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SOCIAL SECURITY DESIGN AND INDIVIDUAL RETIREMENT DECISIONS

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Contents

[1] This chapter is based on joint work with Antoine Bommier.

[2] Large parts of our discussion are based on Bommier (2006) and Bommier (2013). The reader may refer to these papers, as well as to work cited by theses papers, for further information.

[3] This chapter is based on survey data stemming from the Swiss Labour Force Survey (SLFS). I would like to gratefully acknowledge the Swiss Federal Statistical Office for this data set.

[4] This chapter is based on data stemming from a private insurance company. I would like to gratefully acknowledge the insurance company for this data set.

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Part A

Summaries

Deutsche Zusammenfassung

Ziel dieser Dissertation ist es, ausgewählte Aspekte des Sozialversicherungsaufbaus zu erläutern und detailliert zu analysieren. Im Mittelpunkt des ersten Kapitels stehen altersabhängige Renten als Alternative zu konventionellen Rentensystemen. Die Höhe der von einem Versicherten bezogenen Rentenleistungen hängt üblicherweise von Aggregaten - wie beispielsweise demographischen Faktoren oder der Inflation - ab und muss deswegen im Zeitverlauf nicht zwangsläufig konstant bleiben. Das Alter des Rentners wird jedoch praktisch nie explizit in die Berechnungsgrundlage zur Bestimmung der Rentenhöhe miteinbezogen. In der Praxis sind Renten fast überall altersunabhängig. Kernaussage des ersten Kapitels ist, dass altersunabhängige Renten im Allgemeinen nicht Pareto-effizient sind, wenn man die Annahme trifft, dass Rentenbezieher Präferenzen mit intertemporeller Risikoaversion aufweisen. Der auf Mortalitätsdaten beruhenden Modellsimulation im zweiten Teil des Kapitels zufolge könnte eine Lockerung der Einschränkung, dass Rentenzahlungen altersunabhängig sein müssen, die aggregierten Ausgaben für Rentenzahlungen seitens des Staates um bis zu 1% verringern. In den USA hätte eine solche Kostenreduktion einen Nettogegenwartswert von etwa 225 Milliarden Dollar. Dieser Kosteneinsparung stünden allerdings potenzielle Schwierigkeiten - wie etwa eine steigende Altersarmut - gegenüber.

Das zweite Kapitel beschreibt die drei Säulen des schweizerischen Rentensystems und schenkt dem Aufbau der beruflichen Vorsorge besondere Aufmerksamkeit, da diese die Grundlage für die folgenden Kapitel bildet. Bei Renteneintritt können ehemalige Erwerbstätige in der Schweiz zwischen einer Einmalzahlung und einer lebenslangen Annuität als Bezugsform ihrer beruflichen Vorsorgeansprüche wählen. Kapitel III ist eine empirische Analyse, die anhand von Umfragedaten untersucht, inwiefern Witwenrenten diese Entscheidung beeinflussen. Nach dem Tod eines verheirateten Rentners bzw. einer verheirateten Rentnerin hat die Witwe bzw. der Witwer Anspruch auf eine lebenslange Hinterbliebenenrente, deren Höhe sich proportional aus der Höhe der Annuität berechnet. Der Nettobarwert der Annuität ist unter realistischen Mortalitätsannahmen folglich für Rentner und Rentnerinnen am höchsten, wenn diese mit jungen Partnern verheiratet sind. Kapitel III legt anhand nicht-parametrischer und parametrischer Schätzungen dar, dass diese Tatsache auf die Wahl der Bezugsform nur einen Einfluss hat, wenn der Altersunterschied sehr gross ist. Bei geringem Altersunterschied scheinen Rentner diesen Effekt bei ihrer Entscheidung nicht in Betracht zu ziehen.

Das letzte Kapital analysiert Sterberaten von Rentnern in der Schweiz anhand von Versicherungsdaten und Ereigniszeitanalysemethoden. Die Überlebenswahrscheinlichkeit von Annuitätsrentnerinnen der beruflichen Vorsorge scheint, zumindest in den ersten Jahren nach Renteneintritt, beträchtlich höher zu sein als jene der entsprechenden schweizerischen Durchschnittsbevölkerung. Dieses Ergebnis gilt jedoch nur für Rentnerinnen, nicht für Rentner. Die Überlebensraten von Männern im Ruhestand stehen in engem Zusammenhang mit der Höhe ihrer Rentenansprüche, wobei die Sterbewahrscheinlichkeit in einem bestimmten Altersjahr mit zunehmendem Wohlstand sinkt. Auch dieses Ergebnis gilt nicht geschlechterübergreifend: Auf die Überlebenswahrscheinlichkeit von Frauen hat die Rentenhöhe keinen Einfluss.

Résumé en langue française

Cette dissertation porte sur les systèmes de sécurité sociale dont elle analyse certains aspects. Le premier chapitre se focalise sur la définition de pensions de retraite dont les montants dépendraient de l'âge des bénéficiaires. Dans les systèmes de pension conventionnels, le montant perçu par un retraité peut dépendre de certains facteurs agrégés comme l'inflation. Ce montant n'est donc pas nécessairement constant dans le temps. En revanche, l'âge du retraité n'est quasiment jamais pris en compte dans le calcul de ses droits. En pratique, les pensions de retraite ne dépendent pas de l'âge. Ce premier chapitre démontre que les retraites non indexées sur l'âge ne sont pas toujours optimales au sens de Pareto. Plus précisément, elles ne le sont pas dès que l'on introduit l'hypothèse que les bénéficiaires de pensions ont de l'aversion au risque inter-temporelle. Les simulations réalisées par la suite indiquent que, sous cette hypothèse, les dépenses étatiques nécessaires au financement des retraites pourraient diminuer d'environ 1% sans pour autant réduire le bien-être social des retraités si l'on indexait les retraites sur l'âge. Aux Etats-Unis, une telle réduction correspondrait à une économie de 250 milliards de dollars en valeur actuelle. Il convient néanmoins de préciser que ces économies pourraient s'accompagner d'effets indésirables (précarisation des personnes âgées par exemple).

Le deuxième chapitre décrit les trois piliers du système de retraite suisse et accorde une attention particulière à la prévoyance professionnelle. En général, lorsqu'une personne active prend sa retraite, le système suisse lui permet, soit de toucher sa pension professionnelle sous la forme d'une annuité jusqu'à la fin de sa vie, soit de bénéficier d'un paiement unique. Le troisième chapitre présente une étude empirique analysant le rôle des pensions de réversion dans les choix du mode de perception. Dans un couple marié, lorsqu'un conjoint qui aurait souscrit au mode de retraite par annuité décède, le conjoint

survivant peut prétendre à une pension de réversion dont le montant est proportionnel à l'annuité perçue par la personne décédée. Il en résulte qu'en présence de taux de mortalité réalistes, la valeur de l'annuité est plus élevée pour les retraités mariés à des conjoints plus jeunes qu'eux. Les estimations non-paramétriques et paramétriques du troisième chapitre démontrent que les retraités ne prennent en compte cet effet actuariel que lorsque la différence d'âge est particulièrement élevée.

Le dernier chapitre étudie les taux de mortalité différentielle de retraités suisses en s'appuyant sur les données d'une compagnie d'assurance privée et sur des méthodes d'analyse de survie. Les taux de survie de femmes retraitées qui ont choisi de percevoir leur pension professionnelle sous la forme d'une annuité semblent être nettement plus élevés que ceux de la population moyenne. Ce résultat est uniquement valable pour les femmes. A l'inverse, les taux de mortalité des hommes sont étroitement liés au montant de leur retraite professionnelle - plus ils sont aisés, meilleur est leur taux de survie. Ce dernier résultat ne s'applique pas aux femmes.

English summary

This dissertation aims to discuss selected characteristics of social security systems and to analyze them in detail. The first chapter focuses on age-dependent pensions as a potential alternative to conventional retirement schemes. While insurees often receive retirement benefits that depend on aggregate factors, such as inflation or demographic trends, a retiree's age does not directly affect pension entitlements. In practice, pensions are virtually always age-independent. The first chapter points out that age-independent retirement benefits do not achieve Pareto-efficient life cycle consumption if one assumes consumer preferences with intertemporal risk-aversion. We use US-mortality rates to simulate an economic model with such preferences and estimate the welfare gain that could be achieved if pensions were no longer required to be age-independent. According to our simulations, the net present value of future government expenditures on retirement benefits could be reduced by roughly 1% in the case of the United States without lowering retiree welfare. This cost reduction has a net present value of about $225 billion dollars.

The second chapter describes the three pillars of the Swiss retirement system and focuses especially on the occupational pillar (pillar II), thereby preparing the grounds for chapters III and IV. Former Swiss workers can choose between two options to withdraw their second pillar benefits: a life-long annuity or an immediate lump-sum payment. Chapter III analyzes - on the basis of survey data - whether the existence of widow's pensions has an impact on this choice. When married retirees decease, their surviving spouses are entitled to survivor benefits until they decease as well. These widow's pensions are proportional to the annuity that the dead retiree received. Under realistic mortality rates, the actuarial value of the annuity option is thus higher when retirees are married to young spouses. Using non-parametric and parametric estimation techniques,

chapter III points out that this value difference only impacts the annuity vs. lump-sum decision when a couple's age-difference is particularly large. In couples with moderate age-difference levels, retirees do not seem to react to this actuarial effect.

The last chapter analyzes mortality patterns of Swiss pensioners using insurance data and survival analysis techniques. Death rates of female second pillar annuitants are considerably lower than those faced by the overall Swiss population, at least in the first years after retirement. This result does not extend to male second pillar annuitants - their mortality rates match overall Swiss mortality rates very precisely. To the contrary, survival rates of men depend to a large extent on retirement wealth - wealthier men live longer than their poorer peers. This result does not hold for women.

Part B

General Introduction

In its "Pensions at a Glance 2013"[5] report, the OECD notes that in its member countries "the pension landscape has been changing at an astonishing pace over the past few years. After decades of debate and, in some cases, political standstill, many countries have launched significant pension reforms."

From highly developed countries to emerging markets, pension systems are on the move. Designing efficient, fair and affordable social security programs has become a paramount political objective around the globe and economic pressure for reform will most likely remain strong over the next decades. Several demographic and economic trends coincide and exacerbate the complex problem of pension sustainability. Old-age mortality rates decline rapidly and survival curves continue their "rectangularization": While in 1970 a 65 year-old American man was expected to live another 13 years, it is about 18 years today. The size of the labor force has ceased to grow (at least in relative terms) in many places because net birth rates have fallen well below their replacement level of 2.1 children per women after the end of the baby boom: On average, a Swiss woman gave birth to about 2.5 children in the mid-60s, the value has dropped to roughly 1.5 today[6]. Finally, the economic turmoil following the financial crises of 2007-08 has brought about large-scale unemployment, leading to dwindling government revenue. A full recovery is still a long way to go, especially in southern Europe. All these dynamics put traditional unfunded pay-as-you-go pension systems under considerable pressure. In these systems, a large number of young workers is supposed to finance retirees through a small part of their working income, thereby acquiring the right to receive old-age benefits one day as well. As age dependency ratios keep increasing, contribution rates have to increase alongside if one wants to sustain pension levels and retain the same

[5] OECD (2013), Pensions at a Glance 2013: OECD and G20 Indicators, OECD Publishing. http://dx.doi.org/10.1787/pension_glance-2013-en

[6] See official statistics.

retirement entry age.

The major alternative to unfunded schemes is pension financing through fully-funded capitalization systems. According to the so-called Samuelson-Aaron rule [see Samuelson (1958) and Aaron (1966)], this option is more advantageous from an individual perspective if the sum of the labor force growth rate and the real wage growth rate is smaller than the interest rate. In a time where risk-free remuneration rates of money are very low in several major economic areas, or even negative in real terms, funded capital accounts, too, expose their flaws.

New and creative ideas on pension systems as well as thorough sustainability assessments are becoming ever more important. Research needs to gather further information and accumulate knowledge on the financial cost of pension system designs, their efficiency, their redistributive effects and the behavioral incentives they provide. A quickly growing literature on this subject area has evolved, but many questions still remain to be answered. This dissertation aims to add its share to this research. It consists of three main analyses and is divided into four chapters. The first chapter discusses, based on joint work with Antoine Bommier, the possibility of age-dependent pensions. Pensions are age-dependent if they vary over the life cycle not only as a function of time (e.g. inflation or some other aggregate index), but also as a function of age. This option has received very little attention so far, both academically and politically. After theoretical considerations, chapter I proceeds to a quantitative efficiency evaluation of age-dependent pensions and shows that they are potentially able to reduce costs without reducing social welfare. The second chapter describes the Swiss retirement system in some detail, thereby preparing the grounds for two empirical assessments. Chapter III analyzes the importance of survivor benefits in the lump-sum vs. annuity decision of Swiss retirees in this context. While one's spouse's age has a considerable effect on the actuarial attractiveness of an annuity with survivor benefits, its empirical relevance is limited. The fourth chapter remains in the Swiss pension framework and studies differential retiree mortality using private insurance micro-level data. Male and female survival rates both react to expected mortality determinants, yet in quite different ways.

Part C

Main Part

Chapter I

Evaluating Age-Dependent Pensions[7]

I.1 Introduction

The unprecedented demographic change and quickly rising life expectancy in industrialized economies put pension systems increasingly under stress. The share of national income devoted to finance public expenditures on old-age pensions has grown considerably in many OECD countries over the last 20 years. In some particularly salient cases, such as Portugal, Korea and Mexico, this share has more than doubled.

Policy makers have implemented a variety of reforms in recent years in order to cope with the increasing cost burden. Most of the amendments postpone retirement entry ages, adjust benefit and contribution levels, or index pensions to economic and demographic factors. Notwithstanding the diversity and creativity of all these changes, they all converge in that they propose to pay retirees a constant income level over

[7]This chapter is based on joint work with Antoine Bommier.

their whole retirement period, at least in nominal terms. The idea of indexing pensions explicitly on age and letting them vary along the life cycle has virtually remained unexploited[8] and excluded from political debate.

This chapter addresses this possibility. Our contribution to the existing literature is twofold. First, we develop a discussion on the theoretical foundations of age-dependent pension profiles and investigate when they could be used to implement Pareto improving pension reforms. Second, we provide an estimation of the monetary gains that could potentially result from indexing pensions on age while keeping lifetime welfare at the same level.

In the theoretical part (section 2), we compare two distinct classes of consumer preferences and focus on their implications on the efficiency of age-independent pension profiles. The first class of preferences comprises time-additive expected utility models with stationary preferences and a constant intertemporal elasticity of substitution (henceforth the "time-additive model"). Yaari's (1965) seminal paper demonstrates that an agent's optimal consumption growth rate is constant and independent of age in such a setting. A constant consumption growth obviates the need for age-dependent pensions. Even in the case of credit-constrained agents, who are bound to consume their retirement benefits in each period, it is possible to achieve optimality through uniform pension level adjustments that are identical for agents of all ages.

Yet the result that optimal consumption grows at a constant rate hinges on the assumption of intertemporal risk neutrality which is inherent in Yaari's model specification. With temporally risk averse agents, by contrast, the shape of optimal consumption is not linear. Optimal consumption growth in such a setting is related to

[8] We are aware of only one exception: air traffic controllers in France. In compliance with legislation adopted in 1989, they are granted "temporary complementary payments" that start decreasing 5 years after retirement and come to a permanent end after an additional 8 years.

mortality rates and indirectly also to age, as age and mortality strongly correlate. This class of preferences (henceforth the "time multiplicative model") was first introduced in Bommier (2006) and theoretically axiomatized in Bommier (2013). As pointed out in the latter paper, the combination of intertemporal risk aversion and increasing mortality rates typically generates non-monotonic life-cycle consumption patterns. As a consequence, pension systems that offer age-independent pensions are suboptimal and subject to Pareto improving reforms.

The second part of the chapter evaluates the monetary gain that could result from shifting to age-dependent pensions in the case that agents have preferences with intertemporal risk aversion. In particular, we explore the case of a multiplicative life-cycle model which is calibrated based upon demographic data from the United States. In this model, indexing retirement benefits on age makes it possible to cut the present-value of aggregate expenses by more than \$ 225 billion without reducing any retiree's expected welfare. In relative terms, this amount corresponds to an expenditure reduction of 1%, which would be a considerable gain.

This chapter relates to several strands of literature. First, it is linked to numerous studies that focus directly on pension systems and pension reforms. Examples of this abundant literature are Heijdra and Romp (2009), which analyzes the repercussions of demographic shocks and the efficiency of pension reforms in this context, and Golosov et al. (2013), which examines optimal pension systems when working hours and the retirement choice are endogenous. Second, this chapter relates to the literature discussing the shape of life-cycle consumption, such as Fernández-Villaverde and Krueger (2007), Gourinchas and Parker (2002) and Carroll and Summers (1991). It is also connected to research on the implications of uncertain life duration. Kalemli-Ozcan and Weil (2010), for example, examines the impact of mortality reduction on the retirement decision.

Last, the study fits in a series of papers that investigate the impact of temporal risk aversion on an agent's choice under uncertain lifetime, initiated by Bommier (2006). The reader may refer to Bommier (2013) for a discussion about the theoretical foundations of the time-multiplicative model and to get an overview of the applications that have been developed so far.

The remainder of the chapter is organized as follows. The next section introduces the setting and discusses possible ways of modelling life cycle preferences. In particular, we explain the theoretical foundations of time-multiplicative preferences and point out that optimal consumption profiles in such a setting are usually non-monotonic. If retirement benefits matter for the timing of consumption, e.g. due to missing markets, age-dependence might be necessary to achieve Pareto-efficiency. Section 3 details the policy reform we analyze, describes how we calibrate our model, presents the main numerical results and provides a short sensitivity analysis. The final section concludes.

I.2 Theory[9]

I.2.1 Setting

In the remainder of the chapter we consider expected utility maximizers who face mortality risk. Our analysis uses a discrete time setting. Mortality follows an exogenously given survival pattern. By $s_{\tau,t}$ we denote the conditional probability of being alive at age $\tau \geq t$, knowing that the agent is alive at age t. We assume that there is a maximum age T a human can attain, such that $\forall t \leq T$, $s_{T+1,t} = 0$. Instantaneous mortality rates

[9] Large parts of our discussion are based on Bommier (2006) and Bommier (2013). The reader may refer to these papers, as well as to work cited by theses papers, for further information.

are denoted by μ, where $\mu_\tau = \frac{s_{\tau,t} - s_{\tau+1,t}}{s_{\tau,t}}$. With the convention that $\mu_\tau = 1$ if $s_{\tau,t} = 0$, the probability of dying exactly at age τ, conditional on being alive at age $t \leq \tau$, is given as $\pi_{\tau,t} = s_{\tau,t}\mu_\tau = s_{\tau,t} - s_{\tau+1,t}$. For some parts of our analysis it is convenient to note that $s_{\tau,t} = \sum_{\nu=\tau}^{T} \pi_{\nu,t}$. In our setting, workers retire at an exogenously given age T_0. The risk-free interest rate is denoted by r.

Given some specific pension profile $p_{\tau,t}$, that may or may not be constant in τ, we want to determine whether this profile is optimal for an agent. The following notion of efficiency defines optimality.

Definition 1 (Efficiency) *Consider a pension profile that starts at age t and pays $p_{\tau,t}$ at age τ. The pension profile is said to be efficient if there does not exist any profile $q_{\tau,t}$ that simultaneously satisfies the following properties:*

1)

$$\sum_{\tau=t}^{T} \frac{q_{\tau,t}}{(1+r)^{\tau-t}} s_{\tau,t} < \sum_{\tau=t}^{T} \frac{p_{\tau,t}}{(1+r)^{\tau-t}} s_{\tau,t}$$

2) The agent weakly prefers consumption profile $c_\tau = q_{\tau,t}$ to consumption profile $c_\tau = p_{\tau,t}$.

Intuitively speaking, a pension profile is said to be efficient whenever no dominating benefits trajectory exists, in the sense that the alternative plan a) causes lower expected costs and b) provides higher or equal expected utility. Note that the notion of efficiency is geared to a situation in which consumption and retirement benefits coincide. Section 3.1. will make clear why this definition is pertinent in our framework. Whenever a pension profile is constant over the life-cycle and identical for all retirees, we refer to this payment stream as $\overline{p}$ for the sake of clarity.

TABLE 1 Notation summary

T_0	exogenous retirement age
$s_{\tau,t}$	probability of being alive at age τ, conditional on being alive at age t
$\pi_{\tau,t}$	probability of dying at age τ, conditional on being alive at age t
μ_τ	instantaneous probability of dying at age τ
$p_{\tau,t}$	pension level at age $\tau \geq t$ as planned when payments start at age t
r	risk-free interest rate
$\overline{p}$	pension level if pensions are age-independent and uniform
T	maximum age a human being can attain

I.2.2 Age-dependence

Before entering deeper into the discussion, we start by defining age-dependence explicitly. A pension profile is said to be age-dependent whenever pension growth rates are a function of the agent's age. Formally speaking:

Definition 2 (Age-dependence) *Consider a pension profile that pays $p_{\tau,t}$ at age τ. The pension profile is said to be age-independent if and only if $\frac{p_{\tau+1,t} - p_{\tau,t}}{p_{\tau,t}}$ is independent of τ. Otherwise, it is said to be age-dependent.*

It is noteworthy that age-independence does not necessarily imply that agents receive constant pension payments over their whole life cycle. As long as the benefit growth rate is constant, age-independence is not violated. Adjustments that are uniform across the entire population still lead to age-independent pension profiles. Uniform adjustments can for example result from indexing pensions on some rate that does not involve a specific relation between age and pension levels, e.g. on inflation.

I.2.3 Preference classes

This section summarizes results on two distinct classes of consumer preferences, namely time-additive and time-multiplicative preferences. Their diverging implications on the optimality of age-independent pensions are of particular interest for us.

