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Health shocks, risk preferences and annuity choices

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Health shocks, risk preferences and annuity choices *

by

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Abstract

This study examines the simultaneous impact of risk type and risk preferences on annuity demand. Through a quasi-experimental design that leverages individuals' reactions to their first malignant cancer diagnosis around retirement, we show that a 30% reduction in the present value of life annuities from decreased life expectancy results in just a 5% decline in annuitization rates. We further demonstrate that risk-averse individuals drive this effect, whereas the risk-tolerant remain unchanged in their demand. Our findings suggest that risk-averse individuals view life annuities as a means to ensure against longevity risk.

Keywords: Annuity puzzle; Adverse selection; Advantageous selection; Health shocks
JEL-codes: G50, G52, D12, D14

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1 Introduction

Many studies have shown that annuities have substantial value in mitigating retirees' longevity risk (Brown, 2003; Davidoff, Brown, & Diamond, 2005; Gong & Webb, 2010; Yaari, 1965). Nevertheless, voluntary annuitization remains surprisingly low in many countries (Beshears, Choi, Laibson, Madrian, & Zeldes, 2014; Brown, 2001; James & Song, 2001; Pashchenko, 2013; Reichling & Smetters, 2015). Researchers have actively sought to identify the factors that determine demand for annuities, particularly the puzzling phenomenon of low annuitization rates. Proposed factors include bequest motives, the presence of public social security programs, market incompleteness, frictions, and other behavioral explanations (Benartzi, Previtero, & Thaler, 2011; Brown, Mitchell, Poterba, & Warshawsky, 2001; Hagen, Hallberg, & Sjögren-Lindquist, 2022; Horneff, Maurer, Mitchell, & Dus, 2008; Hurwitz & Sade, 2020).

Asymmetric information has long been recognized as a significant determinant of demand in insurance markets by numerous economists. Risk type, in particular, is one dimension of asymmetric information shown to have a significant impact on annuity demand in the literature. The implication of this dimension is adverse selection, which suggests that individuals hold private knowledge about their longevity risk (hereafter, "risk type"). Specifically, it suggests that ex-ante riskier individuals—those with a higher longevity risk—are more likely to seek life annuities, as they have more to gain from pooling their risk with others (Cutler, Finkelstein, & McGarry, 2008; Finkelstein & Poterba, 2004; Hosseini, 2015; McCarthy & Mitchell, 2010; Sheshinski, 2008).

More recently, a growing body of research has challenged the traditional understanding of unidimensional asymmetric information and revealed that individuals possess multidimensional private information. Specifically, studies have shown that individuals hold private information about both their risk type and risk preferences (Fang, Keane, & Silverman, 2008; Fang & Wu, 2018; Finkelstein & McGarry, 2006).[1] In the annuity market, exploring how individuals' decisions on annuitization are influenced by private information across various dimensions presents a challenge due to practical and methodological constraints. As a result, there have been limited empirical attempts to investigate this multidimensional private information, leaving us with an incomplete understanding of how it impacts the demand for annuities and the underlying mechanisms by which it operates.

[1] In health insurance Fang et al. (2008) showed that, conditional on health status, individuals who invested in Medigap, also spent more on medical care. In the context of long-term care (LTC) insurance, Finkelstein and McGarry (2006) showed that more cautious individuals were both more likely to buy LTC insurance and less likely to use it.

The impact of risk preferences on demand for annuities is complex and not straightforward. The choice of annuities at retirement is part of a portfolio problem for which the optimal allocation depends also on risk preferences. According to some studies, individuals tend to acquire more insurance not necessarily because their risk is higher, but rather due to their inherent risk aversion. This phenomenon is referred to as "advantageous selection," which occurs when those who are more risk-averse are also more likely to purchase insurance coverage (De Meza & Webb, 2001; Fang et al., 2008; Fang & Wu, 2018).[2] This argument is consistent with evidence that risk aversion is positively correlated with annuity demand (e.g., Agnew, Anderson, Gerlach, & Szykman, 2008; Chalmers & Reuter, 2012). However, this view contradicts research indicating that risk-averse individuals (with bequest motives) may choose not to annuitize (Bommier & Grand, 2014), as well as other behavioral economics research that have claimed some individuals perceive annuities as a gamble rather than insurance (Benartzi et al., 2011; Hu & Scott, 2007).

Considering these differing viewpoints, it is likely that the decision to purchase a life annuity in equilibrium may not solely reflect an individual's longevity risk. This notion holds especially true when both risk type and risk preference dimensions of private information are present, as discussed in prior theoretical and empirical research (Hosseini, 2015; Illanes & Padi, 2019). Therefore, identifying the exact impact of risk type and risk preference on annuity demand can be particularly challenging, as correlated factors may exist known only to the actual retirees. Moreover, to properly analyze these factors, a comprehensive database of retirees' annuity choices would be necessary, including measures of risk types and risk preferences based on health records and financial information.

In this study, we examine how both risk type and individual risk preferences jointly impact annuity demand, while overcoming existing challenges. We answer the question of how a change in risk type affects retirees' choices to purchase a life annuity and determine whether and how this impact is shaped by individuals with risk-averse or risk-tolerant tendencies. We use a comprehensive administrative dataset from a major Swedish occupational pension company spanning 2008 to 2015. The dataset includes detailed information on each retiree's hospitalizations, medication prescriptions, employment and financial information, and mortality data, and it allows us to link individuals across generations. The dataset also enables us to construct various proxies for risk preferences, thereby enhancing our understanding of the multidimensional private information effect on annuity choices.

Our empirical approach leverages the timing of an unpredictable health shock with potentially severe consequences—the first malignant cancer diagnosis—that is known to affect subjective

[2] To illustrate, if highly risk-averse individuals are likely to be both more intrinsically attracted to longevity insurance and live longer than the insurance company would predict, private information about risk preferences could mask the longevity-enhancing effect of adverse selection.

longevity risk (McGarry, 2022; O'Dea & Sturrock, 2021). Specifically, our identification strategy rests on the assumption that the timing of an initial cancer diagnosis is unforeseen in relation to the annuity payout decision, which occurs a few months prior to retirement age, and that the diagnosis is likely to affect one's longevity expectations. We use variation in the timing of the unexpected shock to construct two groups of individuals: (1) a treatment group composed of retirees who experienced the shock immediately preceding the annuity payout choice, that is, just in time to re-optimize their payout plans, and (2) a control group composed of ex-ante similar retirees who experienced the shock immediately after the payout choice, when the choice was irreversible.[3] Importantly, our analysis exploits the fact that within the Swedish annuity market, the insurance price (i.e., "conversion factor") remains consistent for all retirees. Specifically, this factor is calculated using actuarial life tables encompassing the entire population and notably remains unaffected by individual traits such as gender or health condition.

Our findings identify a significant causal effect of a change in risk type on the decision to choose a life annuity plan. Specifically, retirees diagnosed with malignant cancer prior to retirement are 4 percentage points less likely to choose a life annuity, compared to retirees in the control group diagnosed with cancer after retirement. Moreover, retirees who receive a diagnosis of digestive cancer prior to retirement, known to be associated with lower survival probably (Tuo et al., 2022), experienced a more substantial reduction of approximately 8 percentage points in annuitization rates. Conversely, we find that individuals diagnosed with skin cancer before retirement, which is recognized for its likely higher survival rates (Fontanillas et al., 2021), experience a very low and statistically insignificant decrease in their annuity choices, and that the impact of a benign tumor diagnosis—which is known not to be cancerous and poses little risk of metastasizing (Patel, 2020)—is approximately half the size of the effect observed for malignant cancer.

Although our findings align with the concept of adverse selection, it is noteworthy that the magnitude of the effect appears surprisingly low. To gauge the extent of this effect we use the estimates we derived to calculate the money worth ratio (MWR) of retirees' choices, comparing the life annuity choice to a five-year payout for individuals diagnosed with malignant cancer prior to retirement. We find that the MWR stands at 68%, which means that the expected present discounted value (EPDV) of a life annuity payout amounts to only 68% of the EPDV of the five-year payout option. In financial terms, a retiree who receives a malignant cancer diagnosis could potentially forfeit more than $20,000 by choosing a life annuity over a five-year payout option. Given the high baseline annuity rate of roughly 75%, the 4-percentage point decline attributable

[3] The vast majority of the population claim at age 65; hence, the groups belong to a similar age group.

to a cancer diagnosis demonstrates a significant majority face considerable financial setbacks from less-than-optimal annuity decisions.

Next, we study whether and how the effect of a change in risk type on annuity choices varies across individuals with different risk preferences. Current literature offers measures of risk preferences obtained from various sources.[4] We utilize two proxies to assess risk preferences. First, we use information on the volatility of individuals' financial portfolio. Second, we draw on the pioneering work of Levine and Rubinstein (2017, 2018) to construct a measure based on entrepreneurship, using self-employment and incorporation records.

Our findings reveal a striking effect of risk preferences on the demand for life annuity. Specifically, we find that the decrease in demand for life annuities following a health shock is primarily driven by risk-averse individuals, i.e., those with low volatility in their financial portfolios or non-entrepreneurial individuals. Conversely, we find that those who are risk-tolerant do not change their annuity demand despite the change in their risk type—an outcome that aligns with prior research on annuities conducted by Brown, Kling, Mullainathan, and Wrobel (2008) and Hu and Scott (2007)—suggesting that certain individuals do not view annuities as insurance against longevity risk but rather as an investment tool. This idea closely relates to the concept of choice bracketing, which posits that individuals compartmentalize choices and assess them individually. In our context, if retirees shift their focus to risk and return—similar to how they approach other investment products—rather than seeing life annuities as a means to hedge against longevity risk and ensure consistent consumption over time, it is possible that the demand for life annuities will remain relatively stable even in the face of significant shifts in risk type (Brown et al., 2008).

To complement our findings, we use parental longevity information as a proxy for retirees' risk types. Specifically, we rely on the literature that establishes a relationship between individuals subjective survival probabilities and parental longevity (see, e.g., Hurd & McGarry, 1995; Salm, 2010). We show that private information regarding risk type based on parental longevity yields results similar to the abovementioned findings, reinforcing our main findings. Finally, we supplement our findings by conducting the analysis by marital status. The evidence from these analyses contributes to the discussion regarding the "family risk-pooling" argument presented in the literature (Kotlikoff & Spivak, 1981).

Our results carry substantial implications for policymakers, insurers, and financial planners. In particular, the results emphasize the key role of risk preferences in shaping annuity decisions. This insight can inform pricing strategies, guide the development of effective financial education

[4] Examples include financial and assets investment (Hoopes, Reck, Slemrod, & Stuart, 2020), behaviors such as smoking, drinking, and use of seat belts, as well as health care-related measures (Cutler et al., 2008), such as preventive care usage and drug adherence.

programs, and enhance the quality of advice to retirees (see detailed discussion in Section 7). Furthermore, our findings contribute to the theoretical and empirical annuity literature. They advance our understanding of the factors driving retirees' annuity choices, offer insights into the persistently low rates of annuitization, and highlight the importance of incorporating both risk type and risk preferences into the modeling and study of life annuities.

