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Financial Study

Longevity Risk within Pension Systems

(A Background Paper to the OECD Policy Report)

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1 Introduction

"It's tough to make predictions, especially about the future"

Lawrence Peter 'Yogi' Berra, US baseball player and team manager

Even though Berra's words relate to sports and sound all but serious, there is lots of truth in them with respect to mortality or longevity. For centuries, people have tried to predict human mortality but in almost every case predictions have turned out to be wrong. This has led to the recognition of mortality or longevity risk which Antolin (2007) defines as "the uncertainty regarding future mortality and life expectancy outcomes".

An example of inaccurate mortality predictions is given in Figure 1 which shows life expectancies for males in the United Kingdom (UK). The black line describes realized life expectancies whereas the colored lines represent life expectancy forecasts by the Office of National Statistics (ONS) at different points in time. We observe that forecasts mostly start at the current level of observed life expectancy but over the years, the forecasts always fall significantly below actual life expectancies. Thus, realized life expectancy has increased much stronger than anticipated at any time. Moreover, we see that predictions have changed enormously over time. From the vertical line in year 2010, we can observe that the life expectancy forecast for 2010 has increased by about 7 years between 1977 and 2000. This gives a very good idea of the magnitude of mortality/longevity risk.

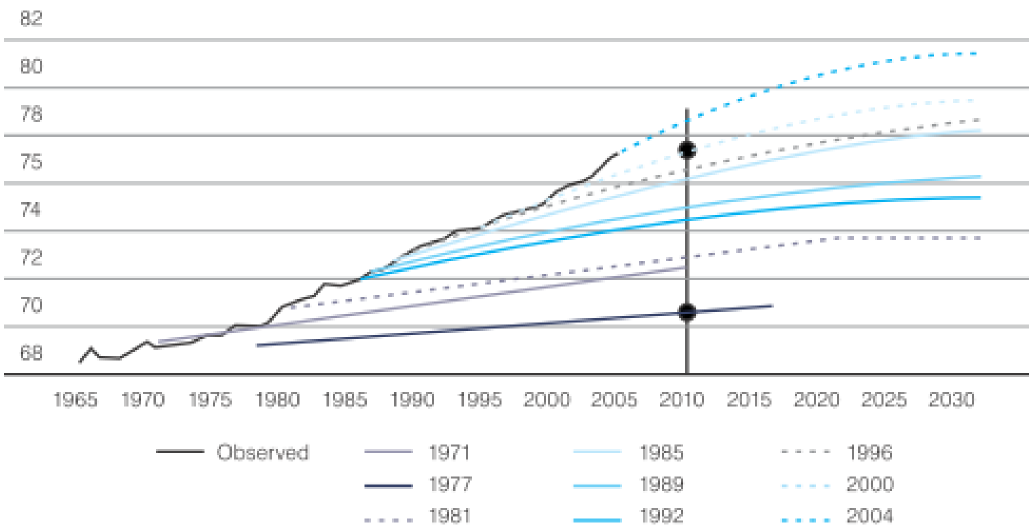

Figure 1: Official life expectancy projections in the UK (Source: CRO Forum (2010) based on Shaw (2007))

In this report, we focus on the ***risk of increasing life expectancy***, i.e. longevity risk. This is the risk which has materialized in basically every industrialized country in the past as (similar to Figure 1 for the UK) life expectancy forecasts have been constantly too low.

Longevity risk is a critical risk for institutions which provide life-long payments such as pension funds, annuity providers and public pension schemes. These institutions can face serious problems if their beneficiaries live (significantly) longer than expected, i.e. longevity risk can have massive consequences also in monetary terms. We illustrate this for the case of longevity risk in pension schemes: Pension assets in OECD registered countries have lately been estimated at about €15 trillion.[1] This alone is an enormous figure. However, as pensions are often not fully funded – public pensions are typically not funded at all – pension liabilities are in fact significantly larger than that. As a rule of thumb, each additional year of life expectancy adds another 3-5% to the pension liabilities. Thus, an underestimation of worldwide life expectancy by only 1 year would require additional pension assets of more than €500 billion only to maintain the current funding level. This figure clearly illustrates the severity of longevity risk and, as financial resources to cope with this risk are limited for most institutions, there is need for mitigation of this risk.

The ***possibilities for risk mitigation*** differ between institutions. Public pay as you go pension schemes are typically able to reduce benefits and/or increase contributions. Here, longevity risk is transferred to the scheme members as they receive less and/or have to pay more in case of unanticipated longevity. This scenario has occurred in many industrialized countries over recent decades. Pension funds and annuity providers, on the other hand, do not have such opportunities in general. Their obligations are typically fixed which makes them much more vulnerable to longevity risk. Legislation in many countries has further aggravated their situation: As compensation for reduced benefits from public pension schemes, many governments have introduced tax incentives or certain subsidies for private annuities and occupational pensions. Often, the tax incentives / subsidies are linked to mandatory annuitization. This has increased and will further increase the amount of pension liabilities and hence the pension funds' and annuity providers' longevity risk exposure. Furthermore, this development has increased the general importance of pension funds and annuity providers (when compared to public pension schemes) in the provision of retirement income. Thus, adequate and efficient longevity risk mitigation in these institutions is highly relevant not only from a micro-economic perspective but particularly from a macro-economic point of view. Therefore, governments and regulators should generally support pension funds and annuity providers in their attempts of risk mitigation.

Pension funds and annuity providers have different options to mitigate their longevity risk. The longevity risk in a pension fund can, for instance, be reduced by a plan amendment. Instead of guaranteeing plan members a certain retirement income in a defined benefit

[1] Cf. "Longevity Risk", a position paper of the CRO Forum (2010), or the "OECD Private Pension Outlook 2008".

(DB) plan, the plan sponsor can merely guarantee a certain contribution in a defined contribution (DC) plan such that the longevity risk during the deferment period is transferred to the plan member. To eliminate longevity risk during the payout phase, pension funds can purchase bulk annuities from insurance companies in so-called Buy-Out or Buy-In transactions. As the result of such transactions, the insurance company effectively pays the pensions to the plan members and thus, takes over the longevity risk.[2] However, such annuities can be very expensive due to regulatory requirements on the insurance companies' side. Moreover, the capacity in the bulk annuity market is limited as life insurers also sell private annuities and thus, have a limited appetite for additional longevity risk. Their willingness to accept further longevity risk is also restricted by the fact that diversification with mortality risk is limited. This is due to regulatory and legal restrictions in many countries but also due to a significant mismatch between mortality and longevity exposure. Exemplarily, Table 1 gives an overview of mortality and longevity exposures in the US and the UK in 2006. We see that longevity exposure is 30-40 times larger than mortality exposure which means that diversification opportunities for longevity risk have already been more than exploited.

An alternative way of risk mitigation which is open to pension funds and annuity providers from the insurance sector is the risk transfer to reinsurance companies. However, also reinsurers face a situation of limited diversification. There seems to be a common global trend in mortality which means longevity is to increase in almost all countries around the world at the same time.[3] Moreover, the sheer size of longevity risk exceeds reinsurance capacity thus limiting the possibilities for risk mitigation.

	Risk	US	UK
Defined Benefit Pensions	Longevity	£3 trillion	£800 billion
Life Insurance Industry			
Annuity Reserves*	Longevity	£50 billion	£135 billion
Life Insurance Reserves*	Mortality	£75 billion	£38 billion
* These are only the portion of reserves linked to mortality/longevity risk			

Table 1: Longevity/mortality exposure in the US and the UK (Data from: OECD, UK Pensions Regulator, US Council of Insurers, Moody's, JPMorgan)

Since the outlined possibilities for longevity risk mitigation have shortcomings and/or are not available in sufficient capacity, new options have to be explored. One very promising option is the ***transfer of longevity risk to the capital markets*** as they are large enough to

[2] Details on Buy-Out and Buy-In transactions are provided in chapter 4 of this report.

[3] For an analysis of this global trend, see, e.g., "Modeling Mortality Trend under Modern Solvency Regimes" by M. Börger, D. Fleischer, and N. Kuksin (2012).

assume longevity risk on a significant scale. Pension funds or annuity providers would buy or sell special mortality/longevity linked financial instruments in the capital markets in order to hedge their longevity risk (so-called securitization of longevity risk). The cash flows pension funds and annuity providers receive from these instruments would then be generally larger the longer their beneficiaries live. The other party involved in such transactions, i.e. the hedge provider, would be compensated for taking over the longevity risk by a risk premium. This risk premium will offer the hedge provider an investment return above the risk-free interest rate if mortality/longevity evolves as expected. In case of decreasing longevity hedge providers would earn even more but in case of increasing longevity they would possibly lose out on some of their money.

Overall, longevity hedges via the capital markets can be a powerful tool of risk mitigation and therefore, an efficient capital market for longevity risk seems desirable. First steps towards such a market have already been taken but the market needs to be developed further. For that, regulatory and governmental support is crucial. In this report, we provide the necessary technical background and deduce recommendations how regulators and governments could support further market development most effectively.

We start with an introduction of different financial instruments which can be used to transfer longevity risk to the capital markets. We analyze advantages and disadvantages of each of these instruments and compare their applicability in different settings, e.g. in the deferment period or the payout phase. Subsequently, we give a short description of the evolution and the current state of the longevity market. As pension funds and annuity providers are also exposed to other sources of risk, e.g. interest rate risk or inflation risk, longevity related hedging instruments are typically only part of larger hedging solutions for different kinds of risk. Therefore, in chapter 4, we discuss how longevity hedges can be embedded in such hedging solutions and show how they can be implemented in practice. We illustrate our explanations by a qualitative analysis of existing longevity transactions in chapter 5.[4] Finally, we describe and analyze the possible future evolution of the longevity market with a focus on the regulators' and governments' possible role.

[4] As most transactions have taken place in the UK so far many examples in this report are taken from that market. However, this report is not meant to focus on a specific country and the presented results are generally applicable to other countries as well.

2 Capital Market Instruments Related to Longevity and their Characteristics

Four important capital market instruments for longevity hedging have been established so far: q-forwards, s-forwards, longevity bonds and longevity swaps. In this chapter, we will explain each of the instruments and give some numerical examples for a better understanding.