As pointed out in Bommier (2013), rational preferences that fulfill the axioms of independence, continuity and stationarity can be represented within the expected utility framework with a utility index which associates to a life of length $(\overline{T}-t)+1$ periods and a consumption profile $(c_t, ..., c_{\overline{T}})$ utility level $U_{\overline{T}}(c) = \sum_{\tau=t}^{\overline{T}} u(c_\tau)\exp(-\sum_{\upsilon=t}^{\tau-1} g(c_\upsilon))$, where $u(c), g(c)\epsilon\mathbb{R}$.

If, in addition, the preferences are weakly separable, the utility index takes one of two forms: either a time-additive form

$$U_{\overline{T},t}(c) = \sum_{\tau=t}^{\overline{T}} \beta^{\tau-t} u(c_\tau) \tag{I.1}$$

or a time-multiplicative form

$$U_{\overline{T},t}(c) = \frac{1}{k}(1 - \exp(-k\sum_{\tau=t}^{\overline{T}} u(c_\tau))). \tag{I.2}$$

In the presence of mortality risk, the corresponding expected utility representations are given by

$$EU_{T,t}(c) = \sum_{\tau=t}^{T} \pi_{\tau,t} \sum_{\nu=t}^{\tau} \beta^{\nu-t} u(c_\nu) = \sum_{\tau=t}^{T} s_{\tau,t} \beta^{\tau-t} u(c_\tau) \tag{I.3}$$

for time-additive preferences and

$$EU_{T,t}(c) = \sum_{\tau=t}^{T} \pi_{\tau,t} \frac{1}{k}(1 - \exp(-k \sum_{\nu=t}^{\tau} u(c_\nu))) \tag{I.4}$$

in the case of time-multiplicative preferences.

Time additive preferences

Time-additive preferences are extensively used in the economic literature, owing their appeal in part to their mathematically very handy utility representation. As a counterpart for their technical tractability, however, these preferences constrain agents to be temporally risk neutral. To see this point, consider the following thought experiment. An agent cares for consumption in two periods. In each period, her consumption level is subject to risk and its outcome can be either good (upper case C) or bad (lower case c). The agent faces two lotteries, L_1 and L_2. L_1 pays (c, c) or (C, C) with equal probability, while the outcomes of L_2 are either (C, c) or (c, C) with a 50% chance each. Put briefly, in L_1 she gets either always the best or always the worst outcomes, while L_2 provides intermediate outcomes. Under temporal risk neutrality, the agent is indifferent between L_1 and L_2. The degree of correlation between the consumption levels in the two periods has no impact on her expected utility. This property comes as a direct consequences of the additive nature of the utility function. One can recognize that the agent is risk-neutral with respect to her overall lifetime utility and does not claim a risk premium for the risk on her life-time welfare. Time-additivity - and by implication temporal risk neutrality - has strong consequences for the agent's rational life cycle planning. As stated earlier, Yaari (1965) shows that an agent with preferences given by (3) chooses a constant consumption growth rate over her life cycle. This growth rate is determined by the rate of time preference, the intertemporal elasticity of substitution and the interest rate, but it is completely independent of the agent's mortality pattern. Both the lifetime utility function and the budget constraint are indeed additive and are equally affected by variations in death probabilities. If death rates at young ages were to decrease, consumption in future periods would become more probable and hence more important. At the same time, however, the expected expenditures per unit of future consumption would rise. Under additive preferences, these two effects offset one another perfectly so that the consumption profile is, by construction, independent of mortality rates. We have the following result.

Proposition 1 *Assume an agent's preferences are time-additive and exhibit a constant intertemporal elasticity of substitution (IES). If the agent's pension benefits determine her consumption, then any efficient pension profile is age-independent.*

Proof. Proposition 1 follows from Yaari (1965). The agent maximizes $EU_{T,t}(c) = \sum_{\tau=t}^{T} s_{\tau,t}\beta^{\tau-t}u(c_\tau)$ s.t. $\sum_{\tau=t}^{T} \frac{c_\tau}{(1+r)^{\tau-t}} s_{\tau,t} \leq M$, where M is some monetary amount. The first order conditions imply that $\forall \tau > t$, $\frac{u'(c_{\tau-1})}{u'(c_\tau)} = \beta(1+r)$. With a fixed $IES = \frac{1}{\sigma}$, we have that $\forall \tau > t$, $\frac{u'(c_{\tau-1})}{u'(c_\tau)} = \left(\frac{c_{\tau-1}}{c_\tau}\right)^{-\sigma}$ so that the ratio $\frac{c_{t-1}}{c_\tau}$ is a constant. ■

Time-multiplicative preferences

Time-multiplicative preferences are rarely used in the literature. Similar preferences - although non-stationary - can be found in Pye (1973) and van der Ploeg (1993), who consider agents with infinite horizons. The relevance of this type of preferences for discussing choices under uncertain lifetime was first highlighted in Bommier (2006).

In contrast to their time-additive counterpart, time-multiplicative preferences allow for temporal risk aversion, thereby accounting for the fact that an agent might be averse to a positive correlation between the length of her life and her average consumption level. Not only does a temporally risk averse agent dislike risk on period consumption, but she wishes in addition to reduce the risk on her overall lifetime utility. In fact, one may notice that (2) is a concave transformation of the no-time-preference case ($\beta = 1$) of (1) as long as k is strictly positive. The larger k, the stronger is the agent's aversion with respect to lifetime utility risk. When we let the degree of intertemporal risk aversion, k, go to zero, we are back to the time additive model with no time-discounting: $\frac{1}{k}(1 - \exp(-k \sum_{\tau=t}^{\overline{T}} u(c_\tau))) \underset{k \to 0}{\sim} \sum_{\tau=t}^{\overline{T}} u(c_\tau)$.

One can further notice that these preferences do not rely on an exogenously given rate of time discounting. They rather assume that the agent's exogenous time preference always equals zero. A higher valuation of present consumption comes exclusively from the interplay of temporal risk aversion and mortality risk. In the case of multiplicative preferences, consumption growth rates depend on the agent's mortality pattern and are not necessarily monotonic over the life cycle; this result remains true even in the presence of perfect annuity markets and stands in clear contrast to the implications of time-additive preferences. In particular, the simulations in Bommier (2013) suggest a consumption profile which is increasing during the first part of adult life and then starts decreasing somewhere between ages 50 and 70. This feature corresponds to empirical findings, leading to the conclusion that time-multiplicative preferences might do a competent job. In particular, they are able to replicate hump-shaped consumption profiles, with a peak somewhere around ages 50 or 60, without requiring other assumptions such as market imperfections. Fernández-Villaverde and Krueger (2007), for instance, document precisely this kind of consumption profile in their study.

The non-monotonicity of consumption implied by time-multiplicative consumer preferences is at the very heart of our analysis. As age-independent consumption profiles turn out to be suboptimal under time-multiplicative preferences, preventing retirees from choosing their optimal non-monotonic profiles causes a welfare loss in such a framework; conversely, allowing retirees to deviate from the constancy-constrained profile induces a Pareto improvement.

Proposition 2 *Assume an agent's preferences are time-multiplicative and exhibit a constant intertemporal elasticity of substitution (IES). If her pension benefits determine her consumption, then efficient profiles are almost never age-independent. More precisely, assume there is an age-independent pension profile* $p_{\tau,t}$ *which is efficient when the rate of interest is equal to* r. *Then there exists an arbitrarily close pension profile* $\widetilde{p}_{\tau,t} = p_{\tau,t} + \delta p_{\tau,t}$ *and an arbitrarily close interest rate* $\widetilde{r} = r + \delta r$ *such that:* (1) *The pension profile* $\widetilde{p}_{\tau,t}$ *is efficient when the rate of interest equals* $\widetilde{r}$. (2) *The pension profile* $\widetilde{p}_{\tau,t}$ *is not age-independent.*

Proof. Under multiplicative preferences, the first order conditions of the expenditure minimizing problem imply that an optimal pension system must solve $\forall \tau \geq t$:

$$u'(p_{\tau,t}) = u'(p_{\tau+1,t}) \frac{\frac{s_{\tau,t}}{s_{\tau+1,t}}(1+r)}{\frac{\pi_{\tau,t}}{\sum_{v=\tau+1}^{T} \pi_{v,t} \exp(-k \sum_{i=\tau+1}^{v} u(p_{i,t}))} + 1} \tag{I.5}$$

Using the assumption that the intertemporal elasticity of substitution is constant and equal to $\frac{1}{\sigma} \neq 0$, we can rewrite this equation as follows:

$$\left(\frac{p_{\tau+1,t}}{p_{\tau,t}}\right)^{\sigma}=\left(\frac{\frac{s_{\tau,t}}{s_{\tau+1,t}}(1+r)}{\frac{\pi_{\tau,t}}{\sum_{\upsilon=\tau+1}^{T}\pi_{\upsilon,t}\ \exp(-k\ \sum_{i=\tau+1}^{\upsilon}u(p_{i,t}))}+1}\right) \tag{I.6}$$

If $p_{\tau,t}$ is age-independent, $\frac{p_{\tau+1,t}}{p_{\tau,t}}$ must be independent of τ.

Consider $\widetilde{r}=r+\delta r$ and define $\widetilde{p}_{\tau,t}$ recursively as

$$\begin{aligned}\widetilde{p}_{T,t} &= p_{T,t}\\ \forall\tau &< T,\ \widetilde{p}_{\tau,t}=\widetilde{p}_{\tau+1,t}\left(\frac{\frac{s_{\tau,t}}{s_{\tau+1,t}}(1+\widetilde{r})}{\frac{\pi_{\tau,t}}{\sum_{\upsilon=\tau+1}^{T}\pi_{\upsilon,t}\ \exp(-k\sum_{i=\tau+1}^{\upsilon}u(\widetilde{p}_{i,t}))}+1}\right)^{-\frac{1}{\sigma}}\end{aligned}$$

By construction the pension profile fulfills the first order condition and is efficient. We now show that if $\widetilde{r}\neq r$ this pension profile is not age-independent.

One finds

$$\frac{\left(\frac{\widetilde{p}_{T,t}}{\widetilde{p}_{T-1,t}}\right)}{\left(\frac{p_{T,t}}{p_{T-1,t}}\right)}=\left(\frac{1+\widetilde{r}}{1+r}\right)^{\frac{1}{\sigma}}$$

which implies that $\widetilde{p}_{T-1,t}\neq p_{T-1,t}$ if $\widetilde{r}\neq r$. Moreover we have:

$$\frac{\left(\frac{\widetilde{p}_{T-1,t}}{\widetilde{p}_{T-2,t}}\right)}{\left(\frac{p_{T-1,t}}{p_{T-2,t}}\right)}=\left(\frac{1+\widetilde{r}}{1+r}\right)^{\frac{1}{\sigma}}\left(\frac{\frac{\pi_{T-2,t}}{\sum_{\upsilon=T-1}^{T}\pi_{\upsilon,t}\ \exp(-k\sum_{i=T-1}^{\upsilon}u(p_{i,t}))}+1}{\frac{\pi_{T-2,t}}{\sum_{\upsilon=T-1}^{T}\pi_{\upsilon,t}\ \exp(-k\sum_{i=T-1}^{\upsilon}u(\widetilde{p}_{i,t}))}+1}\right)^{\frac{1}{\sigma}}$$

This equality, together with $\widetilde{p}_{T-1,t}\neq p_{T-2,t}$ and $\frac{p_{T-1,t}}{p_{T-2,t}}=\frac{p_{T,t}}{p_{T-1,t}}$, implies that $\frac{\widetilde{p}_{T,t}}{\widetilde{p}_{T-1,t}}\neq\frac{\widetilde{p}_{T-1,t}}{\widetilde{p}_{T-2,t}}$. ■

For very peculiar mortality rates, one might incidentally find an efficient pension profile that turns out to be age-independent. The proposition above states that if this is the case, then there must exist an arbitrarily close pension setting which is efficient and not age-independent. This contrasts clearly with the results one obtains in the additive setting, where efficient pension systems are always age-independent.

I.2.4 Optimal life cycle consumption

Proposition 2 in the previous section shows that an agent with time-multiplicative preferences virtually always opts for a non-monotonic consumption path; one might wonder how a typical optimal consumption trajectory would look like under realistic mortality rates.

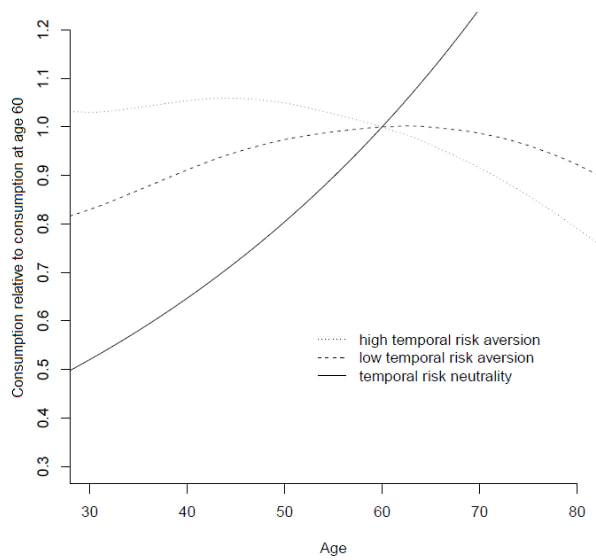
This section sheds some light on this interrogation and illustrates the impact of intertemporal risk aversion on the shape of the consumption curve.

Figure 1 displays three different optimal life cycle consumption profiles that one obtains under time-multiplicative preferences, a perfect annuity market and a calibration that is very close to the one we use in the remainder of this chapter. The details of the calibration are explained in section 3.2. For the purpose of this section, however, it is sufficient to know that we assume a constant interest rate and a constant intertemporal elasticity of substitution. The three consumption profiles in *Figure 1* stem from the same calibrated model and differ solely in the the degree of intertemporal risk aversion.

The solid line with the high positive slope represents the case without intertemporal risk aversion ($k = 0$). As explained earlier, this corresponds to time-additive preferences with no time discounting. As the interest rate is larger than 0, consumption increases monotonously at a constant growth rate. This growth rate is entirely independent of the mortality probabilities and depends solely on the interest rate and the intertemporal elasticity of substitution. It is given by $\forall \tau < T$, $\frac{c_{\tau+1}-c_\tau}{c_\tau} = (1+r)^{\frac{1}{\sigma}} - 1$.

The dotted and dashed curves represent the optimal consumption profiles of temporally risk-averse agents.

Figure 1: Optimal life cycle consumption



The dashed curve mirrors the case of an agent who displays some intertemporal risk aversion, yet to a lower extent (80%) than the agent who prefers the dotted consumption profile.

An interesting property of the last two cases is the non-monotonicity of optimal consumption. Over the first years of her adult life, the agent increases her consumption or keeps it constant. Beyond a certain threshold age, she starts decreasing her consumption. In the dashed curve, the peak is around age 60, in the dotted curve it occurs somewhat earlier. This finding corresponds to the empirically documented consumption hump.

Since the agent is intertemporally risk averse whenever $k > 0$, her desired consumption profile depends on her mortality rates. In the US data we are using, she reaches all ages up to her mid-50s with a fairly high probability. The likelihood for a newborn to die before age 55, for instance, is only 8.5% in our dataset. The increasing or at least non-decreasing consumption profile between ages 25 and 50 is due to these low death probabilities. In fact, consumption growth reacts to the relative likelihood of instantaneous death as compared to a weighted sum of future death rates; if the relative likelihood is low, the rate of time discounting is low. As age increases, the instantaneous probability of dying rises quickly, thereby inducing a higher discount rate and a decreasing consumption profile. This finding is very robust and is valid as soon as we introduce intertemporal risk aversion, independently of the particular calibration we choose.

I.3 A Pareto improving pension reform

The central implication of the previous section is that linear pension benefit profiles cannot, in general, achieve Pareto efficiency in models with time-multiplicative preferences and imperfect intertemporal markets. Constant pensions streams, which have by definition a constant growth rate of zero, are hence (almost surely) Pareto dominated by non-monotonic benefit trajectories. Allowing retirees to shift from constant consumption streams to their preferred non-monotonic streams is tantamount to increasing welfare. This section aims to quantify the welfare improvement associated with a policy reform that removes the constant-benefits constraint.

I.3.1 Description of the reform

The retirement reform we analyze is of simple nature: departing from a conventional defined-benefits scheme that pays a fixed pension every year, the sole amendment is to introduce age-indexed non-constant retirement benefits. Prior to the reform, retirees draw constant retirement benefits $\overline{p}$ in each period. After the reform, payments may vary along an individual's life cycle. Agents, who are t years old when they first receive pension payments from the new post-reform scheme, are entitled to retirement benefits $p_{\tau,t}$ for all $\tau \in \{t, ..., T\}$. Note that $t = T_0$ for all agents who are not retired at the moment of the reform, and $t > T_0$ for agents who are already retired.

In order to quantify the reform's benefits we make two simplifications.

First, we focus on a situation in which a retiree's period consumption is bounded from above by her retirement benefits. Without some constraint of this kind, the shape of the retirement benefits curve over her life cycle would depend on financial market features - and their imperfections - and would be difficult to discuss.[10] The retiree could borrow or use other income sources to move towards her preferred consumption path. While constraining consumption to be below or equal to pensions is not realistic for very wealthy agents, who earn returns on their investments, revenue statistics lead us to conjecture that it is not a particularly strong assumption for middle and low income retirees.[11] Focusing on credit-constraint agents without savings, we can interpret our estimations as an upper bound of the welfare improvement associated with the policy reform. Any kind of savings or loans would indeed alleviate the market failure that results from the mismatch between optimal consumption and pension benefits.

Second, we leave aside potential bequest motives, implying that full annuitization is optimal[12] since optimal consumption profiles are decreasing in our framework. Under

[10] With perfect markets the shape of the retirement benefits curve would be irrelevant.

[11] Middle income elderly in the United States of age 65 or above draw 88% of their income from retirement benefits and only about 5.5% from assets according to the Social Security Administration. Furthermore, as the Survey of Consumer Finance documents (http://www.federalreserve.gov/econresdata/scf/scf_2010.htm), the median consumer credit for households whose head is 75 or older, is only $7800 for installment loans and $1800 for credit card balances. For the $35 - 44$ year-old, these liability levels are almost twice as high.

[12] for a detailed discussion on this topic, the reader might want to refer to Davidoff, Brown and

realistic mortality rates, any strategy involving low consumption at the beginning and high consumption at the end of the retirement period would be suboptimal. Low optimal consumption levels at the very end of the life cycle, induced through high death probabilities at these ages, are indeed a highly robust feature of the time-multiplicative model.

Putting our two assumptions together, we are in a framework in which consumption and retirement benefits coincide. In this setting, agents have access to a government-sponsored annuity insurance (the retirement benefits), but cannot borrow on the financial market.

In a first step, we need to find a retiree's optimal consumption profile. This profile minimizes the expected present value of consumption while providing at least the same expected utility as the flat benefit scheme. It is important to notice that some agents are already retirees at the time of the reform and have been receiving pension payments for several years. Since they do not face the same constraints as an agent who retires instantaneously after the reform, or a young worker retiring years later, their optimal pension profiles will not be identical. Put differently, we have to distinguish "age types", which are determined by the agents' age at the time of the reform. For an agent of type "t" (i.e. who is t years old when he starts receiving pension payments from the new post-reform scheme) we are looking for the vector $p = (p_{t,t}, p_{t+1,t}, ..., p_{T,t})$ that solves:

$$\min_p \sum_{\tau=t}^{T} \frac{s_{\tau,t}}{(1+r)^{\tau-t}} p_{\tau,t} \text{ s.t. } \sum_{\tau=t}^{T} \pi_{\tau,t} U_\tau(p_{\tau,t}) \geq \sum_{\tau=t}^{T} \pi_{\tau,t} U_\tau(\overline{p}) \tag{I.7}$$

With multiplicative preference the problem can be stated as follows:

Diamond (2005).

$$\min_p \sum_{\tau=t}^{T} \frac{s_{\tau,t}}{(1+r)^{\tau-t}} p_{\tau,t} \text{ s.t.}$$

$$-\sum_{\tau=t}^{T} \pi_{\tau,t} \exp\left(-k \sum_{\upsilon=t}^{\tau} u\left(p_{\upsilon,t}\right)\right) \geq -\sum_{\tau=t}^{T} \pi_{\tau,t} \exp\left(-k \sum_{\upsilon=t}^{\tau} u\left(\overline{p}\right)\right) \tag{I.8}$$

As a consequence of preference stationarity, this problem has a recursive structure and can be solved backwards. The first order conditions imply:

$$u'(p_{\tau,t}) = u'(p_{\tau+1,t}) \frac{\frac{s_{\tau,t}}{s_{\tau+1,t}}(1+r)}{\frac{\pi_{\tau,t}}{\sum_{\upsilon=\tau+1}^{T} \pi_{\upsilon,t} \ \exp(-k \ \sum_{i=\tau+1}^{\upsilon} u(p_{i,t})} + 1} \tag{I.9}$$

for all integers $\tau \in [t, T[$.

To every feasible consumption level in the terminal period corresponds exactly one uniquely determined consumption profile that fulfills the first order conditions. Among all these alternatives, one needs to find the lowest value of expected consumption such that the utility constraint be satisfied - in this case it is satisfied with equality. Although there is no way to write down an analytical solution, it is straightforward to solve the problem numerically by backward induction.

I.3.2 Calibration

We start the calibration of the utility function in (4) by specifying a particular instantaneous utility function. In analogy to section 2, we opt for a utility index with a constant intertemporal elasticity of substitution. This kind of utility function takes the general form $u(c) = \frac{c^{1-\sigma}}{1-\sigma} + u_0$, and allows us to choose both the parameter σ and the constant u_0 to fit empirically verifiable measures. The constant σ is the inverse of the intertemporal elasticity of substitution, while u_0 reflects the utility of not being dead. The latter is hence the main determinant of the value of life.