The remainder of the paper proceeds as follows: Section 2 introduce our data and settings. In Section 3 we describe our research design followed by a discussion of the empirical framework in Section 4. Section 5 presents our main findings on multidimensional private information. In Section 6, we provide additional insights regarding family-risk pooling as well as other robustness tests, and Section 7 presents a discussion of policy implications and concludes.

2 Data and settings

To investigate the impact of private information about risk type and risk preferences in the annuity insurance market, we draw on rich administrative data from several registers in Sweden. Specifically, the data contain individuals' health records reflecting individuals' longevity risk, as well as information on annuity choices, and a full set of demographic indicators that are sufficiently detailed to allow us to proxy for individuals' risk preferences. To construct our data set, we link unique personal identifiers to data from the second-largest occupational pension company in Sweden, which manages the pension plans of approximately two million private-sector white-collar workers.[5] By combining this information we generate a comprehensive panel of retirees' annuity decisions, along with a rich set of demographic and health-related information about each retiree.

The advantages of this setup are threefold. First, it allows us to develop multiple proxies for risk type and risk preference, facilitating the recovery of the effects of interest. Second, the large scale of the panel enables us to investigate retiree sub-groups and conduct a more comprehensive analysis, such as by specific cancer type and severity and by marital status. Last, a crucial institutional feature of the Swedish integrated systems enables us to link retirees across generations, broadening the scope of our research.

2.1 Data sources

We utilize data from Alecta, a major occupational pension company that administers pension contributions and payouts for private-sector, white-collar Swedish workers under the ITP

[5] The occupational pension system for white-collar workers in Sweden is quasi-mandatory and did not change during the analysis period, thus generating a clean environment to study annuity choices and precluding potential alternative factors affecting retiree decisions.

plan.[6] [7]Our dataset consists of information on 243,444 of Alecta's retirees born between 1943 and 1953 who retired over an eight-year period ending in 2015. Importantly, it includes information on the year and month each retiree claimed their occupational pension and the payout method used.

For each retiree we extract demographic variables from the Longitudinal Integration Database for Health Insurance and Labour Market Studies (obtained from Statistics Sweden), which covers the entire Swedish population between 1990 and 2014. This database includes information about gender, age, education, various sources of income, wealth, and marital status, as well as details on employment type and status, enabling us to devise proxies for risk preference. Additionally, this database also allows us to match retirees with their biological parents.[8]

We utilize four additional databases provided by the National Board of Health and Welfare. First, we use the National Patient Register covering all inpatient and outpatient hospitalization from 1990 to 2015. For each hospitalization event, the database includes details about the arrival and discharge date, along with detailed diagnoses using ICD codes. This information allows us to identify specific health shocks and their precise timing. Second, we use the Causes of Death Registry from 1969 to 2015 indicating the exact death date and specific causes of death for each person, classified using the International Classification of Diseases (ICD) coding system. Combined with our retiree-parent matches, this information enables us to construct a proxy for risk type based on parental ages and causes of death. Additionally, we use the Prescription Drug Register, containing detailed information about all over-the-counter sales of prescribed medicine from 2005 to 2015. For each record, the dataset indicates the type of medicine (using the Anatomical Therapeutic Chemical [ATC] classification system), and the purchased quantity. From this data, we derive a metric that quantifies an individual's drug consumption and the diversity of drugs they consume.

2.2 The Swedish pension system

The Swedish pension system has two main pillars: a universal (mandatory) public pension system and a quasi-mandatory occupational pension system offered to workers whose employer is tied

[6] ITP (short for *Industrins och handelns tilläggspension*) is an occupational pension resulting from an agreement between PTK (the Council for Negotiation and Cooperation for Salaried Employees), a joint organization of 27 member unions representing 860,000 salaried employees in the private sector in Sweden, and *Svenskt Näringsliv* (the Confederation of Swedish Enterprise), representing 49 member organizations and 60,000 member companies with over 1.6 million employees.

[7] Alecta is one of the largest owners on the Stockholm Stock Exchange, and the fifth largest pension fund in Europe.

[8] Information on parents' date of birth and mortality is available for 91.5% of the sample. The remaining 8.5% have parents who never lived in Sweden and do not show up in the registers for this reason. These individuals are excluded from the sample in some of our relevant analyses.

to an occupational pension plan.[9] Individuals may receive occupational pension income from different occupational pension plans, and hence they are required to make more than one payout decision. Most occupational pension plans in Sweden allow only Defined Contribution (DC) capital to be withdrawn as a fixed-term payout (Hagen, 2017).

The focus of this study is on payout choices in the second pillar, specifically in a pension plan for white-collar workers in the private sector known as the ITP plan. In particular, the payout decision that we study concerns pension wealth in the Defined Benefits (DB) component, called ITP2, which is the only DB plan in Sweden to allow fixed-term payouts.[10] Benefits from ITP2 depend on the final wage prior to retirement. The replacement rate of the ITP2 pension is 10% of the final salary for earnings that fall under the so-called income ceiling of the public pension system. For earnings exceeding this threshold, the replacement rate increases to 65%.[11] [12]

Like many DB plans, ITP2 leaves little room for individual retirement savers to make their own decisions regarding their pensions. Individuals cannot decide on the magnitude of their own contributions nor, offered any investment choice during the accumulation phase, and replacement rates are fixed and apply to everyone.

In the ITP2 plan, the default payout option is a life annuity paid from age 65 onward, while alternative options are term annuities over a fixed number of years, including 5, 10, 15, or 20 years (which became available to insured individuals from 2008). Individuals learn about these options three months prior to their 65th birthday, when they are asked to decide on their preferred payout choices. Once a payout choice is made, this decision is irreversible. The ITP2 pension includes a survivor's benefit specifically tailored for individuals with higher income levels.[13] The remaining pension wealth accrues to other pension plan participants. Payments are adjusted for inflation and wealth and cannot be transferred from the default managing company to another pension company. Payments are adjusted for inflation and wealth and cannot be transferred from the default managing company to another pension company.

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[9] There are four large agreement-based occupational pension plans that cover at least 90% of the total workforce in Sweden. Two of these plans cover workers employed in the public sector, and the other two plans cover white-collar workers and blue-collar workers in the private sector, respectively.

[10] The ITP plan was reformed in 2006 when ITP2 was replaced by a new DC component called ITP1. Because this plan affects workers born in 1979 or later, it is not relevant to this study. The ongoing transition from DB to DC is part of an overall shift in pension provision among all major occupational pension plans in Sweden. The data used in this paper do not include information on annuity choices in other pension plans.

[11] The ITP2 benefit is calculated according to the following equation, where w_i denotes the wage portion related to the IBA_i: $ITP2 = 0.1_{w<7.5IBA} + 0.65_{w_{7.5-20IBA}} + 0.325_{w_{20-30IBA}}$.

[12] The income ceiling is indexed to the average income level in Sweden through the so-called income base amount (IBA). The ceiling is set at 7.5 IBA, which in 2021 corresponded to a monthly pre-tax income of SEK 42,625. Approximately one-third of the white-collar workers within our sample earn above the 7.5 IBA threshold.

[13] The designated survivor benefit, referred to as *Familjepension*, is calculated as 32.5% of the annual earnings that fall between 7.5 IBA and 20 IBA, and 16.25% of annual earnings ranging from 20 IBA to 30 IBA. This benefit is disbursed for the lifetime of the registered partner.

The value of the annuity is determined based on a conversion factor that depends on actuarial assumptions about average life expectancy at claiming age, as well as the rate of return on the pension capital. The conversion factors are, however, independent of gender and marital status, as well as health status.[14] Fixed-term payouts therefore increase liquidity but remove the insurance against longevity. In this context, Hagen (2015) compares the expected discounted present value of the life annuity to that of each of the fixed-term payouts in ITP2. The results indicate that on average, a fixed-term payout is expected to provide a higher payout compared to a life annuity over the remaining expected lifetime of the retiree.

3 Methodology and research design

In this section, we present our methodological approach and provide a detailed description of our empirical model.

3.1 Primary quasi-experiment

The ideal experiment for studying the relationship between risk types and risk preferences on annuity choices would involve randomly assigning shocks that modify longevity risk before retirement to individuals with varying risk preferences (i.e., some risk-averse while others risk-tolerant) and tracking their annuitization decisions. This experiment would allow examining the causal effect of a change in risk type on the demand for annuities, by comparing the response to the shock by individuals who experienced it to similar individuals who did not experience a shock. Furthermore, by comparing the response to a change in risk type of risk-averse relative to risk-tolerant individuals, we could discern the source of the shock's impact.

We utilize a quasi-experimental research design that approximates the ideal abovementioned experiment. Our design leverages the potential randomness in the timing of a severe health shock, specifically a malignant cancer diagnosis, that occurs within a short period around retirement. We form two experimental groups based on the timing of the severe health shock: a Treatment group, composed of individuals diagnosed with cancer τ years pre-retirement, and a Control group composed of individuals who experienced a similar shock at time $\tau + \Delta$ post-retirement.[15]

[14] For example, assume that an individual is entitled to a life annuity of SEK 2,500 per month (1 SEK = 0.11 USD). If the conversion factors at age 65 between the life annuity and the 5-, 10-, 15-, and 20-year payouts are 3.73, 2.02, 1.46, and 1.21, respectively, the retiree can instead choose a 5-year option paying SEK 9,325 (3.73 × 2,500), a 10-year option paying SEK 5,050 (2.02 × 2,500), a 15-year option paying SEK 3,650 (1.46 × 2,500), or a 20-year option paying SEK 3,025 (1.21 × 2,500).

[15] Our choice of Δ is three years. The trade-off in the choice of Δ is the comparability of the experimental groups in terms of the disease state (which is presumably higher when Δ is smaller) against the sample size. We assess the robustness of our analysis to the choice of Δ and find that modifying it between one and three years yields similar results, as presented in appendix Table A.1.

The identification assumption underlying our analysis is that the timing of the malignant cancer diagnosis in the short period around retirement (and annuity payout choice) is as good as random. To strengthen this assumption, we limit our analysis to patients who did not have any cancer-related hospital admissions or specialized care visits before their diagnosis. To further bolster our assumption, we conduct various tests that compare the two groups along various dimensions, including demographic, health-, and financial-related characteristics. Our findings demonstrate that the two groups exhibit virtually no differences–a result that mitigates any concerns about the randomness of the shock's timing.

