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Is longevity an insurable risk? Hedging the unhedgeable

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Is longevity an insurable risk? Hedging the unhedgeable - 3rd quarter 2014

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Abstract

In the 18th century, Benjamin Franklin said that "Nothing is certain but death and taxes". The 21st-century adaptation of this famous expression could be "nothing is certain but longevity and taxes." Longevity risk is a critical risk for institutions that provide life-long payments such as pension funds, annuity providers and public pension schemes. The amount of unfunded liabilities institutions face will be massive if their beneficiaries live considerably longer than expected. This paper addresses the problem of longevity risk and discusses the ways in which individuals, life assurers, annuity providers and pension plans can manage their exposure to this risk. We discuss whether the traditional insurance mechanism, involving risk transfer and pooling, can deal appropriately with longevity risk. We then review longevity risk management solutions, comprising both traditional insurance and reinsurance techniques and recently developed capital market instruments.

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1. Introduction

Increasing life expectancy at all ages in the developed world is one of the success stories of the last century. Improvements in survival are pushing new limits: today more than half of all males and two thirds of all females born in Western countries may reach their 80th birthday. The proportion of centenarians increased about ten times over the last thirty years, as more and more people celebrate their 100th birthday (Robine and Vaupel, 2001).

These mortality improvements are a clear evidence of how far society and science have come in improving general living conditions, promoting healthier lifestyles, and offering better medical and healthcare services that have helped to prolong our lives. As a result, the demographic structure of the population in developed countries has changed significantly, mostly because an increasing proportion to the overall improvement in mortality is due to a faster than expected reduction in mortality rates at advanced ages. Developments in the treatment of heart diseases, or greater awareness of the dangers of smoking are just some of the reasons behind this trend that has resulted in a rapidly increasing number of centenarians in the industrialized world (Vaupel, 2010).

Although the evolution of mortality improvement is a slow but persistent process, which is influenced by socioeconomic, biological, environmental, and behavioural developments, past trends suggest that further changes in mortality levels are to be expected. But the truth is that future life expectancy improvements are uncertain and difficult to predict. "Nothing is certain but death and taxes," Benjamin Franklin once said. That was in the 18th century. The 21st-century adaptation might be "nothing is certain but longevity and taxes."

One of the most challenging tasks in longevity risk modelling is the issue of systematic longevity risk and of rare but extreme longevity events. These events are those cases where individuals live far longer than expected. Predicting how long humans can live is a difficult task that requires high quality mortality data, complex statistical and mathematical models, and information on the dynamics of biological factors and causes of death.

Longevity implies that individuals increasingly face the risk of outliving the savings that they have accumulated during their working lives and, therefore, that they seek to insure this risk through public PAYGO social security systems, occupational pension plans, private life insurance and annuity products, or reverse mortgages. These various forms of annuities are in reality insurance against individual longevity risk, because these products pool the risk of living longer than expected, and therefore needing more resources in retirement, among the annuitants or pension-scheme members.

For actuaries within the insurance and pension fund industries, it has always been crucial to have access to a reliable model of mortality that can be used to compute prices and reserves and to manage risk, particularly in products such as annuities whose payments are contingent on survival. Therefore, assumptions about the survival probabilities given the actual age of the annuitants or pensioners, the interest rate used to discount expected contingent benefit payments, and the cost structure of the insurance company are critical when pricing these contracts.

Life tables that incorporate a forecast of future mortality trends are the most popular instrument used to represent the underlying distribution of the duration of future lifetimes, and the accuracy of these tables depends on the reliability of the mortality data. In traditional contracts, the insurer -governments, pension fund sponsors, insurance companies, or annuity providers- bears the risk that the mortality projections may turn out to be incorrect, and that the policyholders end up living longer than expected. Measuring and managing longevity risk is a big challenge for the risk managers of annuity providers and of public and private pension plans. The total amount of global pension-related longevity risk exposure in private-sector corporations has been estimated at $25 trillion[1].

Insurance companies used to be able to offset any adverse developments in longevity risk with the returns of profitable investments. This, however, has become increasingly difficult, because the global trend towards deregulation and liberalization of insurance markets has led to fiercer competition and diminishing profit margins, and because investment profits have almost vanished in a historically low interest rate environment. As a result, sound assessment and pricing of longevity risks has become absolutely crucial.

At the individual level, providers can diversify longevity risk using pooling mechanisms that follow the **law of large numbers**[2], assuming insured lives are homogeneous and independent. In aggregate terms, longevity risk is the risk that people of a certain population might live longer than expected on average. The risk of systematic deviations is different in nature from that of random fluctuations around the trend. This risk is well-known in the insurance business, since it breaks down risk-pooling mechanisms, it becomes non-diversifiable, and it makes the provision of risk management tools increasingly difficult.

For public pension systems, the challenges of growing life expectancy and aggregate longevity risk are both financial and political. As a consequence of demographic, social, and economic changes, most OECD countries have

[1] The Life and Longevity Markets Association (LLMA).
[2] In statistics and probability theory, the law of large numbers is a theorem that states, in simple terms, that the average of the results obtained from a large number of trials of a random event (e.g., death) should be close to its predicted expected value, and will tend to become closer to this value as more trials are performed.

changed their pension systems since 1990 to ensure long-term affordability. The different ways in which future pensions will be affected by changes in life expectancy and the issue of how to share the burden of such adjustments between today's taxpayers, contributors, and retirees and future taxpayers, contributors, and retirees is a critical but less debated question.

In many countries, pension reforms have been parametric, and they have preserved the overall structure and philosophy of the public, earnings-related schemes. Recent measures include adjustments in either the benefit level or the qualifying conditions to reflect changes in life expectancy (e.g., Portugal or Finland), adjustments in the benefit levels according to the numbers of pensioners per contributor (e.g., the German sustainability factor), delays of the standard retirement ages, increases in the number of contribution years needed to qualify for full benefits (e.g., Denmark, France, Portugal), adjustments in the contribution levels (e.g., Canada), or changes in the valorisation of pension entitlements.

In many other countries, pension reforms have been systemic since they have changed the way in which future benefits will be determined. For instance, Italy, Poland, Sweden and Latvia have replaced defined-benefit, earnings-related public pensions with notional-accounts schemes. These schemes are pay-as-you-go schemes but the notional accounts that mimic some of the features of funded defined-contribution schemes. At retirement, the notional capital accumulated in these accounts is transformed into an annuity, but at a rate set by the government, which is generally determined to reflect changes in life expectancy over time automatically.

Forecasting how long people will live has large public policy and public health implications, since it is very possible that life may be extended curing deadly diseases such as cancer, heart disease, and diabetes, but without curing other debilitating but non-fatal conditions, such as arthritis, Alzheimer's, and vision and hearing loss. This may lead to an older population that will be larger, but less healthy, and more dependent.

Although systematic longevity risk is traditionally viewed as non-insurable, a new market for mortality-linked derivative securities has been developing since the turn of the century. Alternative risk transfer (ART) mechanisms such as longevity-linked securities (see e.g., Blake, 2006; Cummins, 2006; Cummins and Weiss, 2009) offer a natural capital market solution to the longevity risk problem since there is insufficient capital in the insurance and reinsurance industry to absorb the total exposure to this risk. The real challenge for public pension systems and for private insurance companies consists precisely in the design of products that can absorb any adverse events related to future mortality. In other words, the true challenge is how to deal with the longevity risk.

Payment of retirement pensions is usually an integral part of funded pension schemes. The basic forms of retirement payout options available to allocate the savings for retirement include lump sums, programmed or phased withdrawals, annuities, and hybrid solutions that can involve any combination of these options (see Bravo and Holzmann, 2014). Life annuities have obvious attractions from the point of view of the pensioner, since the payments continue for as long as she lives, and this reduces the risk of outliving one's financial resources substantially. In other words, life-annuities offer unique insurance features against individual or family longevity risk. However, despite the apparent attractions of life-annuities, they are usually not very popular with the investing public due to various demand and supply constraints.