Along the lines Bommier and Le Grand (2014), who carry out a comparable calibration for a model with bequest decisions, we proceed in two steps: first we fix the values of the components that are entirely exogenous to the model; after that, we choose values of k and u_0 such that the Value of a Statistical Life and the consumption growth rate at retirement correspond to conventional empirical estimates. We refer to the first step as exogenous calibration and to the second step as endogenous calibration.

Exogenous calibration

Having the instantaneous utility function on hand, we can set values for:

σ	inverse of the intertemporal elasticity of substitution
$\overline{p}$	constant reference payment before the reform
r	risk-free interest rate
T_0	universal retirement age
T	highest age a human can achieve

Our choices are motivated as follows.

- σ We set the intertemporal elasticity of substitution $\frac{1}{\sigma}$ close to 1. This choice is an attempt to fit diverging empirical results on this topic as far as possible. While Hall (1988) estimates the intertemporal elasticity of substitution to be very close to zero, Attanasio and Weber (1995) find higher values and more recent research such as Gruber (2006) even yields estimates of about 2. An intertemporal elasticity close to 1 lies in the commonly used range. We avoid a value of exactly 1 for technical reasons.
- $\overline{p}$ We set the constant reference payment that an individual would have received without the reform to \$11,276. According to the Employee Benefit Research Institute, this level corresponds to the average revenue from Social Security of people 65 and older in 2007.
- r The risk-free interest rate is 2.32%. We choose this value on the basis of the average 3-months rate of US Treasury Bonds between 2000 and 2011.
- T_0 the universal retirement age is assumed to be 65.
- T We set the maximum potential life span to 110 because the data we use for the simulation is only available up to this age.

Endogenous calibration

Besides purely exogenous elements we can also pick values for k and u_0. The constant k measures the agent's intertemporal risk aversion, while u_0 is a constant that impacts the utility gap between being alive and being dead. Larger values of k correspond to stronger intertemporal risk aversion. If k is large, the agent dislikes a strong correlation between the length of her life and her overall consumption level. In this case, she tends to shift consumption to earlier periods. The larger u_0, the more agents consider life per se as valuable and the higher is the value of life.[13]

We calibrate k and u_0 in such a way that the value of a statistical life (VSL) for a 65-year-old worker and the consumption growth rate at retirement correspond to values reported in the empirical literature. In order to make the connection between k, u_0, VSL and consumption growth clear, the reader might want to recall definition (3).

Definition 3 (Value of a Statistical Life) *The Value of a Statistical Life at the retirement age equals the opposite of the marginal rate of substitution between mortality rate μ and consumption, both evaluated at age T_0.*

$$VSL_{T_0} = -\frac{\frac{\partial EU}{\partial \mu_{T_0}}}{\frac{\partial EU}{\partial c_{T_0}}}$$

The target value for VSL_{65} in the baseline case is $500\overline{p}$, that is, 500 times the yearly retirement benefit before the reform. We choose this value in view of the results of the empirical literature. Viscusi and Aldy (2003) suggest, for instance, that the VSL of prime-aged US-American workers could equal about \$7,000,000 and that the VSL tends to decrease with age. Five hundred times the references value reflects the pattern reasonably well.

Furthermore, one can show that $\frac{c_{T_0+1}-c_{T_0}}{c_{T_0}}\sigma \approx r+\mu_{T_0} - \left(\left. \frac{\frac{\partial EU}{\partial c_{T_0}}}{\frac{\partial EU}{\partial c_{T_0+1}}} \right|_{c_{T_0}=c_{T_0+1}} - 1 \right)$.

Using this approximation, we target a consumption decrease of slightly over 1% p.a. at age 65 in accordance with empirical findings. Carroll and Summers (1991)

[13] In the standard additive case, when considering exogneous mortality patterns, the constant u_0 has no impact on individual behavior. This is the reason why it is omitted in most papers that are based on the time-additive specification. However, with multiplicative preferences, this constant cannot be ommitted, even if the results that are obtained do not vary a lot when u_0 changes.

and Fernández-Villaverde and Krueger (2007) find declining consumption profiles at these ages, controlling or not for household size. Section 3.4 describes the impact of modifications of the exogenous or endogenous calibration on the results.

TABLE 2 Summary of the calibrated model

Parameter	*Interpretation*	*Value*
$\frac{1}{\sigma}$	intertemporal elasticity of substitution	0.95
$\overline{p}$	constant reference payment	11,276
r	risk-free interest rate	0.023
T_0	retirement age	65
T	highest attainable age	110
k	intertemporal risk aversion	0.008
u_0	instantaneous utility without consumption	21.7

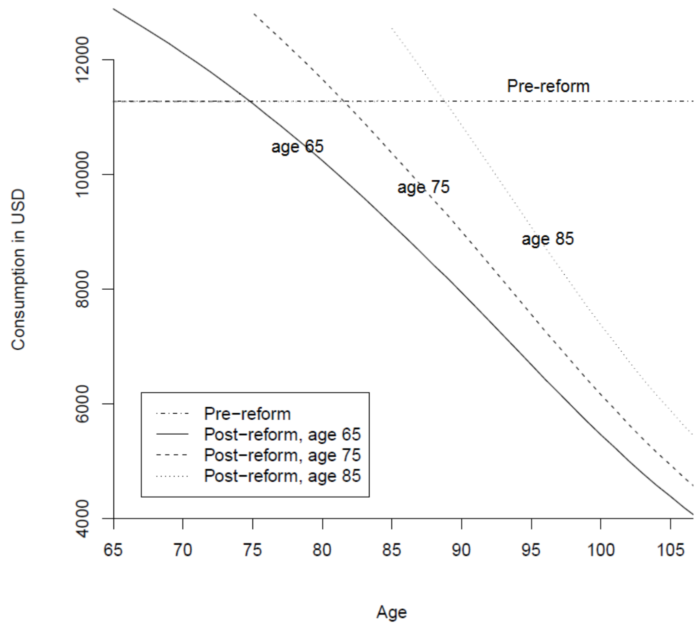
I.3.3 Results

Figure 2 depicts the optimal consumption profiles of three agents with time-multiplicative preferences who are 65, 75 and 85 years old when the reform takes place. All demographic data we use in our calculations stem from the Human Mortality Database (HMD)[14] and describe the demographic structure in the United States in 2007.

The straight horizontal line corresponds to $\overline{p}$, the constant reference payment the retirees would have received without the reform. The solid, decreasing curve indicates the new retirement benefits of a 65-year-old under the reform. Notice that the 75 and

[14] Human Mortality Database (HMD). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany).

Figure 2: pre and post−reform consumption profiles



85-year-old consumers (dashed and dotted curve, respectively) receive the pre-reform reference payment over the first years of their retirement period. After the reform, they switch to the optimal non-constant benefits. The decreasing structure of the post-reform consumption profiles is in line with the results of *Figure 1*. As it is very unlikely that the agent survives to very high ages, she prefers to consume today or in the near future, with high probability, rather than consuming at the very end of the life cycle. A decreasing consumption path enables her to trade future consumption against present consumption, which means that she will at least have experienced high consumption in case of a premature death. Put differently, she prefers a negative correlation between her lifetime duration and her average period consumption level. This result is directly connected to the agent's intertemporal correlation aversion.

The monetary gains one can generate without lowering expected utility by shifting to the agent's optimal pension profile depend on her age at the time of the reform. For an individual who is 100 years old at the time of the reform, there remains only a little amount of pension benefits to be paid in any case, and the absolute gain is correspondingly small. In *Table 3* we report the absolute and relative gains for several cohorts (or "age-types"), that can be obtained from a shift to the new pension system.

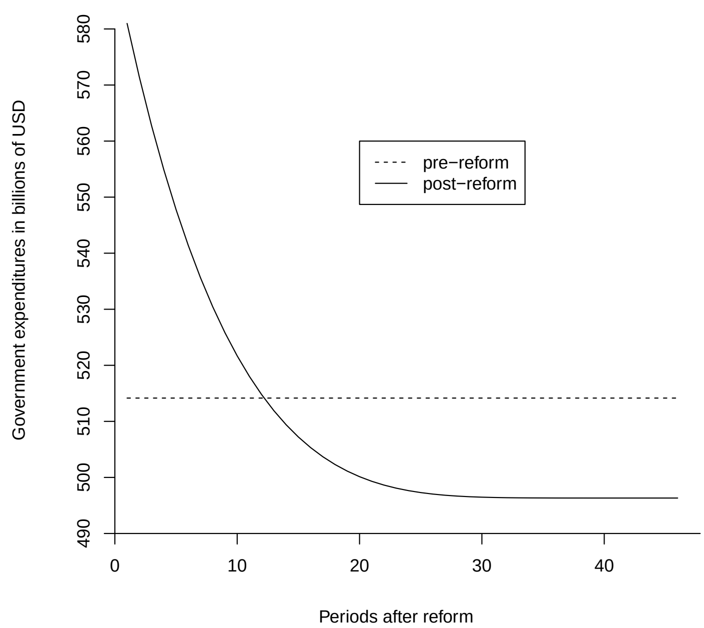
TABLE 3 Results

	Exp. expenditures no reform	*Exp. expenditures with reform*	*Absolute gain*	*Percentage gain*
Age-type 65	\$ 171,029	\$ 169,280	\$ 1749	1.02 %
Age-type 75	\$ 118,355	\$ 117,291	\$ 1064	0.9 %
Age-type 85	\$ 70,685	\$ 70,216	\$ 469	0.66 %
Age-type 95	\$ 36,586	\$ 36,445	\$ 141	0.39 %

In order to indicate the order of magnitude of the aggregate gains resulting from such a pension reform, we assume a stationary population with a constant number of new retirees every year. We compute the aggregate payments in all periods following the reform and compare the results for the two alternatives - the constant payments system and the age-varying payments system.

Figure 3 displays the aggregate government expenditures in the years following the reform.

Figure 3: Government expenditures after the reform



One can make two important observations in *Figure 3*. First, directly after the reform, government expenditures jump up to a significantly higher level. In the first period after the reform, expenditures are 13% higher than prior to the reform. This finding comes from the fact that it is optimal for every "age-type" to transfer consumption from the end of their life cycle to earlier periods. Second, from the second period on, expenditures start declining quickly. It takes slightly more than a decade until the government reaches its initial expenditure level and then falls permanently below it.

In present value terms, the gain of the reform equals over $ 225 billion, which corresponds to almost exactly 1% of all future government expenditures on retirement payments. The savings potential of such a reform can hence legitimately be considered as substantial.

I.3.4 Sensitivity analysis

The exact shape of the optimal benefits profile and the corresponding savings potential hinge on the parameter values one uses in the model calibration. With the objective of verifying the robustness of our results, we modify the parameters underlying both the exogenous and endogenous calibration.

Exogenous calibration:

Table 4 outlines how a ceteris paribus change of one of the parameters affects the generated savings. The way to read *Table 4* is: "If exogenous variable x takes value y and all other exogenous variables are as in the baseline case, what would be the savings potential?".

It turns out that the exogenous parameters have a fairly limited impact on the results. In fact, the variable that affects the outcome most strongly is the universal retirement age. If it is lower than in the baseline calibration, individuals have a longer potential lifespan left when they retire and can optimize their consumption levels over a longer horizon. The desired benefits profile can deviate to a larger extent from the constant profile before the reform, that is to say the government's savings potential rises. However, even with a universal retirement profile of only 60 years, the savings potential is 1.3% and remains relatively close to the results in the initial case. Modifying the other purely exogenous variables yields to outcomes that are in a close range around the result in our baseline calibration.

TABLE 4 Ceteris paribus impact of parameter changes

Exogenous Variable	*Value*	*% Savings*
Intertemporal elasticity of substitution	0.55	1.2%
	0.95	1%
Risk-free interest rate	0.023	1%
	0.035	0.9%
Universal retirement age	60	1.3%
	65	1%

Endogenous calibration:

The main assumption we had to make for the endogenous calibration was the 1 % consumption decrease target in the first period after retirement. While this value is consistent with empirical findings, it has a crucial impact on the results. To verify the robustness of the results, we calculated the model for different consumption growth targets. It turns out that the savings potential is considerably affected by the choice of this parameter. If we impose a constant consumption profile in the first period, the governments relative savings drop to only 0.2%, while larger target decreases yield to larger gains. A consumption decrease of -2% at age 65, for example, would induce a savings potential of almost 2%. It is noteworthy, however, that the optimal benefits profile is nonetheless decreasing over the last years of the life cycle at a non-constant rate - this remains true if we impose somewhat unrealistically a zero consumption decrease or even a rapid increase in consumption at the beginning of the retirement period. The result that agents prefer to transfer consumption to earlier periods remains unaffected.

The impact of the VSL-target, the second endogenously calibrated variable, is less important. In fact, letting VSL vary between 200 times the reference payment and 800 times the references payment, the savings potential oscillates between 0.8% and 1.3%. Unless we assume unrealistically low values for VSL, the main results remain unaltered.

Demographic change:

So far our analysis has focused on a stationary population with an age-distribution mirroring US death rates in 2007. Considering the quickly changing demographic patterns, however, one might wonder how strongly the rectangularization of the survival curve impacts the benefits of such a reform.

At a first glance it might seem intuitive that lower death rates increase the probability of reaching higher ages, thereby preventing agents from choosing sharply declining consumption profiles. Whether this intuition is correct or not depends on how quickly mortality at young ages declines in comparison to that at old ages. According to projected data, the decline in mortality will most likely be stronger at high ages. In our data sets, the mortality decrease between actual 2007 mean death rates of agents in their 70s and projected data for 2050 is expected to be about 5%; for agents in their 90s, the mean death rate is expected to decrease by about 17%. The death probability in the initial phase of the retirement becomes therefore increasingly important relative to the sum of weighted future death rates. Accordingly, agents optimally decide to reduce their consumption even faster in the first years of their retirement. This stronger decline leads to an increased savings potential of the reform.

We use projected death rates from the Berkeley Mortality Database[15] for the year 2050 in order to quantify the potential benefits of the reform in the future. It turns out that lower death rates raise the savings potential to over 1.2%.

I.4 Conclusion

Age-dependent pensions can be optimal and might constitute a potential policy alternative. We have shown that under the assumption of time-multiplicative preferences, the government could reduce its expenditures substantially, by up to 1%, without reducing any retiree's expected utility. This high savings potential is surely appealing to policy makers who are interested in increasing overall welfare.

However, one should keep in mind that implementing a reform of this kind does not come without difficulties. In particular, if health insurance and long-term care insurance turn out to be insufficient, opting for decreasing pension profiles may just increase the number of people that fall in financial distress after suffering adverse health shocks that require significant expenditures. Cutting down the elderly's income might inhibit their ability to carry the incurred costs by themselves. A reform as described in this chapter is only a viable option if it goes hand in hand with a comprehensive health plan that insures the risk of increasing health expenditures at old ages.

Moreover, the suggested reform is only interesting if it can be sustained in the long run. In the short run, the reform will make all retirees better off and might be widely accepted if the initial increase in expenditures is not immediately handed down to tax-payers. In the long run, however, the elderly might try to use their political

[15] The Berkeley Mortality Database has been replaced by the Human Mortality Database (see before).

power to move back to flat pensions after having profited from the reform. An in-depth investigation of the political sustainability of such a reform might therefore be worthwhile.

A particularity of the reform is that it suggests an increase in government expenditures in the short term. For a small open economy, this would mean an increase of the debt in the short term, which may be difficult to achieve. When considering a "non small" economy, one needs in addition to account for the impact that such a reform would have on capital accumulation, which may reduce the estimation of the benefits of such a reform.

Despite these caveats, considering the option of age-dependent pensions is worthwhile. The increase in short term expenditures comes along with a significant decrease in future pension claims, which outweighs the initial cost accruements by far. Moreover, with the new schedules, pension systems would be less impacted by an unexpected decrease of mortality at old ages. In addition to financial gains, the reform would generate a pension system that is more resilient to demographic risk.

Chapter II

The Swiss Retirement System

This short chapter gives a broad overview of the Swiss retirement system and prepares the grounds for the following chapters - both of them rely on this institutional framework. The retirement system in Switzerland is unique in several respects and regularly cited as one of the most sustainable retirement schemes in the world. The Allianz Pension Sustainability Index 2014[16] ranks it 7^{th} out of a total of 45 pension systems and evaluates the pressure for reform as less pressing than in most other schemes. The first section of this chapter provides general background information, the second section stresses some aspects which are particularly relevant for the remainder of the analyses.

II.1 Background

Voted in the 1970s, the current retirement financing scheme in Switzerland is organized in three distinct pillars. Pillar I is predominantly a pay-as-you-go system and financed through income-linked contributions. Pillar II is the occupational pension scheme and organized in capital accounts. Pillar III (a) is a voluntary retirement sav-

[16] currently available at https://www.allianz.com/de/presse/news/studien/news_2014-04-01.html/

ings device and grants tax benefits on fixed pension plans, pillar III (b) covers private flexible pension plans which typically do not involve tax advantages. Pillars I and II are most important in determining the financial situation of the elderly in Switzerland. According to the Swiss Federal Statistical Office (FSO), among young retirees who received some payment from at least one of the three pillars in 2012, 98.5% got payments from pillar I, 66.8% from pillar II (men: 77.6%, women: 57.7%) and 27.7% from pillar III (a) (men: 33.9%, women: 22.3%). These numbers come from the fact that Pillar I contributions are mandatory for almost everybody under 64/65, even unemployed Swiss residents. Pillar II contributions are mandatory for employees only, and pillars III (a) and (b) are voluntary. In the future one can expect an increasing share of retirees with second and third pillars, as statistics on the current working generation demonstrate. FSO figures indicate that the proportion of 18-64 year-old workers who save in the second pillar has risen from 82.2% to 90.2% between 2004 and 2012 and the share of those saving in pillar III (a) has reached over 60% in 2012.[17] The official retirement age for men is 65 and has been progressively raised from 62 to 64 for women.

Pillar I aims to provide the elderly with sufficient resources to cover fundamental needs. As of 2015, the maximum monthly benefit from pillar I is *CHF 3525* for a married couple and *CHF 2350* for singles, thereby inducing a considerable redistribution from high-wage earners to poorer individuals, since the former contribute strongly but cannot exceed the benefit cap. In 2013, almost 60% of the couples receiving pillar I retirement benefits were at the upper cap. The first pillar is paid out as a life-long annuity. In

[17] All values are currently available at http://www.bfs.admin.ch/bfs/portal/de/index /themen/13/04/02/data/02.html#parsys_47662

case the insuree is a married man and dies, his surviving spouse is granted a widow's pension; if the insuree is a married woman, however, the surviving husband does not receive survivor benefits except under very specific circumstances. As of December 2013, 2.1 million people received pillar I retirement benefits and 133,000 survivor payments.[18]

Receiving pillar I benefits up to two years prior to the statutory retirement age is possible but involves a life-long benefit reduction of usually 6.8%.[19]

Pillar II is the occupational pension scheme. Unless workers receive yearly wages inferior to roughly *CHF 20,000*, they are legally required to save some proportion of their salaries in capital accounts. This proportion is often age-dependent and can vary between pension-funds as long as it complies with specific legal requirements. Swiss law distinguishes between the *mandatory* and the *supermandatory part* of a salary. The mandatory part includes the lower part of a salary up to some frequently adjusted limit (about *CHF 80,000* per year). The supermandatory part covers everything above this limit. As its name indicates, pillar II contributions on the mandatory part are compulsory, while they are voluntary on the supermandatory part. In addition, money stemming from the mandatory part is subject to tight legal requirements. Pension funds are for example bound to pay a minimum yearly interest rate on it. Employers are in charge of organizing their employees' second pillars. Large companies choose sometimes to run individual pension funds (so does the state), smaller companies tend to outsource this obligation to insurance companies. Upon retirement, former employees can withdraw the money they have accumulated either partially or totally as a lump-sum payment or convert it into a life-long annuity with widow's pensions.

Pillar III (a) is a non-mandatory additional retirement savings device, which is

[18] These values, too, are currently available at www.bfs.admin.ch

[19] 6.8% applies to women born on or after 01.01.1948 and all men. Women who were born before 1948 only face a reduction of 3.4% per pre-retirement year.

organized in the form of capital accounts. The amounts employees save in this pillar are tax-deductible and it is impossible to withdraw them before retirement unless some specific circumstances apply (e.g. primary residence real estate purchases). There is a rather restrictive upper limit to the tax-deductible amount one can save per year. In most cases, pillar III is paid out as a lump-sum and many providers do not offer the possibility to annuitize pillar III. Amounts saved in this pillar are typically smaller than the savings in the occupational scheme, but they are far from negligible in many cases. In practice, pillar III (a) is predominantly used by middle and high income earners who can spare money and wish to reduce the amount of taxes they have to pay.

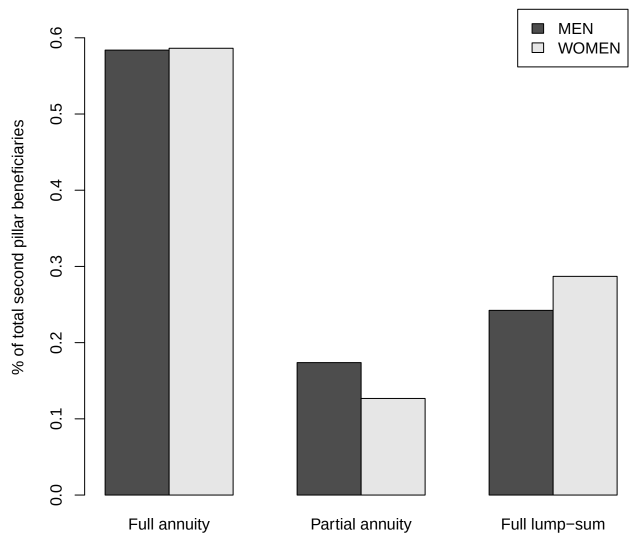
II.2 Relevant issues

Chapter III and IV analyze different aspects related to the withdrawal choice between an annuity and a lump-sum in pillar II.