2.1 q-forwards

The q-forward was introduced by JPMorgan and can be defined as follows[5]:

*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 (floating leg), in return for an amount proportional to a fixed mortality rate (fixed leg) that has been mutually agreed at inception of the contract.*

The mortality rate used for q-forwards is the one-year death probability[6], i.e. the probability to die within a year. The fixed mortality rate is determined at inception of the contract and is calculated with actuarial and statistical methods, whereas the realized mortality rate depends on the outcome of a longevity index (e.g. LifeMetrics from JPMorgan) at maturity. Figure 2 shows the cash flows of a q-forward contract between a pension plan and a hedge provider (e.g. an investment bank) at maturity.

The net settlement of a q-forward depends on the outcome of the realized mortality rate. Table 2 gives an example of possible net settlements (from the pension plans' perspective), where we assume that the fixed mortality rate in this q-forward contract is 1.20% and the notional amount is £10 million. In these fictive scenarios, the realized mortality rate varies from 1.00% to 1.40%. It is obvious, that the net settlement is 0 if the realized mortality rate is equal to the fixed mortality rate.

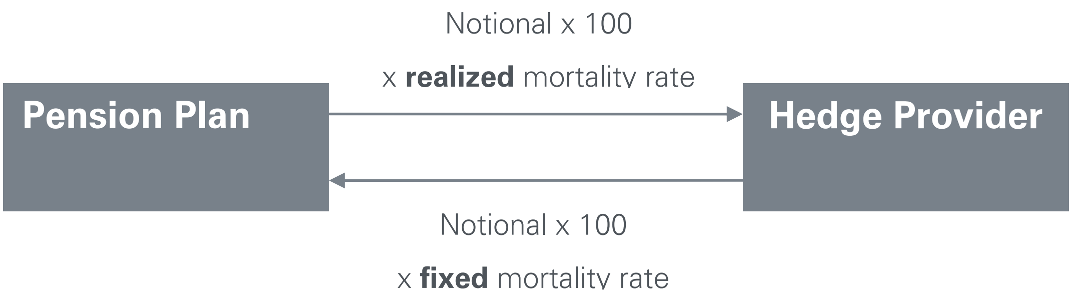

Figure 2: Cash flows of the q-forward at maturity

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[5] This definition as well as a detailed information about q-forwards can be found in "q-Forwards: Derivatives for transferring longevity and mortality risk" (2007) by G. Coughlan, D. Epstein, A Sinha and P.Honig.

[6] "q" is the letter used to describe the one-year death probability in actuarial science.

Realized mortality rate	Fixed mortality rate	Notional (£)	Settlement (£)
1.00%	1.20%	10,000,000	2,000,000
1.10%	1.20%	10,000,000	1,000,000
1.20%	1.20%	10,000,000	0
1.30%	1.20%	10,000,000	-1,000,000
1.40%	1.20%	10,000,000	-2,000,000

Table 2: Settlement depending on the different outcomes of the realized mortality rate. A positive settlement means a cash flow from the hedge provider to the pension plan.

If the realized mortality rate is 1.00%, then the difference between the realized and fixed mortality rate is 0.20%:

$$1.20\% - 1.00\% = 0.20\%$$

Therefore, the hedge provider has to pay £2 million to the pension plan:

$$10{,}000{,}000 \bullet 100 \bullet 0.20\% = 2{,}000{,}000$$

If the realized mortality rate is 1.40%, then the hedge provider receives £2 million from the pension plan. These results are also visualized in Figure 3. This example of a q-forward reflects a longevity hedge because lower mortality rates means that people survive longer than expected. So, if the realized mortality rate is below the fixed one, the pension plan is able to pay the additional pension benefits since it receives money from the hedge provider.

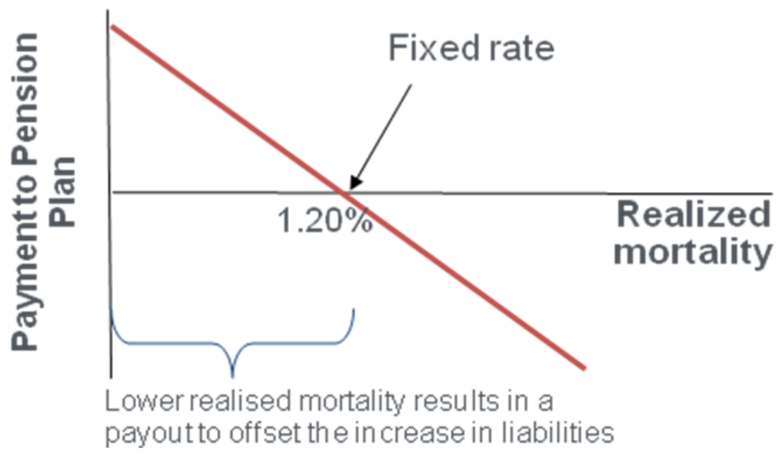

Figure 3: Payout from q-forwards (Source: "Longevity Hedges and Longevity Investments" (2008) by JPMorgan)

Usually, a q-forward is collateralized in order to reduce counterparty risk as collateralization of assets gives lenders a sufficient level of reassurance against default risk.[7] In case of a q-forward, if mortality decreases and the payer of the fixed leg (i.e. the hedge provider) becomes insolvent the pension plan would receive the assets deposited as collateral and could use these to offset a drop in mortality. In case of an increase in mortality, the payer of the fixed leg would be exposed to the risk of a defaulting counterparty and thus, the payer of the floating leg (i.e. the pension plan) would have to provide a collateral.

2.1.1 Pricing of q-forwards

The first step for the pricing of a q-forward is the calculation of the best estimate mortality curve[8]. It represents the best estimate of the mortality rates of a given population at different years in the future and is determined with a statistical or actuarial model. However, the best estimate of the mortality rates is not used for the fixed rate of the q-forward because the longevity investors want to receive a risk premium in order to take over the longevity risk. For that reason, a so-called forward mortality curve is determined, where the difference between the best estimate of the mortality rate and the forward mortality rate is exactly the risk premium. Consequently, the forward mortality curve is below the best estimate mortality curve. Figure 4 gives an illustrative example of both curves.

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[7] Collateralization is defined as the act where a borrower pledges an asset as recourse to the lender in the event that the borrower defaults on the initial loan.

[8] The best estimate mortality curve is also called expected mortality curve.

Then, the forward mortality curve is used to determine the fixed mortality rate of the q-forward. The fixed rate is simply the forward mortality rate at the maturity date of the contract. For example, if we have a q-forward starting in the year 2005 with a term of 20 years, the fixed mortality rate would be the forward mortality rate in the year 2025, which is around 0.70% in Figure 4. The best estimate of the mortality rate would be 0.95% and the risk premium would be equal to 0.25%.

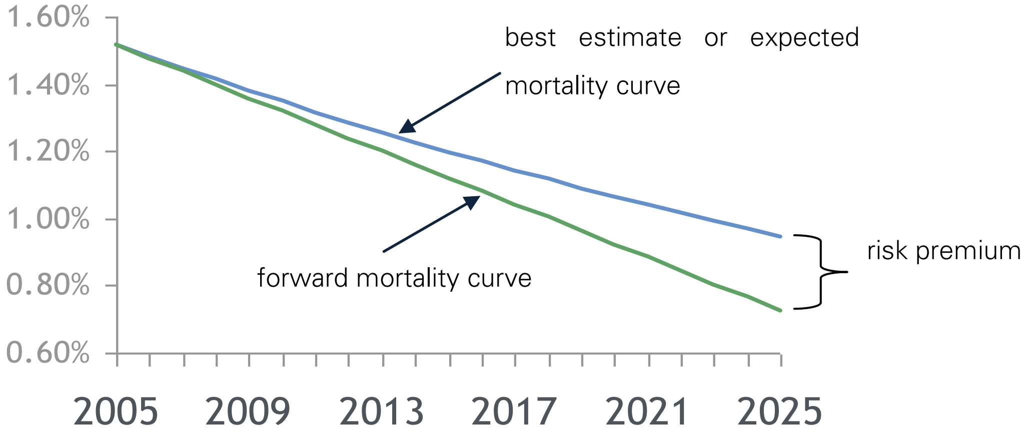

Figure 4: Best estimate mortality curve and forward mortality curve

2.1.2 Example of a q-forward

We present a case study[9] to explain all important aspects about q-forwards. We suppose a 5-year q-forward contract on a population aged between 58 and 60 years at 1[st] January 2011. The cash flows at maturity depend on the average mortality rates of the three ages in 2016, i.e. the average mortality rate of the ages between 63 and 65.The maturity date is the 1st[th] January 2016 and the notional amount is £1 million. Let q(x,t) be the one-year death probability of an x-year old person in the year t. The relevant one-year death probabilities in 2010 are given in Table 3.

Age	q(x,2010)
63	1.80%
64	2.00%
65	2.20%
Average	2.00%

Table 3: One-year death probabilities in 2010

[9] This case study is based on an example of Life & Longevity Markets Association (LLMA):"Longevity Pricing Framework – A framework for pricing longevity exposures developed by the LLMA" (2010)

Thus, the average one-year death probability for the given population is 2.00%. We assume an expected decrease of the mortality rate in the population in question of 1.50% per year, i.e. the best estimate of the one-year death probability is 98.5% of the rate in the previous year. Consequently, the best estimate of q(63,2011), i.e. the one-year death probability of a person aged 63 in the year 2011, is

$$1.773\% = 1.80\% \bullet 0.985.$$

Therefore, **the best estimate of the mortality rate** of our group in 2015 is

$$1.85\% = 2.00\% \bullet (0.985\%)^5.$$

As mentioned before, we need the forward mortality rate to determine the fixed rate. Here, we assume that the risk premium is equivalent to a decrease of the mortality rate of 1.00% on top of the expected decrease of 1.50%. So the overall decrease is now 2.50% per year. Therefore, the forward mortality rate of our group in 2015 is

$$1.76\% = 2.00 \bullet (0.975\%)^5.$$

Thus, the **fixed rate** is 1.76% in our q-forward and the **risk premium** is equal to 0.09% because

$$0.09\% = 1.85\% - 1.76\%.$$

The price of the q-forward at any time is the net value of the two present values, i.e. the difference between the present value of the fixed leg and the one of the floating leg. At inception, the **present value** of both legs is the same (ignoring any bid-offer spread) and the present value of the fixed leg is calculated by:

$$PV = 1{,}000{,}000 \bullet 1.76\% \,/\, (1 + 3\%)^5 = 15{,}182$$

where we have assumed a risk-free interest rate of 3%.

