pay for the lifetime benefit withdrawals, and payments continue out of insurance company funds if the account is exhausted. Therefore, unlike the relatively simple predictions about when to purchase an income annuity (depending on annual survival probabilities, the degree of actuarial unfairness, and the household's aversion to uneven consumption flows), the optimal timing of when to exercise the GLWB rider also depends on what has happened and what is expected to happen with investment returns. Furthermore, the optimal decision of whether and when to purchase this option is solved by working backwards from an assumed maximum survival age, and then comparing immediate exercise of the option versus postponing the decision until the next period. By so doing, an individual must consider all possible return realizations, and also must consider that the household makes optimal consumption and asset allocation decisions conditional on whether it exercises or defers the option.

Suppose the GLWB rider is exercised at time t. In that case, the expected present value of the rider equals the expected present value of the annuity income minus the GLWB rider fee. Delay from time t to t + 1 in exercising the GLWB option will affect both expected present values. Income will be received for one fewer year, but the annual amount may increase either by aging past a GLWB payment threshold—for example, from receiving 4.5 percent at 64 to 5.0 percent at 65—or by attaining a new high-water mark in the asset value. The GLWB rider fee offers further complications, since it is typically defined as a percentage of either the contract value or the greater of the purchase price and the high-water mark;

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that fee will cease when the investments in the annuity are exhausted. The effect of delay on the expected present value of GLWB fees is ambiguous. Delay enables the account to grow for one more year, postponing exhaustion and the termination of the fee payments. Delay may also result in larger annuity payments due, for example, to the use of higher age-based payout rates and a higher probability of the benefit base hitting a new high-water mark if distributions are not being taken, which could hasten exhaustion. Households, though, do not care about maximizing some risk-adjusted measure of net benefits but rather care about the utility of consumption. Therefore, income flows must be translated into household utility via decisions about saving; this is grist for future research by economists.

To gain some insights into the value of GLWB riders, we conduct Monte Carlo simulations and compute the impact on lifetime utility of exercising the GLWB option at ages 60, 65, 70, or 75. As before, we consider a single man age 60 with \$300,000 in financial assets and \$1,800 a month Social Security income starting at age 62.45 We assume a standard utility function in which individuals dislike uneven consumption streams (constant relative risk-aversion preferences), with moderate levels of risk aversion, bracketing the levels believed to be exhibited by most households (Chetty 2006). We focus exclusively on the allocation of 70 percent of wealth to stocks and 30 percent to bonds when investment returns are assumed to be somewhat less buoyant going forward than in the recent past, and now consider whether the individual invests 25 percent, 50 percent, or 75 percent of wealth in a VA. One of the potential benefits of a VA with GLWB rider is that the insurance against bad market returns increases the share of wealth that households should optimally allocate to stocks, but we defer this question to future research.

4.4. GUARANTEED LIFETIME WITHDRAWAL BENEFIT EXERCISE SIMULATION: RESULTS

Our metric for understanding the value of the GLWB option is annuity-equivalent wealth: If a GLWB were not available, how much more (or less) wealth would the

individual need in compensation to be as well off (or less well off) as when purchasing a GLWB rider? As before, the analysis does not consider optimal behavior. We also note the same important limitation as earlier in 4.2: the analysis does not incorporate other annuity products, such as income annuities, that might be advantageous as well. Exhibit 4 reports results.

Except for the most risk-tolerant individuals, annuity equivalent wealth almost invariably exceeds one which means that the individual is better off holding the GLWB than holding nothing—and sometimes exceeds one by substantial amounts. To illustrate, annuity equivalent wealth is 1.266 for an individual in the most-riskaverse category (with a coefficient of risk aversion of five), who allocates 50 percent of wealth to a VA and exercises the variable GLWB option at age 60. Since the individual started with financial assets of \$300,000, annuity equivalent wealth of 1.266 implies that 26.6 percent of that would be required as compensation to give up the opportunity to invest 50 percent of wealth in a VA—or \$79,800.