3.2 Empirical approach

3.2.1 Risk type response

Our empirical strategy proceeds in two steps. In the first phase, we rely on existing literature that points to the notion that life annuity choices are dictated by risk type (Cutler et al., 2008; Einav, Finkelstein, & Schrimpf, 2010; Finkelstein & Poterba, 2004; Rothschild, 2009). Based on this approach, we define the probability to annuitize as a function of true longevity, all else equal, as follows:

$$Prob(Life\ annuity_i = 1) = f\ (Longevity_i), \quad (1)$$

where Life annuity_i is a binary variable for whether the individuals chose a life annuity upon retirement and Longevity_i is the underlying longevity risk.

Understanding the shape and direction of the function ***f***, which indicates the impact of private information on annuity choices, holds significant economic importance. An annuity serves as a vital insurance tool against longevity, and comprehending its implications is crucial for individuals' personal financial security by preventing the risk of outliving their savings. Additionally, this understanding bears immense significance for policymakers, as it empowers them to guide and educate individuals effectively before retirement.

In practice, individuals usually hold a noisy proxy of their true longevity, for example, based on their parental longevity, diet, or exercise levels. Existing literature exploits similar proxies to generate measures for subjective survival probabilities (Beauchamp & Wagner, 2020; Bloom, Canning, Moore, & Song, 2006; Hamermesh, 1985; Hurd, McFadden, & Gan, 1998; Hurd & McGarry, 1995). We use an individual's first cancer diagnosis as a sharp estimate of longevity risk. Using this health shock, we examine the hypothesis that a change in an individual's (private) information about risk type causes a change in annuity choice. Specifically, we define the variable D_i as an indicator that takes the value of 1 if retiree *i* has experienced a diagnosis of malignant cancer before making an annuity choice and 0 otherwise. We utilize the diagnosis health shock to identify how a change in longevity risk affects the likelihood of choosing a life annuity using the following binary choice model:

$$Prob(Life\ annuity\ =\ 1) = \phi\ (\alpha\ +\ \tau D_i\ +\ \beta X_i\ +\ \varepsilon_i), \qquad (2)$$

where the outcome variable Life annuity takes the value 1 if retiree *i* chose the life annuity, and 0 if she/he chose a 5- or 10-year fixed-term payout.[16] The vector X_i comprises an extensive range of control variables that have the potential to impact the annuity decision. These variables encompass demographics including gender, marital status, number of children, and education, providing crucial contextual information.[17] Additionally, the vector incorporates a comprehensive set of health-related factors, including the average number of days of hospitalizations in each year (before retirement/diagnosis [from 1990]), the average number of unique drugs consumed by each individual (at the 3-digit ATC level per year [between 2005 and 2015]); a variable that indicates whether an individual has received sickness benefits before retirement/cancer diagnosis (from 2003);[18] and a variable that indicates whether an individual received disability pension the year before claiming ITP2. These health-related variables are instrumental in capturing individuals' underlying health status and mitigating concerns that influence one's annuity choice. We further control for retirees' financial positions through records of individuals' average disposable income five years before retirement, and real and financial assets in 2007.This enables us to address the concern that wealth is positively correlated with longevity (Finegood et al., 2021) and to preclude the potential bias that arises from retirement wealth being part of a portfolio problem (Hurwitz & Sade, 2021).

The inclusion of this rich covariates set is informative in determining how much of the private information about longevity risk can be unambiguously attributed to predetermined (pre-shock) characteristics, beyond the "raw" (adverse) selection effect (ruling out moral hazard). The error term ε_i is assumed to be uncorrelated across individuals. We estimate the model using a logit procedure and calculate the marginal effect to facilitate interpretation. This estimation exploits time variation in the health shock to identify the effect of a decrease in longevity risk due to an unexpected cancer diagnosis on annuity choice, as represented by the key parameter of interest, τ. It allows us to test the null hypothesis of asymmetric information (i.e., $\tau = 0$), and if this hypothesis is rejected, it reveals the direction of the effect. The sign and magnitude of τ offer

[16] An alternative dependent variable could have been the realization of the payment duration. However, due to constraints related to data availability, we only have access to health records and death registry information up to the year 2015. We also confirmed that defining the 15- and 20-year fixed-term payout as an outcome variable (in addition to life annuity) yields consistent results.
[17] The main results are preserved when including the age fixed effect.
[18] Sickness benefits are received in cases of absence from work for more than 14 days.

valuable insights into our current understanding of the annuity puzzle and potential correlation between risk type and annuity demand. Specifically, if $\tau < 0$, it indicates that experiencing a health shock decreases the likelihood of opting for a life annuity, aligning with the predictions of adverse selection. The magnitude of τ enables us to learn whether retirees might be foregoing potential benefits and to what extent other factors, such as risk preferences, are either reducing or amplifying the adverse-selection effect.

3.2.2 Risk-preference heterogeny

Our approach builds upon existing literature that has proposed that the probability of purchasing insurance is a function of both risk preference *and* risk type (De Meza & Webb, 2001), a concept previously examined in the context of long-term care and health insurance (Fang & Wu, 2018). According to this perspective, individuals' preference variations counteract risk-type-based selection, masking the anticipated positive correlation between insurance coverage and the occurrence of risks. Building on this viewpoint, we redefine the probability of annuitization to not only consider risk type but also incorporate risk preferences, as follows:

$$Prob(Lifeannuity_i = 1) = f(Longevity_i, Preference_i) \quad (3)$$

where $Preference_i$ represents risk preferences. Defining the probability to annuitize as a function of both longevity risk and risk preference allows us to study whether individuals' choices regarding annuities differ based on their risk preferences, given a specific risk type. Furthermore, this analysis enables us to explore whether the equilibrium choice deviates from the expected positive correlation between life annuities and longevity risk, as predicted by unidimensional models of asymmetric information. By doing so, we can gain valuable insight into the interplay of risk factors and personal risk preferences that shape annuity decisions.

To examine the shape and direction of the relationship between multidimensional private information and annuity choice, we leverage diverse financial and occupational information to construct proxies for individuals' risk preferences as presented in Eq. 3. Specifically, we introduce the variable Ri as an indicator for risk aversion, taking the value 1 if retiree i is considered risk-averse and 0 otherwise (further details about the proxies are provided in the following sections). To explore this relationship, we employ a binary choice model represented as follows:

$$Prob(Life\ annuity = 1) = \Phi\ (\mu + \delta D_i + \lambda R_i + \gamma R_i D_i + \phi X_i + \zeta_i), \quad (4)$$

in which the components of the model are identical to those in Eq. (2). This approach provides a direct evidence of the offsetting preference-based selection in annuity choices, shedding light on the magnitude and relevance of the relationship between multidimensional private information and the decision to purchase annuities.

As before, we estimate the model in Eq. 4 using a logit procedure and calculate the marginal effect to aid interpretation. By including an interaction term between *Di* and *Ri*, we are able to study how the response to the health shock differs based on risk preferences and identify the equilibrium relationship between longevity risk, risk preferences, and life annuity choice. Specifically, the key parameter of interest is γ, which captures whether the effect of a health shock on annuity choice varies based on an individual's risk preference.

4 Empirical framework

In the following section, we present our main empirical framework variables and provide detailed description of the proxies used to identify risk type and evaluate the influence of risk preferences. Thereafter we discuss our empirical methodology, analysis sample, and provide test results that validate our research design.

4.1 Defining health shocks

Our primary approach defines individuals' longevity risk based on the timing of their first cancer diagnosis. The term "first cancer diagnosis" denotes an individual's initial record in either inpatient or specialized outpatient care, starting from the year 1990 and onwards. We focus on this diagnosis as the primary health shock for several reasons. First, the timing of initial cancer diagnoses within the short window we consider around retirement should be difficult to predict, allowing us to approximate a randomized experiment. In our analysis, we categorize individuals with a cancer diagnosis as having low longevity risk, and those with no such diagnosis as having high longevity risk. Additionally, we distinguish between diagnoses of malignant tumors (categorized under ICD-10 code C) and benign tumors (categorized under ICD-10 code D), enabling us to examine the relationship between risk type levels and the likelihood of investing in annuities.[19] Second, cancer diagnoses have been shown to significantly impact individuals' subjective survival probabilities, leading to a change in perceived risk type. For instance, McGarry (2022) found a significant decline in self-reported survival probabilities to a target age of 75 among older persons diagnosed with cancer, and O'Dea and Sturrock (2021) reported that a new cancer diagnosis caused a significant decrease of 4 percentage points in survival expectations. Finally, the prevalence of this health shock makes our analysis relevant for a large

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[19] For example, Sada et al. (2021) studied malignant vs. benign insulinoma and showed that survival probabilities for 120 months among patients diagnosed with benign insulinoma are close to 90%, while survival probabilities for individuals with malignant insulinoma are less than 60%.

share of the population, as cancer is the second leading cause of death both in the U.S. (Ahmad & Anderson, 2021) and in Sweden (Debiasi, Dribe, & Brea-Martinez, 2021).

4.2 Defining risk preferences

Past literature has attempted to proxy for risk preferences by employing measures from diverse domains. Notably, Cutler et al. (2008) used measures encompassing areas such as smoking behavior, alcohol consumption, job-based mortality risk, preventive health care, and seat belt usage to proxy for risk preferences and investigate how heterogeneous risk preferences are associated with the demand for different types of insurance. Hoopes et al. (2020) suggested using investment behaviors to infer risk preferences, while other studies, such as Barseghyan, Prince, and Teitelbaum (2011); Blais and Weber (2006); Einav, Finkelstein, Pascu, and Cullen (2012); Weber, Blais, and Betz (2002) found that risk-taking behavior was highly domain-specific. Consequently, to proxy for risk preferences, we utilize indicators from the financial domain that have been recognized as influential factors in the decision-making process of annuitization (Benartzi et al., 2011; Yogo, 2016).