The forward mortality rate is set such that the price at inception of a q-forward is zero. This means that there is no initial funding.

Again, we want to explain possible cash flows at maturity of the contract. The settlement shown in Table 4 depends on the outcome of the realized mortality rate, where the pension plan receives money, if the realized mortality rate is below the fixed rate, and has to pay money in the other case.

Realized mortality rate	Fixed mortality rate	Notional (£)	Settlement (£)
1.56%	1.76%	1,000,000	200,000
1.66%	1.76%	1,000,000	100,000
1.76%	1.76%	1,000,000	0
1.86%	1.76%	1,000,000	-100,000
1.96%	1.76%	1,000,000	-200,000

Table 4: Net settlement of the q-forward in our case study depending on the outcome of the realized mortality rate

2.2 s-forwards

An s-forward or "Survivor" forward[10] is quite similar to a q-forward. The main difference is the underlying mortality rate. In an s-forward contract, the underlying rate is the survival rate of a given population:

*An **s-forward** is an agreement between two parties to exchange at a future date (the maturity of the contract) an amount proportional of the realized survival rate of a given population (floating leg), in return for an amount proportional to a fixed survival rate (fixed leg) that has been mutually agreed at inception of the contract.*

The exchange of cash flows can be seen in Figure 5. The fixed survival rate is the best estimate of the survival rate of the given population plus a risk premium payable by the pension plan. The floating leg depends on the realization of a longevity index underlying the contract. The price at inception of an s-forward is zero and there is no initial funding. Counterparty default risk is typically accounted for by collateralization as for the case of a q-forward.

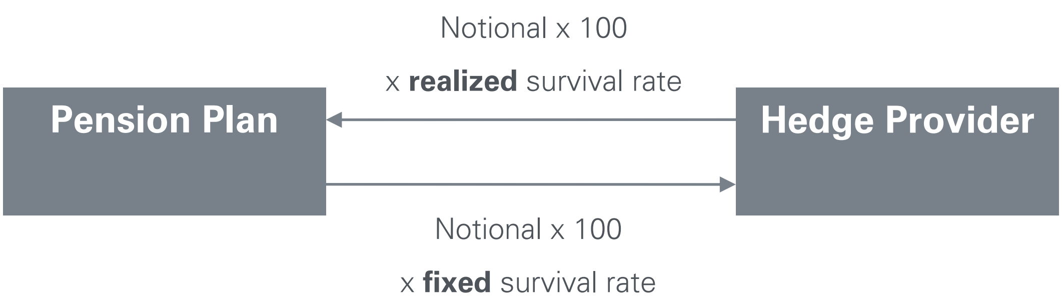

Figure 5: Cash flows of the s-forward at maturity

[10] Detailed information about s-forwards can be found in "Technical Note - The S-forward" (2010) by Life & Longevity Markets Association (LLMA).

2.2.1 Example of an s-forward

We present here an example of an s-forward[11] with a term of three years and a notional amount of £1 million. The s-forward is based on males aged 65 years at inception of the contract, which is the 1st January 2011. Thus, the underlying survival rate is the three-year survival probability of a person aged 65 at inception, i.e. the probability of a person aged 65 to survive three more years. Let q(x,t) be the one-year death probability of a person aged x in the year t, i.e. the probability that an x-year old person dies in the year t, and let p(x,t) be the corresponding one-year survival probability such that

$$p(x,t) = 1 - q(x,t).$$

We assume an expected decrease of the one-year death probability of 2% for each year and age. Thus, if the one-year death probability of a person aged 65 in the year 2010 is 1.80%, the best estimate of the one-year death probability of a person aged 65 for the year 2011 is 0.98 • 1.80% = 1.76%. Consequently, we obtain Table 5, where the mortality rates of the year 2010 (called base mortality rates) and the best estimate of the one-year death probabilities are shown. The one-year death probabilities relevant for the s-forward are in bold and the corresponding one-year survival probabilities can be found in Table 6.

Age x	q(x,2010)	q(x,2011)	q(x,2012)	q(x,2013)
65	1.80%	**1.76%**	1.73%	1.69%
66	1.90%	1.86%	**1.82%**	1.79%
67	2.00%	1.96%	1.92%	**1.88%**

Table 5: The best estimate of the mortality rates and the base mortality rates for 2010

Age x	p(x,2010)	p(x,2011)	p(x,2012)	p(x,2013)
65		**98.24%**		
66			**98.18%**	
67				**98.12%**

Table 6: The best estimate of the one-year survival probabilities

[11] The example is based on "Longevity Pricing Framework- A framework for pricing longevity exposures developed by the LLMA" (2010) by Life & Longevity Markets Association (LLMA).

The three-year survival probability can be calculated as the product of these one-year survival probabilities, such that

$$0.9664 = 0.9824 \bullet 0.9818 \bullet 0.9812.$$

Therefore, the best estimate of the three-year survival probability is 96.64%.

The next step is to calculate the forward survival rate, i.e. we have to consider a risk premium. This can be done as described in subsection 2.1.2. In this example, we ignore the risk premium and so we get a fixed survival rate of 96.64%. This means that 96.64% of the given population (males aged 65 years) is expected to survive to the end of the year 2013. In Table 7, the net settlement of this s-forward is shown, where the exact cash flow depends on the realized survival rate. If the realized survival rate is above the fixed one, the pension plan receives money from the hedge provider since more people survived than expected.

Realized survival rate	Fixed survival rate	Notional (£)	Settlement (£)
96.44%	96.64%	1,000,000	-200,000
96.64%	96.64%	1,000,000	0
96.84%	96.64%	1,000,000	200,000

Table 7: Net settlement of the s-forward in our example depending on the outcome of the realized survival rate

2.2.2 Comparison of a s-forward and a q-forward

Next, we give a short comparison of a s-forward and a q-forward. The use of the survival rate in a s-forward has an advantage over the one-year death probability used in a q-forward because pension plans' sponsors are more interested in the survival rates of a given population than in the one-year death probability. Consequently, a s-forward is more convenient than a q-forward since the underlying rate is the *n*-year survival probability (i.e. the probability to survive *n* years), whereas it is only the one-year death probability in a q-forward. Note, unlike in a q-forward contract, where the pension plan is a realized-rate payer, the pension plan is a fixed-rate payer in a s-forward. An increase of the survival rate leads to a higher liabilities of the pension plan since the pension plan's members live longer than expected. Thus, if the realized survival rate is above the fixed rate, the pension plan receives money in order to offset the additional retirement payments.

2.3 Longevity Bonds

There are two important kinds of longevity bonds: the "Principle at risk" longevity bond and the "Coupon-based" longevity bond.

*The **"Principal at risk" longevity bond** pays an annual coupon and a refund of the principal. The repayment of the principal is reduced, when a mortality event (e.g. pandemic) occurs.*

Consequently, this is a hedge against catastrophic mortality risk. One example of such a bond is the Swiss Re mortality bond VITA 1 which we already mentioned in section 3.1. However, this bond is not a useful instrument for the sponsors of pension plans since they are concerned about an increase of life expectancy.

*In the "**Coupon-based" longevity bond,** the coupon payments are linked to the survival rate of a cohort and there is typically no principle to be repaid.*

One example of a "Coupon-based" longevity bond is the announced EIB/BNP Longevity Bond (see section 3.1).

In the following, we will concentrate on the "Coupon-based" longevity bond because it represents a useful instrument for pension plans' sponsors. There are some possible variations of a "Coupon-based" longevity bond such as a **zero-coupon longevity bond,** a **deferred longevity bond** (deferred coupon payments) and the **"classical" longevity bond**[12]**.** We will mainly concentrate on the classical longevity bond, where the coupon payments are linked to the survival rate of a predefined reference population. Such a bond is also called survivor bond.

2.3.1 Classical Longevity Bond

The coupon payments are proportional to the survival rate of the specified reference population S(t) at time t as it can be seen from Figure 6. The longevity bond can be limited (e.g. 25 years) or ends when the last survivor of the reference population dies. A longevity bond reduces the longevity risk since an increase in longevity leads to higher coupon payments, which helps the pension plan's sponsors to manage their exposure to longevity risk.

In order to reduce counterparty risk, the payments are usually collateralized. In the case of a longevity bond, this is particularly important from the pension fund's point of view as he makes an upfront payment and then receives payments according to the overall survival,

[12] Details of the different kinds of longevity bonds can be found in "LIVING WITH MORTALITY: LONGEVITY BONDS AND OTHER MORTALITY-LINKED SECURITIES" (2006) by D. Blake, A. J. G. Cairns and K. Dowd.

i.e. the evolution of S(t), and not only to the difference between forward mortality and realized mortality (as in the case of an s-forward).

An example of a classical longevity bond is the EIB/BNP Longevity Bond in 2004. This bond was a first attempt to securitize longevity risk, but the bond issue failed due to limited demand. However, this is a good example to explain the basics of a longevity bond, wherefore we give a short overview about the main characteristics of this bond.

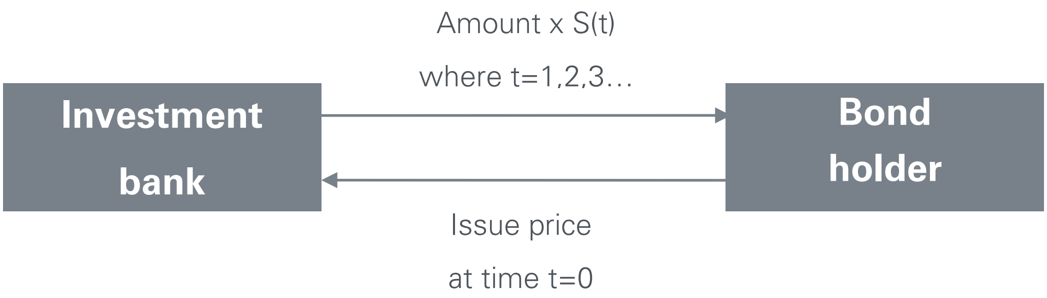

Figure 6: Structure of a longevity bond

The EIB/BNP Longevity Bond[13] had a 25-year maturity where the coupon payments were linked to a cohort survivor index. This survivor index depends on the realized mortality rates of 65-year-old English and Welsh males in 2003. The initial coupon payment was £50 million. Let q(x,t)[14] be the mortality rate of a person aged x in the year t and the survivor index S(t) was constructed as follows:

$S(0) = 1$

$S(1) = S(0) * (1 - q(65,2003))$

$S(2) = S(1) * (1 - q(66,2004))$

$S(t) = S(t-1) * (1 - q(64+t,2002+t))$

The coupon payment was £50 million • S(t) with t = 1, 2, …, 25 and the issue price was £540 million determined by projected coupons which are discounted at LIBOR minus 35 basis points. The projected coupons are based on survival rates calculated by the UK Government Actuary's Department.