Several patterns emerge. The GLWB rider is, of course, more valuable to individuals who are more risk averse. Although, under our assumed utility function, the marginal value of further annuitization declines as larger shares of wealth are annuitized, it is also true that annuity equivalent wealth is higher when 50 or 75 percent of wealth is annuitized than just 25 percent; that result reflects our decision rule that individuals are allowed to exercise their annuity option earlier than planned if non-annuity assets are exhausted. This result highlights the value of holding riskier assets in the VA and safer assets outside-subject to constraints imposed by the insurer, which no doubt arise because the value of an option (in this case, to exercise the GLWB) rises with the volatility of the underlying assets. The results point to the importance of understanding asset allocation decisions in future research. Interestingly, when only 25 percent of wealth is placed in the annuity contract it is better to exercise the annuity option early (annuity equivalent wealth is higher when the GLWB option is exercised at younger ages); when 75 percent is annuitized, however, it is better to delay, especially if the individual

45. To simplify the analysis, we also give the household \$1,800 a month labor market earnings from age 60 to age 62.

SHARE OF WEALTH INVESTED IN ANNUITY	WITHDRAWAL COMMENCEMENT AGE						
	60	65	70	75			
	COEFFICIENT OF RISK AVERSION EQUALS 1 (LEAST RISK AVERSE)						
25%	0.977	0.961	0.983	0.959			
50%	0.973	0.940	0.954	0.949			
75%	0.968	0.984	0.989	0.989			
COEFFICIENT OF RISK AVERSION EQUALS 2							
25%	0.998	0.979	0.997	0.969			
50%	1.006	0.966	0.979	0.974			
75%	1.007	1.023	1.028	1.028			
COEFFICIENT OF RISK AVERSION EQUALS 3							
25%	1.029	1.007	1.018	0.987			
50%	1.053	1.005	1.016	1.011			
75%	1.064	1.080	1.085	1.085			
COEFFICIENT OF RISK AVERSION EQUALS 4							
25%	1.077	1.050	1.053	1.016			
50%	1.129	1.065	1.077	1.072			
75%	1.156	1.172	1.177	1.177			
COEFFICIENT OF RISK AVERSION EQUALS 5 (MORE RISK AVERSE)							
25%	1.160	1.123	1.114	1.068			
50%	1.266	1.170	1.185	1.180			
75%	1.325	1.345	1.353	1.353			

EXHIBIT 4. Annuity Equivalent Wealth

Source: Authors' calculations.

Note: This exhibit displays risk-adjusted measure of value of a VA GLWB rider. See appendix A for further details.

is risk averse. When a high percentage of wealth is annuitized, the individual annuitizes early when financial returns are poor, non-annuity assets are exhausted, and there are scant prospects for post-annuitization stepups in annuity payments. In contrast, the individual delays annuitization when financial returns are favorable, non-annuity assets remain unexhausted, and there are good prospects for post-annuitization step-ups in annuity payments. We conclude from the analysis that households need to act strategically to maximize the value of GLWB riders, since annuity equivalent wealth varies considerably across the different choices they can make. They need to consider what share of their financial assets to invest in the VA; to choose an optimal annuity and non-annuity asset allocation, perhaps with dynamic rebalancing; and to exercise their GLWB option optimally in the light of realized investment returns.

4.5. LONG-TERM CARE RIDERS

An additional, and considerable, source of uncertainty that households face in retirement revolves around late-life-care costs (Friedberg et al. 2014). Traditional annuities result in a loss of liquidity that may be disadvantageous to households facing uncertain healthcare and long-term care costs. A potential solution is to purchase a stand-alone long-term care insurance policy. Unlike the case for income annuities, however, theoretical models predict that many single individuals would shun even an actuarially fair policy because much of the benefit accrues to the government in the form of lower Medicaid costs rather than to the policyholder (Brown and Finkelstein 2008). Worse, insurance companies frequently increase premiums on existing policies and policyholders let their policies lapse; often the lapsers are those most at risk of needing care (Friedberg et al. 2019), leaving those policyholders worse off than if they had never purchased coverage.