Withdrawal-choice

The right to withdraw at least 25% of one's 2^{nd} pillar capital as a lump-sum was made legally binding in 2005. In practice, however, most pension funds allow larger lump-sum withdrawals (often 100%) and have done so for many years. Especially the two polar cases (full annuitization and full lump-sum) are common, but combinations are also possible. In case the retiree chooses to withdraw some share of the capital as an annuity, a conversion factor α is applied to the 2^{nd} pillar capital to determine yearly payments. If policy holders are married when they die, their surviving spouses receive a 60% survivor benefit until they decease as well. Unlike pillar I, widow's pension eligibility does not depend on gender. Importantly, marital status, as well as spouse age, have no impact on conversion rate α because it is determined for a collective of

Figure 4: Second Pillar Withdrawal Choice



insured workers and not individually. Pillar II creates therefore strong redistributive effects from singles (lower life expectancy, no widow's pension) to married retirees with young spouses. According to the FSO, the withdrawal choice of recent retirees in 2008 was as shown is *Figure 4*[20].

Taxation

Regular payments from the annuity option, along with all other income, are subject to usual income taxes. To the contrary, a specific tax is applicable when a retiree chooses a second-pillar lump-sum payment. More precisely, lump-sum payments stemming from pillar II and pillar III (a) are added and taxed together. As a general rule, tax rates are progressive, but there are tremendous differences depending on the beneficiary's residence. As of 2014[21], a 65-year-old man from Neuchâtel had to count a tax rate

[20] The numbers can be deduced from http://www.bfs.admin.ch/bfs/portal/de/index /news/publikationen.html?publicationID=4376

[21] See corresponding tax regulation.

of about 6% for a *CHF 100,000* withdrawal and of about 9.5% for *CHF 2,000,000.* In Zurich, rates were more progressive, starting at a lower level (under 5% for *CHF 100,000*) and reaching almost 18% for a lump-sum of *CHF 2 million.* In Zug, finally, rates were low both for small withdrawals (2.1% for *CHF 100,000*) and large lump-sums (6.7% for *CHF 2,000,000*).

It is possible to reduce taxes quite significantly in this legal framework through the lump-sum vs annuity decision, the timing of one's withdrawals as well as one's residence choice.

Preretirement

As in pillar I, pillar II benefits are adjusted downwards when an employee retires prior to the official retirement age and chooses an annuity. In practice, this adjustment translates usually into a reduction of conversion factor α by 20 basis points per pre-retirement year.

Chapter III is based on the fact that the total annuity value of a married man depends on his spouse's life-expectancy, which is primarily determined by a couple's age-difference. I test whether this annuity value difference has an impact on annuitization behavior.

Chapter IV analyzes mortality probabilities of pillar II annuitants in their early retirement. The annuity option is actuarially more interesting for agents who face favorable survival rates. One would expect annuitant survival rates to exceed the average population survival rates if people have private information on their own mortality probabilities.

Chapter III

The Role of Widow's Pensions in the Annuitization Decision[22]

III.1 Introduction

Consumer demand for annuities remains puzzling. Economic theory suggests that utility maximizing agents have a great interest in investing a substantial part of their wealth in annuities. For one thing, annuities insure against the risk of outliving one's resources. Despite the ongoing rectangularization of the survival curve, one's unknown life span remains a major source of uncertainty and complicates intertemporal consumption planning. For another, surviving annuitants profit from the "mortality premium" and can increase their lifetime consumption. This premium arises because resources are divided among fewer and fewer survivors as the proportion of dead annuitants increases.

In spite of these attractive characteristics, private - and to some extend also public -

[22] This chapter is based on survey data stemming from the Swiss Labour Force Survey (SLFS). I would like to gratefully acknowledge the Swiss Federal Statistical Office for this data set.

markets for annuities are small in practice. Numerous explanations have been put forward to explain the discrepancy between theoretical predictions and theoretical findings, including high annuity prices, bequest motives and behavioral aspects. Intensive research efforts notwithstanding, certain dynamics of the so-called "annuity puzzle" are still not fully understood. The importance of survivor benefits in the annuitization decision is not well scrutinized. In this chapter I address this topic using a particularity of the Swiss retirement system.

Upon retirement, employees in Switzerland can split their occupational retirement wealth into an immediate lump-sum payment and a joint-and-survivor annuity. The lump-sum option does not grant extra survivor benefits and singles and married retirees face comparable financial incentives[23]. Conversely, the annuity option includes a 60% widow's pension, thereby inducing a systematically different treatment of married and single individuals. The price of the annuity (that is, the lump-sum forgone to receive some annual payment), however, does not depend on the policy holder's marital status, nor on his/her spouse's age. The expected value of the annuity option is therefore higher for married retirees with young spouses.

Unless there is a strong systematic relationship between a couple's age-difference and confounding factors, one should expect that annuity demand decreases with spouse age within the subgroup of married policy holders.

Testing this hypothesis on Swiss survey data is at the core of this chapter. It turns out that the economic incentives translate somewhat, but only relatively sparsely, into actual behavior. While policy holders with very young spouses tend indeed to annuitize more, this result does not extend to the bulk of the population. Other factors seem to

[23]The financial incentives faced by married and single individuals might still diverge to some extent due to differential tax treatment. These differences are less important than in the case of the annuity, though.

matter more. The remainder of this chapter is organized as follows. Section 2 gives a brief overview of the related literature. Section 3 details the economic forces that might impact the lump-sum vs. annuity choice, with a particular focus on the Swiss context. Section 4 is devoted to the econometric analysis. It is divided into a non-parametric and a parametric part. The final section concludes.

III.2 Related literature

This chapter fits into the literature on annuity demand. Theoretical contributions to this strand of literature, most notably work by Yaari (1965) and Davidoff et al (2005), suggest that annuities should be valuable to agents in the presence of mortality risk. This finding is fairly robust in the standard economic framework and remains true in different contexts, e.g. in the case of individuals with a bequest motive, moderate deviations from actuarially fair pricing and some degree of pre-existing annuities. Mitchell, Poterba, Warshawsky, and Brown (1999) point out that in reality annuity prices do not deviate strongly enough from actuarially fair prices to outdo the attractiveness of annuitization. Yogo (2011) estimates in a stochastic health model that having access to a perfect annuity market raises welfare by 10%-20%, depending on the person's health status. Empirical research, however, tends to conclude that annuitization rates are low, although estimates vary considerably depending on their precise contexts and data sets. James and Song (2001), for instance, document low annuity take-up rates despite attractive returns in various high and middle income countries around the world. To the contrary, Butler and Teppa (2007), who analyze the lump-sum vs. annuity choice of Swiss retirees and find that annuity demand reacts to a utility measure of annuity attractiveness, report relatively high annuitization rates compared to other studies (about 80 % of annuitizable capital is annuitized).

In addition to actuarially unfair pricing, numerous other reasons have been invoked in the literature to explain low annuity take-up rates. Milevsky and Young (2007), for instance, point out that rigid annuity contracts can render annuitants unable to invest in the stock market. Bommier and Le Grand (2014) emphasize that risk aversion with respect to life-time utility can erode the benefits of annuitization.

The role of survivor benefits in the choice to annuitize or not has also been scrutinized, but to a lesser degree. Brown and Poterba (2000) investigate the dynamics of joint life annuities and conclude that married couples who face actuarially fair annuity markets (that is, survivor benefits are priced) value annuitization less than singles. Aura (2005) and Johnson et al (2003) analyze the active choice of retirees to opt out of a pension provision mode that grants survivor benefits but comes at the cost of lower monthly payments. That is, they examine the choice between two different actuarially equivalent annuities, one of which includes widow's pensions. The former paper finds that a new regulation in the United States, which requires spouses to consent if they forgo the survivor option, increased the proportion of retirees who choose an annuity with survivor benefits. The latter paper points out that those elderly foregoing survivor protection for their spouses mostly have good reasons for their choice, e.g. pre-existing survivor insurance or a low life-expectancy of the spouse.

This study is also connected to the literature on adverse selection in life insurance markets. Although the age-difference between spouses could potentially be observed, this information is not used for annuity pricing in the Swiss occupational pillar and therefore typically not even gathered by pension providers. As the age-difference is a strong predictor of future survivor benefit claims, and is known by insured and unknown (or unused) by insurers, it can be interpreted as information that is *de facto* hidden.

Existing studies on adverse selection in life insurance markets are not concerned with survival probabilities of spouses, but focus on the mere survival of policy-holders. Most of these studies, such as Cawley and Philipson (1999) and Hendel and Lizzeri (2003) cannot find any evidence of adverse selection, that is, agents with life-insurance do not die sooner than their non-insured peers. More recently, He (2008), using HRS Panel data to avoid bias from pre-sample deaths, concludes that adverse selection is present in the market.

III.3 Lump-sum vs. annuity trade-off

This section puts the lump-sum vs. annuity choice in perspective. Section $III.3.1$ highlights some of the most important potential determinants of this choice, in particular in light of the specificities in the Swiss system. The second part emphasizes that one might expect married policy holders with young spouses to value the annuity option more. Furthermore, it gives an overview of demographic data and annuity values in Switzerland.

III.3.1 Potential determinants of the annuitization decision in the Swiss framework

Various factors have been identified in the literature as potential determinants of the annuitization decision, including pre-existing annuities, private information on health and risk aversion. The relative importance of these factors in the annuitization decision depends to a large extent on the institutional framework behind the choice. In the Swiss case, for instance, almost all policy holders have some level of pre-existing annuities in the first pillar. Furthermore, lump-sum payments and annuities are subject to different taxation rules. Aiming to give an insight into the determinants of the annuitization decision in view of the Swiss context, this section summarizes the results of an unofficial survey that was implemented independently of this dissertation. In this survey, several hundred retirees were asked how they decided to split their 2^{nd} pillar capital between a lump-sum and an annuity, and why. The results of this survey are probably not representative of all Swiss old-age pensioners, but they do account for regulatory specificities and can serve as guidance for the following parts.

Frequently stated reasons in favor of the annuity

Among the most popular reasons why retirees chose to annuitize at least some part of their 2^{nd} pillar wealth were:

1. *Preference for regular and safe income*

   Many respondents in this survey state that they chose the annuity option in order to secure a safe and (nominally) constant income stream. This finding underpins how relevant risk aversion is in practice.

2. *Poor outside investment opportunities* & *lack of financial literacy*

   Retirees opting for a lump-sum payment are confronted with a situation that is unknown to many of them : managing a (mostly) large amount of money. Policy holders who do not consume the entire amount instantaneously need to decide on investment strategies. Individuals with pessimistic views on current and expected future investment opportunities are less likely to make lump-sum withdrawals. The same is true for elderly who are unwilling or unable to manage large amounts of money.

3. *Access to widow's pensions*

A large fraction of married policy holders mentions survivor benefits as a reason why they opted for the annuity. Although widow's pensions in the 1^{st} Swiss pension pillar exist for women, these benefits are fairly modest and many retirees seem to value additional survivor protection in the form of 2^{nd} pillar annuities.

Frequently stated reasons in favor of the lump-sum

Among the pensioners who opted for a partial or full lump-sum withdrawal, some of the most prominent reasons for their choice were:

1. *Desire to consume or invest shortly after retirement*

Numerous retirees wish to have a large amount of money at their disposal directly after retirement to consume or invest. Elderly who intend to leave Switzerland and/or to buy real estate abroad frequently belong to this group. According to the Federal Department of Foreign Affairs, in 2011 almost 20% of all Swiss citizens living abroad were 65 or older.

2. *Tax reasons*

Tax optimization is a relevant issue in the annuity vs. lump-sum trade-off in Switzerland. While annuity payments are taxed according to usual income tax rates, lump-sum withdrawals are subject to specific regulation. Lump-sum withdrawals are typically less heavily taxed than annuities. Tax rates vary considerably across cantons both in terms of level and structure, and it is crucial to account for these variations.

3. *Pre-existing annuities*

   Researchers often argue that pre-existing annuities can partially explain the low annuity demand in private markets. Retirees in Switzerland have at least some level of pre-existing annuities through the 1^{st} pillar, although these benefits are not very generous. Many of the policy holders who chose to withdraw a lump-sum payment claim that pre-existing annuities prompted them to forgo the longevity insurance associated with annuity payouts.

The findings of this survey suggest that survivor benefits are likely to be an important determinant of the annuity vs. lump-sum decision. Furthermore, it seems crucial to account for regional lump-sum tax rates and outside income as important factors in this choice.

III.3.2 Annuity value and age-difference

This section aims at making the importance of the age-difference between spouses in the annuity vs. lump-sum trade-off explicit.

For the sake of clarity, I define the age-difference A between a policy-holder and his or her spouse without exception from the policy-holder's point of view throughout the whole chapter, that is $A = age_{policy-holder} - age_{spouse}$.

As highlighted earlier, the widow's pension has neither an impact on the conversion factor, nor on any other parameter affecting the annuity value; from an actuarial point of view, a married retiree's annuity is worth more than an annuity offered to a single because there is some positive probability that the spouse will outlive the policy holder. The survey results presented in the previous section suggest that this impact might be quite strong. Furthermore, within the group of married retirees, the actuarial annuity value is increasing in A; indeed, mortality hazard rates increase with age and younger spouses are predicted to receive widow's payments for a longer time.

As the actuarial value of the annuity is a function of a couple's age-difference, a policy holder's demand for the annuity withdrawal option should in theory react to his or her spouse's age.

Consider a married individual who chooses between an annuity and a (partial or full) lump-sum payment of some exogenously given amount k. Denote by $\eta \in [0, 1]$ the share of the capital that the agent decides to withdraw as a lump-sum. We call $k_l = \eta \cdot k$ and $k_a = (1-\eta) \cdot k$ the capital withdrawn as a lump-sum and as an annuity, respectively. The annuity pays a fixed proportion α of k_a every year until the policy-holder dies and subsequently a 60% annual widow's pension in case there is a surviving spouse. The payments come to a permanent end once the spouse deceases as well. Let us further denote the constant risk-free interest-rate by r, by s_t^h and s_t^s the probability that the policy-holder, respectively the spouse, survives from period 0 (in which the annuity vs. lump-sum decision is made) to period t. By $\overline{s_t^h}$ and $\overline{s_t^s}$ we denote their complements. The net present value of the annuity directly after retirement is readily given as

$$NPV_{annuity} = \sum_{t=0}^{\infty} \frac{\alpha k_a}{(1+r)^t} \cdot s_t^h + \frac{0.6 \cdot \alpha k_a}{(1+r)^t} \cdot s_t^s \cdot \overline{s_t^h}.$$

More handily, the money's worth ratio, $MWR = \frac{NPV_{annuity}}{k_a}$, states how much money, in present-value terms and including the widow's pension, a policy holder can expect to get back for every *CHF* invested in the annuity. The expression for MWR simplifies to

$$MWR = \sum_{t=0}^{\infty} \frac{\alpha s_t^h}{(1+r)^t} + \frac{0.6 \cdot \alpha s_t^s \overline{s_t^h}}{(1+r)^t}.$$

If instantaneous mortality rates increase with age, MWR increases in A.

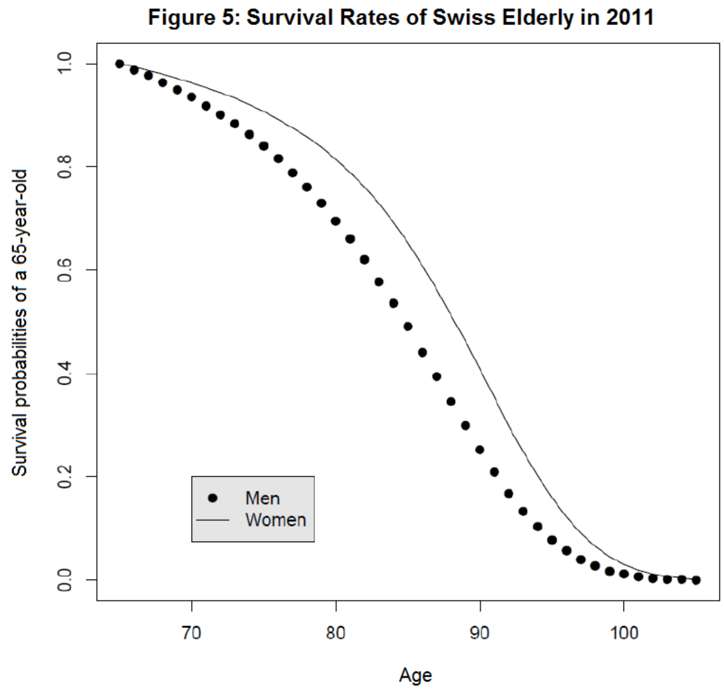
Practical relevance

Figures 5 through *9* give an overview of mortality patterns in the Swiss population in 2011 and the corresponding money's worth ratios of annuities.[24] All calculations are based on smoothed instantaneous death probabilities from period life tables[25] and assume that survival rates between spouses are independent.

Figure 5 reflects the survival distribution of men and women who are alive at age 65. The median man of this age has almost another 20 years to live and dies at age

[24] Mortality data stem from the Human Mortality Database (HMD). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany).

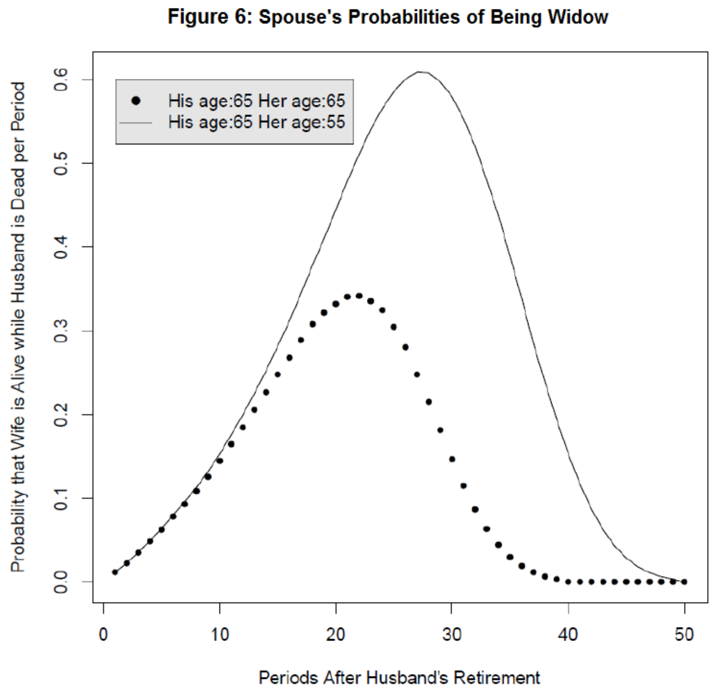
[25] Potential mortality reductions in the future are not taken into account.



84, while the median women dies at age 88. Under these mortality rates, 10% of the 65-year-old women will still be alive on their 96^{th} birthday.

Figure 6 indicates the probability that a woman, who is married to a currently 65-year-old man, will be alive and widowed in a given period. If the woman is 55 today, for instance, the likelihood that she will be alive and her husband will be dead in 20 years from now is almost 45%. *Figure 6* can be interpreted as the probability that a widow's pension is paid in a certain period if the husband chooses the annuity option.

Analogously, *Figure 7* depicts the likelihood that a husband outlives his 64-year-old wife. 64 is the official retirement age in Switzerland for women (65 for men). The figures show that women have fairly high chances of outliving their spouses even if they are not substantially younger than their husbands. In the very common case of a 65-year-old man who is married to a 3 year younger woman, the probability that she will become



a widow at some point is about 70%.