We use financial wealth volatility to proxy for risk preference. This proxy is grounded in the idea that an individual's risk preferences impact the composition of their financial portfolio, particularly the allocation of high-risk assets. As a result, this can result in portfolio-volatility variations over time.[20] [21] Our aim is to focus on volatility derived from financial wealth resulting from differences in investment returns, rather than changes in income or deposits. To achieve this, we estimate a regression model with a financial wealth logarithm as the dependent variable, and an income logarithm, and a lagged wealth logarithm as independent variables, following a method similar to Atkeson and Irie (2020). Subsequently, we use the standard deviation of the residuals from the regression as a proxy for risk preferences. We define portfolios with volatility above the 80th percentile of the distribution of these residuals as high volatility portfolios, such that individuals with high-volatility portfolios are considered risk-tolerant, while those with low-volatility portfolios as risk-averse.[22]

As an additional proxy for risk preferences, we follow the approach of Kerr, Kerr, and Dalton (2019) and Levine and Rubinstein (2017, 2018), who proposed that individuals who exhibit a

[20] This assumption relies on the idea that changes in wealth do not affect the proportion of portfolios invested in risky assets (Brunnermeier & Nagel, 2008).
[21] We acknowledge that our assessment of risk preferences relies on an ex-post realization, and we recognize that an alternative approach could involve measuring risk preferences using information from individuals' financial portfolios. Currently, however, such information is inaccessible to us.
[22] For robustness, we replicate the analysis, by defining risk-tolerant individuals as those with volatility above the 50th–70th percentiles, and the results of this analysis are robust and available from the authors upon request.

greater propensity for risk-taking are more inclined to pursue entrepreneurship as a profession.[23] [24] Particularly, we adopt the methodology of Levine and Rubinstein (2017, 2018), which, considered an incorporated self-employed individual as an indicator of entrepreneurship. We define individuals who were incorporated self-employed (hereafter, entrepreneurs) at least once between the years 2007 and 2014 as risk-tolerant individuals, and all other individuals as risk-averse.[25]

4.3 Analysis samples

Our primary analysis is implemented on individuals diagnosed with cancer three years around retirement ($i.e., \Delta = 3$).[26] Table 1 presents descriptive statistics of the entire sample, as well as a description for the analysis sample of individuals that have experienced a cancer diagnosis.[27]

The primary outcome variable is the choice of a life annuity over the fixed-term payout option, as described in the first row of Table 1. In the entire sample (Column 1), 74% of employees chose the life annuity, which is consistent with the pattern observed in the analysis sample presented in Column 2. Life annuity is the default option, so this rather high annuitization rate could be attributed to inertia (Bütler & Teppa, 2007; Handel, 2013). This rate is also similar to that of other countries with mandatory pension schemes, such as Chile (Illanes & Padi, 2019). The share of employees who chose the 5-year payout (the most common fixed-term payout plan) was 16% in the entire sample and slightly higher at 17% in the analysis sample. The remaining 10% of the population selected fixed-term payouts of either 10, 15, or 20 years.

Table 1 provides further information on a variety of variables. The average pension payout from Alecta is approximately SEK 5,000, constituting around 20% of an individual's total pension provision. The average monthly benefit of the ITP2 component, which is the primary subject of our study, is approximately SEK 3,350. The *Early withdrawal* variable, which indicates the proportion of individuals who claimed their pension before the full retirement age of 65, shows that 14% of the entire sample retired early, and this proportion was similar among those diagnosed with cancer.[28]

[23] Our design precludes concerns related to other characteristics correlated with selection into entrepreneur- ship, which are assumed to be homogeneously distributed between those diagnosed pre- or post-retirement.
[24] Barsky, Juster, Kimball, and Shapiro (1997) also report that self-employed are more risk-tolerant than employees.
[25] The abovementioned wealth volatility proxy is significantly higher among the group classified as entrepreneurs relative to non-entrepreneurs.
[26] For robustness, we report additional analyses on individuals diagnosed with cancer one and two years around the retirement decision in appendix Table A.1.
[27] We also omit 1,548 observations (0.6% of the sample) with negative assets to calculate the log of financial and real assets.
[28] Previous studies have shown that smaller pension accounts are more likely to be withdrawn during a fixed number of years compared to larger accounts (Hagen, 2015; Hurwitz & Sade, 2021).

Table 1. Descriptive statistics

	(1) All			(2) Cancer		
	Mean	SD	N	Mean	SD	N
Life annuity	0.74	0.44	241896	0.73	0.44	30062
5-year payout	0.16	0.37	241896	0.17	0.37	30062
10-year payout	0.06	0.25	241896	0.06	0.24	30062
Pension from Alecta (SEK/Year)	60079	82124	241896	65491	88208	30062
Pension from ITP2 (SEK/Year)	40242	60727	241896	44241	66533	30062
Public pension (SEK/Year)	156223	55761	175446	159816	54966	24019
Total pension (SEK/Year)	304609	196843	175446	320980	211610	24019
Early withdrawal	0.14	0.35	241896	0.14	0.34	30062
Disability pension	0.16	0.36	241896	0.16	0.37	30062
Claimed public pension	0.26	0.44	241896	0.27	0.44	30062
Age (at claim)	64.72	0.91	241896	64.76	0.87	30062
Male	0.60	0.49	241896	0.63	0.48	30062
Married	0.63	0.48	241896	0.66	0.47	30062
Single	0.11	0.31	241896	0.10	0.30	30062
High school	0.48	0.50	241896	0.48	0.50	30062
University	0.32	0.46	241896	0.34	0.47	30062
Number of children	1.89	1.13	241896	1.90	1.12	30062
log financial assets	10.92	4.01	241896	11.30	3.64	30062
Wealth volatility	0.10	0.08	212428	0.10	0.08	27091
log disposable income	7.72	1.38	241868	7.91	0.80	30062
log real assets	10.52	6.02	241896	10.92	5.81	30062
Self-incorporated	0.06	0.25	241896	0.07	0.25	30062
Sickness benefits (yes/no)	0.10	0.19	241896	0.13	0.21	30062
Mean hospitalization days per year	0.33	1.58	241896	0.40	1.64	30062
Number of unique drugs	3.70	2.49	241896	4.32	2.61	30062
Partner's age	62.68	7.09	137258	62.72	6.87	18597
Partner's *log* disposable income	7.70	0.87	137258	7.71	0.84	18597
Parent died of cancer	0.34	0.47	241896	0.36	0.48	30062
Dead within 2 years	0.02	0.14	210214	0.05	0.23	27645
Dead within 5 years	0.05	0.22	116542	0.12	0.32	16227

Notes: Column (1) represents descriptive statistics of the entire dataset, while Column (2) shows descriptions of individuals diagnosed with cancer. The variable *life annuity* is a dummy variable that indicates whether a retiree has chosen the life annuity option. The variable *five-year payout* is a dummy variable that indicates whether a retiree has chosen the five-year payout option. The variable *Pension from Alecta* represents the yearly amount of the occupational pension the employee receives from Alecta. The *Early withdrawal* variable equals 1 for employees that have claimed their pension before the normal retirement age of 65, and the *Late withdrawal* equals 1 for employees have claimed their pension after 65. The variable *Disability pension* is an indicator for receiving disability pension prior to retirement. The variable *Sickness benefits* is an indicator for absences from work due to illness for more than 14 days at any point in time between 2005 and retirement but prior to a cancer diagnosis. *Log financial assets* and *log real assets* are measured for 2007. The variable *Mean number of hospitalization days per year* is measured between 1990 and retirement, but prior to cancer diagnosis. *Medical possession ratio (MPR)* is a measure for drug adherence (see text). The variable *Parent died of cancer* is an indication that equals 1 if one of the parents died of cancer. The variable *Number of unique drugs* captures the number of drug substances (at the 3-digit ATC level) taken between 2005 and retirement, but prior to a cancer diagnosis.

The share of retirees who claimed a disability pension is 16% of the entire sample and roughly 16% of the analysis samples. The share of retirees who claimed public pension is 26% of the entire sample and 27% of the analysis samples. Table 1 also reports a comprehensive set of demographic statistics that are mostly consistent across the entire sample and the analysis sample. In the entire sample, the average age at claim was 64, and the majority of retirees were males (60%), married (63%), had an average of two children, and held similar education records. Information on the financial and real assets of retirees in the analysis sample shows they were slightly wealthier on average compared to those in the entire sample.

Table 1 further presents health-related information, which reveals that the rate of sickness benefits was lower in the entire sample relative to the analysis sample. Additionally, hospitalizations and drug utilization rates were higher in the analysis sample relative to the entire sample. The drug adherence measure (MPR) was 0.73 for the entire sample and 0.71 for the analysis sample. Furthermore, the table illustrates that the age and income of the retirees' parents were comparable across both samples, and around 35% of retirees in both samples had at least one parent who died from cancer.

4.4 Research design validation

Table 2 compares individuals in the treatment and control groups (those diagnosed with cancer before vs. after retirement) across various dimensions, allowing us to validate the identifying assumption. The sample used for the comparison in Table 2 includes all individuals diagnosed with cancer around retirement as described above. This comparison confirms that our quasi-experiment induces treatment and control groups that are balanced on demographic characteristics and healthcare-utilization patterns *within* each category of risk preferences. Dissimilarity in healthcare utilization may imply differences in expectations of a cancer diagnosis and in perceived longevity risk.

The findings in Table 2 provide strong evidence that individuals did not have prior knowledge of their future cancer diagnosis, as shown by the similarity in hospitalization days and other health-related characteristics measured prior to diagnosis, such as their disability pension. Moreover, the proportion of retirees with a parent who passed away from cancer is comparable in both groups. Moreover, retirees in the two groups are largely similar in terms of demographic variables. Regarding the outcome variable of interest, Table 2 indicates that individuals diagnosed with cancer before retirement were less likely to choose a life annuity, providing support for the hypothesis that private information about longevity risk affects the decision to invest in annuities.

Table 2. Comparison between retirees diagnosed with cancer before and after retirement

	Diagnosis pre-retirement		Diagnosis post-retirement		Difference	
	Mean	SD	Mean	SD	Diff	t
Life annuity	0.72	0.45	0.75	0.43	0.04***	(7.11)
5-year payout	0.18	0.38	0.06	0.23	-0.02***	(-5.17)
10-year payout	0.07	0.25	0.16	0.36	-0.01***	(-3.80)
Pension from Alecta (SEK/Year)	66449	90559	64543	85813	-1905	(-1.87)
Pension from ITP2 (SEK/ Year)	32979	50087	33499	48485	519	(0.91)
Public pension (SEK/ Year)	159786	54250	159839	55526	53	(0.07)
Total pension (SEK/month)	319081	200422	322478	220024	3397	(1.25)
Early withdrawal	0.14	0.35	0.14	0.34	-0.01	(-1.45)
Disability pension	0.16	0.37	0.16	0.37	-0.00	(-0.17)
Claimed public pension	0.28	0.45	0.27	0.44	-0.01	(-1.80)
Age (at claim)	64.77	0.91	64.75	0.84	-0.02*	(-2.02)
Male	0.62	0.49	0.64	0.48	0.02**	(3.09)
Married	0.66	0.47	0.67	0.47	0.01	(1.00)
Single	0.10	0.30	0.10	0.30	-0.00	(-1.41)
High school	0.48	0.50	0.48	0.50	-0.00	(-0.01)
University	0.34	0.48	0.33	0.47	-0.01	(-1.88)
Number of children	1.89	1.12	1.90	1.12	0.00	(0.23)
log financial assets	11.26	3.61	11.34	3.66	0.07	(1.77)
Wealth volatility	0.10	0.08	0.10	0.08	-0.00*	(-2.41)
log disposable income	7.93	0.74	7.90	7.90	-0.02*	(-2.52)
log real assets	10.94	5.79	10.90	5.84	-0.03	(-0.48)
Sickness benefits (yes/no)	0.13	0.21	0.13	0.20	-0.00	(-0.84)
Number of hospitalization days	0.40	1.78	0.39	1.50	-0.00	(-0.20)
Number of unique drugs	4.32	2.64	4.31	2.59	-0.01	(-0.21)
Self-incorporated	0.07	0.25	0.07	0.25	-0.00	(-0.75)
Partner’s age (at claim)	62.70	7.00	62.73	6.76	0.04	(0.36)
Partner’s log disposable income	7.71	0.84	7.70	0.83	-0.01	(-1.09)
Parent died of cancer	0.36	0.48	0.36	0.48	-0.00	(-0.12)
Dead within 2 years	0.06	0.24	0.05	0.22	-0.01***	(-4.05)
Dead within 5 years	0.11	0.31	0.12	0.33	0.01*	(2.55)
Observations	14945		15117		30062	

Notes: $* \ p < 0.10, ** \ p < 0.05, *** \ p < 0.01$. Variables are defined as in Table 1.