The main problem for the insurers is to make the annuities market attractive to the insured. Indeed, the risk borne out by insurers for life-annuities, which is most probably too high, is reflected in the high premiums charged for these products. These premiums can be so high that they discourage the individuals who intend to purchase the annuities.

In this paper we analyse the insurability of longevity risk and we discuss briefly the traditional insurance schemes and the innovative capital-market-based risk transfer solutions. The paper is organized as follows. In Section 3 we briefly review the mortality trends observed in most OECD countries and we illustrate the consequent need for appropriate longevity-risk measurement. To improve our understanding of the precise nature of longevity risk, in Section 4 we briefly review the concept of risk and some basic insurance principles. The goal is to clarify whether longevity risk can be classified as an insurable risk, in general terms. In Section 5 we describe the main tools available to manage longevity risk, which comprise both traditional insurance and reinsurance techniques and recently developed capital market instruments. In Section 6 we offer some concluding comments.

2. What drives the demand for longevity risk protection?

The demand for longevity risk protection has been increasing in the last years. This is a consequence of an aging population, of the increase in life expectancy at old ages, and of the shift in the responsibility for providing sufficient retirement income from governments and enterprises to individuals. This shift has resulted from the substantial underfunding of many defined benefit schemes, and from an increase in the disclosure and regulatory obligations of funded pensions schemes. These two trends are expected to increase the recognition liabilities and of funding needs.

The increase in the percentage of people that are approaching or entering retirement is a significant driver of the growing need to address longevity risk. In western countries, a fraction of the ageing of the population is largely attributed to the so-called baby boomers, the large cohorts born in the fifties and sixties after the end of World War II.

At the same time, a growing proportion of the population that reaches retirement age is also living longer than before. Improved hygiene and living standards, unparalleled medical progress, better and healthier lifestyles, and the absence of global military conflicts and of major pandemic crises are the main reasons why individuals around the world are enjoying rising longevity. In the last six decades, we have been observing a decline in mortality rates in western countries at all ages. To illustrate this trend, Figure 1 shows the so-called mortality profiles at ages 0-95 from 1950 to 2010 in Portugal, and Figure 2 illustrates the dynamics of mortality rates by age during that same period.

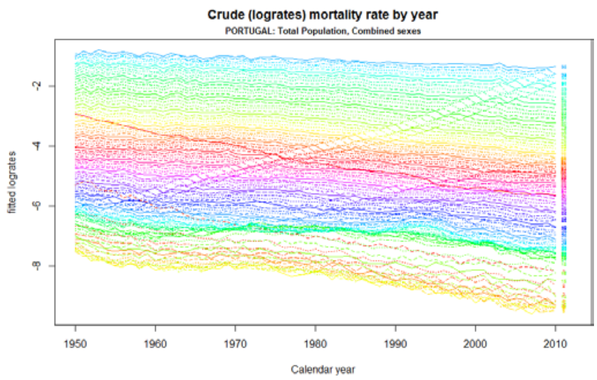

Figure 1: Crude mortality rates by year, Portugal 1950-2010, both sexes

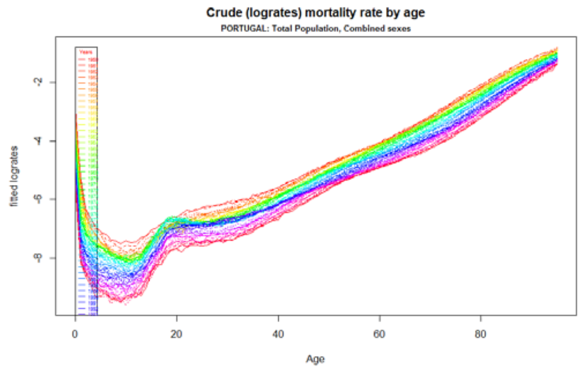

Figure 2: Crude mortality rates by age, Portugal 1950-2010, ages 0-100, both sexes

Mortality rates were calculated using data provided by Statistics Portugal. We can observe a downward trend in mortality rates at all ages, with rates of improvement being higher at young ages. In Spain, in Portugal and in many other developed countries, mortality experience over the last decades shows some patterns that affect the shape of curves that represent mortality as a function of the attained age. Figures 3 and 4 illustrate the moving mortality scenario referring to the Portuguese overall population, in terms of survival functions (survival probability as a function of the attained age x) and curves of deaths (number d_x of the people who dye as a function of age x, expressed as a proportion of those initially alive, l_0). Survival functions and curves of deaths relate to various cross-sectional mortality experiences.

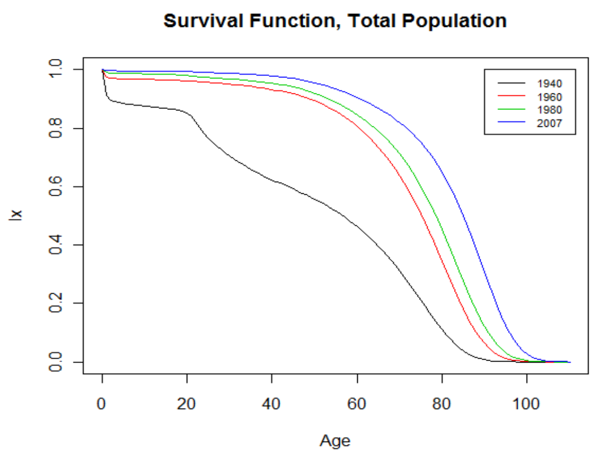

Figure 3: Survival function, Portugal, total population, selected years

The results from experienced trends in mortality are self-evident. In particular we want to highlight the following aspects: (I) an increase in the life-expectancy, both at birth and at old ages for both sexes (II) an overall increase in the most probable age of death, as shown by the mode of the curve of deaths.

Turning back to the shape of the survival function and the curve of deaths, the following aspects of mortality must be pointed out in Portugal, in Spain, and in most developed countries:

a) we observe an increasing concentration of deaths around the mode (at old ages) of the curve of deaths. As a consequence, the survival function moves towards a rectangular shape, a phenomena called "rectangularization" in the actuarial/demographic arena;
b) owing to this rectangularization phenomena, the mode of the curve of deaths tends to coincide with the highest attained age of the population, and this age is moving towards very old ages; in the scientific literature related to this subject, this trend is called "expansion" of the survival function (see Figure 4);
c) more recently, we observe higher levels and a larger dispersion of accidental deaths at young ages (the so-called young mortality hump), particularly in the male population.

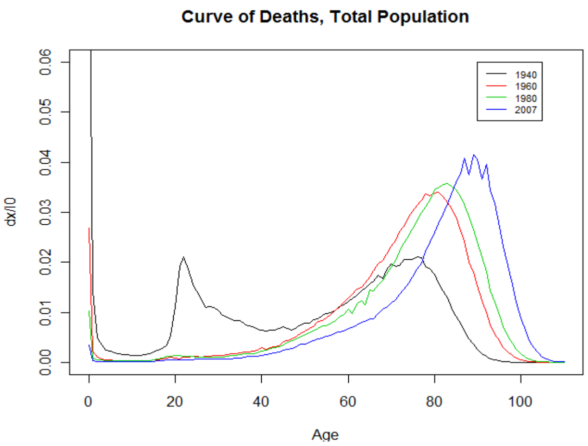

Figure 4: Curve of deaths, Portugal, total population, selected years

At another level, in recent years we have observed a shift in responsibility for bearing longevity risk. The role of funded individual retirement provisions has increased over recent decades. Among the reasons that explain this trend we include the following (see Holzmann, 2014): (i) Systemic reforms of public pension schemes and the move from collective, unfunded, and defined-benefit (NDB) schemes towards individualized, funded, and defined-contribution (FDC) schemes; (ii) the decreasing generosity of public annuities as the result of fiscally driven public pension reforms across the globe and the encouragement by governments for voluntary supplementary saving to cover the old-age income gap; and (iii) the fact that many existing funded defined-benefit schemes have been replaced by funded defined-contribution schemes.