We present a fictive scenario in order to describe the coupon payments in the first three years.

[13] See also "Pricing Risk on Longevity Bonds" (2005) by A.J.G. Cairns, D. Blake, P. Dawson and K. Dowd.

[14] Note that for the EIB/BNP Longevity Bond the definition of q(x,t) slightly differed from the definition used in sections 2.1 and 2.2.

Table 8 shows a possible development of the mortality rates, where the ones for the cohort aged 65 in 2003 are in bold since we need them for the calculation of the survivor index.

Thus, the coupon payment at time t = 1 is

$$48{,}975{,}000\ £ = 0.9795 \bullet 50{,}000{,}000\ £.$$

Age x \ Year t	2003	2004	2005
65	**2.05%**	2.00%	1.95%
66	2.15%	**2.10%**	2.05%
67	2.25%	2.20%	**2.15%**

Table 8: Possible development of the mortality rates q(x,t), i.e. the mortality rate of a person aged x in the year t

All coupon payments in the first three years can be found in Table 9. As mentioned before, the EIB/BNP Longevity Bond was not successful and, so far, there has not been a completed longevity market transaction using longevity bonds. Some argue that the government could issue such a longevity bond. We will discuss this in the following subsection.

Time	Mortality rate q(64+t,2002+t)	Survivor index S(t)	Coupon payment (£)
t = 1	2.05%	97.95%	48,975,000
t = 2	2.10%	95.89%	47,945,000
t = 3	2.15%	93.83%	46,915,000

Table 9: The coupon payments in our scenario

2.3.2 Government-issued Longevity Bond[15]

A government-issued longevity bond could basically be a classical or a deferred longevity bond. Here, we show an example of a deferred longevity bond because this bond could be a very useful instrument to hedge longevity risk. In this longevity bond, the coupon payments depend on the survival rate of a given population (e.g. a cohort aged 65 in 2012) and are deferred, i.e. the payments start when the cohort reaches a pre-determined age (e.g. 75 years). The idea behind deferred payments is that the early cash flows in classical bonds have typically low longevity exposure but are the most expensive part of the bond. Therefore, the payments are deferred in order to get more longevity exposure with less capital investment. Besides that, the term of the bond is limited to attract more investors, e.g. the bond terminates after 40 years, when the cohort reaches age 105. The principal is not repaid, but there is a terminal payment at maturity which considers those who survive beyond age 105.

The question, why governments should or should not issue such bonds is discussed in chapter 6.

2.4 Longevity Swaps

The longevity swaps are the most attractive capital market instrument at the moment:

*A **longevity swap** is an exchange of a predefined cash flow (fixed leg) and a variable stream of pension payments (floating leg) at regular time steps, e.g. monthly or yearly.*

The cash flows at each time step are illustrated in Figure 7. The fixed leg is the best estimate projection of the pension payments plus a hedging fee and the floating leg depends on the realized survival rates of a reference population. Thus, as for the q- and s-forwards, the price at inception of a longevity swap is zero. In contrast to longevity bonds, a longevity swap is an unfunded derivative.

There are two different types of longevity swaps: **bespoke longevity swaps**[16] and **index-based longevity swaps**. In a bespoke longevity swap, the cash flows depend on the number of survivors of the pension scheme members. Thus, it includes a full longevity risk transfer. So far, it has been the main type of longevity swaps. The cash flows of an index-based longevity swap depend on a longevity index, i.e. the actual payments are based on the realized survival rates of a general population ("index population"). Thus, the index-based longevity swap is basically a set of s-forwards with different maturities. , It is only a partial protection against longevity risk because the survival rate of the pension scheme members can differ from the survival rate of the general population (so-called

[15] Note, that the idea of government-issued longevity bonds is based on D. Blake. See, e.g. "Sharing Longevity Risk: Why Governments Should Issue Longevity Bonds" (2010) by D. Blake, T. Boardman and A. Cairns.

[16] Note, that a bespoke longevity swap is sometimes called a customized or tailored longevity swap.

basis risk). However, an index-based longevity swap is more flexible than the bespoke longevity swap. We will discuss the differences between both approaches in detail in subsection 4.2.3.

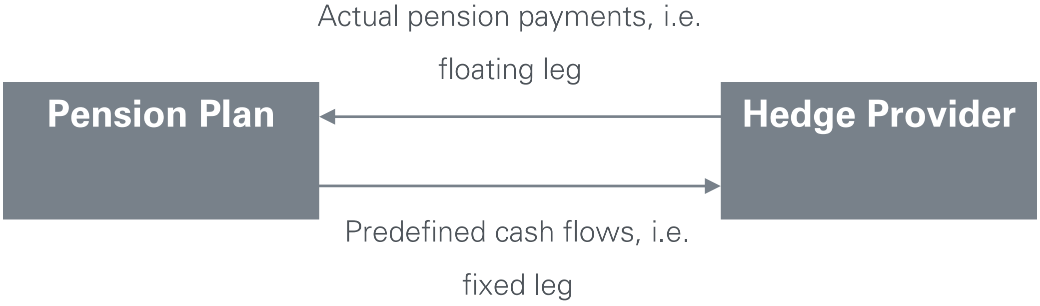

Figure 7: Cash flows of the longevity swap

Date	Actual Pension Payment (£)	Predefined cash flow (£)	Payment to the pension plan (£)
01.02	1,000,000	950,000	50,000
01.03	950,000	930,000	20,000
01.04	900,000	910,000	-10,000
01.05	900,000	890,000	10,000

Table 10: Cash flows in our longevity swap for the first 4 months

Next, we give a numerical example of a longevity swap[17]. We consider a homogeneous pension plan with 100,000 members aged 65 years at 1st January. Each month, the pension plan has to pay £10 to each member of the plan. Our pension plan wants to hedge its exposure to longevity risk and enters the fixed side of the longevity swap with starting date 1st January. Table 10 shows the cash flows for the first 4 months in our fictive scenario. After one month, nobody has died in the pension plan. Therefore, the pension plan has to pay £1,000,000 to the plan members, whereas the predefined cash flow is £950,000. Therefore, the pension plan has to pay more money to the members than expected, but it receives this extra money from the hedge provider. This amount is equal to £50,000. After the second month, 5,000 people have died and so the pension plan pays £950,000 to the pensioners. But in this example, it was expected that the amount of retirement payments would be smaller again with the predefined cash flow of the swap being £930,000. Thus, the pension plan receives £20,000. Between the second

[17] This example is based on "Hedging longevity risk with longevity swaps" (2009), master thesis by H. Westland.

and the third month, more people have died than expected leading to fewer payments to the pensioners. Therefore, the hedge provider receives £10,000 from the pension plan.

Consequently, a longevity swap is a useful capital market instrument to transfer the longevity risk since the pension plan receives money when more people survive than expected. Thus, the pension plan is able to offset the additional retirement payments. In the next subsection, we compare the four capital market instruments explained in this chapter.

2.5 Comparison of Longevity Instruments

The main characteristics of the presented longevity instruments are summarized in Table 18 in the appendix. As it can be seen there, longevity swaps have several advantages. The payment frequency can be monthly or yearly and the reference population can be either a general population (index-based longevity swap) or the pension plan's population (bespoke longevity swap). The underlying mortality rate is the survival rate, which is quite useful for pension plan's sponsors because they are more interested in the survival rates of a given population than in the one-year death probabilities. Moreover, there is also no funding necessary since the price of the swap is zero at inception. This is because the hedging fee is included in the predefined cash flows. All in all, a longevity swap is very flexible, which explains the fact that the longevity swap is the most attractive capital market instrument at the moment. However, there have also been some capital market transactions using q-forwards. These instruments can be particularly useful for a value hedge, i.e. for a hedge against an unexpected change in the liabilities (i.e. the present value of the cash flows) over a limited term, e.g. 10 years. Although there has not been a completed transaction, longevity bonds could also be a very useful instrument to reduce longevity risk.

In general, other capital market instruments like longevity options, futures or swaptions could be possible as well. However, such instruments require a liquid market in longevity bonds, swaps, or forwards first since their payoffs would be based on these basic instruments. As long as there is no such liquid market these instruments will only be of theoretical interest. Furthermore, the exact design of these capital market instruments (i.e. underlying, strike price) is undefined.

3 The Longevity Market (Status Quo)

In this chapter, we describe the evolution of the longevity market to its current state. We highlight the most important steps in that evolution and the main instruments and players involved. The chapter also comprises an account of the current market volume, the market participants, the preferred instruments and the main characteristics of the current market.

3.1 Evolution of the Longevity Market

The traditional way of longevity transfers in the pension sector has been via bulk annuities, i.e. ***Buy-In or Buy-Out transactions***. In a Buy-Out transaction, the pension fund passes over all its assets and liabilities to a life insurance company which then provides the benefit payments to the pension plan members. Since the pension fund and the plan sponsor are no longer liable for those payments Buy-Out transactions have been particularly attractive for pension funds in termination/runoff. In a Buy-In transaction, the pension fund buys annuities from a life insurance company such that the annuity payments coincide with the benefit payments of the pension plan. However, in contrast to a Buy-Out transaction, the assets and liabilities as well as the obligation for the pension payments stay with the pension fund. In both cases though, the pension fund securitizes longevity risk in combination with other risks, e.g. interest rate risk or inflation risk. A pure longevity risk transfer to a life insurance company is not possible via bulk annuities.

Until 2006, bulk annuities had mostly been bought by pension funds in termination. New regulatory requirements, however, made bulk annuities more attractive also to other pension funds in the UK and thus increased the demand. At the same time, new providers entered the market in order to benefit from the pension funds' willingness to accept higher prices for bulk annuities. Over the last two to three years, however, market development has slowed down. Some providers have left or had to leave the market thus limiting market capacity. In other countries, bulk annuity markets have just started to develop on a noticeable scale, e.g. in the Netherlands, or have not yet developed at all, e.g. in Germany.