Theoretical models indicate that adverse selection in both annuity and long-term care insurance markets could be mitigated by bundling a traditional annuity and long-term care insurance policy (Brown and Warshawsky 2013). The idea has received valuable attention (Super and de Cervens 2022), though we are aware of only one insurance company with a VA that included a long-term care rider, now withdrawn. Purchasers of the rider receive benefits in case the need for long-term care arises, with the duration of the benefits being capped. Recently, instead, the insurance industry has begun to offer long-term care insurance riders to life insurance policies, thus allowing policyholders in need of care to tap death benefits.

We regard these innovations as worthy of further study. The addition of a long-term care rider likely addresses three of the drawbacks of traditional long-term care insurance. First, because the premium is paid in a lump sum, there is less temptation to lapse the policy, forfeiting benefits. Second, the policyholder does not face the risk of premium increases because the rider fees are fixed at the outset. Third, although we have not evaluated actuarial fairness of the long-term rider benefits, it is plausible that the insurance company will be willing to price those benefits more competitively than on a traditional stand-alone policy, if it believes that adding such benefits will reduce adverse selection in the annuity market. This is one of the questions that merit investigation in this regard.

As is the case with deferred annuities, analysis of the value of long-term care insurance for households has involved limiting assumptions. Theoretical models have focused on single individuals, have examined only traditional long-term care policies, and have disregarded the option to annuitize wealth. When making annuitization and long-term care insurance purchase decisions jointly, including the decision as to whether to purchase a VA with a long-term care rider, married couples must consider not only their willingness to forgo current consumption to ensure access to non-Medicaid care, but also the impact of their decisions on the surviving spouse. The analysis will require careful modeling of Medicaid rules because they apply to both annuitized and unannuitized wealth. The rules vary from state to state and depend on whether the assets are held in a taxable account, a Roth IRA, or a traditional IRA, and whether required minimum distributions are being taken from a traditional IRA. The rules as they apply to annuities also depend on whether the annuity has a cash surrender value. We defer an assessment of VA long-term care riders until further research has been undertaken.

4.6. REGISTERED INDEX-LINKED ANNUITIES AND FIXED INDEXED ANNUITIES

While our analysis has focused on VAs, which involve mutual fund–like exposure to market risks, RILAs and FIAs permit households to manage exposure to this source of risk. According to conventional wisdom, households should rebalance away from stocks in favor of bonds as they age. The rationale is that, as people age and the present value of their low-risk human capital (i.e., of their lifetime earnings) declines, they should offset this decline by taking less risk with their financial assets (Jagannathan and Kocherlakota 1996; Samuelson 1963). A RILA can provide similar protection, allowing households to set a floor on their risk and thus permitting them to enjoy some upside risk through exposure to the equity premium (Moenig 2021b), while a FIA offers protection with a floor equal to the premium paid. RILAs have the potential to protect against not only market crashes but also against extended periods of subpar returns. Their limitation is that the crediting term—typically one year and as long as six years—remains shorter than the time horizon of most households: a household in their 50s entering what one insurer in an advertising campaign has termed the "retirement red zone" needs protection until the age at which those assets are earmarked for consumption or perhaps are used to purchase some other annuity product providing capital protection.

RILAs provide downside protection that may be particularly valuable in the years immediately preceding retirement. Modeling their value will be challenging because there are many possible post-retirement drawdown strategies that a household might adopt and many possible assumptions that might be made about asset returns.⁴⁶

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Although VAs dominate the annuity market, surprisingly few studies have investigated their value to households seeking to manage investment and longevity risk. When considering households currently age 60-70, for example, the downside risk from this perspective is that at least one member will live into their 90s or beyond. This makes their time horizon for considering future market returns quite lengthy. Other mechanisms besides annuities exist for insuring late life consumption, but all come with drawbacks. Households can reduce the percent of unannuitized wealth they consume. This self-insurance approach will reduce but can never eliminate the risk of outliving their wealth but may make sense for those with a strong bequest motive. Households can adopt a drawdown decision rule that responds to market drops and not just gains. Yet market fluctuations can be severe, and households need to have the ability and willingness to stomach large fluctuations in consumption. From October 2007 to March 2009, the United States equity market fell by 50 percent. The market then recovered and went on to reach new heights—but, not knowing that would happen, the rational and correct response would have been to cut consumption by 50 percent.⁴⁷ If households are not willing to face that risk, they need to either reduce their exposure to the stock market, forgoing the equity premium, or purchase insurance against catastrophic downturns.