In recent years, the number of employees covered by defined-benefit pension plans has been shrinking steadily. The move away from defined-benefit plans and into defined-contribution plans has shifted the responsibility of ensuring a sufficient retirement income stream from employers to individuals. Moreover, benefits expected from public pension systems are increasingly uncertain due to their unsustainable nature. As a result, individuals' exposure to political, investment, and longevity risks has increased.

Facing increasing pension fund liabilities and funding deficits, many private pension plans are increasingly looking towards solutions to reduce their pension obligations and transfer risks. If future funding needs are clearly on an upward trajectory, the persistent low interest rate environment will force private pension plans to cover fund deficits. Additionally, stricter disclosure and funding rules set by regulators (e.g., Solvency II) are expected to increase liability recognition, funding needs and capital requirements. The recognition of longevity risk, and any resulting increase in pension liabilities as companies incorporate new information on longevity (e.g., new life tables) exposes listed companies to potential negative valuation assessments. This will encourage insurers to reduce their exposure to longevity risk and to seek mitigating solutions.

3. Is longevity an insurable risk?

Longevity risk is the risk that future outcomes in mortality and life expectancy will turn out to be systematically different from expectations. Longevity risk expresses itself as either an idiosyncratic risk, unique to each individual, or as an aggregate risk that is due to the uncertainty about overall mortality rates of the entire population. Individuals, life insurance companies, annuity providers, corporate pension funds and governments are all carriers of longevity risk.

An individual self-managing her retirement income through withdrawals from defined contribution plans, individual retirement accounts or other personal savings faces the risk of outliving her assets – individual longevity risk – as she may be depleting her wealth at too high a rate.

For institutions that make payments contingent on how long individuals live, such as life insurance companies, annuity providers, private pension plan sponsors and governments through their social security pension systems, aggregate longevity risk refers to the risk that mortality assumptions are not accurate and retirees live longer than expected, on average. In a historically low, and almost zero, interest rate environment, aggregate longevity risk has become one of the most significant sources of risk faced by financial institutions, with the potential to affect adversely both their willingness and ability to supply retired households with financial products to manage wealth in the payout phase.

A well-functioning annuity market will become increasingly important as Governments cut social security pensions, companies move away from defined-benefit plans and as defined-contribution plans mature. Among the many demand and supply constraints that still hamper the development of annuity markets, the inability of annuity providers to hedge the aggregate longevity risk they face is one of the most significant. Aggregate longevity risk already conditions the price and the availability of annuity products in defined-contribution schemes, and will affect insurance company solvency should the Solvency II proposals be finally adopted. In fact, the new regulatory regime will require insurance companies operating in the European Union to hold significant additional capital[3] to back their annuity liabilities unless longevity risk can be hedged effectively or marked to market. There is insufficient capital in the insurance and reinsurance industry to deal with total global private-sector longevity risk. The extra capital that will be required as a result of this new regulatory regime will have to be passed on to customers, at some point in time, decreasing the money's worth of their annuities.

The question, therefore, is how to manage both idiosyncratic and aggregate longevity risk. Those challenged by uncertain longevity risk have been searching for solutions to mitigate, transfer or share this risk among a larger group of participants. Longevity risk management solutions comprise both traditional insurance and reinsurance techniques and recently developed capital market instruments.

Another question that emerges is whether or not longevity risk is, in general terms, an insurable risk. In other words, the question is whether the traditional insurance mechanisms, that involve risk transfer and pooling, can deal appropriately with longevity risk.

As we will see from the discussion below, the answer to this question is somewhat mixed. In fact, on one hand, as long as certain prerequisites are fulfilled, idiosyncratic longevity risk can be diversified by traditional pooling or insurance mechanisms. However, on the other hand, aggregate longevity risk cannot be eliminated or diversified and, therefore, it can only be managed using appropriate loss-control and loss-financing techniques.

3.1 A Reminder of some Risk and Insurance Principles

To better understand the precise nature of longevity risk and to elaborate on its insurability properties, we briefly review the concept of risk and some basic insurance principles. In the insurance area, the concept of risk refers to the uncertainty concerning the occurrence of a loss or of events that might produce a loss (for example, an event is death of a policyholder). Losses must be measured in financial terms and can be analyzed according to their likelihood (probability or chance), the immediacy of the causes of the losses (peril, e.g., death, fire, theft), the frequency of their occurrence, and the severity of the financial losses incurred when the event occurs.

In its broadest context, the term risk includes all situations in which there is an exposure to adversity. Risks may be classified in many ways: (I) static and dynamic, (II) fundamental and particular, (III) pure and speculative, and (IV) specific and systematic. However, only certain distinctions are particularly important for our purposes.

The distinction between pure and speculative risks is an important one because, normally, only pure risks are insurable. *Speculative risk* refers to speculative risk events in which there is a possibility of loss but also a possibility of gain or a possibility of neither loss nor gain. Gambling is a good example of a speculative risk. In a gambling situation, risk is deliberately created in the hope of gain. The student betting €20 on the outcome of Saturday's football game faces the possibility of a loss, but this is accompanied by the possibility of a gain. Random events cause the possible outcomes to occur. The term *pure risk* (sometimes called *hazard risk* or *accidental risk*), on the contrary, is used to designate those situations that involve only the chances of either loss or no

[3] This is the so-called market value margin (MVM) that reflects the cost of capital to cover 'non-hedgeable' risks.

loss, that is, in which there are only two possible outcomes. One of the best examples of pure risk is the possibility of loss surrounding the ownership of property. The person who buys an automobile, for example, immediately faces the possibility that something may happen to damage or destroy the automobile. The only possible outcomes are loss or no loss.

Typically, only pure risks are insurable and the reason is very simple. Insurance is not concerned with the protection of individuals against the losses that result from speculative risks. Instead, it is concerned with the protection against losses that result from random adverse events. Speculative risk is voluntarily accepted because of its bidirectional nature, which includes the chance of gain.

Not all pure risks are insurable, which means that a further distinction between insurable and uninsurable pure risks must be made. Personal, property and liability risk are pure risks. Personal risks consist of the possibility of loss of income or assets as a result of the loss of the ability to earn income. In general, earning power is subject to four perils: (a) premature death, (b) dependent old age, (c) sickness or disability, and (d) unemployment. Mortality and longevity risks can be considered personal risks.

How does insurance work? Insurance involves the transference and pooling of risk. **Risk** is **transferred** from the insured to the insurer, i.e., the insurer assumes the financial responsibility for the loss and agrees to indemnify the insured in the event of a covered loss. The indemnification can be partial or total, in the form of cash, repair or replacement of an asset, or provision of services, and it can benefit first or third parties.

The insurer dilutes the risk transfer using **pooling** mechanisms. What does this actually mean? Insurers issue policies to a large group of homogeneous people who want to insure against a particular loss, and they collect their premiums into what is called the insurance bucket, or pool. Because the number of insured individuals is normally large, insurance companies can use statistical analysis and principles, such as the *law of large numbers*, to project what their actual losses will for a given group of people and types of risk.

They know that not every insured individual will suffer losses at the same time, that some will not suffer them at all, and they also know that that are exposed to estimation risk (model, parameter, basis risks). For instance, when companies issue life insurance they know that within their own portfolio some policyholders will die before their expected life-times are over, some will die after that date. This is part of the deal. Companies can always improve the accuracy of their predictions of future losses and manage the estimation risk properly. This is what allows them to operate profitably and at the same time to pay for the claims when and if they arise[4]. Policyholders pay for the probability of the loss and for the protection that they will receive for any losses that might occur.