The first solely mortality related transaction was completed in December 2003 when Swiss Re issued the ***mortality bond*** VITA 1. However, this bond did not securitize longevity risk but catastrophe risk in several large populations over a term of 3 years. In case of a massive increase in mortality, e.g. due to a pandemic, investors would have forfeited parts of or even the full terminal payment of the bond. This would have compensated Swiss Re for having to pay significantly more death benefits than expected to its clients.

In November 2004, the European Investment Bank (EIB) in cooperation with BNP Paribas and Partner Re attempted to securitize longevity risk for the first time via a ***longevity bond***. Their bond intended to pay coupons for 25 years according to the survival of the cohort of English and Welsh males aged 65 in 2003, i.e. the more members of that cohort survived the larger the coupons. However, the bond issue failed due to limited demand from the pension and life insurance sector. The reasons for the bond's failure have been discussed extensively both amongst academics and practitioners, and are mainly seen in the capital intensiveness and the relatively 'short' maturity of the bond.[18] Pension funds were asked to pay a huge amount of money at the issue date of the bond which they desired to invest themselves in order to generate investment returns as well as to hedge other risks than longevity. Moreover, pension funds would have received longevity protection only for the next 25 years. Thus, they were not able to hedge the very long-term risk of people becoming 90 and older which is considered the most dangerous component of the longevity risk by many. Nevertheless, the EIB/BNP bond was an important step in the evolution of the longevity market as it highlighted issues to be addressed in subsequent securitization attempts.

Starting from 2005, ***longevity indices*** have been developed. These indices follow the mortality evolution in a given base population, typically the general population of countries like the UK, the US or Germany. Thus, derivatives with payouts depending on the value of a certain index can be used to securitize longevity risk. For more details on longevity indices, see Annotation 1: Longevity indices.

[18] See, e.g., "Pricing Risk on Longevity Bonds" by A. Cairns, D. Blake, P. Dawson, and K. Dowd (2005)

- In general, longevity indices provide the most recent mortality data for a given base population. Such data is generally collected by independent public institutions, very reliable, and publicly available in contrast to the data on specific pension or annuity portfolios.
- Index providers then reformat the data to make them usable for longevity transactions whose cash flows would directly depend on the evolution of a certain index.
- Longevity indices only describe the historical mortality experience and do not offer expectations of future mortality rates. Thus, they can only be used to determine the payout of a longevity derivative at maturity (ex post).
- For pricing a longevity derivative, expected/forward mortality rates must be derived by a statistical or actuarial model. Data for fitting these models can be obtained from the historical index evolution.
- The main goal of longevity indices is to increase market transparency and standardization, and thus capital market investors' trust in the new asset class longevity risk.
- So far, indices have been provided by JPMorgan, Deutsche Börse, Credit Suisse and Goldman Sachs of whom the latter two have terminated their indices again due to limited demand.
- JPMorgan transferred its LifeMetrics Index to the Life and Longevity Markets Association (LLMA) in April 2011. The LLMA is a non-profit organization which aims at improving transparency by setting standards for longevity transactions. Its members are mostly reinsurance companies, insurance companies, and investment banks.

Annotation 1: Longevity indices

The first successful pure longevity transaction was concluded in April 2007 when Swiss Re assumed longevity risk from Friends' Provident. However, even though this transaction was structured in a capital market format, it was still a reinsurance contract.

The first proper capital market transaction was a ***q-forward*** between JPMorgan and the pension Buy-Out company Lucida in January 2008, based on the LifeMetrics Index of JPMorgan. The name q-forward alludes to the standard actuarial notation for the 1-year mortality rate of an x-year old, q_x. In such a q-forward, cash flows are exchanged at maturity of the forward. One cash flows is fixed at inception of the forward and the other cash flow is floating, i.e. it depends on the 1-year mortality rate for an x-year old at maturity of the forward. Thus, if mortality decreases stronger than anticipated over the 10-year maturity of the contract, Lucida will receive more than it pays which will partly offset their higher than expected pension payments. The structure of a q-forward and other longevity instruments will be explained in more detail in section 2.1. Even though the transaction between Lucida and JPMorgan was rather small, i.e. about £100 million, it was a major breakthrough in the evolution of the longevity market.

About half a year later, Canada Life entered into the first ***longevity swap*** with JPMorgan to hedge its longevity risk over the next 40 years. In comparison to the q-forward, in a longevity swap, the floating cash flows depend on multi-year survival probabilities instead of 1-year mortality rates. Moreover, cash flows are exchanged not only once at maturity of the contract but regularly, e.g. monthly or yearly; for details see section 2.4. As opposed to the Lucida q-forward, the Canada Life swap was not based on a mortality index but on the actual mortality evolution in Canada Life's portfolio of contracts.

After the first successful longevity transactions in 2008, several additional transactions have been concluded which we will look at in detail in chapter 5. Here, we just want to briefly mention two of those transactions which have been the first of their kind. In December 2010, Swiss Re launched a bond, the Kortis bond, which securitizes the risk of diverging mortality evolutions in the US and the UK. Swiss Re will benefit from this bond if they cannot diversify their longevity risk in the UK with their mortality exposure in the US. In February 2011, JPMorgan and the pension fund of Pall UK concluded the first transaction on non-retirees' longevity. Before, only longevity risk in the retirement phase had been securitized.

All in all, to the best of our knowledge, there have been 11 publicly announced capital market transactions until September 2011 with a volume of more than £10 billion. The true market volume, however, is probably significantly higher as it is very likely that additional non-public transactions have taken place. It is important to note that – with the exception of the Kortis bond – all public transactions have taken place in the UK. In other countries like the Netherlands, transactions have been discussed but at least no public transaction has been concluded yet.

3.2 Market Participants and Standard Instruments

Participants in the longevity market can be roughly divided into three groups: sellers of longevity hedges (hedge providers), buyers of these hedges (hedgers), and intermediaries. Figure 8 gives an overview of who the typical buyers and sellers of longevity protection are or could be. On the buying side, we obviously find the pension funds which have been involved in most existing longevity transactions. But also annuity providers like Canada Life and pension Buy-Out companies/funds like Lucida have securitized their risk as we mentioned above. Other parties who might be interested in hedging their longevity risk are life settlement or premium finance companies as well as reinsurers who have assumed and bundled longevity risk from primary insurers. However, these parties may also be found selling longevity protection. In fact, the longevity risk of most publicly announced transactions to date has ended up with reinsurers as they have used the longevity risk for diversification with other risks. An analogous diversification argument holds for life insurers and pharmaceutical companies. Life insurers can to some extent offset their mortality risk by longevity risk and pharmaceutical companies generally benefit from people living longer and thus requiring more medical care. However, so far life insurers and pharmaceutical companies have not actively entered the market. The motivation for life settlement or premium finance investors to sell longevity protection is the same as for insurance linked security (ILS) investors, hedge funds, endowments or other capital market investors. They may regard longevity risk as an interesting asset class as they receive a risk premium for taking over longevity risk. Moreover, they could use longevity instruments for diversification with risks from other asset classes as mortality/longevity is believed to be lowly correlated with, e.g., interest rate and stock price movements. Thus, there is a potential for significant demand for longevity instruments in the capital markets. In fact, ILS funds and hedge funds have already participated in some transactions. Life settlement investors may obviously also enter the longevity market on the buying side as they are typically exposed to longevity risk, too. The third important group of market participants, the intermediaries, mostly consists of investment banks. They bring capital market investors and pension funds and annuity providers together and thereby initiate most transactions. Moreover, they sometimes also assume counterparty default risk in the longevity transactions which they are very familiar with from other types of transactions.

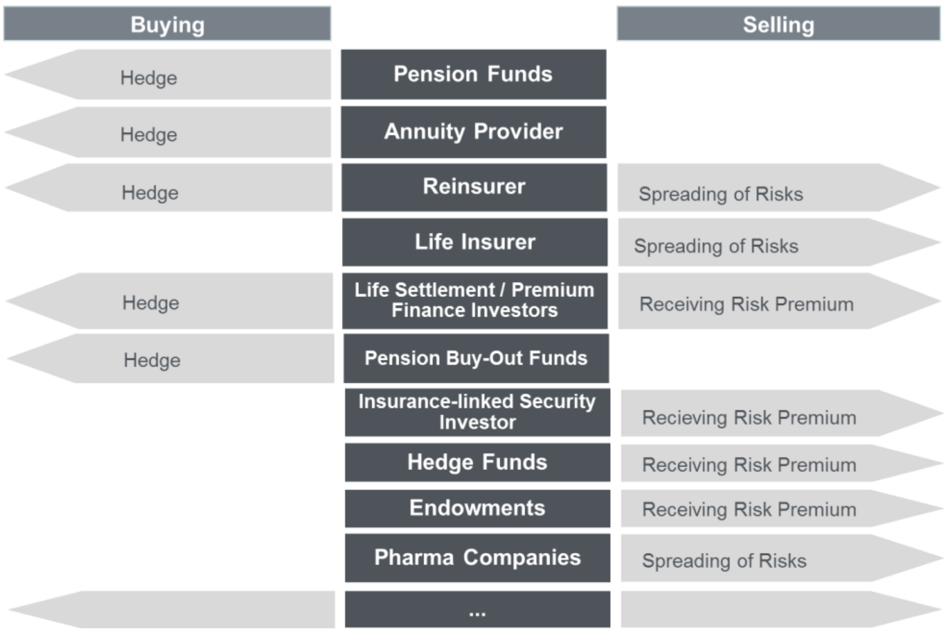

Figure 8: Market participants buying and selling longevity protection

The most successful ***hedging instruments*** so far have been tailored or bespoke longevity swaps as in the above-mentioned Canada Life deal in July 2008. These instruments are particularly attractive to pension funds and annuity providers for three reasons: First, compared to longevity bonds, there is typically no up-front charge when setting up the longevity hedge. Secondly, the tailored swaps are directly linked to the mortality experience of a pension fund's or annuity provider's portfolio which means they provide a perfect hedge. In contrast, instruments linked to a longevity index leave pension funds and annuity providers with some basis risk, i.e. the risk of differing mortality evolutions between their portfolio population and the index population. Finally, longevity swaps with sufficient maturity allow pension funds and insurance companies to hedge all future cash flows to their beneficiaries. Thus, via tailored longevity swaps the entire longevity risk can be hedged whereas other instruments only allow for partial hedges. Therefore, only three rather small transactions have been based on a longevity index. For a more detailed comparison of different hedging instruments, we refer to chapter 2.