Figure 8 plots the money's worth ratios of the annuity option as a function of the age difference between spouses, A, for different conversion rates. In almost all cases, the money's worth ratio for a married man is larger than 1, that is, including the widow's pension he can expect to be paid back more than *CHF 1* in real terms for every *CHF* he forgoes as a lump-sum. Since currently retired men are in most cases between 0 and 5 years older than their wives and the typical conversion rate is somewhat below 6.8% today, one can assume that an average married man, who is about to retire, faces a MWR of about 1.2. The calculations in *Figure 8* are based on a risk-free interest rate of 2%. In view of historically low post-crisis interest rates, $MWRs$ tend to be even higher today. The effect of A on MWR is considerable. A man who is 5 years older

Figure 7: Spouse's Probabilities of Being Widower

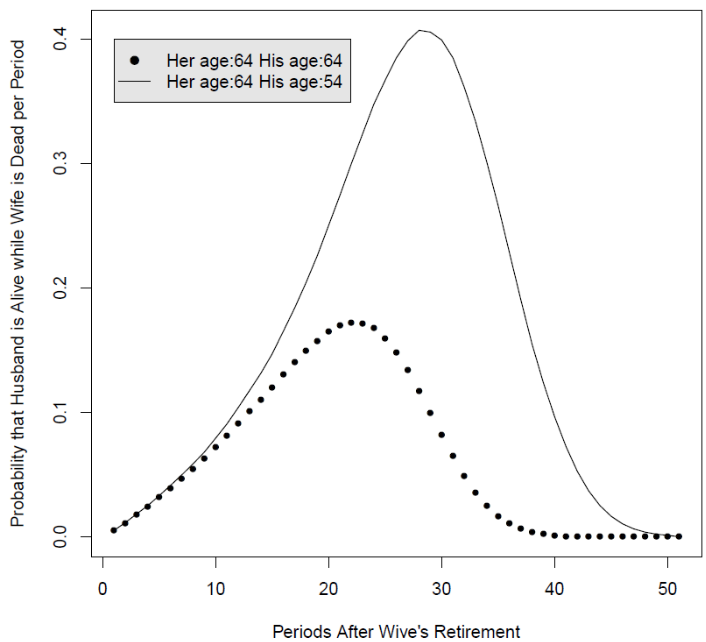
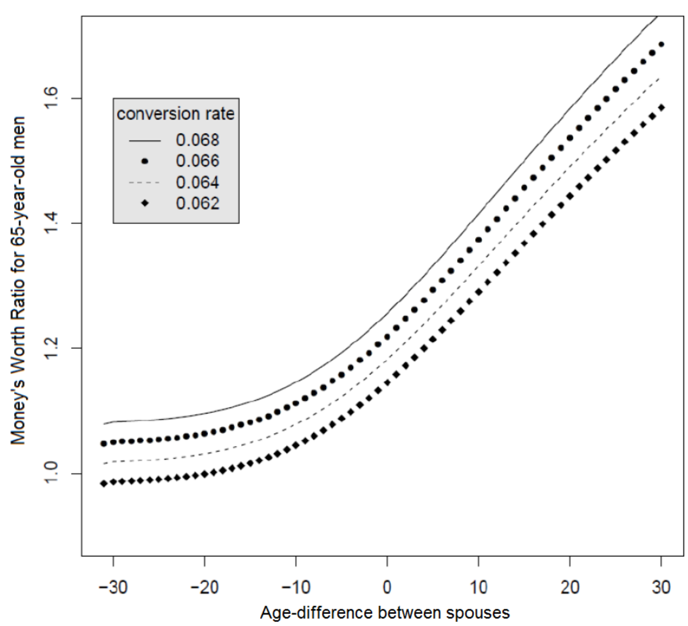


Figure 8: Money's Worth Ratios as Function of Age-Difference

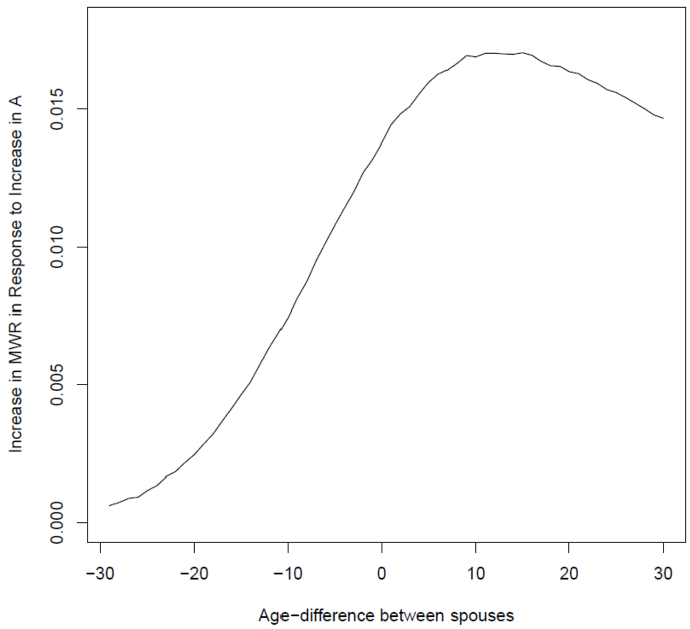


than his spouse, rather than 5 years younger, reaches a MWR that is 0.14 higher (at conversion rate 6.8%). That is, his spouse can expect to receive an additional *CHF 0.14* as widow's pension for every *CHF* forgone as a lump-sum.

While the effect of an increase in the age-difference A on the net present value of the annuity option is strictly positive under realistic mortality rates, the strength of this effect depends on the level of A: The graphs in *Figure 8* are no straight lines. *Figure 9* depicts the slope of the solid graph (conversion rate 0.068) in *Figure 8*. It indicates, for every level of A, the increase in MWR associated with a 1-year increase in A.

The increase in the money's worth ratio induced by a 1-year increase in A tends to be larger at high levels of A, that is, MWR becomes more and more sensitive to A as A increases. The increase in MWR from being 6 rather than 5 years older than one's spouse, for instance, is 50% larger than that from being 5 rather than 6 years younger than one's spouse. As MWR is increasing and convex in A under realistic mortality rates, one might expect a positive impact of A in the empirical analysis that is particularly pronounced at high levels of A.

Figure 9: Money's Worth Ratios as Function of Age-Difference - Slope



III.4 Empirical analysis

III.4.1 Data and sampling

The data used in this study stem from the Swiss Labour Force Survey[26]. This household survey is carried out on a yearly basis and is representative of the Swiss population (of age 15 and above). The survey includes a special part on Social Security every three to four years, thereby providing fairly detailed information on the financial situation of future and current retirees. The survey is organized as a rotating unbalanced panel, in which roughly half of the people are interviewed two to three times and a smaller proportion up to five times.

[26]Swiss Labour Force Survey (SLFS). I would like to gratefully acknowledge the Swiss Federal Statistical Office for this data set.

In this study, I focus on married men and do not analyze women's annuitization behavior. The main reason is that relatively few married women in the age-group retiring prior to 2012 worked, and those who did typically dispose of rather small occupational retirement pillars. At the time, married couples with female sole or main earners were very uncommon indeed. The descriptive statistics in section 4.3 show clearly that annuitization behavior differs substantially between married men and women, so that mixing both groups would be problematic. Analyzing a sub-sample consisting exclusively of women would entail a low sample size.

In the non-parametric analysis I use cross-sectional data on all married male retirees interviewed in 2002, 2005, 2008 and 2012 for whom I have information on their annuitization choice. Whenever a respondent was interviewed in more than one wave, I use the information of his first interview only to avoid double counts. The data set for the parametric analysis (section 4.3) consists only of cross-sectional data collected in 2008 because some relevant information is not available in other years. In order to avoid noise from unsuitable observations, I restrict my attention to individuals retiring after 1997 who a) receive a 1^{st} pillar old-age pension, b) possess 2^{nd} pillar wealth and c) report complete, coherent and credible information on their second pillar. Although the last point suggests that non-response bias might potentially be an issue in the dataset, it is unlikely to be of significant magnitude. In fact, only few respondents in the relevant group lack information on their second pillar.

The final data set used in the parametric part includes 503 married men.

All descriptive statistics and regression results in this chapter are weighted estimates. The weights are individual weights used to make the estimates representative of the Swiss population in this age-group. Non-weighted average values or regressions are close, but cannot be tabled due to confidentiality reasons.

While the Swiss Labour Force Survey data set has the advantage of providing broad information on the financial and demographic background of the respondents, it lacks information on pension plan details. Most importantly, I do not know the exact conversion factor used to translate capital into annuities. To limit the importance of this issue, I focus entirely on dependent variables that remain unaffected by the precise level of the conversion factor.

III.4.2 Non-parametric analysis

In this section I estimate a non-parametric scatter-plot smoother[27] in order to get a first insight into the empirical relationship between annuitization behavior and the age-difference between spouses. The main advantage of the local polynomial regression fitting model over parametric alternatives is its flexibility and the absence of linearity requirements and restricting assumptions on the conditional mean of the outcome. In essence, the procedure performs weighted polynomial regressions on observations lying in the same "neighborhood", that is, close to one another. While the model is mathematically readily extendable to more than one predictor, running augmented models is problematic. Introducing additional dimensions increases the minimum distance between observations that is necessary to find a sufficient number of "neighbors", thereby rendering the estimations less local and increasing their bias. Due to this fact, which is commonly referred to as the"Curse of Dimensionality", I restrict the non-parametric analysis to the bivariate relationship between a couple's age-difference A and annuitization behavior. The outcome is a binary variable indicating whether the respondent converted all of his second-pillar capital into an annuity (Full annuity=1) or withdrew

[27] For more detailed information on this procedure the reader may refer to the literature based on Cleveland (1979).

at least some fraction of it as a lump-sum (Full annuity=0). The independent variable is the age-difference between spouses in years, again from the policy holder's point of view. *Table 5* summarizes the data used for the non-parametric analysis.

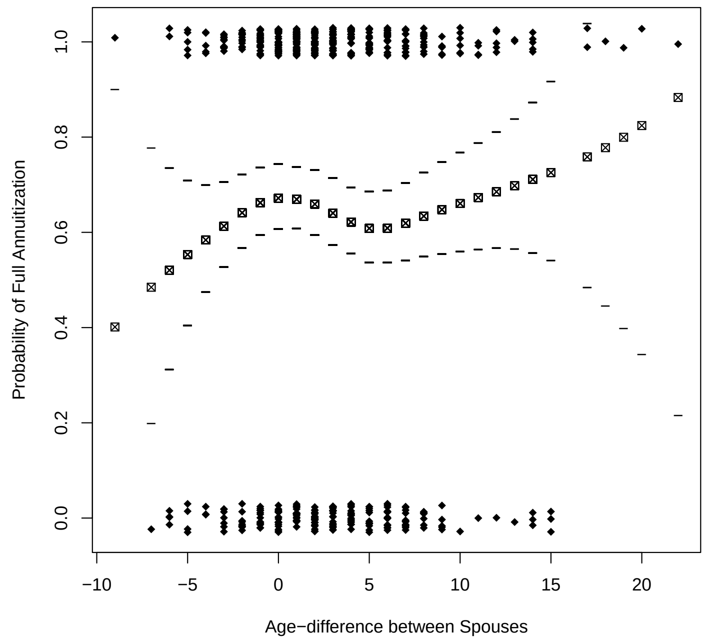
Summary statistics

TABLE 5	Full annuity			Age-difference		
Interview year	mean	std. error	N	mean	std. error	N
2002	0.64	0.02	555	2.75	0.18	555
2005	0.63	0.02	678	2.89	0.19	678
2008	0.61	0.02	664	2.94	0.21	664
2012	0.53	0.02	840	2.92	0.16	840

All means are weighted estimates

Figures 10 through *13* represent the results for the different survey years. The data points in the scatter plot are jittered to make their occurrence frequency visible. Only few observations lie outside of the common age-difference range (-3;10). The thick curves in the figures reflect the scatter-plot smoothers. They are surrounded by certainty intervals which are constructed in analogy to 95% confidence intervals. It is important to notice, however, that the scatter-plot smoothers rely on a fitting procedure rather than concrete probabilistic statements. This implies that the band can be seen

Figure 10
AGE−DIFFERENCE & ANNUITIZATION: 2002



as a measure of precision in a rough sense, yet it should not be interpreted as a precise confidence interval in the usual way.

Several features can be identified in the figures. First, the proportion of married men choosing full annuitization oscillates around the 60% line in the first three survey years and is somewhat lower in the 2012 data. Second, the theoretically expected strictly positive relationship between age-difference and annuitization behavior cannot be detected in general. In each survey year, the relationship is locally decreasing in some part. Third, at relatively high age-difference levels, say 5 or 7 years, a higher age-difference tends to be associated with more annuitization. The fact that this positive association can only be observed at high age-difference levels might potentially be related to the finding in section 3.2 that the impact of A on MWR is growing with A

Figure 11
AGE−DIFFERENCE & ANNUITIZATION: 2005

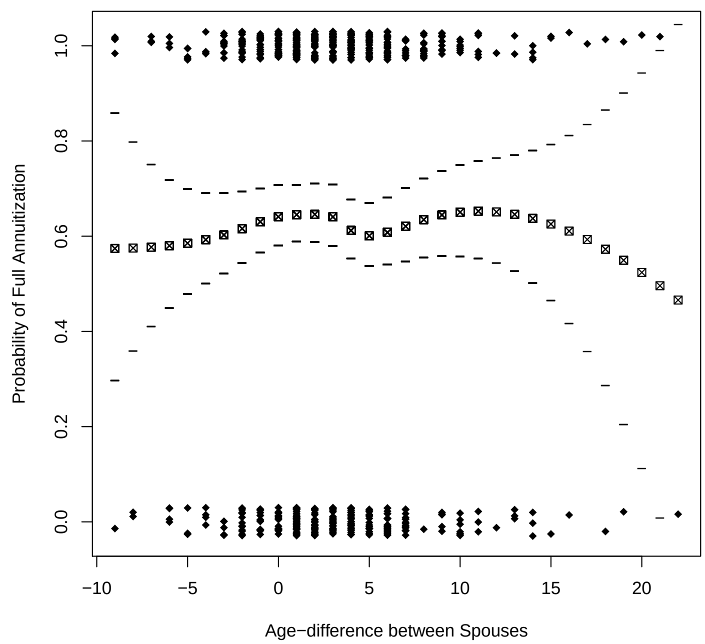


Figure 12
AGE−DIFFERENCE & ANNUITIZATION: 2008

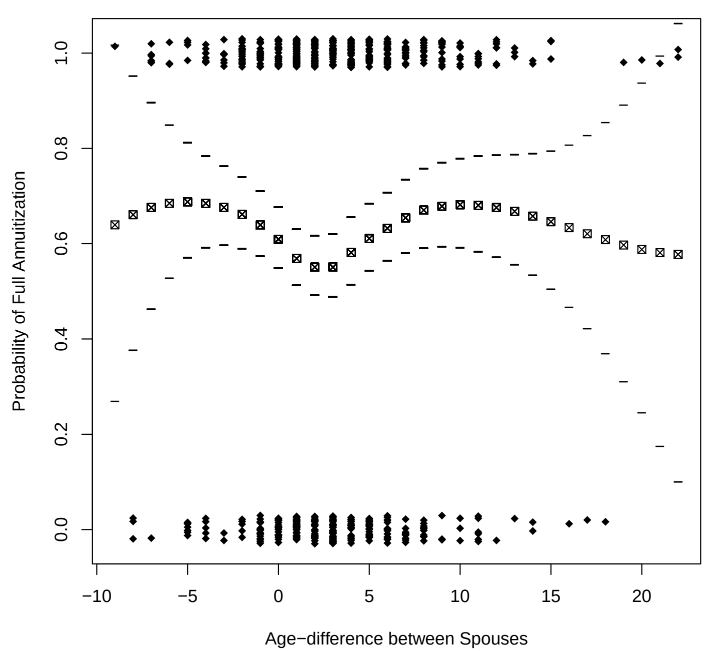
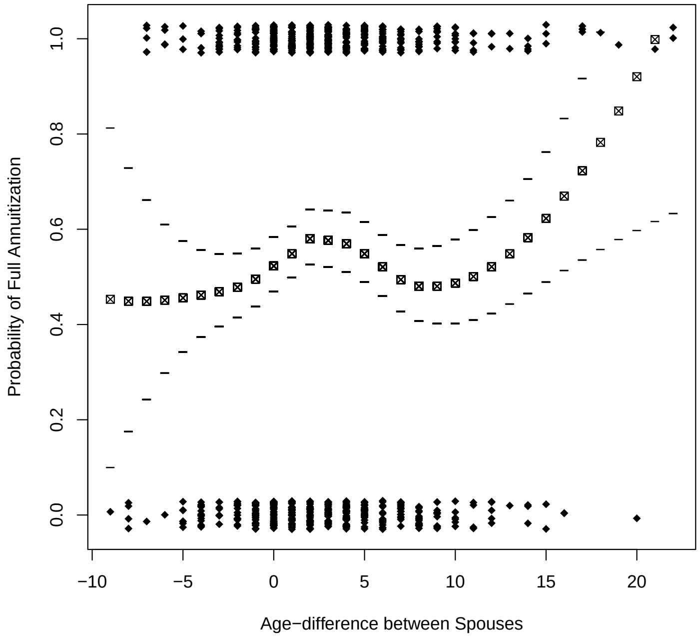


Figure 13

AGE−DIFFERENCE & ANNUITIZATION: 2012



under realistic mortality rates.

III.4.3 Parametric analysis

In this section, I estimate a logit and an ordered logit model with a wide range of explanatory variables using 2008 data only. The main advantage of this survey year over other years is that household income from other sources, such as the first pillar, is available in great detail. Information on 2^{nd} pillar annuities and unique or multiple 2^{nd} pillar lump-sum withdrawals form the basis of the dependent variables in the various regressions. In addition, I use information on the age-difference between spouses, household income from other sources, household size, education and benefits from the 3^{rd} retirement pillar to construct a set of explanatory variables.

Descriptive statistics The summary statistics below describe the final data set used in the parametric regressions. It is important to recall that this data set comprises only married male retirees. For the sake of completeness, *Table 6* additionally includes information on the general population (married and singles, male and female). Annuitization behavior depends clearly on marital status, especially in the case of women.

Dependent variable:

The dependent variables used in the different specifications are a discrete outcome variable and a binary variable indicating the degree to which the policy holder chose to annuitize his 2^{nd} pillar wealth upon retirement. In the ordered logistic regressions, the depending variable is a discrete outcome variable reflecting whether the policy holder chose full annuitization, partial annuitization or decided to withdraw all of his 2^{nd} pillar capital as a lump-sum. As in the non-parametric analysis, the outcome variable in the logistic regressions is reduced to a binary variable that only indicates whether the capital was entirely annuitized or not.

Second pillar withdrawal choices

TABLE 6	married			singles + married		
	mean	std. error	N	mean	std. error	N
Full annuity						
($y^{OL} = 3$)						
all	0.61	0.02	736	0.65	0.015	1244
men	0.63	0.025	503	0.65	0.021	666
women	0.56	0.036	233	0.66	0.022	578
Partial annuity						
($y^{OL} = 2$)						
all	0.14	0.015	736	0.13	0.011	1244
men	0.18	0.02	503	0.17	0.017	666
women	0.07	0.018	233	0.09	0.013	578
Full lump-sum						
($y^{OL} = 1$)						
all	0.25	0.018	736	0.21	0.013	1244
men	0.19	0.02	503	0.18	0.017	666
women	0.37	0.035	233	0.25	0.02	578

All means are weighted estimates

That is,

$$\textbf{ordered logit: } y^{OL} = \begin{Bmatrix} 1 & \text{(no annuitization)} & if & \frac{k_a}{k_a+k_l} = 0 \\ 2 & \text{(partial annuitization)} & if & 0 < \frac{k_a}{k_a+k_l} < 1 \\ 3 & \text{(full annuitization)} & if & \frac{k_a}{k_a+k_l} = 1 \end{Bmatrix}$$

and

$$\textbf{logit: } y^{L} = \begin{Bmatrix} 0 & \text{(no full annuitization)} & if & \frac{k_a}{k_a+k_l} < 1 \\ 1 & \text{(full annuitization)} & if & \frac{k_a}{k_a+k_l} = 1 \end{Bmatrix}$$

where k_a still refers to the second pillar capital transformed into an annuity and k_l to the amount of second pillar capital withdrawn as a lump-sum.

Table 6 indicates that about 60% of all married retirees convert all of their 2^{nd} pillar capital into an annuity. Married men tend to choose full annuitization somewhat more frequently than women. Interestingly, married women seem to select the full lump-sum option quite often, while only very few of them opt for a partial lump-sum. A common explanation of this finding suggests the following: married men have, on average, considerably larger amounts in their 2^{nd} pillars than married women. Retirees with very low pension capital might feel that it is not "worth" transforming the money into a very modest annuity, and prefer the lump-sum. In contrast, agents with very large 2^{nd} pillar wealth might try to reduce their tax burden by deviating from the full annuity option, while they still want to benefit from the longevity insurance of annuities. The systematically different annuitization behavior between married men and married women is apparent in *Table 6*. The average annuitization values reported of this section correspond relatively closely to the ones reported in chapter II.

Independent variables:

Variable of interest

The impact of the age-difference between spouses on the annuitization decision is at the heart of this analysis. In most of the following regressions, I use age-difference quartiles to measure this impact. The quartiles are denoted by $Q_j^{0.25}$, $Q_j^{0.5}$, $Q_j^{0.75}$ and Q_j^1 for individual j. More precisely, calling $F(A)$ the sample distribution function of age-difference A,

$$\begin{aligned} &\forall j, \forall i \in \{0.25, 0.5, 0.75, 1\} \\ &Q_j^i = 1 \quad if \quad i - 0.25 < F(A_j) \leq i \\ &Q_j^i = 0 \qquad\qquad\qquad else. \end{aligned}$$

Among the 503 men in the sample, the ranges of the different quartiles are given as follows:

$Q^{0.25}$	:		A	$\leq$	0	*spouse older or of equal age*
$Q^{0.5}$	:	$<$	A	$\leq$	1	
$Q^{0.75}$	:	$<$	A	$\leq$	5	*spouse younger*
Q^1	:	$>$	A			

One can notice a very high concentration of observations at low positive values of A. 25% of all men in the sample are between 0 and 1 year older than their spouses. Since A is very high for some couples, using quartiles has the advantage of reducing the impact of outliers on the regression results.

Further explanatory variables

Table 7 summarizes the most important independent variables.

Summary statistics

TABLE 7	married men			all (men/women/singles)		
	mean	std. error	N	mean	std. error	N
FI (in *CHF 1,000*)	2.69	0.17	503	3.05	0.11	1243
capital (in *CHF 1,000*)	567.46	17.64	503	417.99	10.8	1244
3^{rd} pillar	0.39	0.03	503	0.34	0.15	1244
retirement age	63.06	0.12	503	62.96	0.08	1244

All means are weighted estimates

FI (further income): This variable represents the monthly household income per person from other sources than the policy holder's 2^{nd} pillar. On average, every household member has *CHF 2690* at their disposal in addition to the policy holder's occupational pillar income. This extra income can come from other benefits paid to the policy holder (e.g. 1^{st} pillar benefits), from income attributable to the spouse (1^{st} pillar, 2^{nd} pillar or else) or from other sources. The seemingly high average value of FI is to a large extent due to a limited number of very rich people; three quarters of the men in the sample report an outside income that is lower than the average value indicated in *Table 7*.

capital summarizes the estimated amount of 2^{nd} pillar capital wealth. This variable is the only variable which is affected by the (unknown) conversion factor. While the lack of information on exact conversion factors introduces noise, a large part of the variation across individuals can be explained by the retirement entry age and the retirement year. I calibrate the average conversion rate to match conventional levels. It turns out that the regression results are very robust to variations in the conversion rate. In my sample, the average estimated capital of married men is high, which can be partly explained by some very rich retirees. About 10% of those receiving an annuity indicate a monthly annuity level of *CHF 6,000* or more. Even with high conversion rates, such levels of occupational pillar annuities can only be attained when one's second pillar capital lies well beyond *CHF 1,000,000*. When considering the whole population (including women and singles), the average capital is about *CHF 418,000*, which corresponds roughly to estimates from other sources. Butler and Teppa (2007) report an average 2^{nd} pillar capital of *CHF 484,360*.