To further support our research design, we further compare personal characteristics for individuals classified as risk-averse and risk-tolerant based on our proxies, as shown in Appendix Table A.2. Panel A compares retirees who were entrepreneurs with those who were not, while Panel B compares retirees with high- and low-financial portfolio volatility. The purpose of this table is to address concerns related to the claim that risk-averse individuals have a lower mortality risk, which could potentially introduce a relationship between health status and risk preferences that might impact our analysis. Our findings show that risk-loving individuals tend to be healthier on average when measured by the entrepreneurship proxy, whereas risk-averse individuals tend to be healthier when measured by the wealth volatility proxy. This evidence helps alleviate these concerns.

5 Multidimensional private information and annuity choices

In this section we report the results of our analysis on how private information related to risk type and risk preferences shapes annuity decisions. We also discuss a complementary analysis that aims to generalize our results using individuals' subjective survival probabilities proxied by parental longevity as an indicator for risk type.

5.1 Effects of cancer diagnosis

Table 3 displays the marginal effect coefficients of the binary choice models derived from Eqs. (2) and (4). Panel A of Table 3 uses wealth volatility to proxy for risk preferences and Panel B reports the estimates using entrepreneurship. Column (1) of each panel shows that individuals diagnosed with *malign cancer* pre-retirement were about 3.8% less likely to choose a life annuity relative to individuals diagnosed post-retirement. These findings provide evidence of adverse selection and are consistent with well-established results in the literature (e.g., Beauchamp, Wagner, et al., 2012; Cohen & Siegelman, 2010; Cutler et al., 2008; Finkelstein & Poterba, 2004; McCarthy & Mitchell, 2010; Rothschild, 2009).[29] [30] Specifically, our findings suggest that holding all other factors constant, individuals diagnosed with malignant cancer pre-retirement (when the decision to purchase an annuity can still be reversed) are less likely to opt for a life annuity.

To further illustrate the results shown in Table 3, Fig.1a visualizes the share of retirees who chose life annuities by the time of the cancer diagnosis relative to their pension-claiming time. The figure (as well as all the following figures) shows the marginal effect with the corresponding 95% confidence intervals. The x-axis denotes the diagnosis month relative to the pension-claiming month, normalized to period 0, and the y-axis denotes the share of retires that chose the life annuity option. The figure provides a clear visual representation of the impact of a malignant cancer diagnosis on the likelihood of choosing a life annuity, which is significantly lower among those diagnosed with cancer before retirement.

Figure 1a further shows that the time window between diagnosis and retirement, whether it is a short period (e.g., two months) or a longer period (e.g., 20 months), has a negligible effect on the magnitude of our findings. That is, those diagnosed *before* retirement consistently exhibit a lower propensity to choose a life annuity regardless of when the diagnosis occurs. This evidence implies that individuals understand the consequences of their longevity risk.

[29] These results remain consistent when estimating a model without control variables, as indicated by the t-test in Table 2. Moreover, the findings remain consistent when parental longevity is included in the set of control variables, as well as when the sample is restricted to individuals without prior hospitalization records (healthy individuals), as show in Appendix Tables A.4 and A.3, respectively.

[30] Including an interaction term between the treatment effect, D_i, and the control set, X_i, does not change our main estimates. These results are available upon request.

Table 3. The effect of a health shock on annuity Investment by risk preference

Panel A. Cancer diagnosis and wealth volatility

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.039	-0.046	-.0011
SE	0.008	0.009	0.018
N	10,538	8,392	2,097
Controls	Yes	Yes	Yes
Benign tumor	-0.025	-0.028	-0.013
SE	0.008	0.009	0.018
N	9,912	7,882	1,978
Controls	Yes	Yes	Yes
Digestive cancer	-0.081	-0.009	-0.035
SE	0.026	0.029	0.062
N	1107	878	224
Controls	Yes	Yes	Yes
Skin cancer	-0.003	-0.008	0.012
SE	0.015	0.016	0.035
N	2932	2338	579
Controls	Yes	Yes	Yes

Panel B. Cancer diagnosis and entrepreneurship

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.040	-0.042	0.015
SE	0.007	0.007	0.027
N	14,990	13,949	1,041
Controls	Yes	Yes	Yes
Benign tumor	-0.023	-0.025	-0.001
SE	0.007	0.007	0.028
N	14,047	13,147	900
Controls	Yes	Yes	Yes
Digestive cancer	-0.086	-0.088	-0.052
SE	0.021	0.022	0.087
N	1690	1585	105
Controls	Yes	Yes	Yes
Skin cancer	-0.008	-0.012	0.056
SE	0.013	0.013	0.049
N	3934	3672	262
Controls	Yes	Yes	Yes

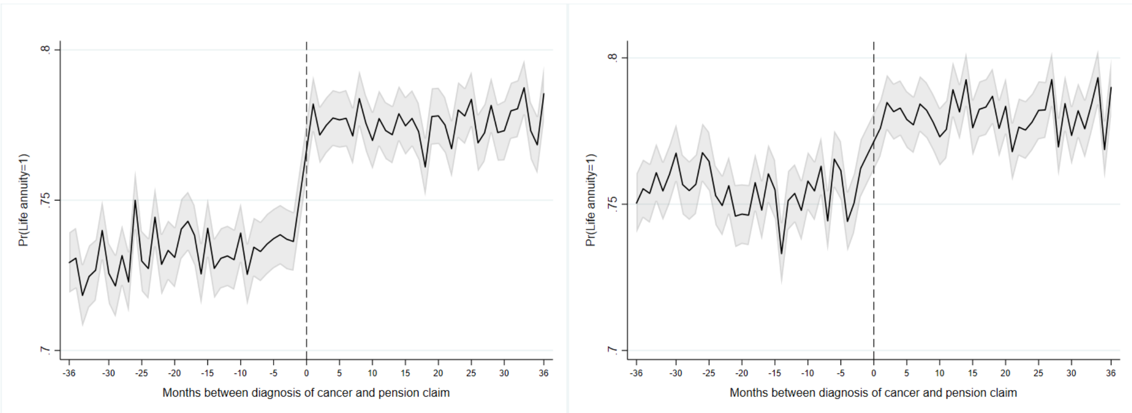
Notes: Risk preferences are defined using two different proxies. Panel A utilizes wealth volatility information, categorizing individuals with portfolio volatility above the 80th percentile as risk-tolerant, while those below are categorized as risk-averse. In Panel B, risk preferences are defined based on entrepreneurship status, in which entrepreneurs are considered risk-tolerant, while non-entrepreneurs are classified as risk-averse. All regressions include control variables, as described in the text.

Column (1) of Table 3 also presents the impact of a *benign tumors* diagnosis, and Fig. 1b visualizes the effect. Both the table and the figure illustrate that that a benign tumor diagnosis has a significantly smaller impact of approximately 2%, on annuity choices. This analysis aligns with the existing literature, which suggests that benign tumors are generally considered less problematic compared to malignant ones (Patel, 2020; Sada et al., 2021).

Additional analyses of specific cancer types is also provided in Table 3. The table compares cancer types with differing mortality rates, including digestive cancer which is associated with lower 5-year survival rates of about 42% in Europe (Tuo et al., 2022) and skin cancer, which has 5-year survival rates of 98% when detected at an early stage (Fontanillas et al., 2021). The table reveals that a diagnosis of digestive cancer results in an 8% decrease in the likelihood of selecting a life annuity, while a diagnosis of skin cancer leads to a 1% reduction in the choice of a life annuity. These results support the concept of adverse selection and indicate that the severity of the cancer diagnosis determines the impact magnitude on the choice of annuity.[31]

The adverse-selection effect size may appear relatively small. This observation can be attributed to several factors such as inertia, psychological differences related to diagnostic focus, and potential bias due to the exclusion of individuals who passed away pre-retirement. Interestingly, the impact of risk preferences on annuity decisions may conceal the impact of risk type, and we will study this important aspect in the upcoming section.

Figure 1. Effects of a cancer diagnosis on retirees' life annuity choices.



(a) Malignant cancer diagnosis

(b) Benign tumor diagnosis

Notes: These figures display the share of retirees who chose a life annuity plan at the time period of the (benign or malign) tumors diagnosis relative to the pension claiming time. The estimates in the figures represent the predictive margin at each month calculated based on the regression model in Eq. (1), and its 95% confidence intervals. The x-axis denotes diagnosis month relative to the pension-claiming month, normalized to period 0. The y-axis denotes the share of retirees that chose the life annuity option. The regression model includes controls for individuals' characteristics, including age, marital status, gender, pre-retirement income, education, and health-related variables, and are based on the sub-sample of all participants who were diagnosed with cancer 3 years around retirement and chose either a life annuity or the 5- or 10-year fixed payments.

[31] Appendix Table A.5 examines mortality-based adverse selection.

5.2 Heterogeneous risk preferences

Next, we examine whether and to what extent risk preferences shape the effect of a change in risk type. To this end, we estimate the binary choice model in Eq. (4) and calculate the marginal effects of the response to the health shock separately for individuals who are risk-averse and risk-tolerant. These results are presented in Columns (2) and (3) in Table 3.