Our analysis shows that households have the potential to enhance household financial well-being, both in retirement and during the years preceding retirement. In contrast to income annuities, which require no further decisions after purchase except in the allocation and drawdown of unannuitized wealth, households seeking to maximize the value of VAs face complex choices as to when and how to exercise the options embedded in the contract. Calculations that assume some arbitrary strategy, such as those we assume here in our Monte Carlo simulations, will understate the value of these products. Furthermore, as we have emphasized throughout, in cases where individuals cannot insure away all the risk they face, then the strategies that extract the most income from the insurer are not necessarily those that maximize the value of annuities to the policyholder. Further research is needed, research that uses numerical optimization techniques.

The ongoing nature of the choices faced by policyholders has implications for financial advisors and plan sponsors. The majority of VAs are purchased through financial advisors. Those advisors would benefit from academic research to assist them in guiding their clients. Similarly, retirement plan sponsors and their advisors would benefit from research to assist them in guiding plan participants.

^{46.} The value of protection against investment risk during the years immediately preceding retirement depends on the household's asset allocation, on whether the household intends to annuitize at retirement, and on the household's beliefs regarding the correlation of returns between asset classes. For example, a household invested in long-maturity bonds will suffer a reduction in the value of its investments if interest rates increase. But, for households that plan to annuitize, that loss will be partly offset by more-favorable annuity rates that the increase in interest rates allows. Likewise, a household that plans a drawdown of unannuitized wealth will be able to recoup some of its losses to the extent that it is able to reinvest maturing bonds at higher yields. The impact of declines in stock process depends on whether the declines are precipitated by an increase in the rate at which future profits are discounted (in which case the outcome will be similar to that for bonds) or a reduction in anticipated profits (in which case the household will be worse off by the decline in stock prices).

^{47.} The response would depend on whether the household believed the prospects for corporate profits had dimmed by 50 percent or whether the rate at which future profits were being discounted had increased. The latter explanation would justify a smaller but still significant reduction in consumption. Of course, households have no means of telling which explanation predominates and, even worse, could be panicked into selling, thus missing out on the recovery.

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APPENDIX A. ASSUMPTIONS

Appendix A describes in detail our assumptions from the two simulation exercises, described in subsections 4.1–4.4.

Mortality: From age 60 using the Society of Actuaries' 2012 individual annuity mortality (IAM) table, projected using Projection Scale G2, so that mortality is representative of the 1961 birth cohort.

Historic Asset Returns: Based on Ibbotson Associates (2017) data on nominal total returns for large capitalization stocks and investment grade corporate bonds covering the period 1926–2016.

$\mu \begin{pmatrix} 0.1195 \\ 0.055 \end{pmatrix}$	Σ	0.039	0.0024
		0.0024	0.0069/

Prospective Returns: Households choose the same asset allocation both within and outside the annuity. For our prospective return model, we assume the interest rate on investment grade corporate bonds declines to the 2.58 percent 4 November 2021 yield on the seasoned Aaa corporate bond, reported by the Federal Reserve Bank of St. Louis (Moody's 2021). We further assume that expected stock returns equal 7.1 percent nominal, equal to the inverse of the November 5, 2021, 21.6 forward price earnings ratio on the S&P 500 reported by Yardeni Research, plus the 2.44 percent long-term inflation rate projected by the Federal Reserve Bank of St. Louis Q3 2021 Survey of Professional Forecasters. We retain the historic variance-covariance matrix.

Household Assets and Income: We assume financial assets of \$300,000 and Social Security income of \$1,800 a month. Withdrawals are made at the start of the year and returns are realized and fees paid at the end of each period.