In summary, we can state that the longevity market has developed enormously over the last 3 years. However, it is still rather illiquid and intransparent. The number of market participants is small and all transactions are over-the-counter deals between just these few market participants. As a consequence, no pricing information is available which could enhance further transactions. Moreover, as most hedging instruments have been tailored to a specific portfolio of pensioners or annuitants a proper secondary market has not yet developed. However, first steps have been made by some intermediaries who have promised investors to take back longevity instruments if the latter desire to sell.

4 Longevity Hedging Solutions

While the previous chapter has focused on longevity-linked instruments, we now give an overview of general longevity hedging solutions. We start with a general description of possible ways to transfer longevity risk.

4.1 Longevity Hedging Solutions in General

There are two main types of risk transfer. The first one is the so-called insurance approach and the second one is the capital market approach. The insurance approach, which is seen as the traditional way of longevity transactions, includes **Buy-Outs** and **Buy-Ins**. A **Pensioner Buy-Out/Buy-In** is a transaction covering only the current pensioners of the pension scheme. We explain the Buy-Out and Buy-In approach in the subsections 4.1.1 and 4.1.2. The capital market approach is characterized by a **longevity hedge using capital market instruments**, i.e. the purchase of a capital market instrument related to longevity like a longevity swap or a q-forward to reduce or remove the longevity risk; we will discuss this approach in subsection 4.1.3.

4.1.1 Buy-Out

A Buy-Out is the process to buy a bulk annuity contract from an insurance company. It can be defined as follows[19]:

A ***Buy-Out*** *is the process whereby a pension scheme's liabilities are transferred to an insurance company using a bulk annuity contract and the obligation for the pension scheme to provide those benefits is ceased.*

Consequently, the pension scheme passes the assets to an insurance company in exchange for taking on the actual pension liabilities. Thus, the pension scheme loses control over the underlying pool and assumes counterparty risk with respect to the insurance company. Most of the Buy-Outs are Pensioner Buy-Outs and the structure of a Pensioner Buy-Out can be found in Figure 9, where the pension scheme receives the pension benefits from the insurance company and passes them to the pensioners. The pricing of a Buy-Out depends on the insurance company's capital requirements, the estimated improvement in longevity and the market value of assets backing the liabilities. With the introduction of Solvency II, insurance companies need to explicitly assess their longevity risk and have to back their longevity risk exposure by a significant amount of risk

[19] See Lane Clark & Peacock: "Pension Buyouts 2010, Buy-Ins, Buy-Outs and Longevity hedging", page 36.

capital (as can be seen from the results of the latest quantitative impact study [20]). Higher capital requirements for longevity risk under Solvency II are expected to result in higher Buy-Out costs.

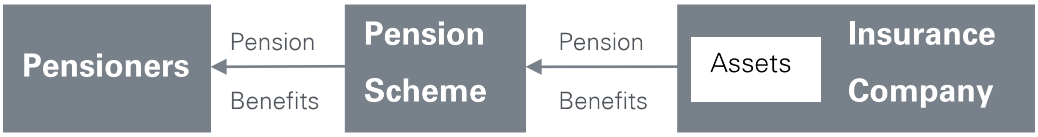

Figure 9: Structure of a Pensioner Buy-Out

4.1.2 Buy-Ins

Next, we explain a Buy-In transaction[21]:

*A **Buy-In** is the purchase of a bulk annuity contract with an insurance company as an investment to match some or all of a pension scheme's liabilities, and therefore reduce risk. Crucially the liabilities remain in the pension scheme and the trustees retain responsibility for them.*

Consequently, a pension scheme purchases a Buy-In policy from an insurance company in order to receive pension benefits from the insurance company, whereby the liabilities as well as the assets, which include the pension entitlements against the insurance company, remain in the pension scheme. The pension benefits are passed to the pensioners of the scheme, as it can be seen from Figure 10. The pricing of a Buy-In is similar to a Buy-Out transaction. Thus, the costs for a Buy-In are also expected to increase because of Solvency II. However, depending on legislation, the counterparty default risk can be significantly larger in a Buy-In compared to a Buy-Out. In a Buy-In, the liability for future pension benefits remains with the pension funds whereas in a Buy-Out, this liability is often transferred to the insurance company.

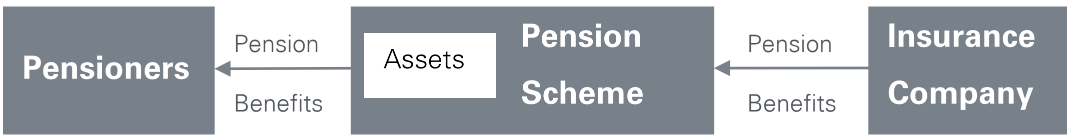

Figure 10: Structure of a Pensioner Buy-In

[20] See, e.g., EIOPA: "EIOPA Report on the fifth Quantitative Impact Study (QIS5) for Solvency II", page 78.

[21] See Lane Clark & Peacock: "Pension Buyouts 2010, Buy-Ins, Buy-Outs and Longevity hedging", page 36

4.1.3 Capital Market Approach

Unlike a Buy-Out or a Buy-In, we focus in the following on longevity hedges based on capital market instruments related to longevity. Obviously, such hedges are open not only to pension funds but also to insurance companies and, theoretically, public pension schemes. However, they are not an equally interesting option for all these institutions. The financial situation of pay as you go pension schemes, for instance, does not only depend on the amount of pensions to be paid but also on the number of future active members making contributions. This would either complicate the structuring of a longevity hedge considerably or decrease the hedge efficiency. Moreover, capital to buy a hedge is typically not available in such schemes. For pension funds and annuity providers, on the other hand, the situation is different as capital is generally available. Here, the efficiency of a longevity hedge particularly depends on whether the amount of longevity risk to be hedged is known. In DB pension plans, the future cash flows are fixed thus facilitating a longevity hedge. The same holds for DC plans during the payout phase. During the deferment phase, however, future pension payments are not yet known in a DC plan. In case annuity rates are only fixed at the end of the deferment phase, this is uncritical. Since the pension fund can change annuity rates according to the recent mortality evolution it is not exposed to longevity risk until the pension payments commence. Should a DC plan contain guaranteed annuity factors, however, longevity hedges may be worthwhile in order to support these guarantees. Setting up such hedges can be rather complex though as it is unknown until the end of the deferment phase how much money is to be annuitized according to the guaranteed annuity factor. The hedge effectiveness and complexity in the case of an annuity provider strongly depends on the design of the annuity products to be hedged. Here, regulatory requirements like surplus participation or lapse options need to be taken into account when setting up a longevity hedge.

Independent of the institution which aims to hedge its longevity risk via the capital markets, such hedges can be divided into two groups: **individual longevity hedges** or **standardized longevity index hedges.**

In an individual longevity hedge, the mortality rates underlying the capital market instrument depend on the actual pension scheme's population. Such a longevity hedge is also called a bespoke or indemnity hedge. An example of an individual hedge is a bespoke longevity swap.

In a standardized longevity index hedge, the mortality rates depend on a longevity index based on a general population. This hedge is also called an index-based longevity hedge and we will use both terms equivalently. Examples of this type are index-based longevity swaps or q-forwards. A detailed description of both types will be given in the following subsection.

4.2 Capital Market Related Longevity Hedge

In this section, we provide more details on longevity hedges based on capital market instruments and give some examples.

4.2.1 Individual Longevity Hedge

An individual longevity hedge is tailored to reflect the actual longevity experience of the pension scheme members. Therefore, the capital market instrument related to this hedge is based on the actual mortality rates of the pension scheme's population. It is an insurance-like approach but there is no funding necessary. In other words, the individual longevity hedge is an exact hedge and is structured as a cash flow hedge.

An example of an individual longevity hedge is an unfunded, bespoke longevity swap. Under the terms of an unfunded longevity swap, the pension scheme pays a pre-defined series of cash flows to the provider of the swap ("fixed leg") and receives the actual pension benefits ("floating leg"). The swap has typically a long time to maturity of sometimes up to 50 years. Due to this long-term nature of the contact, these transactions are typically fully collateralized to mitigate credit (counterparty default) exposure. Consequently, if a pension fund enters into such a swap contract its uncertain cash flows over an unknown future timeframe become certain insurance premiums over a certain premium term. This is also illustrated in Figure 11. Here, the actual pension payments, which depend on the realized mortality rate of the scheme members are indicated by the dashed area between the blue lines. These lines indicate the possible distribution of future pension payments related to future mortality rates. The pre-defined fixed leg curve is the yellow curve in Figure 11 and this fixed leg has to be paid by the pension scheme. It is typically comprised of a best estimate projection of the pension payments plus a longevity hedging fee. The cash flows are typically exchanged on a monthly basis, where only the net amount has to be paid from one party to the other at the end of each month.[22] Possible changes in actuarial assumptions can be reflected in the swap, but might have an impact on its value. It is often agreed that the longevity swap terminates before expiry if the remaining lives or cash flows have dropped below a pre-defined barrier.

Note that the cost of the longevity swap typically consists of two components: the so-called "catch-up" premium, i.e. the difference in value between the best estimate approach applied by the pension scheme and that applied by the swap counterparty, and

[22] As official data is often only available once a year, the payments are based on reasonable expectations and are adjusted as soon as data is available.

the insurance premium or risk premium, i.e. the actual or "true" cost. This shows that the overall costs for a longevity hedge significantly depends on the valuation approach. Here, the provider of the swap often assumes a more conservative estimate of future mortality rates which typically accounts also for future trends, while pension funds often exploit some leeway in the valuation of their liabilities regarding longevity assumptions. Typically, a pension fund underestimates longevity risks. However, this leads to significant longevity hedging costs as a significant part is attributed to the catch-up premium due to different valuation approaches.