Panel A of Table 3, which utilizes wealth volatility as a proxy for risk preference, reveals that risk-averse individuals diagnosed with malign cancer *before* retirement were 4.5% less likely to purchase annuities compared to those diagnosed *after* retirement. Interestingly, the estimate indicates that risk-tolerant individuals did not change their demand for life annuities after receiving a cancer diagnosis before retirement.[32]

Panel B, which uses entrepreneurship as a proxy for risk preferences, yields results consistent with those obtained in Panel A. Specifically, it shows that risk-averse individuals who were diagnosed with malignant cancer before retirement had a 4.1% lower likelihood of purchasing annuities compared those who were diagnosed after retirement, and that risk-tolerant individuals did not exhibit a change in their annuity purchase behavior following a cancer diagnosis before retirement.[33]

Consistently observing a similar pattern using two different proxies provides support for the conclusion that the adverse-selection effect caused by the health shock is primarily driven by risk-averse individuals. This finding could result from the perception held by certain individuals that life annuities serve as an investment tool rather than insurance against longevity risk (Brown et al., 2008). These results emphasize the importance of risk preferences and provide novel insights into the annuity puzzle by suggesting that risk-tolerant individuals may not perceive life annuities as a form of insurance to begin with.

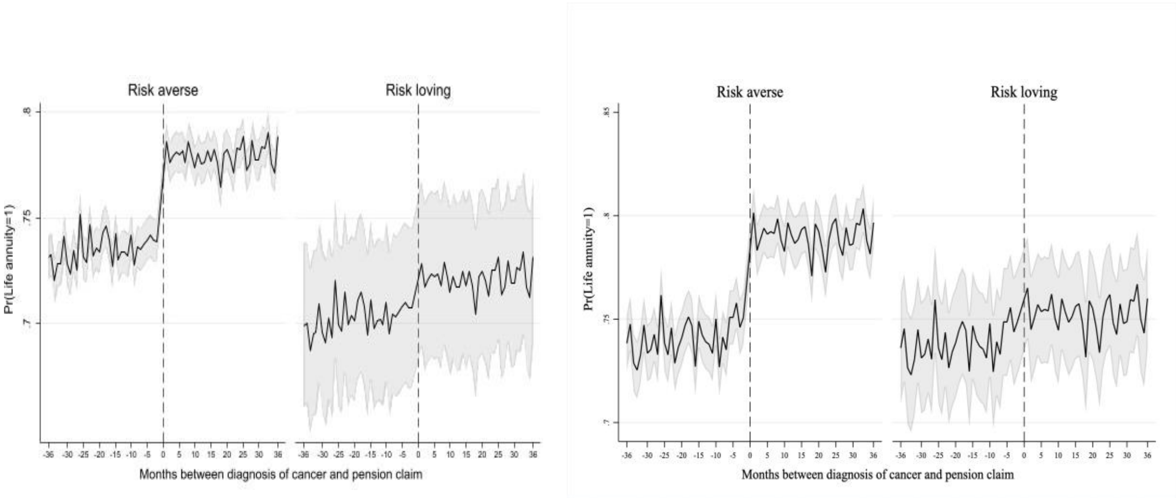
Figure 2 presents a visualization of the share of retirees that chose life annuities by the time of the cancer diagnosis, relative to their pension-claiming time by risk type. These figures offer valuable insight into the substantial differences in annuity choices among retirees with varying risk preferences. First, Figs. 2a and 2b show that at the baseline (for those diagnosed after

[32] To address concerns about the effect of changes in wealth on risk preferences and the choice of life annuity, we further conducted the analysis on a sub-sample of individuals with a positive average change in wealth during the same period, which yielded similar results. Additionally, we employed other proxies for risk preferences, such as the standard deviation of log wealth and the standard deviation of wealth changes divided by average wealth and obtained similar results again (results can be obtained from the authors upon request).

[33] One potential concern is that the entrepreneurs in our sample may not be representative of the broader population of entrepreneurs. It is worth noting that our data consists of individuals insured by ITP2, meaning they were employed for at least one of the years included in our sample. However, we argue that this selection actually strengthens rather than weakens our findings. By including individuals who are relatively less risk-tolerant, our results can be seen as a conservative estimate of the true effect. If we were to include individuals who are more risk-tolerant, it would likely lead to even more pronounced results.

retirement), the demand for annuities is higher among the risk averse. Additionally, these figures illustrate the differential effect of the cancer health shock by risk preferences proxied based on entrepreneurship and wealth volatility, respectively. The figures indicate that risk-averse retirees adjust their annuity payout choices after a cancer diagnosis, while individuals with risk-seeking tendencies show no significant change. The consistent estimates from both proxies reinforce the findings.

Figure 2. Effects of a malignant cancer diagnosis on retirees' life annuity choices by risk preferences



(a) Risk preference based on entrepreneurship proxy (b) Risk preference based on wealth volatility proxy

Notes: These figures display the share of retirees who chose a life annuity plan at the time period of the malignant cancer diagnosis relative to the pension-claiming time by risk preferences. The estimates in the figures represent the predictive margin at each month calculated based on the regression model in Eq. (2), and its 95% confidence intervals. The *x*-axis denotes diagnosis month relative to the pension-claiming month, normalized to period 0. The *y*-axis denotes the share of retires that chose the life annuity. The regression model includes controls for individuals' characteristics, including age, marital status, gender, pre-retirement income, and education.

6 Supplemental analysis

6.1 Financial loss resulting from low response to health shock

Table 3 shows that individuals respond to a malignant cancer diagnosis by reducing their demand for life annuities by 4 percentage points. To provide a more comprehensive understanding and quantify the implications of this estimate, we calculate the monetary effects of the adverse-selection estimate. Specifically, we adopt the approach introduced by Hagen (2015), who calculated the expected present discounted value (EPDV) of a life annuity and compared it with the EPDV of the five-year payout option. Our calculations are based on the following equation:

$$EPDV_{a,c}^{P}(B) = B^{P,C} \sum_{i=1}^{T} \pi_{a,a+1,c}(1+r)^{-i}, \quad (5)$$

where $\pi_{g,a,a+1,c}$ represents the probability of survival for an individual diagnosed with cancer type c at age a for an additional i years. We utilize a Gompertz distribution, adjusted for different cancer types to calculate survival probabilities and model mortality.[34] $B^{p,c}$ denote the average annual gross benefit received by individuals diagnosed with each cancer type *c* under payout option *p*. r_t stands for the annual discount rate applied to payments received in year *t*, and *T* represents the final payment duration determined by the cancer-specific life tables we constructed for the life annuity option, unless the retiree chooses the five-year payout, which then means that *T* is set at a fixed duration of five years. Additionally, we compute the money's worth ratio (MWR), which is the ratio between the expected present discounted value (EPDV) of the life annuity and the EPDV of the five-year payout option.

Table 4 summarizes the results from our analysis. It indicates that for individuals diagnosed with any form of malignant cancer, the EPDV of a life annuity is USD $44,455. In comparison, the EPDV for the five-year payout option for the same group is USD $66,012. This implies that the EPDV of the life annuity option amounts to only 67% of the EPDV of the five-year payout option. Consequently, choosing a life annuity results in an average financial loss of USD $21,558 for those diagnosed with malignant cancer before retirement. Furthermore, for individuals with digestive cancer, the EPDV of the life annuity is comparatively lower at USD $38,423, while the EPDV for the five-year payout option is higher at USD $60,565. Based on a life table of a person diagnosed with malignant cancer, and considering an average remaining lifespan of approximately 13 years, this difference to a decrease in monthly income of around USD $130. These substantial financial disparities underscore the economic significance of the ITP2 pension plan and the profound impact of these health shocks on the value of life annuities.

We also examine how each type of cancer affects the demand for life annuities in relation to corresponding changes in annuity prices. The percent change in the Money's Worth Ratio (MWR) of a life annuity attributable to a specific cancer diagnosis is shown in Column (6).[35] For malignant cancers, there is a significant decrease in MWR, amounting to -32.7% Meanwhile, a diagnosis of malignant cancer results in a 5.7%decrease in the proportion of individuals opting for a life annuity (Column 7). The ratio presented in Column (8) provides an estimation of the elasticity of annuity demand in response to changes in its relative price. In the case of malignant cancers, this

[34] Our calculations of life expectancy tables rely on data of all individuals in Sweden received their first diagnosed malignant cancer between the ages of 62 and 68 during the period from 1997 to 2015. Cancer-adjusted life tables are available upon request. This sample comprises 123,872 individuals, with approximately half of them passing away within the observed time frame.
[35] Under given assumptions, the baseline MWR for an individual with an average life expectancy at age 65 is approximately 1, as noted in Hagen (2015).

results in an elasticity of 0.175.[36] In addition, there is considerable disparity in the observed price elasticity across various types of cancer. For instance, skin cancers demonstrate the lowest price elasticity at 0.048, whereas digestive cancers exhibit the highest at 0.34.

Table 4. EPDV and financial loss by cancer type

	(1) N	(2) Annual pension (USD)	(3) EPDV life annuity	(4) EPDV 5-year payout	(5) EPDV loss annuity	(6) $\%\Delta MWR$	(7) %Δ Annuity	(8) $\frac{\%\Delta \text{Annuity}}{\%\Delta MWR}$	(9) % Dead within 5 years
All malignant	14,990	3,741	44,455	66,012	-21,558	-32.7	-5.7	0.175	18.0
Cancer type									
Digestive	1,690	3,457	38,423	60,565	-22,142	-36.6	-12.6	0.344	42.7
Skin	3,934	3,915	48,867	69,312	-20,444	-29.5	-1.4	0.048	3.4
Breast	1,491	2,069	29,076	36,923	-7,847	-21.3	-6.2	0.290	6.6
Genital	5,535	4,302	55,670	76,373	-20,703	-27.1	-4.5	0.165	10.0
Other	2,326	2,326	36,273	59,165	-22,892	-38.7	-11.5	0.298	48.2

Notes: Column (2) shows the average ITP2 benefit under the life annuity option. Columns (3) and (4) show the EPDV of the life annuity and the five-year payout, respectively. The difference between them gives the loss in EPDV terms of choosing the life annuity (5). Column (6) shows the cancer-induced percent change in the MWR (6). Column (7) shows the annuitization rate difference between individuals who were diagnosed with cancer before and after retirement. Column (8) shows the percentage change in annuity demand (6) divided by the percentage change in the MWR (7). We adopted a discount rate of 1.159%, reflecting the mean yield of 10-year Treasury notes in 2012. We assume that the annuity decision is made at age 65, i.e., *a*=65. Column (9) presents the percentage of individuals who died within five years post-retirement (*restricted to claims in 2011 or earlier).

6.2 Proxy for risk type using parental longevity information

To expand our previous findings to a larger population, we utilize information about parental longevity to form an additional proxy for risk type. Prior research has demonstrated a strong correlation between subjective survival probabilities and parental lifespan (Bloom et al., 2006; Hurd et al., 1998; Hurd & McGarry, 1995), thus allowing us to generalize our previous results to a wider sample of retirees. Parental information is likely known to individuals well in advance of retirement, and individuals may plan based on that information in ways that affect annuity choice. Yet, this analysis has the benefit of providing us with a broader view of the impact of risk type and allows us to estimate a different margin of the effect of risk type on annuity choice.