Household Preferences: We assume a constant relative risk aversion utility function and a rate of time preference of 3 percent.

Investment Expenses: We follow Steinorth and Mitchell (2015) and assume GLWB fees of 100 basis points, a mortality and expenses fee of 124 basis points, administra-

tive and distribution fees of 18 basis points, and investment charges of 105 basis points. Households face the same investment charges on both annuity and non-annuity assets. The remaining fees are incurred only by households investing in VAs; we also assume that those households choose the GLWB rider.

Calculation of Annuity Equivalent Wealth: We normalize assets and income to 5,000 and 30 units. We calculate the average discounted lifetime utility of 1,000 annuity holders. Then we use optimization routine to find the minimal amount of wealth the individuals needed to achieve the same average discounted lifetime utility using only direct investment. Then we divide this amount by the initial 5,000 to get the annual equivalent worth. All the numerical optimization routines are set to a tolerance level of $10 - {}^{64}$.

Calculating Risk of Exhausting Assets: When calculating the risk of exhausting assets (exhibit 3), we assume the household takes no withdrawals prior to exercising the GLWB at age 60, 65, 70, or 75.

Rules Followed in Annuity Equivalent Wealth Calculation: Prior to annuitization, the household withdraws 4.5 percent a year of total initial financial assets from unannuitized wealth with step-ups if the remaining total of annuitized and unannuitized financial assets exceeds initial assets. Household members exercise the GLWB option at age 60, 65, 70, or 75, or earlier if they exhaust their non-annuity financial assets prior to their planned annuitization age. Initial annuity income at exercise ages of 60, 65, 70, or 75 equals 4.5 percent, 5.0 percent, 5.5 percent, or 6.0 percent, respectively, of benefit base. For the year in which they annuitize, they rebase their drawing from unannuitized financial assets so that the total of draw and annuity income equals $D_{t}^{*}(W_{tot}/W_{a})$, which is the draw from the annuity multiplied by total wealth divided by the contract value of the annuity. Both annuity income and the draw from unannuitized financial assets are stepped up in subsequent years if the value of each asset class exceeds the high-water mark set in the year the GLWB option was exercised.

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APPENDIX B. SUMMARY OF ACADEMIC LITERATURE ON VARIABLE ANNUITIES

Huang, Milevsky, and Salisbury (2014) explore the option value of the GLWB rider. Like all options, the GLWB rider is increasingly valuable as the volatility of the underlying asset rises. For a household investing in a portfolio of bonds providing cash flows from interest and maturities that matched their cash flow requirements, the guarantee has little value and might not be worth purchasing because the household is unlikely to outlive its wealth. But, if the household invests in risky assets through the underlying deferred annuity, the guarantee may have considerable value because, if the investment performs well the household benefits from stepup, whereas if it performs badly the guarantee kicks in. As noted by Huang, Milevsky, and Salisbury (2014, 110), "The GLWB is worth something only because the investment account will be (i) depleted by withdrawals by some date, and (ii) the individual annuitant will live well beyond that date. The insurance is paid for by ongoing charges to the account, which come to an abrupt end if and when the account hits zero." Insurance companies understand this, and typically limit the risky stock portion of the annuity portfolio to a maximum of 70 percent.

Our concern with Huang, Milevsky, and Salisbury (2014), and indeed with all studies using option pricing techniques, is that the results rest on an assumption of complete markets. The strategy that maximizes the cost to the insurer might not be the strategy that maximizes the value of the insurance to the household.