3^{rd}*pillar* is a binary variable indicating whether the policy holder disposed of a 3^{rd} pillar upon retirement. Benefits in the 3^{rd} pillar are almost always paid out as a lump-sum. Transforming third pillar wealth into annuities is rare and many providers do not offer this choice. Roughly one third of the retirees state they had access to a third pillar, but the proportion is higher for men than for women. Benefits stemming from pillar 3 are of considerable magnitude in many cases and can be an essential component in a retiree's overall finances.

retirement age indicates the policy holder's age in years when he retired. The retirement age in the sample is lower than in the general population because pre-retirees are slightly over-represented.

Regression strategy and results[28] In this section, I estimate ordered logistic and logistic regressions. The regressions are equivalent except for the definition of the response variable. As defined earlier, the outcome variables are constructed to be independent of the conversion factor that determines the annuity price. Their independence from the conversion factor is important because we do not observe the latter in the data set and use estimates of it to determine 2^{nd} pillar wealth. Using variables that depend on it could bias our estimates. I choose logit (ordered logit) models to account for the binary (discrete) nature of the outcome variable and exploit the convenient interpretation of the estimated parameters in terms of constant odds-ratios. Using alternative forms of link functions instead, in particular probit models, entails virtually no difference on the results.

I estimate both models 3 times, first with relatively few, then with a wider range of explanatory variables. The ordered logit model in (1) to (3) provides estimates for $\forall G \in (1, 2, 3)$

$$\Pr\left(y_j^{OL} \leq G | X_j\right) = \frac{\exp(\beta_G - \sum_{i=1}^{k} \beta_i x_{i,j})}{1+\exp(\beta_G - \sum_{i=1}^{k} \beta_i x_{i,j})}$$

where X_j is a vector of k explanatory factors for individual j. Recall that *G=1* refers to no annuitization, *G=2* to partial annuitization and *G=3* to full annuitization.

[28] All regressions using this data set are weighted regressions.

In $(4)-(6)$, the binary variable logit model estimates

$$\Pr(y_j^L = 1|X_j) = \frac{\exp(\beta_0 + \sum_{i=1}^{k} \beta_i x_{i,j})}{1 + \exp(\beta_0 + \sum_{i=1}^{k} \beta_i x_{i,j})}.$$

Besides age-difference quartiles, X also includes the variables summarized in *Table 7* and information on residence region, retirement year, education, the tax burden in the residence canton and the educational field of the policy holder's highest diploma. While (1) and (4) use only the most important of these explanatory factors, the augmented models in (2), (5) and (3),(6) use increasingly many of them. Indicator variables on region, retirement year, nationality and educational fields are not tabled.

In *Table 8* and *Table 10*, tax is a discrete variable that reflects the tax level on lump-sum payments in the policy holder's residence canton and can take on values from 1 to 3. As discussed earlier, tax differences can be large. The higher the value of this variable, the higher is the tax rate applied to lump-sum withdrawals and the less attractive is the lump-sum option as a tax-saving device.

Education is also a discrete variable with possible values from 1 (basic schooling) to 3 (university degree).

To summarize,

log(FI)	natural logarithm of monthly per capita household income from sources other than the policy holders 2^{nd} pillar in *CHF 1,000*
log(capital)	natural logarithm of policy holder's estimated 2^{nd} pillar capital in *CHF*
$Q_{0.25}$	binary variable indicating that the policy holder falls into the lowest age-difference interval. That is, he is married to a relatively old spouse.

3rd pillar	binary variable indicating lump-sum withdrawals from pillar III
tax	higher values indicate more lump-sum taxation in the residence canton
education	higher values indicate more education

The way to interpret the coefficients in *Table 8* is the following. Values above 1 indicate a positive impact on annuitization[29]. A one-unit increase in the explanatory variable is, all else equal, predicted to multiply the odds of being in a higher annuitization group by the coefficient. For instance, in (3)

$$\frac{\Pr(y_j^{OL}>1|X_j,\text{retirement-age}=65)}{\Pr(y_j^{OL}=1|X_j,\text{retirement-age}=65)} = 0.86 \cdot \frac{\Pr(y_j^{OL}>1|X_j,\text{retirement-age}=64)}{\Pr(y_j^{OL}=1|X_j,\text{retirement-age}=64)}.$$

Higher levels of capital are strongly associated with more annuitization. The coefficients on the natural logarithm of the estimated capital levels are significant throughout all specifications both economically and statistically. The finding suggests that annuity demand in the Swiss 2^{nd} pillar is subject to a strong positive wealth effect. In particular, the coefficient on $log(capital)$ in (1) means that a ceteris paribus increase in $log(capital)$ by 1 unit is associated with a multiplication of the odds of being in a higher category (=more annuitization) by factor 2.25. As an example, the odds of full annuitization rather than partial or no annuitization, $\frac{\Pr(y_j^{OL}=3|X_j)}{1-\Pr(y_j^{OL}=3|X_j)}$ are predicted to be 2.25 times larger if (all else equal) policy holder j had a 2^{nd} pillar capital of *CHF 440,000* rather than *CHF 160,000.* This impact is substantial. Furthermore, per capita household income from other sources seems to play a role. The more outside income household members have, the lower is their demand for the annuity.

[29]Note that the models are defined in such a way that this is true both for the ordered logit and logit regressions.

Ordered logistic regressions

TABLE 8 $y = y^{OL}$	(1) N=503 odds ratios	(2) N=503 odds ratios	(3) N=503 odds ratios
Pseudo R-squared	0.081	0.132	0.152
log(FI)	0.7*	0.61**	0.58**
	(0.13)	(0.13)	(0.13)
log(capital)	2.25***	2.59***	2.59***
	(0.37)	(0.52)	(0.6)
retirement age	0.89**	0.9	0.86*
	(0.05)	(0.07)	(0.08)
$Q_{0.25}$	0.85	0.84	0.75
	(0.27)	(0.28)	(0.27)
$Q_{0.5}$	0.71	0.58	0.52*
	(0.23)	(0.2)	(0.18)
$Q_{0.75}$	0.66	0.56*	0.5**
	(0.19)	(0.17)	(0.16)
3^{rd} pillar		0.66*	0.72
		(0.15)	(0.17)
tax=2		1.64	1.32
		(0.58)	(0.63)
tax=3		1.93**	1.75
		(0.59)	(0.87)
education=2			1.36
			(0.79)
education=3			1.35
			(0.86)

(Robust standard errors in brackets)

The most compelling explanation for this finding is the existence of a strong substitution effect through pre-existing annuities. In (3) the coefficient on log(FI) implies for instance that a ceteris paribus increase in outside per capita income from *CHF 600* to *CHF 1650* reduces the odds of full annuitization by over 40%.

It is possible that FI as explanatory variable suffers from endogeneity problems. If lump-sum recipients do not eat up their benefits shortly after retirement but invest the money in financial assets, they earn returns on these assets. Through the channel of these returns, outside household income of non-annuitants is artificially higher than that of annuitants, thereby introducing a bias on the coefficients on FI. Fortunately, the data also contain information on capital returns. To investigate the severity of the issue, I rerun the regressions under various specifications, e.g. completely excluding capital returns from FI or assuming fixed annual returns on lump-sum withdrawals and adapting FI accordingly. It turns out that the reported coefficients might overestimate the real impact somewhat, but not exuberantly. Most importantly, the coefficients on the other variables of interest turn out to remain unaffected by this problem.

The age-differences between policy holders and their spouses, the key factor in this study, appears to matter. This effect can only be detected, however, when a large set of control variables is added to reduce noise. Policy holders who are married to the youngest spouses (Q_1) seem to annuitize considerably more than elderly married to spouses of approximately their own age. The difference vanishes, though, when one compares them to retirees who are married to older spouses. *Table 9* summarizes this phenomenon. Relying on the results in regression 3, *Table 9* answers for each age-difference quartile combination the following question: "Is it possible to detect a systematic difference in annuitization behavior between policy holders in age-difference quartile Q_i and policy-holders in quartile Q_j"?

TABLE 9	$Q_{0.25}$	$Q_{0.5}$	$Q_{0.75}$	Q_1
$Q_{0.25}$	$---$	NO	NO	NO
$Q_{0.5}$	$---$	$---$	NO	YES
$Q_{0.75}$	$---$	$---$	$---$	YES
Q_1	$---$	$---$	$---$	$---$

"It is possible to document a statistically significant annuitization difference between policy holders of age-difference groups Q_i and Q_j?"

Table 9 points out that there is a systematic difference regarding annuitization between elderly who are more than 5 years older than their spouses (Q_1) and retirees who are between 0 and 1 ($Q_{0.5}$) and 2 and 5 ($Q_{0.75}$) years older than their wives. Retirees with very young spouses annuitize substantially more. This econometrically detectable difference vanishes when one compares other age-difference quartile combinations. Quite unexpectedly, retirees with older spouses ($Q_{0.25}$), for whom the expected survivor benefit level is relatively low, do not seem to behave differently from those elderly with the youngest spouses. This result is in line with the findings in the non-parametric section.

While retirement years and education do not seem to matter conditional on the other explanatory variables, annuitization rates differ across some of the educational fields.

One should bear in mind that the coefficient estimates in (1) to (3) rely on the parallel regression assumption underlying the ordered logit model. In each of these regressions, we estimate two distinct equations, namely one for logit($y^{OL} = 1$) and one for logit($y^{OL} \leq 2$). The assumption states that the impact of covariate x on the transition between outcome $y^{OL} = 1$ and $y^{OL} \leq 2$ is the same as between $y^{OL} \leq 2$ and $y^{OL} \leq 3$; put differently, the coefficients would not vary significantly if both equations were estimated separately. The odds of $y_j^{OL} = i$ for individual j and category i are therefore readily given by $\exp(\alpha_i + \beta' X_j)$; the odds ratios simplify to $\exp(\beta_x)$ for each covariate x.

I repeat the same model as logistic regressions to verify the results. While this comes at the cost of losing some precision because we cannot distinguish between retirees withdrawing the full capital as a lump-sum and those choosing a combination, this method has 2 advantages. First, the parallel regression assumption does not need to apply any longer. Second, we cannot exclude that a few pension funds did not allow full annuitization. In the logistic regression, these factors do not play a role because we focus only on a binary variable indication full annuitization.

Table 10 points out that the main results discussed so far hold also in the logit regressions both from a qualitative and a quantitative point of view.

Logistic regressions

TABLE 10 $y = y^L$	(4) N=503 odds ratios	(5) N=503 odds ratios	(6) N=503 odds ratios
Pseudo R-squared	0.075	0.136	0.171
log(FI)	0.7*	0.62**	0.58**
	(0.14)	(0.14)	(0.13)
log(capital)	1.74***	1.93***	1.95***
	(0.25)	(0.33)	(0.38)
retirement age	0.87**	0.88	0.84**
	(0.05)	(0.07)	(0.07)
$Q_{0.25}$	0.91	0.9	0.82
	(0.29)	(0.3)	(0.29)
$Q_{0.5}$	0.76	0.64	0.57
	(0.25)	(0.22)	(0.2)
$Q_{0.75}$	0.62	0.55*	0.5**
	(0.2)	(0.18)	(0.17)
3^{rd} pillar		0.66*	0.72
		(0.15)	(0.18)
tax=2		1.8	1.61
		(0.67)	(0.9)
tax=3		1.94**	1.96
		(0.64)	(1.16)
education=2			1.71
			(0.93)
education=3			1.61
			(1.02)

(Robust standard errors in brackets)

Alternative regression strategy: estimation with Money's Worth Ratios[30]
The previous regressions are based on the age-difference between spouses A as independent factor to explain annuitization behavior. Ultimately, though, the variable of interest is the expected value of the annuity associated with A. The age-difference itself is just a good proxy variable that circumvents the problem of unobserved conversion factors.

In this section, I assume a standard conversion factor and use money's worth ratios directly. Proceeding in this way introduces noise, thereby making estimates somewhat less precise, but allows us to interpret the results in an intuitive way: If a policy holder can expect his spouse to be paid back a certain amount more in survivor benefits for every *CHF* he invests in an annuity, by how much will annuity demand change?

Table 11 presents the two augmented models that are analogous to regressions (3) and (6), but include different variables of interest:

MWR_{ph} is the money's worth ratio (in percentage points) the policy holder himself can expect to get paid back in present-value terms, excluding the widow's pension. Since I do not know the exact conversion factors, MWR_{ph} is fully determined by the year of retirement and the retirement age. I omit these two factors from the model, assuming that they do not matter per se in the annuitization decision and only impact the choice via their effect on the money's worth ratio.

MWR_{sp} is the additional money's worth from the survivor benefits (in percentage points). On average, MWR_{sp} is 22.8 in the data. For every *CHF* withdrawn as an annuity, the typical policy holder can expect his spouse to receive *CHF 0.228* in survivor benefits, in addition to what he receives as old-age pension. MWR_{sp} is fully determined by the the year of retirement, retirement age and A.

[30] All regressions are weighted regressions.

As the distribution of MWR_{sp} is strongly positively skewed, I drop observations with very high values of MWR_{sp} (about 7% of the sample). With the functional forms in (7) and (8), these observations would have a very strong impact on the estimations and could blur the general picture.

Guided by the results in the previous sections, I include also the square of MWR_{sp} in the regressions to allow a varying effect of MWR_{sp} on annuitization behavior.

The coefficients of MWR_{ph} go in the expected direction, but they are not significantly different from 0 in the regressions. This result is probably due to the fact that too much noise is introduced as I do not observe the precise conversion factor and calculate MWR_{ph} solely on the basis of the retirement year and the age at retirement.

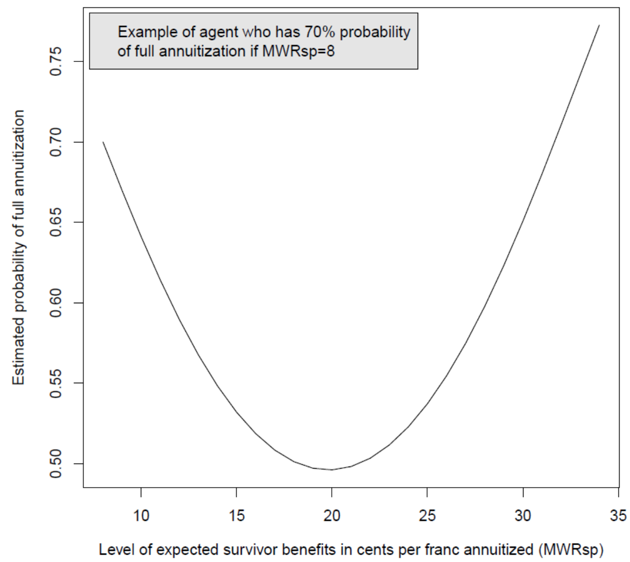
The coefficients on MWR_{sp} and MWR_{sp}^2 are in line with the results of the previous sections. They testify to a decreasing impact of MWR_{sp} on annuitization at low levels of MWR_{sp}. This effect turns positive once MWR_{sp} exceeds a certain level. *Figure 14* plots the predicted probability of full annuitization as a function of MWR_{sp} in the case of a hypothetical retiree whose baseline probability, conditional on the other variables, is 70% at $MWR_{sp} = 8$ (that is, when the spouse can expect to receive 8 cents as survivor benefits for every franc annuitized). One can note that, despite seemingly low coefficients on MWR_{sp}^2 in *Table 11,* annuitization is positively impacted by MWR once MWR exceeds 20.

Regressions with MWRs

TABLE 11	ordered logit (7) N=467 odds ratios	logit (8) N=467 odds ratios
Pseudo R-squared	0.136	0.152
log(FI)	0.6** (0.14)	0.59** (0.14)
log(capital)	2.73*** (0.59)	2.12*** (0.4)
MWR_{ph}	1.05 (0.04)	1.06 (0.04)
MWR_{sp}	0.77** (0.08)	0.78** (0.09)
MWR^2_{sp}	1.01*** (0.003)	1.01** (0.003)
3^{rd} pillar	0.73 (0.17)	0.7 (0.17)
tax=2	1.16 (0.58)	1.33 (0.74)
tax=3	1.48 (0.78)	1.68 (0.98)
education=2	1.05 (0.62)	1.25 (0.7)
education=3	0.97 (0.66)	1.11 (0.74)

(Robust standard errors in brackets)

Figure 14: Effect of Expected Survivor Benefits on Annuitization



III.5 Conclusion

The expected return of an annuity in the Swiss occupational retirement system increases with the life expectancy of the policy holder's spouse. In this study, I find evidence for a positive impact of the age-difference between spouses - the main determinant of spouse life expectancy - on annuitization behavior. It appears, however, that this positive impact only materializes in the case of policy holders married to substantially younger spouses. Financial incentives, which depend in a non-linear way on the age-difference between spouses, might at least partially explain this finding. The monetary value increase of the annuity option associated with an additional year of age-difference is highest at already high levels of A. Besides that, many other potential reasons for this finding are thinkable. Psychological factors, for instance, might play a role. A policy holder married to a young spouse could be overproportionally aware of his higher death probabilities, while a policy holder with an older spouse might pay less attention to the question. Furthermore, in a couple with two workers there might be more coordination between withdrawal choices if both have approximately the same age and retire at the same time. The age-difference impact might therefore be blurred by the spouse's annuitization behavior.

From a policy point of view, the results can be important. In view of decreasing mortality rates and low interest rates in recent years, Swiss pension funds are increasingly struggling to maintain pension levels and calls for lower conversion factors (implying lower annuities) were growing louder. In a national referendum in 2010, however, a large majority of the Swiss electorate (over 70%) rejected an initiative that proposed a reduction of the legal minium conversion factor. Other attempts to cut benefits were equally unpopular and never introduced. One may argue that indexing conversion factors on spouse age could constitute a viable alternative to improve the scheme's sustainability. In light of the annuitization behavior documented in this study, however, it seems important to take potential behavioral responses into account in such discussions. Retirees married to young spouses might tend to choose lump-sum payments more often than they do now, thereby forgoing the inherent insurance against the risk of outliving their resources.

Chapter IV

Differential Mortality of Swiss Retirees[31]

IV.1 Introduction

Albeit later than the United States, Switzerland, too, experienced a baby boom after the end of World War II. The "high-birthrate generation" born in the wave after 1955 will start retiring in the next few years, raising concerns that the large number of new retirees might destabilize the first two Swiss retirement pillars. According to official sources, the capital reserves of the first pillar are predicted to start shrinking from 2020 onwards and pension funds in the second pillar will be struggling to finance the legally defined minimum obligations towards their retirees.[32] From conservative circles to liberal forces, calls for reform are growing louder in light of this development. In a policy

[31] This chapter is based on data stemming from a private insurance company. I would like to gratefully acknowledge the insurance company for this data set.

[32] see http://www.bsv.admin.ch

proposal named "pensions 2020", the Swiss Federal Council suggests a comprehensive retirement reform consisting of various measures, including a decrease in the second pillar conversion factor and an increase of the female retirement age to the male level of 65 years. It cites as a key factor urging for action[33] the fact that "the remaining life-expectancy of a 65-year-old has increased from 15.2 to 22.1 years in the case of women within the past 50 years, and from 12.9 to 19.1 years in the case of men". The true need for reform, however, might be even more pressing than suggested by these numbers. While indicatory, population mean life expectancies can only tell half of the story. Detailed information is necessary to predict retirement obligations accurately. Ultimately, a weighted beneficiary survival curve - weighted according to retirement claims - determines how costly retirement financing will be. If retirees with large regular benefit claims face more favorable survival rates than the average population, the need for additional resources to finance retirement payments will turn out to be even larger. The goal of this chapter is to shed some light on the interrogation on how survival rates and retirement annuity income are linked. In the Swiss retirement system, there are two major channels through which discrepancies between the survival curves of retirees with different annuity levels can occur: First, in the occupational pillar (pillar II) retirees can choose - at least partly - between an annuity and a lump-sum payment. While the expected value of the former depends on the policy holder's life expectancy, the latter is completely independent of it. Second-pillar annuitants and non-annuitants might very well face different survival probabilities due to adverse selection and other selection mechanisms. Second, a worker's salary history, and the number of years he worked, determine his second pillar capital and to some extent his first pillar benefits. As both one's work history (including on the extensive margin, that is, one's choice

[33] see "Altersvorsorge 2020: Botschaft, Bundesbeschluss und Gesetzestext" at www.bsv.admin.ch/altersvorsorge_2020. Translated from German.

and ability to work at all) and work income are likely to be correlated with longevity, mortality could depend on second pillar size.