Consider, for instance, the case of life-annuity contracts, an instrument that is well suited to insure against individual longevity risk. An annuity is a contract that promises to make a regular series of payments over a person's lifetime in exchange for a lump-sum premium or for a sequence of premiums. When an insurance company issues or sells a life annuity to someone, the company must try to predict when she will die, and payments will cease, so that it can determine the appropriate annual or monthly payments. It seems reasonable to think that the longer an annuitant is forecast to live (i.e., the longer her life expectancy), the lower the payments must be. Otherwise, the company will be almost surely end up losing money.

For the sake of simplicity, let us ignore interest and the time value of money. If the annuitant is forecast to die in exactly 20 years, then a €100,000 annuity premium must be returned to the annuitant in 240 monthly payments, each of which of approximately €417 (100,000/240). If, instead, the annuitant is forecast to die in exactly 25 years from now, then the monthly payment must naturally be lower, in this particular example approximately €333 (100,000/300). So, apart from interest and the time value of money considerations, pricing annuities is for the most part about predicting how long the annuitants will live.

How does an insurance company make these predictions? What happens if it is wrong about the expected longevity and the annuitant does not die exactly when she was supposed to? The answer to the first question is that because the insurance company is selling life annuities to many different people, it does not have to predict exactly how long a particular annuitant will live but, rather, how long an individual member of a large group of people will live on average. And, as you can imagine, forecasting the life expectancy of a group is much easier than forecasting the exact length of life of any individual. And the forecast becomes easier with the size of the population.

What makes this principle of offsetting risks work in a precise manner is the law of large numbers. If the insurance company pools a large enough number of annuitants with similar forecasted life expectancies -year-by-year survival probabilities to be more precise- the risk-offsetting process can take place with much more accuracy than what would be possible for a pool of just a small number of individuals. By selling thousands of life annuities to a homogeneous group with the same age, the law of large numbers guarantees that, on average, even though not in any individual case (except by a quirk of fate), they will really live to their life expectancy. Therefore, insurance companies are only concerned by the behaviour of the average of their pool.

Technically speaking, the tool life insurance companies use to make inference about the probability of someone surviving any particular year of age or to estimate their remaining life expectancy is called a life-table, and it is also called a mortality table or an actuarial table. Insurance contracts trade uncertainty for certainty. Without insurance an individual is uncertain about the individual frequency and severity of her losses (e.g., the precise time of death).

By buying insurance, an individual trades a potentially large and unpredictable loss for the relatively small and predictable loss that she incurs when she pays the premium. Premiums can be viewed as small losses with probability equal to 1, that is, certain losses.

[4] For instance, most people have auto and home insurance but only a few actually get into an accident or have their property damaged.

3.2 Are there Ideal Requirements for a Risk to be Insurable?

From the discussion in the previous section, we could be tempted to conclude that for a specific risk (e.g., longevity) to be insurable the only thing that is required is to pool a large number of individual risks. The fact is that this might not be enough and that not all risks are insurable by the private sector. Although, ideally, there are various requirements that risks should meet in order to be insurable, in practice these requirements are rearely fulfilled and the insurer has to decide whether to address the problem through some contractual solution or, simply, not to insure that particular risk.

Risks that can be insured by private companies typically share the following features:

1. **Risk pools must contain a large number of homogeneous exposure units**
   Since insurance operates through pooling resources, the larger the pool the more accurate the predictions will be. This allows insurers to take advantage of the law of large numbers in which actual losses and predicted losses are similar. However, insuring a large group of individuals is not enough, the group should also be homogeneous, that is, the individuals should have similar characteristics with respect to expected losses or, otherwise, the pooling mechanism will not work correctly. Insurance companies spend a lot of effort and money in underwriting and classifying risks in order to produce homogeneous risk pools and to price contracts appropriately, that is to charge higher premiums for higher risk. Risk-based or actuarial pricing tools are used for this purpose. If the underwriting fails, insurance companies face an *adverse selection (anti-selection, or negative selection*) problem.

2. **Loss should be fortuitous**
   The event that constitutes the trigger of a claim should be fortuitous, accidental, or unintentional, or, at least, it should be outside the control of the beneficiary of the insurance. The loss should be "pure" in the sense that it results from an event for which there is only the opportunity for cost. If the event is not accidental, a problem of *moral hazard* might arise, that is, the existence of insurance changes the behaviour of the insured who acts to increase the frequency or the severity of the losses. Events that contain speculative elements, such as ordinary business risks, are generally considered uninsurable.

3. **Loss should be definite and measurable (time, place, and amount)**
   For a risk to be insurable, there must be certifiable evidence to establish "proof of loss," not just casual references. This means that the loss must have taken place at a known time, in a known place, and from a known cause. Loss should be definite in order to be easy to verify that a loss has in fact occurred. It should be measurable in order to measure or determine the amount of the loss. A very simple example is the death of an insured person who has taken a life-insurance policy. Ideally, the time, place and cause of a loss should be clear enough that a reasonable person, with sufficient information, could objectively verify all three elements.

4. **Insuring loss must be economically feasible**
   The size of the loss must be meaningful from the perspective of the insured. Insurance premiums need to cover both the expected cost of losses, plus the cost of issuing and administering the policy, adjusting losses, and supplying the capital needed to reasonably assure that the insurer will be able to pay claims. For small losses these costs may be several times the size of the expected cost of the losses. There is little interest in paying such costs unless the protection offered has real value to the insured.

5. **Premium should be affordable**
   If the likelihood of an insured event is so high, or the cost of the event is so large that the resulting premium is large relative to the amount of protection that the policy offers, it is unlikely that anyone will buy insurance, even when it is available.

6. **The loss should be predictable**
   To calculate losses and premiums, there are two elements that must be at least estimated, if not formally calculated: the probability of frequency of the loss and its severity. Other elements of pricing include expenses and investment income.

7. **There is no catastrophic loss possibility to the insurer**
   All individual losses are off course personal catastrophes. The reference here is to national or area disasters, such as floods, riots, wars, earthquakes, etc. The insurer's cost of these disastrous events must be within the insurer's ability to pay the claims. Insurers very often limit their exposure to a loss from a single event to some small portion of their capital base or try to manage it through financial diversification or reinsurance.

In principle, mortality and longevity risks accomplish most of the requirements to be insurable by private companies. By implementing proper underwriting and risk evaluation and classification, insurers can build up homogeneous risk pools, and address potential adverse selection problems resulting from information asymmetries. Mortality events are, normally, unintentional, losses that result from death are for the most time definite and measurable, longevity protection has real value to the annuitant, because they eliminate the risk of outliving one's assets and, premiums are in general affordable in competitive insurance markets. For long term contracts like annuities, the critical point comes from the predictable nature of the risk. This is because it is difficult to predict how long the members of a pool will live with sufficient accuracy and because systematic deviations from the expected duration of their lifetimes may occur.

3.3 Diversifiable and non-diversifiable longevity risk

In Figures 5(A), 5(B) and 5(C) we represent the projected mortality rates at a given age x (the solid blue line) and three sets of possible future mortality experience (the black dots). Deviations from the projected mortality rates in Figure 5(A) can be explained in terms of random fluctuations of observed mortality rates around the corresponding projected mortality rates. Random fluctuations are a recognized component of risk in the insurance business often named process risk. In simple terms, random variation risk is the risk that individual mortality rates differ from the outcome expected as a result of chance, some people will die before their life expectancy and some will die after. In risk theory, there is one fundamental result which states that the severity of *process risk* decreases in relative terms as the pool size increases. Life insurance companies deal with this random variation of risk by pooling and relaying on the law of large numbers to reduce its variability.