Xiong, Ibbotson, Idzorek, and Chen (2010) use option pricing theory to price the guarantees embedded in GLWB riders. They show that the price is higher when the VA portfolio is more volatile; this finding fits with the prediction we mentioned in 4.4 that options are more valuable when the underlying asset is more volatile. The price is lower at older ages because the age-related increase in annuity rates is insufficient to compensate for shorter remaining life expectancy. The price is higher when the guarantee step-up occurs at more-frequent intervals. The authors show that the put option embedded

in the GLWB enables the household to tolerate more risk in the remainder of its portfolio, as we noted in 4.4, but only over longer time horizons. Our analysis similarly shows that, with the value of an option depending on the volatility of the underling assets, households may be better off holding riskier assets in the VA, subject to constraints imposed by the insurer; this is a topic we defer for future research. The authors then use these insights to determine the product split that maximizes the ex-post utility of a hypothetical household that lives to its life expectancy. The fact that the authors propose a non-zero VA allocation for all household types tells the reader that these products add some value, but the authors do not quantify the value with calculations of annuity equivalent wealth.

The key takeaways for us are that households will generally be better off holding more-risky assets in the VA and that VAs permit households to increase their exposure to equities. But we have several concerns about the methodology: First, it ignores the longevity insurance value of the VA.⁴⁸ Second, the analysis does not permit us to determine whether the household used the options embedded in the policy to best advantage.

The two studies that we discuss next use numerical optimization techniques, which we consider to be the most effective means of determining the value of VAs to households. The studies suffer from the limitations referred to earlier in 1.2, however: they do not consider the full menu of annuitization options (resulting in some strategies that appear optimal yet could be dominated by others not considered in the papers), nor do they investigate how optimal use of the options embedded in VAs may affect their value. Yet we can still glean insights from them that point to future research.

Horneff, Maurer, Mitchell, and Rogalla (2015) study guaranteed minimum withdrawal benefit (GMWB) riders, a guarantee somewhat related to but not identical to GLWB riders. A GMWB rider guarantees that a policyholder can withdraw a periodic amount equal to the pre-

^{48.} They include total expected future guaranteed incomes from VA + GMWB conditional on being alive at the life expectancy. But a dollar increase in the expected present value of annuity income is worth more than a dollar of unannuitized wealth because of the longevity insurance provided by the annuity.

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mium paid (e.g., 5 percent of the premium for 20 years) but does not guarantee a lifetime benefit. The GMWB rider is therefore a less effective means of hedging longevity risk and plays a greater role instead in insuring against market downturns. Horneff and colleagues assumed the annuity was purchased at age 40 or 45 with deferral to age 65 when the balance in the account was converted into an income annuity. In the event of death prior to age 65, the balance in the account passed to the insurance company. These mortality credits boost the return. But if the household needs to insure its future labor market earnings, this benefit may be offset by the need to purchase additional life insurance relative to a household that invests in traditional mutual funds.

The analysis in the paper does not permit the reader to disaggregate the benefit of the policy between the value of the mortality credits and the value of the financial options. An obvious benchmark would be the purchase of a series of traditional income annuities with payments deferred to age 65. Furthermore, the restriction that any GMWB payments are taken during the 20 or 25 years ending at age 65 means that the paper tells us nothing about the value of GMWB riders in managing post-retirement wealth drawdown, a life stage at which such policies are most commonly used. Some of the behavior observed in the simulations likely reflects the assumption that income annuities are unavailable. For example, the purchases of the VA in the years immediately preceding retirement are likely motivated not by a desire to hedge stock market risk, but rather by a desire to access the income annuity option embedded in the contract. Given the opportunity, the household may prefer to forgo the VA and either buy an income annuity with payments deferred to retirement or wait and purchase an immediate annuity at retirement.

In our view, the importance of this paper is its focus on both the accumulation and the drawdown phases. Most other papers take wealth at retirement as a given, as we do our analysis. Households approaching and entering retirement—a period referred to by one insurer in an advertising campaign as the "retirement red zone"—face sequence-of-return risk. Conventionally, a household contemplating the purchase of an income annuity would hedge the risks of stock market declines and interest rate declines (which increase the cost of annuitization) by reallocating wealth from stocks to bonds whose duration matches those held by the provider of the prospective annuity. Our takeaway from the paper is that investing retirement plan contributions in a GMWB policy when a household is in its 40s and 50s is a potentially useful mechanism for hedging these risks. What we are unable to determine is whether it would be more effective than purchasing DIAs.