To construct the parental longevity proxy for risk type, we apply several restrictions to ensure accuracy and relevance. First, we exclude individuals whose parents died from external causes such as accidents or specific injuries to avoid measurement bias. Second, we use a same-gender

[36] Peijnenburg, Nijman, and Werker (2016) reported a 17% decrease in demand for life annuities in response to a reduction of 8% in annuity value, implying higher demand elasticity compared to our findings. Meanwhile, Chalmers and Reuter (2012) observed a restrained reaction in the demand for annuities to changes in prices, indicating a limited elasticity. While these studies concentrated on variations resulting from changes in actual prices or conversion factors, our methodology diverges by examining price shifts resulting from exogenous variations in life expectancy.

information to construct the proxy, meaning that subjective survival probabilities were calculated based on maternal longevity for females and paternal longevity for males. This approach accounts for the gender gap in life expectancy and the evidence that individuals rely more heavily on the longevity of their same-gender parent when forming subjective survival probabilities (Pinkhasov et al., 2010; Rochelle, Yeung, Bond, & Li, 2015; Waldron, 1993). Using this measure, we set the lower tail of the parental death age distribution at the 10th percentile to account for the significant decline in mortality among young individuals over the past century (Crimmins, 1981; Hoekelman & Pless, 1988). We classify individuals with high longevity risk as those with parental longevity above the median and individuals with low longevity risk as those with parental longevity equal to or below the median.

We implement the binary choice models in Eqs. (2) and (4) such that the variable D_i in Eq. (2) is an indicator that equals 1 if retiree *i* has low parental longevity, and 0 otherwise. The key parameter of interest in Eq. (2) is τ, which captures the relationship between family longevity risk and the propensity to choose life annuity. In Eq. (4), the key parameter of interest is γ, which estimates whether the annuity choice of retirees with low- and high-risk types varies along the risk preferences dimension.

Table 5. The effects of longevity expectations on annuity investment by risk preference

Panel A. Longevity expectations and wealth volatility

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Longevity effect	Risk-averse	Risk-tolerant
Low longevity risk	-0.020	-0.020	-0.024
SE	0.002	0.003	0.005
N	131,184	104,298	26,198
Controls	Yes	Yes	Yes

Panel B. Longevity expectations and entrepreneurship

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Longevity effect	Risk-averse	Risk-tolerant
Low longevity risk	-0.019	-0.020	-0.012
SE	0.002	0.002	0.007
N	188,525	175,786	12,739
Controls	Yes	Yes	Yes

Notes: Risk preferences are defined using two proxies. Panel A, utilizes wealth volatility information, categorizing individuals with portfolio volatility above the 80th percentile as risk-tolerant, while those below are categorized as risk-averse. In Panel B risk preferences are defined based on entrepreneurship status, where entrepreneurs are considered risk-tolerant, while non-entrepreneurs are classified as risk-averse All regressions include control variables, as described in text.

Table 5 presents the marginal effects estimates of the analysis. Column (1) shows that retirees with low-risk types are about 1.9% less likely to choose a life annuity at retirement, which provides evidence to support our previous findings. The size of this effect is roughly half that of a malignant cancer diagnosis, and it resembles the impact of a benign tumor diagnosis. Columns (2) and (3) explore the sources of this reduction in life annuity choice and whether it varies by risk preferences. Panel A presents results for the wealth-volatility proxy for risk preferences and, indicates that both risk-averse and risk-tolerant individuals respond similarly to the private information about lower parental longevity. This finding may be driven by the fact that wealth levels are correlated with parental longevity, meaning that individuals with advance knowledge of a high longevity risk may also possess greater wealth.[37] Panel B indicates that when using entrepreneurship as a proxy for risk preference, the reduction in demand for annuities is driven by risk-averse individuals. Specifically, risk-averse retirees are about 1.8% less likely to choose the life annuity, while risk-tolerant individuals do not respond to private information about lower parental longevity.

6.3 Family risk pooling

In this section we address concerns about the potential impact of family risk pooling on our results. The literature has suggested that the utility gain from annuitization is smaller for couples than for single individuals since married individuals are able to pool their longevity risk (Kotlikoff, Shoven, & Spivak, 1986; Kotlikoff & Spivak, 1981). To investigate this issue, we focus on married individuals diagnosed with malignant cancer before retirement and examine their annuity choices. As shown in Table 6, we find that the reduction in demand for a life annuity following a health shock among married retirees is similar in magnitude and significance to the decrease observed in the full sample when using both the cancer diagnosis health shock, as well as when using parental longevity as a proxy for risk type. This evidence suggests that the "family self-insurance" argument may have limited implications for the settings we study in this paper and could be attributed to the quasi-mandatory nature of the Swedish occupational pension plans, leading to high pension coverage rates for both household members.

Furthermore, our analysis of the sub-group of married individuals provides further insight into the impact of risk preferences on the demand for life annuity. We find that the source of the reduction in life annuity demand is consistent with the results obtained from the full sample of

[37] A vast literature has established a positive association between health (proxied by life expectancy) and income. At first, the argument explaining this relation was that higher income provides access to better healthcare services. However, more recent work has highlighted the potential impact of health on income, which can be attributed to several mechanisms such as an enhanced productivity of healthier individuals, stronger motivation to invest in education, and higher incentives to save more (Bloom & Canning, 2000). Some studies have further demonstrated that increased subjective survival probabilities results in increased household wealth accumulation (e.g., Bloom et al., 2006).

retirees (when using both a health shock and parental longevity expectations). Specifically, we find that risk-averse individuals drive the reduction in demand for annuities. These findings reinforce our main results and suggest that marital status has limited explanatory power.

Table 6. The effects of a health shock on annuity investment by risk preference for married retirees

Panel A. Cancer diagnosis and wealth volatility

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.036	-0.048	0.009
SE	0.010	0.011	0.022
N	7,313	5,826	1,456
Controls	Yes	Yes	Yes

Panel B. Cancer diagnosis and entrepreneurship

	Cancer effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.033	-0.034	-0.019
SE	0.008	0.009	0.030
N	9,959	9,154	805
Controls	Yes	Yes	Yes

Panel C. Longevity expectations and wealth volatility

	Longevity effect	Risk-averse	Risk-tolerant
Low longevity risk	-0.021	-0.020	-0.024
SE	0.003	0.003	0.006
N	89,459	71,211	17,842
Controls	Yes	Yes	Yes

Panel D. Longevity expectations and entrepreneurship

	Longevity effect	Risk-averse	Risk-tolerant
Low longevity risk	-0.020	-0.021	-0.015
SE	0.002	0.003	0.009
N	121,012	111,377	9,635
Controls	Yes	Yes	Yes

Notes: See notes of Table 5.

7 Discussion and conclusions

This study examines the impact of risk type and risk preferences on the demand for life annuities. Using data from a major occupational pension company in Sweden and merged with detailed information on retirees' demographics, mortality, and healthcare utilization, we construct proxies for risk type and risk preferences. Our aim is to understand and quantify how these aspects of private information impact annuity choices and the underlying channels by which they operate. Employing a quasi-experimental research design, we uncover compelling causal evidence of adverse selection and delve into the differential effects of risk preferences in driving this phenomenon.

Our analysis reveals that retirees diagnosed with cancer *before* retirement exhibit a significant decrease of 4 percentage points in annuitization rates compared to those diagnosed after retirement. Based on cancer-specific life tables, we further show that this reduction in demand for annuities leads to a significant loss. Specifically, for the average person diagnosed with malignant cancer before retirement, opting for a life annuity results in a loss of USD $21,158 (which reflects an MWR of only 67%). By employing various strategies to proxy for risk preferences, we find that risk-averse retirees are the main drivers of the adverse-selection effect, while the risk-tolerant do not adjust their demand for annuities following a cancer diagnosis. These findings underscore the importance of considering this channel of private information in the context of annuity choices, particularly as a potential explanation for the annuity puzzle.

Our findings contribute valuable insights to the ongoing discourse in the literature regarding the role of risk preferences in annuity markets (Agnew et al., 2008; Bommier & Grand, 2014; Chalmers & Reuter, 2012). By incorporating risk preferences into our analysis, we enhance our understanding of how health shocks impact the demand for annuities. Moreover, our research contributes to the growing body of literature that explores the effects of multidimensional private information on financial decision-making. We demonstrate that individuals' observed annuity choices, in equilibrium, are influenced not only by longevity risk but also by the intricate interplay between risk type and risk preferences when individuals possess private information about both.

Our findings carry significant implications for policymakers and insurers. First, we emphasize the need to consider differential pricing mechanisms that take into account individuals' health status (risk type) when determining relevant conversion factors. This approach resembles the "enhanced annuities" concept found in the U.K. By integrating health-related risk data into pricing models, insurers can offer life annuity options that align more closely with the specific health profiles of individuals, and thus enhance the suitability of these financial products. Yet, the distributional impact of such pricing strategies should be carefully examined by regulators. Second, our findings serve the foundations for creating innovative retirement solutions tailored to people with impaired health. One illustrative concept for such a product involves a short-term annuity (for example for five years) calculated using standard life tables, along with the possibility of extending it contingent upon the individual's continued survival, while ensuring a partial capital guarantee.

Furthermore, our findings underscore the significance of financial initiatives that emphasize the insurance aspect of annuities and customize their messaging to align with the anticipated risk preferences of retirees. These programs can enhance retirees' comprehension of annuities as a risk management tool and help them make informed decisions. Importantly, when individuals are confronted with significant life expectancy challenges, such as those arising from illnesses like cancer, strokes, or work-related accidents, they typically receive medical guidance. We contend that in such situations, individuals should also be encouraged to seek financial counseling. Financial consultation in such times would help retirees address informational biases problems and other behavioral factors, ultimately assisting them in navigating financial decisions during times of critical life transitions to avoid significant loss. Moreover, acknowledging the impact of risk preferences would improve the precision and suitability of guidance provided to retirees with diverse health situations, and direct them towards more favorable outcomes.

Lastly, pension providers can apply our findings by recognizing the influence of risk preferences on annuity choices and personalize their approaches to participants accordingly. Specifically, pension providers can offer customized solutions and support to self-employed individuals or entrepreneurs.