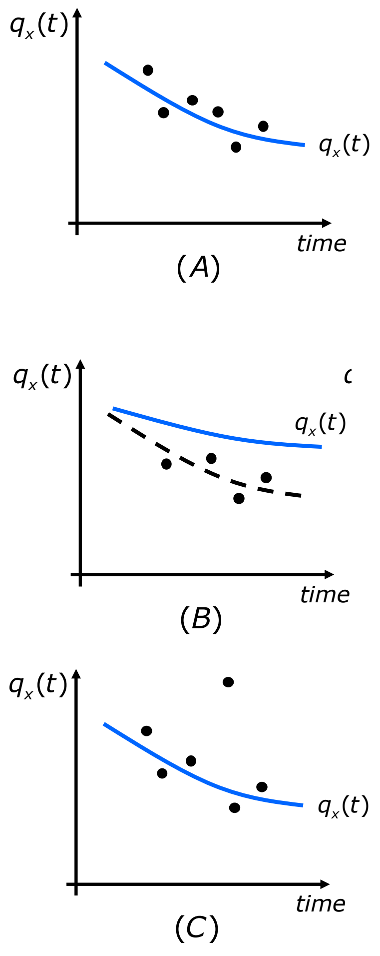

Figure 5: Experienced mortality vs. random fluctuations and systematic deviations

The experienced profile depicted in Figure 5(B) cannot be accredited to random fluctuations only, since we can clearly observe random fluctuations around and random deviations from expected values. This pattern can be explained as the result of an actual mortality trend being different from the trend that was forecasted and, as a consequence, systematic deviations arise.

The risk of systematic deviations can be attributed either to *model risk* or to *parameter risk*. This means that the either the model used to project mortality or the relevant parameters that identify that model do not represent actual mortality trends. Trend risk is, in some sense, like inflation risk, an aggregate risk that cannot be diversified away by pooling or diversification mechanisms. Moreover, the bigger the number of individuals in an insure pool, the larger the relative impact of trend risk.

The law of large number does not apply in the case of trend risk. In trend risk, all the insured people or annuitants will deviate in the same direction and the realizations will not get closer to expected values as the size of the pool increases. When individuals live systematically longer than expected, insurers face with aggregate longevity - or mortality - risk. Private insurers that pay lifetime benefits are unable to hedge this risk effectively without suitable hedging instruments.

The experienced mortality profile depicted in Figure 5(C) most likely represents the consequence of a catastrophic risk, namely the risk of a sudden and short-term rise in the mortality frequency, as a result, for instance, of an epidemic or a natural disaster. Catastrophic mortality risk is also, by definition, a non-diversifiable risk. Process risk, model and parameter risk, and catastrophic risk constitute the four mortality risk components.

Finally, empirical studies in some countries suggest that generations born in certain years, or cohorts, are experiencing a specific improvement in their mortality risk. Under these circumstances, the notion of *cohort mortality* risk follows.)

4. How to manage longevity risk

Insurers provide most of the products that help individuals to manage the risk of outliving their assets. Individuals can insure their lifetime income by purchasing annuities in the pay-out phase of their defined contribution plans and personal retirement accounts. They can also voluntarily purchase a single premium immediate annuity (or a deferred annuity) through other lump-sum savings.

For insurers, longevity risk management solutions currently in place include both loss control and loss financing techniques. Loss control techniques are for the most part performed via product design, that is, via an appropriate choice of the various items that constitute an insurance product (for example, risks covered, maturity, price). Loss control techniques include both loss prevention and loss reduction strategies. Loss prevention comprises risk management techniques whose purpose is to reduce the frequency of losses, and loss reduction tools attempt to reduce the severity of those losses.

In managing individual and aggregate longevity risk, the pricing of insurance products provides a tool for loss prevention. If we consider, for instance, a life annuity product, expected longevity improvements recommend the use of a projected or prospective life table to price the annuities. Additionally, because of uncertainty in future mortality trends -which constitutes a non-diversifiable risk- a safety loading is typically added onto the prices, increasing the premiums paid by the policyholders. If life insurers have conducted their underwriting and risk classification operations properly, specifying different contingency loading for various categories of risk may also be a solution to enforce pooling effects and to reduce systematic risks.

Pursuing loss reduction requires controlling the amounts of benefits paid. With traditional level annuity contracts this is not possible since the product guarantees the same amount of benefit for the duration of the insurer's lifetime, and regardless of its length. Hence, to pursue loss reduction some flexibility must be added to the annuity product. One solution could be to reduce the annuity benefit in the occurrence of an unforeseen mortality improvement, for instance, by developing longevity-linked annuity contracts. This would share the longevity risk between annuity providers and annuitants and could contribute to reduce the premiums paid by the policyholders and the capital requirements demanded to back the annuity promises made by the insurers. However, in this case the resulting product would be a *non-guaranteed annuity*, something that may be difficult to sell to customers. A potential alternative solution could be to reduce the level of investment profit participation if adverse mortality is experienced in a with-profit annuity contract.

Loss financing techniques include hedging, transfer and retention solutions. Risk transfer can be realized via traditional reinsurance arrangements, longevity swaps (swap-like reinsurance), Alternative Risk Transfers (ART) that involve securitization (e.g. longevity bonds, mortality bonds), pension buy-in and pension buy-out operations and Q-forwards. Risk transfer can also be realized through longevity-linked annuities, which are annuity contracts that adjust their benefits if observed mortality improvements differ sizably from expected mortality paths.

Hedging strategies in general consist in assuming a risk that offsets another risk borne by the insurer involving, for instance, various portfolios or lines of business within the company. In particular, a natural hedging of longevity risk consists in underwriting both life insurance and life annuities for similar groups of policyholders.

4.1. Annuities

Standard annuities are the classical tool in the management of individual longevity risk. They are present in defined benefit and notional defined contribution social security systems provided by governments, defined benefit plans provided by corporations through pension funds, and life annuities provided by insurance companies. Life annuities constitute a unique financial instrument that accomplishes two of the most important objectives of a pension scheme: (i) they protect the annuitant from outliving her assets; and (ii) they provide retirement income for the remaining life of the annuitant and her dependants, offering therefore longevity insurance.

In the absence of aggregate longevity risk, the pooling mechanism implicit in the Law of Large Numbers would be sufficient to make longevity risk manageable for annuity providers. In the presence of systematic longevity risk, the provision of longevity insurance for individuals becomes a difficult task since existing instruments do not allow annuity providers to effectively hedge aggregate longevity risk. Despite their appeal, the annuity market remains small relative to the magnitude of risk that individuals are exposed to. Life annuity products have been sold in the past primarily as retirement accumulation vehicles, rather than pay-out products (Brown *et al*., 2001). Several demand and supply impediments may explain this under-annuitization[5].

On the demand side, limitations to the development of annuity markets include, first, the level of annuitization from pay-as-you-go financed pensions, that is, the amount by which annuities are crowded out by social security provision and the amount buy which they are crowded out by other forms of pension saving such as defined benefit occupational schemes. Second, annuities are perceived to be unfairly priced, mostly because life insurance companies do not fully disclose information on the techniques used to calculate the annuity premiums. Third, the possibility to bequest assets to dependents is not covered by "plain vanilla" annuities.

[5] For a detailed discussion on this subject see, for example, Stewart (2007) and Rusconi (2008).

Fourth, the demand for annuities is determined to some extent by personal considerations such as family support, the need to cover the costs of unexpected medical expenses, the inexistence of sufficient liquid assets to purchase an annuity, or other liquidity concerns. For example, for older people, the risk of having to pay large medical bills or to cover special health care costs induces them to retain at least a fraction of their assets instead of annuitizing them.

Fifth, fiscal incentives are considered insufficient to stimulate insurance protection against longevity risk. In modern competitive markets, individual financial decisions are also driven by people's perceptions about the appeal of alternative investments, both during their working lifetime and after retirement. For instance, some individuals may avoid annuitization on the grounds that they can manage their assets better than institutional fund managers. In this scenario, introducing tax incentives (or tax-favoured competing assets) could undermine the saving decisions in favour of buying annuity protection. Finally, in some cases there is a general mistrust of the institutions that provide the annuities.