Steinorth and Mitchell (2015) model post-retirement drawdown using VAs with GLWB riders. They find that VAs with GLWBs increase household financial well-being, but by less than traditional income annuities. We fear their study may understate the value of the VA. First, their study assumes that households invest all their financial assets in either a VA or a traditional stock-bond portfolio and do not consider the option to hold part of the household's wealth in each, with riskier assets in the VA and safer assets in the traditional portfolio. A further negative consequence of the all-or-nothing approach is that it is frequently optimal for households to take excess withdrawals. These excess withdrawals reduce the VA guarantee base. A household that invested part of its wealth in regular financial assets would face less of a liquidity constraint and would be less likely to take excess withdrawals. Second, the model assumes that the household holds the same portfolio whether or not it purchases a VA. A VA permits a household to take on additional financial market risk, and a more appropriate comparison would be between the optimal portfolio for annuity purchasers and the optimal portfolio for non-purchasers. Third, the model assumes that households exercise the annuitization option immediately on purchase and do not time the exercise strategically.

Our takeaways from this paper, besides the authors' own takeaways, are as follows. First, households should not invest such large shares of their financial assets in VAs that they are forced to take excess withdrawals. Second, households and their advisors need to consider both asset allocation and asset location (i.e., which assets are held in the VA and which are held outside the VA).

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APPENDIX C. TERMS

annuity-equivalent wealth: The amount by which the household's wealth must be increased so that, from the vantage point of the start of retirement, the household is indifferent between (a) its original wealth plus access to the annuity market, and (b) increased wealth, but no access to the annuity market.

annuity puzzle: The puzzle that rates of annuity ownership fall far short of the predictions of economic theory.

deferred annuity: A term that we use to describe a variable annuity, fixed index annuity, and registered index-linked annuity, whose common feature is that the "act of annuitization" the irrevocable exchange of the assets in the annuity for a lifetime income, occurs not on purchase, as with an immediate annuity, but at some future date.

deferred income annuity (DIA): An annuity in which the purchaser exchanges a lump sum for a fixed periodic income, starting at some predetermined future date, and payable for life.

fixed immediate income annuity: See income annuity.

fixed index annuity (FIA): A type of deferred annuity that pays a return equal to some predetermined percentage of the return on some stock market index (e.g., the S&P 500), subject to a ceiling and a floor of a zero return.

income annuity: An annuity in which the purchaser exchanges a lump sum for a fixed periodic income, starting immediately, and payable for life.

life annuity with period certain: An annuity in which the purchaser exchanges a lump sum for a fixed periodic income, starting immediately, and payable for life or a predetermined period, whichever is greater.

longevity risk: The risk that an individual lives longer than expected.

long-term care cost risk: The risk that out-of-pocket long-term care costs are larger than expected.

period certain annuity: An annuity in which the purchaser exchanges a lump sum for a fixed periodic income, starting immediately, and payable for a predetermined period.

rate-of-return risk: The risk that the rate of return on a financial asset is less than expected.

registered index-linked annuity (RILA): A type of deferred annuity that pays a return equal to some predetermined percentage of the return on some stock market index (e.g., the S&P 500), subject to a ceiling and a floor of a return of less than zero (e.g., losses may be capped at 10 percent in the event of the S&P 500 declining by more than 10 percent).

single-period annuity: A theoretical annuity that pays a lump sum conditional on an individual surviving to a specified age, and that pays zero otherwise.

traditional annuity: See income annuity.

variable annuity (VA): An annuity whose value is linked to the returns on investment subaccounts, and contains insurance features such as a death benefit or the right to take a lifetime income.

variable immediate income annuity: An annuity in which the purchaser exchanges a lump sum for a periodic income, the amount of which depends on the return on an investment fund, starting immediately, and payable for life.

variable index annuity: A type of deferred annuity that pays a return equal to some predetermined percentage of the return on some stock market index (e.g., the S&P500), subject to a ceiling and a floor of a return of less than zero (e.g., losses may be capped at 10 percent in the event of the S&P 500 declining by more than 10 percent).

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