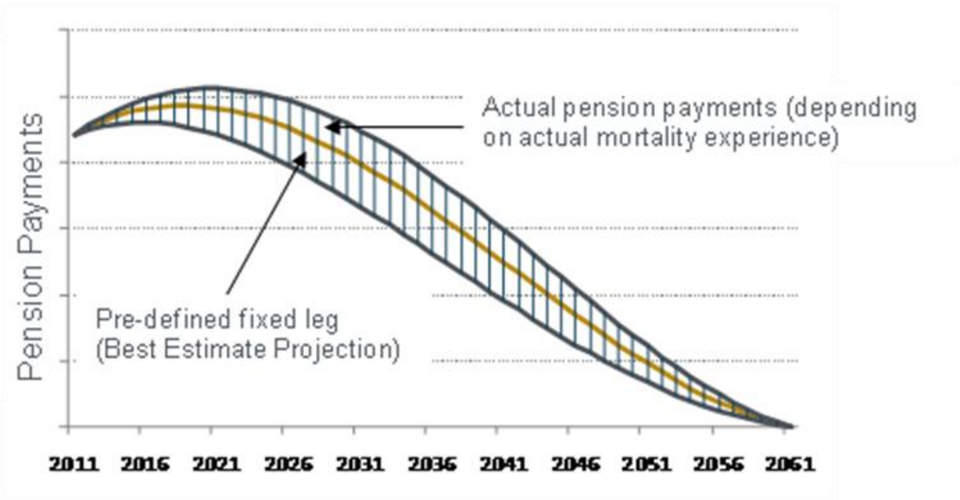

Figure 11: Projection of future cash flows of the pension scheme

Usually, the pre-defined cash flows are linked to inflation (in the same way as the actual pension benefits). Therefore, the level of inflation risk within the scheme is not reduced by this swap. It is important to note that in this hedge the risk associated with the underlying assets is also retained by the pension scheme .

4.2.2 Standardized Longevity Index Hedge

In a standardized longevity index hedge, the underlying mortality rate depends on a longevity index. This index typically reflects the observed longevity of a national population (e.g. UK, Germany, Netherland or USA). The index-based longevity hedge is designed to mimic the sensitivity of liabilities with respect to longevity. In other words, the hedge is set up as a value hedge with a best possible match to a given portfolio. It is not a perfect hedge, but a risk management approach, i.e. a way to reduce the longevity risk, but not to remove the entire risk.[23]

Until now, two financial products for index-based hedging have been established. The q-forward of JPMorgan based on the LifeMetrics Index and an index-based longevity swap.

[23] For more details on longevity indices see chapter 3.

In the following, we will concentrate on the q-forwards. An important feature of a q-forward is the "building block" approach[24]. In this approach, a portfolio of q-forwards is constructed to match the longevity profile of the pension scheme as closely as possible. The starting point for the construction of this portfolio is to build sensitivity blocks, i.e. groups with a similar risk profile related to longevity, e.g. males aged 50-59 or females aged 70-79. The sensitivity blocks depend on the actual population of the pension scheme and the mortality experiences of this population. For each block, the pension scheme enters into a q-forward contract based on the corresponding group (e.g. males aged 50-59). These q-forwards[25] depend on the mortality of the national population measured by the LifeMetrics index since it is an index-based hedge. This leads to a portfolio of q-forwards. An overview of this "building block" approach is given in Figure 12.

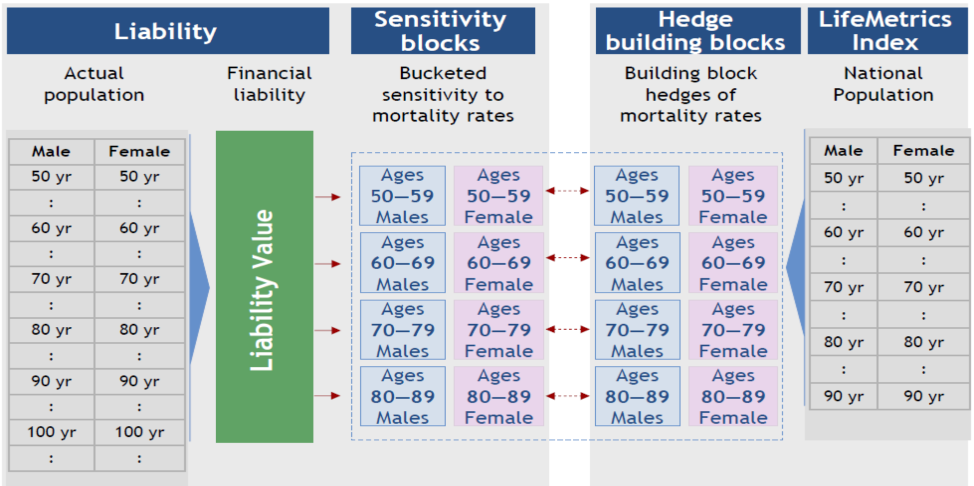

Figure 12: Building block approach (Source: "Longevity Hedges and Longevity Investments" by JPMorgan)

Consequently, a standardized hedge can be tailored to individual pension schemes and this allows for an exact hedging, except for the basis risk. Basis risk means the extent to which the payoff from the hedge (or its valuation) does not correspond with the cash impact (or valuation impact) on the pension scheme's liabilities if a change in longevity occurs. This risk arises because the development of the mortality rates of the national population can differ from the ones of the actual population of the pension scheme.

4.2.3 Comparison of Standardized and Individual Longevity Hedge

In this subsection, we explain the main differences between both types of longevity hedging, where an overview of this comparison is given in Table 11.

[24] See also "Longevity Hedges and Longevity Investments" (2008) by JPMorgan.
[25] A numerical example of a q-forward contract can be found in Subsection 2.1.2.

Type of hedge	Advantages	Disadvantages
Standardized longevity index hedge	• Cheaper than customized hedge (lower set-up / operational cost) • Comprehensive and objective calculation of reference index • Potentially more liquid and flexible • Risk transfer also for very special pension funds (e.g. chimney sweeper) possible	• No perfect hedge: o Population Basis Risk (and idiosyncratic risk) o Structural risk o Rollover risk
Individual longevity hedge	• Perfect hedge • Therefore, no basis risk	• More expensive (high set up / operational risk) • Provision of detailed data • Lower liquidity due to missing standardization

Table 11 : Advantages and disadvantages of hedging alternatives

A standardized longevity index hedge has the advantage that it is cheaper than an individual hedge because the set-up/operational costs are lower. Besides that, the calculation of the reference index is comprehensive and objective. Thus, a standardized longevity hedge attracts more investors and so, such a hedge is potentially more liquid than an individual hedge. Furthermore, it is the only possibility for very special pension schemes (e.g. chimney sweepers) to implement a longevity hedge using capital market instruments. This is because not enough investors are attracted by an individual hedge of such a very special pension scheme given the lack of data, e.g. the mortality experiences of this group of workers. However, a standardized longevity index hedge has also some disadvantages. It is not a perfect hedge because of the basis risk, the idiosyncratic risk and the rollover risk. Basis risk is related to any differences between the actual pension members and the reference index. Idiosyncratic risk refers to the risk of more or less pensions dying by chance in a rather small portfolio. Rollover risks arise as the standardized contracts typically have shorter maturities than individual hedges and therefore these contracts have to be rolled into new contracts at expiry. Note that due to the shorter maturities it might be difficult to hedge long-term trends in longevity. Additionally, there is also a structural risk through a limited range of available ages and terms. The structural risk is similar to a key-rate interest rate hedge where only some buckets are hedged and not each maturity.

Unlike an index-based hedge, the individual longevity hedge is a perfect hedge without any basis risk. But it is also necessary to provide detailed data. Therefore, the implementation of this hedge takes a longer time than in an index-based hedge. Moreover the liquidity is lower due to missing standardization.

Finally, we explain the pension funds' and the capital market's points of view related to the hedging alternatives. The pension funds' points of view depend on the size of the fund. For a sufficiently large pool, we can reasonably expect that the longevity experience of the pool match with the longevity experience of the index leading to a low basis risk. However, we also observe that larger pension schemes have sufficient liabilities to actually execute individual hedges and are large enough to be able to spread fixed costs over a large transaction. Therefore, it is hard to see a financial reason for a large pension fund to pursue an index-based hedge. For smaller pension schemes, the basis risk is an important metric to analyze since the smaller the size of the fund is the higher the basis risk (and also the idiosyncratic risk) can potentially be. Consequently, a standardized longevity index is less favorable for small pension schemes. The capital market point of view is different. For investors, industry standards are necessary for a more liquid longevity capital market. Thus, they prefer an index-based longevity hedge since a longevity index increases transparency and raises standards. In chapter 6, we discuss in more detail how the demands of pension funds and capital market investors can possibly be aligned.

4.3 Longevity Hedging in a Liability Driven Investment (LDI) Context

An unfunded longevity swap is a hedge only against longevity risk, whereas the risk associated with the underlying assets is retained by the pension scheme. Thus, the longevity swap can be combined with a Liability Driven Investment Strategy which hedges the remaining capital market risks. This strategy is called a **Do-It-Yourself (DIY) Buy-In** or a **Synthetic Buy-In** and can be defined as follows[26]:

*A **Do-It-Yourself (DIY) Buy-In** is the process whereby a pension scheme purchases inflation, interest rate and longevity swaps to achieve similar levels of risk transfer to a Buy-In or Buy-Out. It is sometimes also called Synthetic Buy-In.*

The structure of a DIY-Buy-In is shown in Figure 13. It consists of a longevity swap and a separated hedge for interest-rate risk (and possibly inflation risk). The counterparty risk is reduced by collateralization. Consequently, a DIY-Buy-In is a full hedge of longevity risk combined with a hedge against interest-rate and inflation risk, where the pension scheme retains the underlying assets. However, remaining risks can exist due to some residual risks from the interest rate and inflation hedge as well as through possible investments into other growth assets (e.g. equities, corporate bonds, etc.). The resulting asset portfolio of a pension scheme is shown in Figure 14. These remaining risks can be avoided by a so-

[26] See Lane Clark & Peacock: "Pension Buyouts 2010, Buy-Ins, Buy-Outs and Longevity hedging", page 36

called Full Do-It-Yourself Buy-In („DIY Buy-In") or Full Synthetic Buy-In (see Appendix 1.1 for more details).