On the supply side, the type and scope of the limitations to the development of annuity markets is also significant. First, high-quality information on mortality tables depicting a particular group's distribution of expected remaining lifetime is required. Projected mortality tables should take into consideration the stochastic nature of the remaining lifetime and encompass cohort effects. Uncertainty regarding mortality tables can cause insurance companies to price annuities conservatively, exacerbating any adverse selection problems and lowering the access to the market. Additionally, uncertainty regarding mortality data can cause individuals to seriously underestimate their survival prospects, which, in turn, can lead them to undervalue the importance of longevity insurance. Dissemination of mortality information should, in this sense, be considered a matter of public interest and form part of a transparent supervision policy[6].

Second, annuity markets are often affected by strong adverse selection problems. This arises if buyers of annuities prove to live longer than average, inducing insurance companies to devise separate mortality tables for annuitants as opposed to those for the general population. The existence of adverse selection problems induces companies to include significant margins in their pricing of annuity contracts. Whether adverse selection is quantitatively important may depend on whether annuitization is considered optional or mandatory. In this sense, increasing compulsory annuitization can significantly reduce adverse-selection problems.

Third, the potential for growth in annuity markets cannot be fully realized if insurance companies lack assets with which to back the long-term promises represented by annuities. Insurance companies that offer annuity products are faced with three major sources of risk: interest-rate risk, inflation risk, and longevity risk. Appropriate asset types that address these risks either do not exist or are available in insufficient quantities.

Fourth, traditional annuity markets are incomplete, in the sense that they do not offer protection against inflation, they lack equity market exposure, they are illiquid, and they do not insure against multiple shocks. Finally, there are concerns regarding regulatory capital requirements, and about the market power of existing providers that would make it difficult for new entrants to survive. In order to address these problems, many policy options exist to encourage and promote annuity markets. Examples include mandating annuitization, improving financial literacy, dealing with longevity risk, and producing longevity indexes.

4.2. Pooled Annuity Funds

In standard level annuities, annuity providers bear both systematic and idiosyncratic mortality risks. Some authors have proposed an alternative annuity structure in which pool participants are insured against idiosyncratic longevity risk but still have to bear systematic longevity risk[7] The idea is to construct a *pooled annuity fund* (PAF) considering groups or cohorts of retirees and follow a *Group Self Annuitization* (GSA) strategy. Pooled annuity funds have many similarities with standard annuities in that the funds released by the participants who die prematurely (mortality credits) are redistributed among the survivors, in that participants give up their bequest or liquidity motives, in that the decision to purchase a pooled annuity fund units is irreversible, and in that the advantages of investment diversification are exploited. But they present a crucial difference: benefit payments are linked to the mortality experience of the group and, as such, leave annuitants' incomes and consumption possibilities exposed to the uncertainty associated with the mortality risk of the group. Insurers and other institutions setting up a pooled annuity fund act only as managers of the accounts and, thus, do not bear either the investment risk or the mortality or longevity risk. This means that pooled annuity funds transfer aggregate longevity risk from annuity providers to fund participants, thus offering an alternative hedging solution.

In a pooled annuity fund, the future value of annuity benefits remains constant over the whole contract unless deviations from expected mortality rates are observed. If that is not the case, that is, if the number of those surviving up to higher ages is different from expected, the remaining capital has to be redistributed among the remaining survivors. In a scenario where the number of those surviving is systematically higher than initially expected, benefit payments will be reduced to prevent fund imbalances. Pooled annuity funds introduce an automatic adjustment mechanism to economic and demographic risk factors, and they ensure that the fund assets are in balance with its liabilities.

[6] In Portugal, for instance, there are no regulatory life tables (either contemporaneous life tables or prospective life tabla) either for the Portuguese overall population or for life-insured populations. As a result, life insurance companies are forced to use as their technical basis the life tables compiled for other countries. Although this practice is authorized by the Portuguese supervisor, the use of survival tables compiled for a different population is potentially biased when compared to the demographic conditions observed in Portugal, and it involves significant basis risks, in particular the risk of overestimating the mortality risk of the population.

[7] See, e.g., Piggott et al. (2005) and Valdez et al. (2006).

4.3. Longevity Insurance

An alternative longevity risk hedging solution is a deferred inflation-adjusted life annuity contract called advanced-life delayed annuity (ALDA).[8] This product should be acquired at a given early age, it would be paid in instalments over a long period and it would have no cash value or survival benefits. In this contract, the deferment period can be seen as a deductible since the policyholder finances his consumption until some advanced age (ranging from 80 to 90, say), after which the insurer starts paying the annuity for as long the annuitant remains alive.[9]

These annuities are often called "longevity insurance" because they start paying you a lifetime income stream at a later age to prevent you from exhausting the rest of your savings and offer a remaining lifetime income. Individuals facing a significant risk of running out of money may want to consider purchasing a deferred annuity that will kick in at a later age. This way they can insure their retirement income against individual longevity risk without all the downsides of purchasing an immediate annuity when they retire (lack of liquidity and flexibility to use accumulated savings in whatever way they choose, lost investment earnings, inability to pass it on to their heirs, and so on).

4.4. Pension Buy-outs and Pension Buy-ins

Pension buy-outs and pension buy-ins are a type of transaction that has long been used to transfer liabilities and associated assets for a specified set of pension plan participants to an insurance company under a group annuity contract. The operations can be designed to reduce the size of the pension plan on the sponsor's balance sheet or to relieve the sponsor permanently of the investment and longevity risks associated with the pension benefits.

In a pension buy-out, existing pension plan assets or an insured annuity block are transferred to an insurance company. All asset and longevity risk is transferred, including the administration of the plan. Insurers usually issue a group annuity contract as part of a buy-out in return for a single premium payment. The transaction provides the insurer with complete ability to control and manage the underlying assets, but also leaves him exposed to all the asset management related risks (investment risk, credit risk, inflation risk, longevity risk, and liquidity risk).

A pension buy-in transaction allows for more flexibility in that the underlying assets remain with the pension plan manager, who pays a single premium to an insurance company in exchange for a group annuity that makes periodic payments that match those of its pension obligations. The annuity is recorded as an asset on the pension plan's books. All asset and longevity risk is transferred but the administration of the plan is not. A buy-in provides for partial risk transfer, with the buyer retaining liability for ultimate payment to annuitants. The buy-in may be revocable and provide for a conversion into a buy-out at some later point in time.

Pension buy-outs and buy-ins allow the plans to dispose of longevity, inflation, and asset investment risks. In exchange, plan members become exposed to counterparty risk from the insurer (annuity provider). Full buyouts are usually followed by the shutdown of the pension scheme. Pension buy-outs can be an attractive solution for smaller plans that want to eliminate their longevity risk exposure.

Annuities resulting from buy-out or buy-in transactions can be very expensive due to regulatory requirements on the insurance companies' side. Additionally, the capacity in the bulk annuity market is limited as life insurers have a limited appetite for additional longevity risk. Their willingness to accept further longevity risk is also restricted by the fact that diversifying the mortality risk is limited. Moreover, regulatory and legal restrictions in many countries and large mismatches between mortality and longevity exposure may hinder the development of these transactions.

4.5. Longevity risk hedging contracts

Longevity risk hedging contracts, whether structured as longevity insurance or as a longevity swap, provide pension plans with a longevity risk mitigation strategy. By entering into a longevity risk hedging contract, pension plans seek to hedge longevity risk while retaining interest rate and investment risk. Longevity risk hedging contracts are designed to reduce the risk to pension plans of increased costs associated with unexpected unfavourable longevity experience, namely plan members living systematically longer than reflected in their mortality assumptions.