It is important to acknowledge certain limitations of our study. First, it is worth noting that different countries have varying types of annuity programs, which can be more complex than the one examined in our study. These programs may be voluntary in nature and may not necessarily default to a life annuity as the primary alternative. The variation in annuity plans across countries can potentially impact the magnitude of adverse selection and consequently, the influence of risk preferences on annuity choices. For instance, in voluntary annuity markets, annuitants may represent a subset of the population that is not fully representative, leading to different selection patterns. Moreover, when the default option is a lump sum rather than a life annuity, the dynamics of annuity demand and the role of risk preferences may differ. Therefore, extending our analysis to investigate different pension schemes and annuity programs in various countries as well as other related questions such as how the total cost of the insurer changes as a function of a change in an annuity payout would be a valuable avenue for future research. By examining diverse contexts, we can gain a more comprehensive understanding of the interplay between risk preferences, adverse selection, and annuity choices, thus enhancing the generalizability and applicability of our findings.

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Appendix tables

Table A 1. The effect of a health shock on annuity investment by financial risk preferences for individuals diagnosed ±24 and ±12 months pre- and post-retirement.

Panel A. Cancer diagnosis and wealth volatility, ±24 months before/after retirement

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.037	-0.046	-0.005
SE	0.010	0.011	0.023
N	7,356	5,852	1,462
Controls	Yes	Yes	Yes

Panel B. Cancer diagnosis and wealth volatility, ±12 months before/after retirement

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.037	-0.046	-0.002
SE	0.014	0.015	0.032
N	3,788	3,015	753
Controls	Yes	Yes	Yes

Panel C. Cancer diagnosis and entrepreneurship, ±24 months before/after retirement

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.040	-0.042	-0.012
SE	0.008	0.009	0.032
N	10,385	9,653	732
Controls	Yes	Yes	Yes

Panel D. Cancer diagnosis and entrepreneurship, ±12 months before/after retirement

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.042	-0.042	-0.035
SE	0.012	0.012	0.046
N	5,373	4,990	383
Controls	Yes	Yes	Yes

Notes: Risk preferences are defined based on entrepreneurship status, where entrepreneurs are considered risk-tolerant, while non-entrepreneurs are classified as risk-averse.

Table A 2. Comparison between risk-averse and risk tolerant.

A. Wealth volatility	Low volatility		High volatility		Difference	
	Mean	SD	Mean	SD	Diff	t
Life annuity	0.74	0.44	0.73	0.45	0.01***	(4.74)
5-year payout	0.15	0.36	0.17	0.38	-0.02***	(-8.47)
Pension from Alecta	73132	94193	69653	92798	3478	(1.86)
Public pension	163067	56026	162895	54085	172	(0.14)
Total pension	346521	228360	335968	227665	10553*	(2.05)
Pension from ITP2	49779	70955	47463	72297	2315	(1.59)
Early withdrawal	0.14	0.35	0.15	0.36	-0.01***	(-4.16)
Age (at claim)	64.75	0.88	64.69	1.03	0.06***	(9.02)
Disability pension	0.13	0.34	0.14	0.35	-0.01**	(-3.08)
Claimed public pension	0.26	0.44	0.29	0.45	-0.03***	(-10.55)
Male	0.60	0.49	0.64	0.48	-0.05***	(-13.86)
Married	0.69	0.46	0.65	0.48	0.04***	(11.98)
Single	0.11	0.31	0.09	0.28	0.02***	(12.04)
High school	0.48	0.50	0.47	0.50	0.02***	(4.70)
University	0.35	0.48	0.37	0.48	-0.02***	(-4.66)
Number of children	1.81	1.06	2.02	1.11	-0.21***	(-26.64)
log disposable income	7.98	0.72	7.96	0.91	0.02**	(3.06)
log financial assets	12.71	1.37	11.84	1.89	0.87***	(67.33)
Wealth volatility	0.07	0.03	0.22	0.07	-0.15***	(-312.65)
log real assets	11.82	5.14	11.43	5.49	0.39***	(9.98)
Sickness benefits (yes/no)	0.11	0.19	0.12	0.20	-0.01***	(-5.31)
Number of hospitalization days	0.35	1.42	0.39	1.63	-0.04***	(-3.42)
Number of unique drugs	3.59	2.33	3.77	2.45	-0.18***	(-10.36)
Self-incorporated	0.07	0.26	0.10	0.30	-0.03***	(-15.53)
Partner’s age (at claim)	63.25	6.21	61.97	7.61	1.28***	(18.41)
Partner’s log disposable income	7.75	0.79	7.69	0.93	0.06***	(7.03)
Parent died of cancer	0.35	0.48	0.35	0.48	-0.00	(-0.61)
Dead within 2 years	0.02	0.12	0.02	0.14	-0.00***	(-3.95)
Dead within 5 years	0.04	0.19	0.05	0.22	-0.01***	(-5.31)
Observations	139895		23117		163012	

B. Entrepreneurship	Non self-incorporated		Self incorporated		Difference	
	Mean	SD	Mean	SD	Diff	t
Life annuity	0.74	0.44	0.73	0.44	0.01**	(2.85)
5-year payout	0.16	0.37	0.18	0.38	-0.02***	(-5.94)
Pension from Alecta	65652	88223	6320	87974	2447	(1.20)
Public pension	159601	54312	162890	63502	-3289*	(-2.00)
Total pension	316774	206857	380965	263308	-64191***	(-9.47)
Pension from ITP2	44360	66460	42562	67545	1798	(1.15)
Early withdrawal	0.14	0.35	0.12	0.32	0.03***	(10.62)
Age (at claim)	64.72	0.90	64.73	1.07	-0.01	(-1.19)
Disability pension	0.16	0.37	0.05	0.23	0.11***	(56.14)
Claimed public pension	0.25	0.43	0.38	0.48	-0.13***	(-33.03)
Male	0.59	0.49	0.81	0.39	-0.23***	(-70.12)
Married	0.63	0.48	0.75	0.43	-0.13***	(-35.46)
Single	0.11	0.31	0.06	0.24	0.05***	(23.84)
High school	0.48	0.50	0.43	0.49	0.06***	(13.87)
University	0.31	0.46	0.44	0.50	-0.14***	(-33.41)
Number of children	1.87	1.13	2.11	1.08	-0.23***	(-26.02)
log disposable income	7.68	1.40	8.27	0.86	-0.59***	(-79.47)
log financial assets	10.84	4.05	12.11	3.00	-1.27***	(-50.47)
Wealth volatility	0.10	0.08	0.12	0.09	-0.01***	(-19.16)
log real assets	10.38	6.07	12.48	4.85	-2.10***	(-52.05)
Sickness benefits (yes/no)	0.13	0.20	0.06	0.14	0.07***	(57.99)
Number of hospitalization days	0.43	1.80	0.24	0.65	0.19***	(29.16)
Number of unique drugs	3.71	2.51	3.47	2.21	0.24***	(13.19)
Partner’s age (at claim)	62.75	7.10	61.86	6.96	0.89***	(12.58)
Partner’s log disposable income	7.68	0.86	7.83	0.91	-0.15***	(-15.85)
Parent died of cancer	0.34	0.47	0.35	0.48	-0.01***	(-3.56)
Dead within 2 years	0.02	0.14	0.01	0.11	0.01***	(6.34)
Dead within 5 years	0.05	0.22	0.03	0.18	0.02***	(7.63)
Observations	225898		15998		241896	

Notes: Variables are defined as in Table 1.

Table A 3. The effect of a health shock on annuity investment by risk preference among healthy individuals.

Panel A. Cancer diagnosis and wealth volatility

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.053	-0.060	-0.029
SE	0.011	0.013	0.027
N	5,031	3,998	1,003
Controls	Yes	Yes	Yes
Benign cancer	-0.020	-0.026	0.008
SE	0.012	0.013	0.027
N	4,477	3,566	888
Controls	Yes	Yes	Yes

Panel B. Cancer diagnosis and entrepreneurship

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.057	-0.058	-0.044
SE	0.010	0.010	0.038
N	6,780.000	6,263.000	517.000
Controls	Yes	Yes	Yes
Benign cancer	-0.029	-0.032	0.002
SE	0.011	0.011	0.043
N	6,012.000	5,616.000	396.000
Controls	Yes	Yes	Yes

Notes: Risk preferences are defined using two proxies. In Panel A, risk preferences are de- fined based on entrepreneurship status, where entrepreneurs are considered risk-tolerant, while non-entrepreneurs are classified as risk-averse. Panel B utilizes wealth volatility information, categorizing individuals with portfolio volatility above the 80th percentile as risk-tolerant, while those below are categorized as risk-averse.

Table A 4. The effect of a health shock on annuity investment by risk preference when parental longevity is included in the control set.

Panel A. Cancer diagnosis and wealth volatility

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.040	-0.045	-0.018
SE	0.009	0.010	0.021
N	7,936	6,326	1,577
Controls	Yes	Yes	Yes
Benign cancer	-0.021	-0.024	-0.004
SE	0.009	0.011	0.022
N	7,384	5,878	1,472
Controls	Yes	Yes	Yes

Panel B. Cancer diagnosis and entrepreneurship

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Risk-averse	Risk-tolerant
Malignant cancer	-0.044	-0.046	-0.018
SE	0.008	0.008	0.030
N	11,063	10,270	793
Controls	Yes	Yes	Yes
Benign cancer	-0.019	-0.021	0.016
SE	0.008	0.0084	0.032
N	10,191	9,522	669
Controls	Yes	Yes	Yes

Notes: Risk preferences are defined using two proxies. In Panel A, risk preferences are de- fined based on wealth volatility information, categorizing individuals with portfolio volatility above the 80^{th} percentile as risk-tolerant, while those below are categorized as risk-averse. Panel B utilizes entrepreneurship status, where entrepreneurs are considered risk-tolerant, while non-entrepreneurs are classified as risk-averse.

Table A 5. Mortality based adverse selection effect.

Panel A. Dead within 2 years

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Dead=0	Dead=1
Malign cancer	-0.0368	-0.0247	-0.1639
SE	0.007	0.000	0.025
N	13,992	1,214	12,778
Controls	Yes	Yes	Yes

Panel B. Dead within 5 years

	Marginal effect of risk type on investment in life annuity	Marginal effect of risk type by risk preference	
	Cancer diagnosis effect	Dead=1	Dead=0
Malign cancer	-0.0232	-0.0006	-0.1001
SE	0.008	0.009	0.022
N	8,526	1,548	6,978
Controls	Yes	Yes	Yes

Notes: The table presents a measure of mortality based adverse selection by comparing the difference-in-difference in annuity choice between before-vs-after retirement cancer diagnosis comparing those who die or did not die within 2 and 5 years from all causes (with 85% attributed to cancer). The estimates in the tables are marginal effects generated based on a model similar to Eq. 3, in which instead of risk preferences the model incorporates mortality. The samples in Panel A include individuals who claimed their pension in 2014 or earlier, while those in Panel B are from individuals who claimed in 2011 or earlier. *Dead=1* indicates individuals who have deceased by the end of the observation period (i.e., 2015), while Dead=*0* indicates individuals who remained alive by the end of the observation period.