This chapter is based on a unique private insurance micro-level data set with information on second pillar withdrawal choices and second pillar levels. While the data set includes only information on mortality in the first years of retirement, it has several significant advantages. Attrition can be ruled out, measurement error is no issue and non-response bias cannot occur. The analysis aims to answer two main questions. First, do average second pillar annuitants face the same mortality probabilities as the whole Swiss population? That is, are average life tables adequate to determine second pillar annuitant mortality? Second, among second pillar annuitants, is higher second pillar capital associated with lower mortality? Both points are crucial to determine the value of the retirement benefits a pensioner can expect to receive. The remainder of this chapter is organized as follows. In section IV.2, I discuss reasons why one might expect mortality differences to exist between annuitants and non-annuitants for one thing, and between retirees with large and small occupational retirement pillars for another. After that, I present the data set in section IV.3 and provide some summary statistics. Section IV.4 compares the mortality experience of the second pillar annuitants in the sample to overall mortality rates in Switzerland. Section IV.5 analyzes whether second pillar capital levels have an impact on survival in the data. Section IV.6 extrapolates the results to older ages to derive (hypothetical) complete survival curves and make statements about the net present value of the annuity option. The final section concludes.

IV.2 Potential reasons for mortality differences

This section describes forces that might lead to mortality differences across various retiree groups. The first part focuses on reasons why mortality differences between annuitants and non-annuitants might arise, the second on mortality depending on second pillar wealth.

IV.2.1 Why mortality between annuitants and non-annuitants might differ

There are two main forces that could result in mortality differences between annuitants and non-annuitants: Adverse selection due to private information in the lump-sum vs. annuity choice and selection into the labor force.

Adverse selection in lump-sum vs. annuity choice

Annuity markets are often cited as a prime example of markets impacted by adverse selection. If predominantly high-risk (in this context long-lived) agents buy annuities, annuity prices must be adjusted upwards, thereby deterring low-risks from purchasing.

It is often suggested that this mechanism is one of the key explanations why private annuity markets are small. The topic has received considerable attention in the theoretical literature and some attention in the empirical literature. Finkelstein and Poterba (2002, 2004) and McCarthy and Mitchell (2010) provide evidence that information asymmetry is present in various annuity markets and leads to adverse selection.

In our context, adverse selection can occur if retirees have private information on their survival probabilities and use this information for their lump-sum vs. annuity decision. As annuities are not priced individually but collectively, many pieces of information are de facto "hidden" - they affect longevity but have no impact on annuity prices. One's smoking behavior, one's overall health status and one's family history of cancer all belong to this long list. Long-lived agents, e.g. healthy non-smokers, might tend to annuitize more frequently if they are aware of their favorable survival rates and do not discount future consumption more heavily than their short-lived peers.

In what follows, I display some comparative calculations in order to quantify the importance of private information in this context. Recall that the value of an annuity has two components in the Swiss pension system: first, the part the policy holder himself/herself can expect to receive and second - if the policy holder is married - the part the spouse can expect to receive in the form of survivor benefits[34]. I use the same notation as in the previous chapters: The conversion factor is given by α, the instantaneous risk-free interest rate by r_t, where t refers to the number of years after the policy-holder's retirement, mortality rates are given by μ_t^h (policy holder) and μ_t^s (spouse) and the corresponding survival curves by s_t^h (policy holder) and s_t^s (spouse).

Assuming that survival rates between spouses are statistically independent, the net present value at retirement of *CHF 1* invested in the annuity option is given as

$$MWR = \underbrace{\alpha \cdot \sum_{t=0}^{\infty} \frac{s_t^h}{(1+r_t)^t}}_{\text{Policy holder}} + \underbrace{0.6 \cdot \alpha \cdot \sum_{t=0}^{\infty} \frac{(1-s_t^h) \cdot s_t^s}{(1+r_t)^t}}_{\text{Spouse}}.$$

[34] I abstract from benefits paid to children. In practice, these benefits do not play a central role.

Consider a male married policy holder who has private information on both his own and his spouse's mortality rates. More precisely, assume he knows that their mortality probabilities μ_t^h and μ_t^s differ by factors β^h and β^s from the corresponding average mortality rates in every period: $\forall t$, $\mu_t^h = \beta^h \cdot \mu_t^{average\ male}$ and $\mu_t^s = \beta^s \cdot \mu_t^{average\ female}$. That is, their mortality rates are proportional to the corresponding average mortality rates in each period. If $\beta^h > 1$, the policy holder himself has a lower life expectancy than the average male of the same age, if $\beta^h < 1$ it is higher. The same applies for spouses and β^s correspondingly. As a rule of thumb, in order to get an order of magnitude, when one compares female to male mortality, β is slightly larger than 0.5 for large parts of adult life in Switzerland.

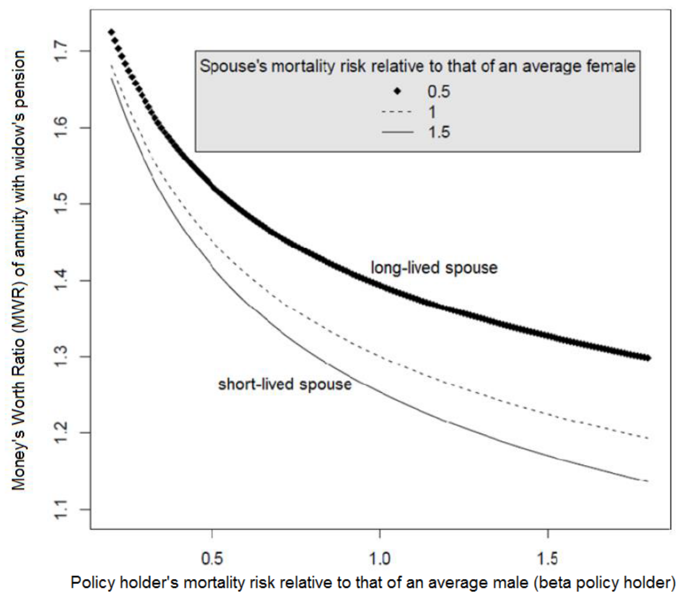
Noting that $\forall t$, $\mu_t^* = \beta \cdot \mu_t \leftrightarrow \forall t$, $s_t^* \sim s_t^\beta$, one can now specify the expected value of the annuity for the policy holder with private information on his own and his spouse's survival probabilities as

$$MWR(\beta^h, \beta^s) \approx \alpha \cdot \sum_{t=0}^{\infty} \frac{(s_t^{average\ male})^{\beta^h}}{(1+r_t)^t} + 0.6 \cdot \alpha \cdot \sum_{t=0}^{\infty} \frac{(1-(s_t^{average\ male})^{\beta^h}) \cdot (s_t^{average\ female})^{\beta^s}}{(1+r_t)^t}$$

Figure 15 plots $MWR(\beta^h, \beta^s)$ for different levels of β^h and β^s for a male policy holder retiring in 2011 at age 65 who is married to a 3 years younger woman and receives the legal conversion factor of 6.8%[35]. The risk-free interest rate is assumed to be constant and equal to 2%. $MWR(1,1) \simeq 1.3$, that is, in the baseline case with no private information, a policy holder can expected to receive about *CHF 1.3* (including survival benefits) for every *CHF* withdrawn as an annuity rather than a lump-sum.

[35] Mortality data stem from the Human Mortality Database (see before).

Figure 15
Private Mortality Information and Joint-and-Survivor Annuity Value



The three different lines reflect the $MWR - \beta^h$ relation for three different values of β^s. One can make two major observations:

1. The effect of private information β^h on the annuity value is large. If a man is pretty confident about his own health, say β^h is 0.6, the expected value of his annuity rises from 1.3 to over 1.4 (for $\beta^s = 1$). Put differently, for every *CHF* invested in the annuity option, he can expect to be paid back more than *CHF 0.1* more. While $\beta^h = 0.6$ might look like a very optimistic example at a first glance, it corresponds to less than the mortality difference between men and women over large parts of adult life.

2. Second, the higher β^s, the steeper is the slope of the curve, $\frac{dMWR}{d\beta^h}$. Intuitively speaking, the presence of survivor benefits reduces the impact of β^h on MWR. On the one hand, low values of β^h mean that policy holders can expect to receive

the annuity for a longer time, on the other hand they imply at the same time that survivor benefits become less likely.

In light of these observations one can suspect that private information and individual expectations on one's own mortality rates play an important role in many cases. While people who are almost sure to live exceptionally long ($\beta^h << 1$) may be rare, very high values of β^h are relatively common: elderly who are aware of a severe or even fatal disease when they retire face $\beta^h >> 1$ and probably take this piece of information into account when they choose on the lump-sum vs. annuity trade-off.

Actuarially, private information on one's own mortality probabilities is most valuable to singles as point (2) points out. In practice, this means that women tend to profit more from private information than men. The proportion of singles among all workers is indeed significantly higher among women than among men.

Selection into workforce

Besides adverse selection in the lump-sum vs. annuity choice, a second selection process can result in differential mortality between an average second pillar annuitant and the overall Swiss population: selection into the workforce. Regular employment and health are most likely not entirely independent of each other and correlate in some way. The correlation between education and health, for instance, is ubiquitous and very well established (see Goldman (2001) for an overview), although causal statements should be treated with caution (see Clark and Royer (2013)).

If especially people with low education never work - and never build up a second pillar -, a correlation between the existence of second pillar savings and health can mechanically arise.

In the Swiss case, this type of selection is unlikely to be relevant for men as labor force participation is high and unemployment low. The OECD estimates that in recent years about 95% of all 34-44 year-old men in Switzerland worked[36]. The proportion of never-workers who do not save in a second pillar is correspondingly smaller. For women, the effect might be stronger. As of today, the proportion of working women is still clearly lower than that of men and this was even more the case in the generation of current retirees. According to the same data source, about 78% of all 34-44 year-old women in Switzerland had a job in the last years.

As in the case of adverse selection in the lump-sum vs. annuity trade-off, selection effects through the work decision are likely to be more relevant for women than for men.

IV.2.2 Mortality depending on second pillar wealth

Extensive previous research has shown that individuals with high income tend to live longer. In their seminal contribution, Marmot et al. (1984) study mortality rates of civil servants in Britain. They document a strong relationship between an employee's work grade and his death probability. Duleep (1986) studies mortality of Caucasian men and finds that higher income is associated with lower mortality, the effect is stronger at low income levels. Explicitly focusing on pensioners, Bommier et al. (2006) shows that male retiree mortality in France depends crucially on pension income. At age 70, the mortality elasticity with respect to pension income is estimated to be around -0.5. For women, though, the effect is less clear.

Putting the pieces of this section together, one can expect mortality differences between annuitants and the overall population, especially in the case of women. Furthermore, one can expect mortality to depend on second pillar capital, especially in the

[36] See http://stats.oecd.org/Index.aspx?DataSetCode=LFS_SEXAGE_I_R

case of men. As the remainder of this chapter shows, these patterns can be found in our data and are very stable indeed.

IV.3 Data

The data set stems from a private insurance company that is active in the Swiss 2^{nd} pillar market. Contrary to many other data sources, it is comprehensive and excludes attrition: for every individual it is possible to state with certainty whether he/she was still alive in 2014 and, if not, when death occurred. As mortality rates are low, this feature is particularly important to make meaningful statements on mortality differences. Even small levels of attrition can heavily bias true mortality rates. In addition, we can exclude problems related to measurement errors and non-response. The data set has the disadvantage, however, that it cannot be considered as representative of the entire Swiss working population. Even though it includes retirees from many different sectors and socioeconomic backgrounds, some population groups are systematically excluded from the data, e.g. state workers. The data provide mortality information on slightly more than 13,000 individuals who retired between 2007 and 2014 and who withdrew at least some share of their second pillar capital as an annuity. Background information on pure lump-sum recipients is also available, but the insurance company does not keep track of their post-retirement mortality. I observe annuitant mortality from the date of retirement until mid-2014.

IV.3.1 Structure of the data and descriptive statistics

The median retirement date was at the beginning of 2011 and I can observe an average individual for 3.4 years (until 2014.4). 15% of the sample retired at least 6 years prior to the end point of the observation period. On the basis of this data it is possible to make conjectures on mortality differences at early retirement ages (up to age 72), with the most precision for ages directly after retirement. Due to this structure, the data are heavily right-censored. In total, 442 deaths occurred while 12,650 individuals were still alive at the end of the observation period.

Table 12 summarizes some relevant descriptive statistics and background information.

Summary statistics

TABLE 12	obs	mean	sdv
male	13096	0.67	
dead	13096	0.034	
early retirement	13096	0.22	
second pillar capital (CHF)	13096	251368	223708
age at death	442	67.4	1.93
strenuous sector	12888	0.42	

Male and *dead* are two dichotomous variables. Their mean values show that two thirds of the sample are men and 3.4% of all retirees deceased prior to the end of the observation period. The large share of male retirees is due to two facts. First, male exceeds female labor force participation (see IV.2.1), especially in the generation of current retirees. One can suspect that a relatively high share of married women did not work. Second, the share of full lump-sum withdrawals is considerably higher among women than among men in the data. As the insurance company does not keep track of their mortality, they are not in the final data set.

Early retirement is a binary variable and indicates whether the worker retired before the official retirement age (65 for men and between 62 and 64 for women, depending on their year of birth) or not. The share of early retirees is higher among women than among men.

Second pillar capital is the wealth individuals possess in their professional retirement pillars. On average, this value is about *CHF 250,000*, yet there are substantial differences between men and women as well as between pre-retirees and former workers retiring at the official retirement age. In comparison to other sources, the average amount is low.

Those retirees who died prior to the end of the observation period died, as indicated by *age at death*, on average when they were 67.4 years old.

Strenuous sector indicates whether the individual used to work in a physically tough sector such as mining, construction, food production or security services. This variable will remain unused in the remainder of the chapter but can provide some background information.

IV.4 Mortality differences annuitants - general population

This section compares the mortality experience in the sample to mortality rates that would have been observed with average Swiss mortality curves: it compares second pillar annuitant mortality to overall Swiss population mortality. For simplicity, I refer to the former as *Insurance Population* and the latter as *General Population*. The data for the *General Population* mortality rates stem from the Human Mortality Database[37].

In order to make the survival curves of both groups comparable, I simulate a very large *General Population* that corresponds to the *Insurance Population* in terms of gender, age-structure and age at retirement. If mortality probabilities were equal in both populations, their survival curves would coincide. Some small differences might incidentally arise because the *Insurance Population* sample is small for higher ages (especially ages > 70).

For both populations, I determine the nonparametric maximum likelihood Kaplan-Meier (KM)[38] estimates of the survival curve $S(t)$. These estimates are very intuitive and remain unbiased even with heavy right-censoring, as in this context.

More precisely, the KM-estimates are given as $\widehat{S}(t) = \prod_{t_i<t} \frac{n_i - d_i}{n_i}$,

where n_i refers to the number of people at risk at age t_i, that is, the number of people alive and in the sample at age t_i. The number of deaths at age t_i is denoted by d_i.

[37] Human Mortality Database (HMD). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany).

[38] See literature initiated by Edward Kaplan and Paul Meier.

Figure 16: Kaplan-Meier Survival Estimates

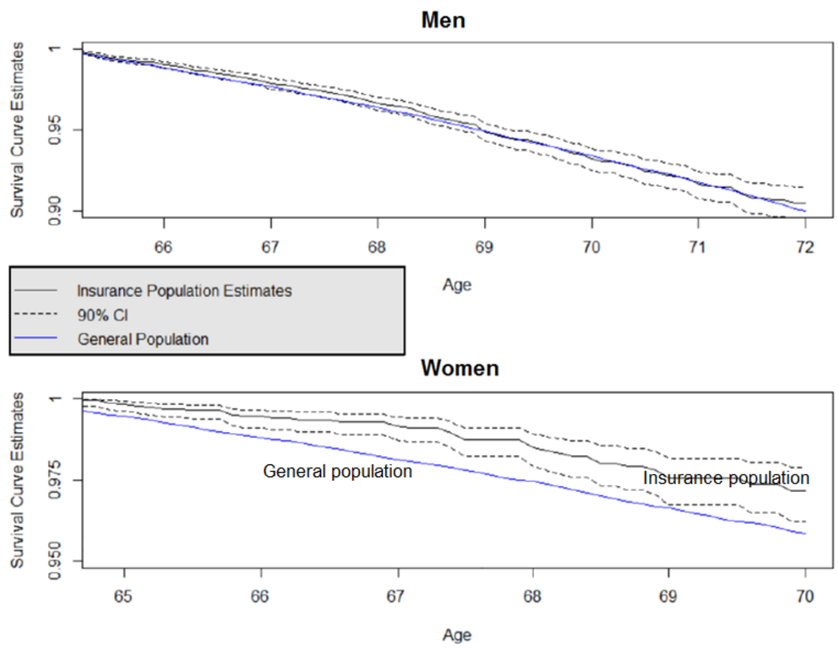


Figure 16 compares the KM estimates of the male and female *Insurance Population* to their corresponding *General Population* counterparts. The graphs include only elderly retiring at the official retirement age, that is, there is a common starting point (the retirement age) at which $\widehat{S}(t) = 1$.

The mortality data of the *General Population* are based on smoothed period mortality rates.

Figure 16 suggests that the male *Insurance Population* dies almost exactly as the male *General Population.* At no age the *General Population* survival curve lies far from the KM estimates of the *Insurance Population*, from age 69 on the estimated survival curves are indistinguishable.

The situation of female mortality looks quite different. The KM estimates for the *Insurance Population* survival curve lie well above the *General Population* survival curve. While the KM estimates for the *Insurance Population* get less precise at higher ages, the two curves do not seem to converge: for every age observed in the sample, the female *Insurance Population* faces more favorable survival rates than the *General Population*.

To test for mortality difference formally, I run a series of tests, including the log-rank test[39]. This statistical test verifies whether two survival curves can be considered as being different from each other on some confidence level.

The log-rank test is based on so-called "expected cell counts": If both survival curves were indeed perfectly identical, how much deaths would we observe at a given age in each of the two groups (*Insurance Population* and *General Population*)?

Applying the same notation as above, the expected cell count for group 1 at age t is given as

$e_{1,t} = \left(\frac{n_{1,t}}{n_{1,t}+n_{2,t}}\right) \cdot (d_{1,t} + d_{2,t})$.

It can be shown that the log-rank statistic for group one, $LR = \frac{\left(\sum_{i=\min(t)}^{\max(t)} d_{1,i}-e_{1,i}\right)^2}{VAR\left(\sum_{i=\min(t)}^{\max(t)} d_{1,i}-e_{1,i}\right)}$, follows approximately a chi-square distribution of degree 1.

Observed and expected deaths of the *Insurance Population*

Table 13	observed deaths	expected deaths if survival rates identical	p-value
men, all retirees	367	385.08	0.351
women, all retirees	72	97.74	0.029
men, normal retirement age	325	333.19	0.650
women, normal retirement age	38	63.51	0.001

[39] This test is routinely included in econometric statistical software. The analytical results displayed in this section are well-known and formal proofs are easily found in the literature.

Table 13 displays observed deaths and expected cell counts in the *Insurance Population* both for men and women. It includes additional estimates which are based only on pensioners who retired at the normal retirement age.

All p-values in the last column confirm the Kaplan-Meier graphs: the survival curves in early retirement faced by the *Insurance Population* and the *General Population* are statistically different for women, but not for men.

Quantifying the observed mortality differences

Given that the female *Insurance Population* faces more favorable mortality rates than the corresponding *General Population*, the next step involves a quantification of this difference. In order to come up with handy estimates, we need to make some distributional assumption on the mortality difference.

A very common assumption is the proportional hazard assumption, which I used already in IV.2.1: it states that the instantaneous mortality hazard rate may differ between groups, but the ratio must remain constant over all ages. The widely used Cox-proportional[40] hazard model is a semi-parametric model relying on this assumption.

The model implies that the mortality hazard in our case can be written as

$$\log \mu_j(t) = \alpha(t) + \beta \cdot D_j$$

for $j = \{General\ Population,\ Insurance\ Population\}$,

where μ is the mortality hazard and D_j a binary variable which is equal to 1 if $j = Insurance\ Population$ and to 0 if $j = General\ Population$.

[40] For more information the reader may refer to the literature based on Cox (1972).

The first term, $\alpha(t)$, represents the baseline risk and is very flexible. It can take any form. The hazard ratio between the two groups is independent of age and given by $\exp(\beta)$.

Using the sample of women, the estimated hazard ratios are 0.78 in the case all retirement ages are included, and 0.59 if we exclude pre-retirees.

The former means that the mortality hazard of women in the *Insurance Population* is about 22 percentage points (pp) lower than that in the *General Population*, if we focus only on women retiring at the statutory retirement age, the difference is even 41pp. These mortality differences are substantial.

The reader may refer to the appendix for a discussion on the proportional hazard assumption and an alternative specification with an age-varying relationship.

Mortality discrepancies between the sample and the *General Population* cannot be detected for men while they are very strong for women. Stronger selection effects for women might play a key role in explaining this difference. As section IV.2.1 points out, there are good reasons to think that adverse selection and selection into the workforce effects are stronger for women. Unfortunately it is impossible to conclude whether adverse selection in the lump-sum vs. annuity trade-off or selection into the workforce is the main driving force. In view of the very strong mortality difference for women, however, one may suspect that both dynamics are at work.

IV.5 Mortality depending on second pillar wealth

In this section, I estimate survival probabilities of second pillar retirees as a function of their second pillar wealth. There are of course many factors that jointly determine mortality, such as a healthy lifestyle, genetics, medical spending, the working sector and many more. Second pillar wealth is likely to be correlated with many of them. It is important to notice that the estimates stemming from regressions with only second pillar capital as explanatory factors do not reflect the ceteris paribus effect of income on survival probabilities; they rather represent the crude association between retirement income and mortality. The goal of this study, though, is to link benefit claims to survival probabilities without any causal interpretation. It is therefore sufficient to focus on the mere relationship between mortality and second pillar wealth.

Table 14 displays various regressions. They are all based on the proportional hazard Cox-model, just as in the previous section. The only difference is that the explanatory variables are not binary in this case, but continuous.

All the regression specifications point in the same direction and indicate that male mortality is strongly related to second pillar wealth, while female mortality is not.