There are two roughly types of longevity risk hedging contracts: indemnity-based and index-based contracts. With both types of contracts, the pension plan (hedge buyer) agrees to provide a counterparty (hedge provider) with regular pre-determined, or "fixed", payments based on agreed upon mortality assumptions. In return, the counterparty provides the pension plan with regular floating payments based on either the pension plan's actual mortality experience (*indemnity-based longevity contract*) or an agreed upon mortality or longevity index (*index-based longevity contract*). For the pension plan, the goal is to have more predictable outflows over the period covered by the longevity risk hedging contract. The counterparty to the contract assumes the longevity risk over the period covered by the contract. However, the ultimate responsibility for paying pension benefits to the plan beneficiaries remains with the pension plan.

[8] See, e.g., Milevsky (2005).

[9] Recently, the US Treasury Department announced that new tax rules will allow people to use up to 25% of their 401(k) and IRA (Individual Retirement Account) balances (to a maximum of $125k) to purchase a deferred income annuity as long as they begin collecting income by age 85.

In the case of *indemnity-based longevity contracts*, if the pension plan's beneficiaries live longer than was assumed on the plan's actuarial valuations, higher payments from the counterparty to the pension plan serve to offset the plan's higher pension costs. In this scenario, the indemnity-based contract will generally be "in the money", or have a positive value, for the pension plan. If, on the other hand, beneficiaries live shorter than expected, lower payments from the counterparty to the pension plan mean that the overall cost to the pension plan of paying beneficiaries' pensions will effectively be held constant. In this way, indemnity-based contracts protect pension plans both from increases and decreases in costs arising from unanticipated changes in the longevity of the plan's beneficiaries.

In the case of index-based contracts, the actual mortality experience of the pension plan does not affect the amount of the payments from the hedge provider to the pension plan directly. However, if there is an increase in longevity as measured by the index used to set the counterparty's payments to the pension plan, the payments from the counterparty to the plan will be higher. Pension plans that pursue an index-based contract are exposed to basis risk. Basis risk refers here to the risk emerging from the possibility that the mortality experience of the pension plan can differ from that of the index on which the contract is based. This means that the plan's longevity risk will be mitigated by the contract only to the extent that the changes in the mortality of the beneficiaries of the pension track the changes in the index. On the contrary, indemnity-based longevity risk hedging contracts introduce no basis risk as they indemnify the pension plan for their actual experience (i.e. the floating payments are based on the actual mortality experience of the plan).

Unlike a pension buy-out or buy-in, a longevity hedge only allows the pension plan to transfer longevity risk, while other sources of risk remain on its books and must be managed separately. There are no transfer of assets, allowing the plan sponsor to retain investment control and exposure to asset returns. In a longevity hedge risks are hedged with a counterparty, normally an investment bank, an insurer or a reinsurer.

Contrary to both pension buy-out and buy-in, which require a significant up-front premium and the immediate recognition of a loss if the premium is higher than the current asset reserve, longevity risk hedging contracts allow plan providers to manage the longevity risk more efficiently, without having to pay an up-front premium and with no immediate impact on their balance sheets.[10]

But longevity risk hedging contracts present some risks for a pension plan or annuity provider. First, hedge buyers become exposed to counterparty risk, i.e., to the risk that the counterparty to the longevity risk hedging contract will not live up to its contractual obligations. Although payment flows between the counterparties are generally netted, the hedge buyer may demand collateral to further mitigate this type of risk or require a credit rating for the counterparty.

Second, hedge buyers are exposed to rollover risk if the longevity risk hedging contracts are negotiated for a shorter time period than the liabilities that they cover. The rollover risk comes from the fact that entering into a new contract will be more expensive if longevity ultimately increases faster than expected. Rollover risk will be more significant for index-based risk hedging contracts since indemnity-based contracts carry little or no rollover risk as they are typically structured for the remaining life of the covered populations, or at least for a period that is long enough to cover the maturity of the living benefits of the majority of the covered population. Third, hedge buyers are exposed to basis risk as explained above. Finally, contracts are subject to legal risk since they are not traded on an exchange.

The issue of basis risk is critical for the development of a longevity market. Full population mortality indices carry basis risk to liabilities of individual pension funds and insurers. Basis risk originates from age, gender, regional, and socio-economic sources. An important challenge for the market is the need to develop transparency and liquidity by standardization while maintaining the hedging purposes of the capital market instruments. In recent years, a number of initiatives have been undertaken to foster transparency in the market around longevity risk and to contribute to the development of longevity risk transfer mechanisms, namely the creation of longevity risk indexes. Thos most significant examples include the Credit Suisse Longevity Index, launched in December 2005, the JP Morgan Index with LifeMetrics, launched in March 2007, the Goldman Sachs Mortality Index, launched in December 2007 and the Xpect Data, launched in March 2008 by Deutsche Borse.

4.6. Longevity and Mortality Bonds

An alternative capital market solution for longevity risk hedging involves securitization, namely the issuance of longevity or mortality bonds. These bonds are essentially financial debt instruments with a stochastic maturity in which future principal or coupon cash flows depend on the realization of a survivorship or mortality index of a selected birth cohort or population (Blake *et al*, 2006). The survivorship index represents, typically, the proportion of some initial reference population aged at time who are still alive at some future time. The mortality index represents, typically, the mortality level for year compared to that on the base year.

Longevity bonds were first proposed by Blake and Burrows (2001), and the first operational mortality-linked bond -the Swiss Re mortality catastrophe bond- was successfully issued in 2003. A second mortality-linked bond -the EIB/BNP Paribas longevity bond- was announced in 2004 but ultimately failed to come to market, and various other mortality-linked products have been issued afterwards. The underlying idea beyond the use of liquidity bonds as hedging instruments to the holders -annuity

[10] For a detailed list of longevity swaps, longevity risk transfer and longevity reinsurance transactions that have taken place in the reinsurance and capital markets see, for instance, http://www.artemis.bm/library/longevity_swaps_risk_transfers.html.

providers and pension funds- is very simple: if the reference population lives longer than expected, coupon payments will be larger than predicted and they will generate additional cash flows for annuity providers who face longevity risk in their annuity portfolios. The bond should be, in principle, a very long-term bond designed to protect the holder against any unanticipated improvement in mortality up to the maturity of a sizable fraction of the annuity portfolio cash flows.

Longevity bonds provide a perfect hedge only for providers with plan members or annuitants who have exactly the same mortality experience over time as the cohort underlying the bond. If the plan members or annuitants have a mortality experience that differs from that of the national population, it will once again introduce basis risk.

Mortality-linked bonds correspond to a general class of bonds whose cash flows are linked to realised mortality. They differ from longevity bonds in that their cash flows are linked to a mortality index, whereas in the case of longevity bonds cash flows are linked to a survivor index. The first bond with cash flows linked to the realisation of a composite mortality index was the Swiss Re bond issued in December 2003. This bond had a maturity of three years, a principal of $400m, and it offered investors a floating coupon of LIBOR+135 basis points. In return for this coupon rate, the principal was unprotected, and was dependent on the realized value of a weighted index of mortality rates in five countries: the United States of America, the United Kingdom, France, Italy, and Switzerland. The principal was repayable in full only if the mortality index did not exceed 1.3 times the 2002 base level during any year of the bond's life, and it was otherwise dependent on the realized values of the mortality index. This short-term mortality catastrophe bond was designed to hedge the issuer against an extreme increase in mortality, i.e., the risk of policyholders living on average shorter than expected and so, from the insurer's perspective, the risk that benefits on life policies will have to be paid before expected.

There are many possible types of longevity bonds that could be developed. Two broad categories include "principal-at-risk" longevity bonds, that is, bonds in which the investor risks losing all or part of the principal if the underlying mortality event is actually observed, and "coupon-based" longevity bonds in which the coupon payment is linked to mortality. Other potential categories include Zero Coupon Longevity Bonds, Geared Longevity Bonds and Longevity Spreads, Inverse Longevity Bonds, Deferred Longevity Bonds, Survivor Bonds amd Collateralized Longevity Bonds.[11]

The market for mortality-linked bonds has been increasing steadily since their first issue in 2003. This notwithstanding, if longevity bonds are to provide effective hedging instruments for the longevity risks actually borne by pension plans and annuity providers, various problems associated with creating a new liquid market in mortality-linked securities need to be resolved. First, there is a potential weak point in the longevity bond market on the supply side, because there are potentially few natural issuers. Because of this problem, some advocate the issuance of longevity bonds by governments. There are a number of arguments pro and against the government issuance of longevity bonds. Authors like Blake and Burrows (2001), Blake (2003), and Brown and Orzag (2006) favour the government issuance of longevity bonds invoking some of the classic arguments for government intervention (public goods, externalities, market failures, adverse selection, intergenerational issues, etc.).

Specifically, the authors argue that government issuance will suppress a market failure created by market incompleteness (governments acting as lenders of last resort), and that by spreading the risk over a very large number of taxpayers the market price of longevity risk will be eliminated. They also argue that governments contribute to the increase in longevity and that government issuance of longevity bonds will allow for a more efficient intergenerational risk sharing. Regarding the intergenerational issues, if financial markets share with governments the capacity to allocate risk across risk bearers and across time, governments have the unique power to allocate risk across both current (born) and future (unborn) generations. A relevant argument against government issuance of longevity bonds is that governments already have a large exposure to longevity risk through defined benefit pension systems and public health care systems, and that by issuing longevity bonds governments would be diversifying only within their group of taxpayers (Dowd, 2003).

Second, the choice of survivor index is critical to the success of longevity bonds since the bond's cash flows must provide a reasonably close match to the payments the hedger needs to make if the bond is to provide an effective hedge. Survivor indices suffer from some problems since (i) they are constructed from mortality data that is published infrequently and subject to measurement and statistical errors, (ii) the historical mortality data backing the index typically needs to be smoothed and it is subject to integrity and contamination risk, and (iii) the index design involves projections of future mortality scenarios that are subject to both model and parameter risk.

Third, longevity-linked securities entail significant valuation problems since they cannot be valued using the standard spot yield curve and zero-arbitrage (or net present value) methods because of market incompleteness. Alternative methods to estimate the market price of longevity risk have been suggested and include distortion approaches to pricing, the use of classic premium principles (for example, the standard deviation principle) or traditional performance measures (for example, the Sharpe ratio), adopting a risk-neutral approach, using mean-variance and risk minimization strategies or a derivation of the consumption capital-asset pricing model.

Fourth, standardization, liquidity, and transparency have proven to be crucial to develop the market for every financial product and they need to be addressed in the case of longevity bonds as well. Fifth, longevity risk hedges via capital market instruments must result in an appropriate risk capital relief for pension funds so as to increase the attractiveness of longevity hedges. Finally, credit risk issues must be addressed properly since longevity bonds transfer longevity risk to counterparties.

11 For a detailed analysis of the categories of longevity bonds and other longevity-linked securities see, for instance, Blake et al. (2006).

4.7. Q-Forwards

Introduced by the investment bank JPMorgan, a q-forward is an agreement between two parties to exchange at a future date (the maturity of the contract) an amount proportional to the realized mortality rate of a given population or subpopulation, in return for an amount proportional to a fixed mortality rate that has been mutually agreed at inception. In other words, a q-forward is a zero coupon swap that exchanges fixed mortality for realized mortality at maturity (Coughlan *et al*., 2007). In this contract, the q-forward seller, that is, the hedge buyer, say a pension fund, will be paid by the counterpart of the forward if longevity increases by more than expected.

Contrary to longevity bonds and swaps that are linked to a survival rate that depends on a series of mortality rates, q-forwards are based on a single mortality rate. The floating leg of q-forwards is linked to a broad-based index (the LifeMetrics index), which is derived from national population statistics. Relevant data are available in the public domain for investors' reference. The fixed rate payers (that is, those who receive a floating mortality rate) require compensation to take on the longevity risk. The forward rate will lie below the corresponding expected mortality rate so that on average (that is, if mortality is realized as expected), a net payment will be made from the fixed rate receivers to the fixed rate payers. The spread can be regarded as the risk premium for assuming the longevity risk.

In principle, q-forwards could be the basic building block for the development of many other more complex longevity-linked derivatives, for instance index-longevity swaps. By setting up a portfolio of q-forwards, providers (life insurance companies, pension plans, or annuity providers) could in principle engineer an effective hedge of the mortality or longevity risks.

4.8. Reinsurance arrangements

Insurers and banks can diversify away specific longevity risk by pooling annuitants and managing the foreseeable part of aggregate longevity risk and by charging appropriate premium. Risk transfer can be realized via traditional reinsurance arrangements or via swap-like reinsurance. In the later case, the interest of this reinsurance arrangement is mainly due to the possibility that it creates for the reinsurer to hedge the risk taken from the issuer via a transfer to the capital market, namely via longevity bonds.

Traditional reinsurance arrangements (e.g. surplus reinsurance, XL reinsurance, Stop-Loss, etc.) can also be, at least in principle, applied to annuity portfolios (see, e.g., Olivieri, 2005). Risk transfer via traditional reinsurance mainly relies on the improved diversification of risks when these are taken on by the reinsurer, thanks to an enforcement of pooling effects. However, such enforcement of pooling effects can be achieved only in relation to random fluctuations in mortality, whilst systematic longevity risk cannot be diversified inside the insurance and reinsurance process. Hence, to be more effective, the reinsurance transfer must be complemented with a further transfer to capital markets, namely through longevity or mortality linked bonds.

5 Final Remarks

Longevity risk, which is the uncertainty in future mortality developments, affects pension providers, life insurers, and governments. The population structure of developed countries is increasingly leaning towards the old, and the effects of medical advances and lifestyle choices on mortality are to some extent unpredictable. Until recently, the importance of longevity risk was not fully recognized. For individuals, the ability to hedge against longevity risk depends on the existence of an appropriate insurance market, namely a well-developed market for lifetime annuities. For providers, the ability to make good on their pension or benefit promises depends, to a considerable extent, on how well they manage this risk.

The possibilities for risk mitigation differ between institutions. Public pay-as-you-go pension schemes are typically able to reduce their benefits and to increase their contributions. In these schemes, longevity risk is transferred to the scheme members as they receive less or pay more to compensate for unanticipated increases in longevity. This scenario has indeed occurred in many OECD countries during recent decades.

In contrast, pension funds and annuity providers do not usually have such opportunities. Their obligations are usually fixed which makes them much more vulnerable to increases in longevity. Therefore, adequate and efficient longevity risk mitigation for these institutions is highly relevant from both a microeconomic and a macroeconomic perspective.

Part of the answer to aggregate, non-diversifiable, longevity risk is to ensure that annuity providers, insurance companies and pension plans have access to suitable hedge instruments. These instruments include traditional insurance-based solutions, namely pension buy-ins and buy-outs, reinsurance arrangements, annuities and longevity insurance, and also more recent capital market solutions.

Various longevity-linked instruments have been proposed to manage longevity risk. These instruments include longevity bonds, mortality bonds, longevity swaps and q-forwards. We have discussed how such instruments, once in existence, can be used to hedge longevity and mortality risk exposures in pensions or life insurance liabilities. Recent data suggests that the demand for longevity-linked instruments is a reality, and that the number and significance of longevity transactions is increasing.

The traditional insurance-based options and the new capital market solutions to hedge of longevity risk are not a substitute for good risk management, but they will be very useful for well-managed institutions who want to confront the problems of managing their longevity risk exposures seriously. Once the difficulties associated with creating a new liquid market in mortality-linked securities are resolved, markets in these securities will develop and mature, and they will provide the insurers with useful tools specifically designed to manage longevity risk. We are probably seeing the rise of a completely new class of assets that will enrich the global financial market of the future.

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