The coefficient in regression (1) in *Table 14* indicates that a retired man faces mortality rates which are by 15 percentage points lower if his second pillar wealth is *CHF 100,000* larger. In regression (2) higher second pillar capital is associated with lower mortality, but its marginal impact is decreasing. This decreasing second-order effect is so weak, however, that it can be neglected.

Alternative specifications, e.g. excluding retirees with very high or very low second pillar wealth, lead to similar conclusions. Male mortality in the sample is highly reactive to second pillar capital, female mortality is not.

Cox model regressions

Table 14	(1) men, all retirees ($n = 8650$)	(2) men, all retirees ($n = 8650$)	(3) women, all retirees ($n = 4273$)	(4) women, all retirees ($n = 4273$)
capital (*CHF 100k*)	0.849*** (0.00)	0.823*** (0.00)	0.896 (0.26)	0.989 (0.96)
capital^2 (*CHF 100k*)		1.003** (0.029)		0.982 (0.68)

	(5) men, ret. age 65 ($n = 7298$)	(6) men, ret. age 65 ($n = 7298$)	(7) women, ret. age 64 ($n = 2903$)	(8) women, ret. age 64 ($n = 2903$)
capital (*CHF* 100k)	0.84*** (0.00)	0.815*** (0.00)	1.005 (0.97)	1.302 (0.48)
capital^2 (*CHF* 100k)		1.004** (0.05)		0.954 (0.5)

(p-values in brackets)

IV.6 Extrapolation

Using the results of the previous sections, I turn now to the derivation of complete survival curves for men and women under various assumptions. In the scope of this extrapolation, the distinction between period and cohort life tables is worth some attention. Cohort life tables indicate the survival experience of an entire cohort over time, e.g. all Swiss men born in 1900. Mortality rates in this kind of table are age and year specific - men born in 1900, for instance, faced mortality rates of 25-year-olds in 1925 and of 26-year-olds in 1926. Period life tables, to the contrary, reflect the mortality experience of an entire population (all ages) at a given point in time. Ideally, it would be most appropriate to use projected future mortality rates to estimate differential survival curves for the age groups in our sample. As individuals in the sample retired in 2007 or later, their true mortality rates at high ages are still unknown. For a variety of reasons (most notably due to limited availability of projected mortality tables and to ensure coherence with the previous results), however, I refrain from using predicted mortality and rely on period life tables. It is important to bear in mind that all calculations in this chapter abstract from survival rate changes in the future.

a) Female mortality

Female annuitants in our sample face more favorable survival rates than the average population, but their mortality rates are not related to second pillar wealth in any statistically significant way. To find an upper bound for age-specific survival probabilities, I assume that the hazard ratio between female annuitant mortality and the female *General Population* of 0.78 (see section IV.4) applies equally to older ages. Most likely, though, female *Insurance Population* and *General Population* mortality rates converge at high ages for several reasons. First, adverse selection effects can be expected to get smaller at higher ages. One's private information on one's own survival rates is usually assumed to get less accurate as the time horizon gets larger. Second, mortality rates rise quickly to high levels at very old ages and a constant mortality ratio would imply very large mortality differences in absolute terms. It is in fact a common finding that mortality differentials - measured as hazard ratios - tend to decrease at high ages.

Conversely, to define a lower bound of the survival curve, I assume that the hazard ratio from IV.4 applies only to the ages we can observe, and mortality differences vanish at higher ages.

Finally, I also plot an intermediate curve as a plausible middle course. More precisely, I determine the maximum-likelihood estimator of a time dependent mortality hazard model (see appendix).

Figure 17

Female Annuitants – Range of Survival Probabilities

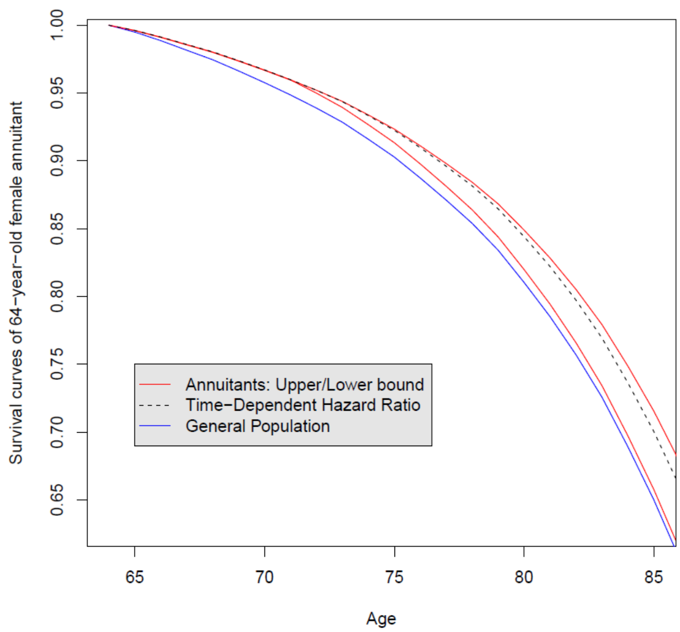
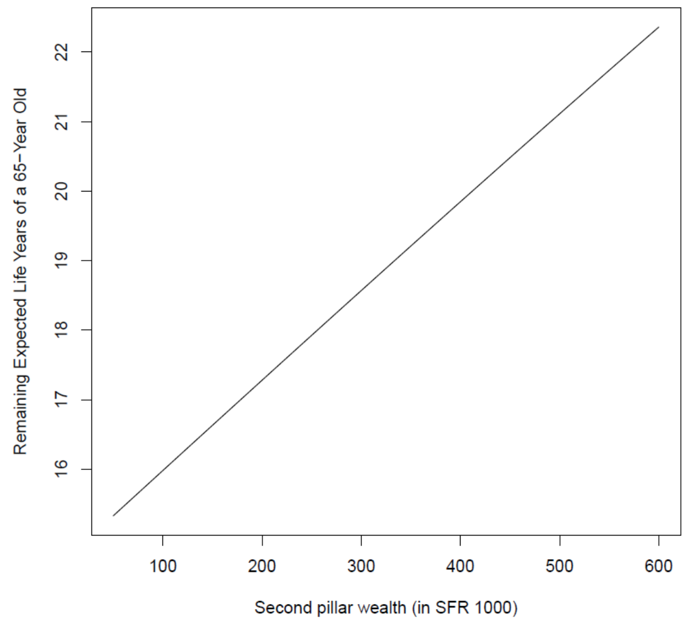


Figure 17 displays the three curves and the *General Population* survival curve as a comparison.

The lower bound converges quickly to the *General Population* survival curve, the intermediate curve remains close to the upper bound and approaches the *General Population* survival curve only very slowly. In terms of life-expectancy, a 64-year-old woman with *General Population* mortality rates can expect another 22.55 years to live. With lower bound mortality rates this number increases slightly to 22.78 and to 23.71 (intermediate curve) and 24.35 (upper bound). In light of these results, one can deduce that average female annuitants in the sample can expect to live between 3 and 21 months longer than under *General Population* mortality rates.

Figure 18
Male annuitants – life expectancy and second pillar wealth



b) Male mortality

Male mortality does not differ between the annuitants in the sample and the *General Population*. However, it depends on second pillar wealth.

Assuming that the effect persists at higher ages, I derive a set of survival curves to account for different second pillar levels on the basis of regression (2) in *Table 14*.

Figure 18 plots the corresponding life expectancies as a function of second pillar wealth.

The effect is substantial. If the relationship between mortality and second pillar wealth held true at all ages, a rich male retiree with a *CHF 600,000* occupational retirement pillar could expect to live more than 6 years longer than a poor pensioner with only *CHF 100,000.*

It is quite likely that mortality rates converge at higher ages and that the true differences are somewhat weaker. Given how large the estimated differences are, though, one can still expect large mortality discrepancies between retirees with large and small second pillars - even if mortality rates converge.

Impact on money's worth ratios

Using the survival rates displayed in *Figure 18*, one can also make conjectures on annuity value differences. Two counteracting factors are at work: On the one hand, higher second pillar capital is associated with lower mortality rates, thereby increasing the annuity value. On the other hand, though, conversion factors are lower when workers have large second pillars because a larger fraction of their salaries is insured in the supermandatory part (see chapter II). Conversion rates applied to the supermandatory part are usually lower. *Figure 19* combines these two effects and plots annuity money's worth ratios for men (excluding potential widow's pensions)[41].

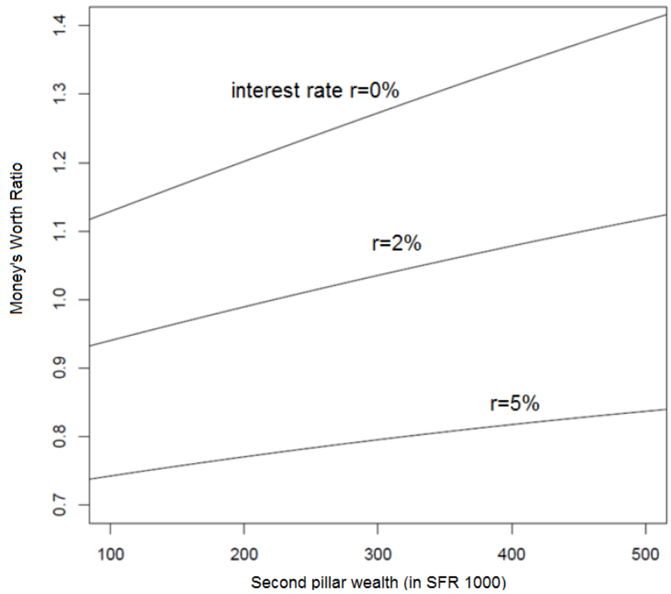
The impact of differential mortality on the net present value of the annuity is large. While a man with *CHF 200,000* on his second pillar can expect to be paid back just under *CHF 1* (for himself, no widow's pension) in present value terms for every franc invested in the annuity, it is almost *CHF 1.2* in the case of a man with *CHF 500,000* second pillar wealth and an interest rate of 2%. One should be cautious about the interpretation at very high and low values of second pillar wealth, though, because the estimates in the previous sections contained only few observations in these ranges. Even so, the figure clearly indicates that lower mortality rates of wealthier retirees outweigh the effect of lower conversion rates, annuities are more attractive for them.

The influence of differential mortality on the annuity value is larger when the interest

[41] Assumptions on the precise relationship between second pillar size and conversion rates are data-driven and based on the sample. Mortality data stem from the Human Mortality Database (see before).

Figure 19

Male annuitants - Money's Worth Ratio and Second Pillar Wealth



rate is low because future annuity gains from higher survival probabilities are discounted less heavily. In view of currently very low interest rates, the effect is likely to be strong.

IV.7 Conclusion

Mortality differences between annuitants in the sample and the overall Swiss population are very strong for women and statistically inexistent for men. Conversely, second pillar wealth is strongly associated with low male mortality rates but seemingly unrelated to female mortality. The results imply that both men and women with large regular pension annuities face particularly favorable mortality rates over their first retirement years, even though the differences arise through different channels. Using standard *General Population* mortality tables to assess the cost burden of future retirement payments would most likely lead to an underestimation of their true level.

The next steps in a thorough differential mortality assessment could focus on two points. First, it is essential to verify whether survival differences also extend to older ages or whether they are restricted to early retirement. Especially adverse selection effects in the lump-sum vs. annuity choice could vanish at very old ages. Private information on one's own survival probabilities is typically assumed to be most accurate for the near future. Second, it is important to understand the various selection dynamics precisely. Calls for an abolishment of the lump-sum option have recently been growing louder in Switzerland, based on the argument that this option may lead to old-age poverty. In view of the results in this chapter, though, an additional aspect seems to deserve some attention in this discussion. Women in the data seem to take their survival probabilities - at least those faced in the first retirement years - into account when they decide on the lump-sum vs. annuity trade-off. Preventing retirees who already face very low life expectancies from large immediate consumption would make them even worse off. It is indeed well-known that annuity pensions generate a redistribution from short-lived to long-lived agents, see Bommier et al. (2011) as an example. This feature can be mitigated if one allows retirees to choose between lump-sum payments and annuities.

Part D

Appendix

(1) Proportional Hazards Assumption[42]

The Cox-model relies on the assumption that hazard ratios are constant and independent of age. This so-called Proportional Hazard Assumption makes Cox-models very handy and easy to interpret, but results can be misleading if proportionality is erroneously assumed. There are various possibilities to verify the assumption. One way, for instance, is to plot log-log Kaplan-Meier curves and to evaluate the distance between the curves. Under the Proportional Hazard Assumption the distance should be constant over the whole graph. Alternatively, one might include an age-dependent term in the model (see below) and test its statistical significance. In light of the short age-span in the sample (only early retirement years), the proportional hazard assumption underlying the estimations in chapter IV seems to be innocuous.

(2) Age-varying differential mortality model[43]

In certain circumstances, the Proportional Hazard assumption is questionable and age-dependent hazard ratios seem more convincing. Departing from a usual Cox-model, it is straight-forward to implement age-varying hazard ratios.

Consider a univariate Cox-model of the form $\log \mu_j(t) = \alpha(t) + \beta \cdot D_j$. Let us now define some function of age, $g(t)$, and include this function in the model: $\log \mu_j(t) = \alpha(t) + g(t) \cdot \beta \cdot D_j$.

As $g(t)$ can be chosen very flexibly, the model specification is most interesting if one has some prior idea on how $g(t)$ should look like. In our case, I choose $g(t)$ such that: 1) the hazard ratio $\frac{\mu_{D=1}(t)}{\mu_{D=0}(t)}$ is steadily growing with age t and 2) converges to 1 as t approaches the maximum age a human can possibly attain. These two requirements correspond to the standard prediction that one's private information on one's

[42] For more information the reader may refer to the literature based on Cox (1972).

[43] This and other deviations from the proportional hazard assumption are discussed in the corresponding literature.

own survival probabilities are getting less accurate as the time horizon increases. Put differently, one might know fairly precisely whether one has a high chance of dying during the next two years - but it is harder to determine whether one is likely to face above-average mortality rates 30 years from now.

Denoting the highest attainable age by $t_{\max}$, $g(t) = t_{\max} - t$ fulfills these two requirements. As IV.4 points out, the mortality hazard ratio between *Insurance Population* women and women in the *General Population* is constant - at about 0.78 - according to the Cox-model. With age-dependence, the corresponding hazard ratios are 0.76 at age 64 and about 0.79 at age 70.

Bibliography

[1] Aaron, Henry (1966). "The social insurance paradox." Canadian Journal of Economics and Political Science, 32 (3) : 371-374.

[2] Attanasio, Orazio and Guglielmo Weber (1995). "Is Consumption Growth Consistent with Intertemporal Optimization? Evidence from the Consumer Expenditure Survey." Journal of Political Economy, 103(6) : 1121 -1157.

[3] Aura, Saku (2005). "Does the Balance of Power within a Family Matter? The Case of the Retirement Equity Act." Journal of Public Economics, 89(9-10) : 1699-1717.

[4] Bommier, Antoine (2006). "Uncertain Lifetime and Intertemporal Choice: Risk Aversion as a Rationale for Time Discounting." International Economic Review, 47(4) : 1223-1246.

[5] Bommier, Antoine (2013). "Life-Cycle Preferences Revisited." Journal of the European Economic Association, 11(6) : 1290-1319.

[6] Bommier, Antoine and Francois Le Grand (2014). "Too Risk Averse to Purchase Insurance? A Theoretical Glance at the Annuity Puzzle." Journal of Risk and Uncertainty, 48 : 135-166.

[7] Bommier, Antoine and Marie-Louise Leroux and Jean-Marie Lozachmeur (2011). "On the Public Economics of Annuities with Differential Mortality." Journal of Public Economics, 95 (7-8) : 612-623.

[8] Bommier, Antoine and Thierry Magnac and Benoit Rapoport and Muriel Roger (2006). "Droit a la Retraite et Mortalité Différentielle." Économie et Prévision, 168 : 1-16.

[9] Bovenberg, Ary (2003). "Financing Retirement in the European Union." International Tax and Public Finance, 10(6) : 713 -743.

[10] Brown, Jeffrey and Poterba, James (2000). "Joint life annuities and annuity demand by married couples." Journal of Risk and Insurance, 67(4) : 527-554

[11] Butler, Monika and Federica Teppa (2007). "The Choice between an Annuity and a Lump Sum: Results from Swiss Pension Funds." Journal of Public Economics, 91(10) : 1944–66

[12] Carroll, Christopher and Lawrence Summers (1991). "Consumption Growth Parallels Income Growth: Some New Evidence." National Saving and Economic Performance, eds. B.D. Bernheim and J.B- Shoven, Chicago: Chicago University Press for the National Bureau of Economic Research.

[13] Cawley, John and Tomas Philipson (1999). "An Empirical Examination of Information Barriers to Trade in Insurance." American Economic Review, 89 : 827-846.

[14] Clark, Damon and Heather Royer (2013). "The effect of education on adult mortality and health: evidence from Britain." American Economic Review, 103 (6) : 2087-2120.

[15] Cleveland, William (1979). "Robust locally weighted regression and smoothing scatterplots." Journal of the American Statistical Association, 74: 829–836.

[16] Cox, DR. (1972). "Regression methods of life tables." J R Stat Soc, B34: 187-220.

[17] Davidoff, Thomas and Jeffrey Brown and Peter Diamond (2005). "Annuities and Individual Welfare." American Economic Review, 95(5) : 1573-1590.

[18] Duleep, Harriet Orcutt (1986). "Measuring the effect of income on adult mortality using longitudinal administrative record data." , The Journal of Human Resources, 21 (2) : 238-251.

[19] Fernández-Villaverde, Jesus and Dirk Krueger (2007). "Consumption over the Life Cycle: Facts from Consumer Expenditure Survey Data". The Review of Economics and Statistics 89(3) : 552-565.

[20] Finkelstein, Amy and James Poterba (2002). "Selection Effects in the United Kingdom Individual Annuities Market." Economic Journal, 112: 28-50.

[21] Finkelstein, Amy and James Poterba (2004). "Adverse Selection in Insurance Markets: Policyholder Evidence From the U.K. Annuity Market." Journal of Political Economy, 112: 183-208

[22] Goldman, Noreen (2001). "Social Inequalities in Health." Annals of the New York Academy of Sciences 954 (1) : 118–39.

[23] Golosov Mikhail and Ali Shourideh and Maxim Troshkin and Aleh Tsyvinski (2013). “Optimal pension systems with simple instruments.” American Economic Review,103(3) : 502-507.

[24] Gourinchas, Pierre-Olivier and Jonathan Parker (2002). "Consumption Over the Life Cycle." Econometrica 70(1) : 47-89.

[25] Gruber, Jonathan (2006). "A Tax-Based Estimate of the Elasticity of Intertemporal Substitution." NBER Working Paper NO.11945.

[26] Hall, Robert (1988). "Intertemporal Substitution in Consumption." Journal of Political Economy, 96(2) : 339-357.

[27] He, Daifeng (2008). "The Life Insurance Market: Adverse Selection Revisited." Working paper,Department of Economics, Washington University in St. Louis.

[28] Heijdra, Ben and Ward Romp (2009). "Retirement, pensions, and ageing". Journal of Public Economics, 93(3-4) : 586-604.

[29] Hendel, Igal and Alessandro Lizzeri (2003). "The Role of Commitment in Dynamic Contracts: Evidence From Life Insurance." Quarterly Journal of Economics, 118: 299-327.

[30] James, Estelle and Xue Song (2001). "Annuities Markets Around the World: Money's Worth and Risk Intermediation," CeRP Working Papers 16/01, Center for Research on Pensions and Welfare Policies, Turin (Italy).

[31] Johnson, Richard and Cori Uccello and Joshua Goldwyn (2003). "Singe life vs.joint and survivor pension payout options: How do married retirees choose?" Washington, DC: The Urban Institute

[32] Kalemli-Ozcan, Sebnem and David Weil (2010). "Mortality change, the uncertainty effect, and retirement." Journal of Economic Growth, 15(1) : 65-91.

[33] Marmot, MG and M.J. Shipley and G. Rose (1984). "Inequalities in death-specific explanations of a general pattern?" Lancet 323 : 1003-1006

[34] McCarthy, David and Olivia Mitchell (2010). "International Adverse Selection in Life Insurance and Annuities." in "Ageing in Advanced Industrial States", edited by S. Tuljapurkar, A. H. Gauthier, and N. Ogawa. New York: Springer-Verlag: 119–35.

[35] Milevsky, Moshe and Virginia Young (2007). "Annuitization and Asset Allocation." Journal of Economic Dynamics & Control, 31 : 3138-3177.

[36] Mitchell, Olivia and James Poterba and Mark Warshawsky and Jeffrey Brown (1999). "New Evidence on Money's Worth of Individual Annuities." American Economic Review 89 : 1299-318.

[37] Pye, Gordon (1973). "Lifetime Portfolio Selection in Continuous Time for a Multiplicative Class of Utility Functions." The American Economic Review, 63(5) : 1013-1016.

[38] Samuelson, P.A. (1958). "An exact consumption loan model of interest with or without the socialcontrivance of money", Journal of Political Economy 66 : 467-482

[39] Van der Ploeg, Frederick (1993). "A Closed-form Solution for a Model of Precautionay Saving." The Review of Economic Studies, 60(2) : 385-395.

[40] Viscusi, W. Kip and Joseph Aldy (2003). "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." Journal of Risk and Uncertainty 27(1) : 5-76.

[41] Yaari, Menahem (1965). "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer." The Review of Economic Studies, 32(2) : 137-150.

[42] Yogo, Motohiro (2011). "Portfolio Choice in Retirement: Health Risk and the Demand for Annuities, Housing, and Risky Assets." AFA 2009 San Francisco Meetings Paper.