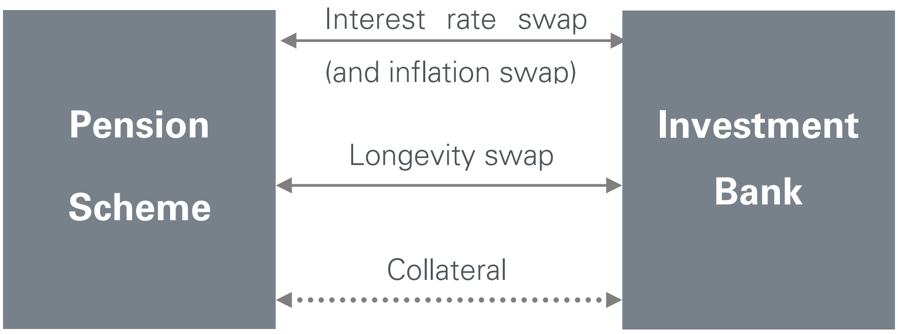

Figure 13: Structure of a Do-It-Yourself Buy-In

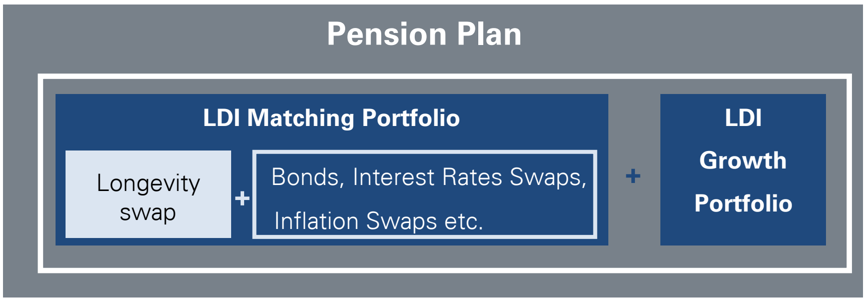

Figure 14: Pension Plan Portfolio

4.4 Comparison of General Longevity Hedging Solutions

In this last section, a comparison between the traditional longevity transaction and the longevity hedge using capital market instruments is given. In the following, "longevity hedge" refers to any capital market related longevity hedge whereas "traditional longevity transactions" include Buy-Ins and Buy-Outs.

The first difference is the costs in terms of initial investment of the transaction. Typically, a longevity hedge based on swaps or other derivatives is unfunded, but there could also be a funding strain as in case of a longevity bond. In a traditional longevity transaction, assets (or at least investment strategies) are passed to the hedge provider on first day of the deal. Therefore, the flexibility regarding the pension scheme's assets is limited in a traditional longevity transaction. In a longevity hedge, the pension scheme retains the inve stment control and the return on the assets, but bears also the associated risk.

Typically, only the longevity risk is transferred to the capital market in a longevity hedge. Therefore, a longevity hedge only addresses longevity risk and ignores other LDI risks. However, it can be combined with a DIY-Buy-In to hedge against all risk factors of the liabilities. In a Buy-In or Buy-Out, the longevity risk as well as the investment and inflation risk is transferred to the counterparty. Thus, all risk factors of the pension scheme's liabilities are considered.

	Longevity Hedge	Buy-In or Buy-Out
Cost	Typically unfunded – paid for 'as you go' – but could be funding strain	Assets (or at least investment strategy) passed to the provider on day 1
Flexibility	Retains investment control and associated risk/return	Flexibility allowed if pre-written into contracts, but not on investment strategy
Risk transferred	Longevity	Longevity, investment and inflation risk all transferred
LDI risks	Addresses only longevity risk but can be combined with a LDI strategy (DIY Buy-In)	Considers all risk factors of liabilities
Collateral	Typically two-sided	Typically one- sided
Structures	Capital market ISDA or Insurance Regulator policy	Typically Insurance Regulator policy

Table 12: Comparison of Longevity hedge and Buy-In/Buy-Out

Normally, collateralization is done to reduce counterparty risk in each longevity transaction. The collateral is usually two-sided in a longevity hedge, whereas it is usually one-sided (from the hedge provider to the pension scheme) in traditional transactions. Besides that, longevity hedges come under the regulatory standards of the ISDA, whereas the Insurance Regulator is responsible for Buy-Ins and Buy-Outs. An overview of this presented comparison can also be found in Table 12.

Finally, we analyze the longevity hedging solutions regarding the transaction volumes and their funding impact, which is done in the next two subsections.

4.4.1 Market Transaction Volumes

In the last three years, a trend towards longevity hedging, in particular longevity swaps, is observable, which can also be seen in Table 13. There are several reasons for this trend.[27]

[27] See also Lane Clark & Peacock: "Pension Buyouts 2010, Buy-Ins, Buy-Outs and Longevity hedging"

First of all, after the bankruptcy of Lehman Brothers in 2008 the prices for Buy-Outs/Ins increased, which led to a rising demand for alternative hedging solutions. This was also reinforced by the fact that the pension scheme's sponsors wanted to reduce counterparty risk after Lehman Brothers' insolvency. As mentioned before, capital requirements for Buy-Ins/Outs are expected to increase due to Solvency II. Thus, insurance companies typically demand higher safety margins to be able to meet future capital requirements, wherefore pension schemes' sponsors tend to avoid traditional longevity transactions. Moreover, there was an increased competition among the hedge providers resulting in lower prices for longevity swaps. Consequently, longevity swaps became very attractive for pension schemes which explains the fact that the transaction volume of longevity swaps has increased in the last years.

	2007	2008	2009	Q1 2010	Total
Buy-Outs	1.7	4.2	1.5	0.3	7.7
Buy-Ins	1.2	3.7	2.2	0.7	7.8
Longevity Swaps	0.0	0.5	3.8	3.0	6.8
Total	2.9	7.9	7.5	4.0	22.3

Table 13: Market transaction volumes £ billion with focus on the UK (Source: Lane Clark & Peacock)

4.4.2 Funding Impact

Another very important implication of the choice for a certain hedging solution is its impact on the funding level of the pension plan. Basically, all hedging solutions have some impact on the funding level, however, a Buy-Out transaction can lead to a significant drop in funding level. Therefore, a hedging approach's impact on the funding level has to be considered carefully.

In the following we will demonstrate the impact of different hedging solutions on the funding level with the help of a simple example. Assume a pension scheme with EUR 200m of funded liabilities equally split between pensions in payment and non-pensioners (which could include some active members) and EUR 180m invested in assets split about 70:30 between gilts and equities. This results in a surplus deficit of EUR 20m and a funding level of 90%. Further assume that the pension fund intends to hedge its pension liabilities and finance the hedge by the gilt holdings at an additional cost of EUR 5m. For comparison, we assume that these additional costs are the same for all hedging solutions. This leads to an increase in the surplus deficit of EUR 5m independent of the particular hedging approach. Table 14 summarizes the initial situation and demonstrates also the impact of different hedging solutions on the surplus deficit and the funding level. Both, the classical Buy-In and also the Synthetic Buy-In using a longevity swap, lead only to a moderate decrease of the funding level. The main difference is that in case of a Synthetic Buy-In, the pension fund still controls all the assets including gilts while in the classical Buy-In, the policy is financed by the gilt holdings. In contrast, a Buy-Out transaction reduces both the liability and asset values. This leads not only to a significant drop in funding level but also to a higher funding level volatility if the assets are not reallocated accordingly.

This simple example shows that, independent of the hedging solution, its impact on all relevant pension plan risk figures has to be considered carefully.

in million EUR	Initial Situation	Post Buy-In	Post Buy-Out	Post Synthetic Buy-In
Pensioners	100	105*	0	100
Non-pensioners	100	100	100	100
Total liability value	200	205	100	200
Buy-In policy	0	105	0	-5*
Index-linked gilts	125	20	20*	125
Equities	55	55	55	55
Total assets	180	180	75	175
Surplus/(deficit)	(20)	(25)	(25)	(25)
Funding level	90%	88%	75%	88%

Table 14: Impact of different longevity hedging solutions on funding level
*: Includes hedging costs of EUR 5m.

5 Examples of Completed Longevity Market Transactions

As mentioned before, there are different types of longevity transactions: traditional longevity transactions (i.e. the so-called insurance approach: Buy-Out and Buy-In) and transactions using capital market instrument such as longevity swaps. In this chapter, several examples of completed transactions for each type are shown. All of them took place in the UK, which will be discussed in more detail in the following chapter.

5.1 Buy-Outs and Buy-Ins

Table 15 gives an overview of some Buy-Outs in the UK, where the value of liabilities ranges from £230 million to £1,100 million. One of the largest Buy-Out transactions was the Thorn Buy-Out[28] in 2008. Thorn was a lighting and electrical retailer and the Thorn Pension Fund consists of former staff of the company, altogether 15,000 members. The trustees of the Thorn Pension Fund decided to buy a bulk annuity contract from Pension Corporation. Thereafter Pension Corporation provided an individual policy to each member of the pension fund including an increase of the members benefit by 5%. The Pension Fund was winded up and so all investment and longevity risk were removed from the fund.

An overview of Buy-In transactions can be seen in Table 16. This is similar to the range in Buy-Out transactions. A prominent Buy-In example is the British Airway's (BA) Pension Scheme Buy-In[29] with Rothesay Life in 2010, which affected one of the two defined

Pension Fund (Hedger)	Date	Value of liabilities in £m	Provider of Longevity Hedge
Thorn	December 2008	1,100	Pension Corporation
Rank Group	February 2008	700	Rothesay Life (Goldman Sachs)
Delta	June 2008	450	Pension Corporation
Powell Duffryn	April 2008	400	Paternoster
Leyland Daf	January 2009	230	Pension Corporation

Table 15: Overview of Buy-Outs in the UK (Source: Tower Watson)

[28] See also http://www.prnewswire.co.uk/cgi/news/release?id=245071

[29] See also http://www.independent.co.uk/news/business/news/ba-buys-16313bn-pension-insurance-from-goldmans-2017288.html

benefit pension schemes sponsored by British Airways. This Buy-In covered 20% of the pension payments to the scheme members.

Pension Fund (Hedger)	Date	Value of liabilities in £m	Provider of Longevity Hedge
British Airways	July 2010	1,300	Rothesay Life (Goldman Sachs)
Cable & Wireless	September 2008	1,000	Prudential
P & O	December 2007	800	Paternoster
Merchant Navy Officers Pension Fund	September 2009	500	Lucida
Cadbury	December 2009	500	Pension Corporation

Table 16: Overview of Buy-Ins in the UK (Source: Tower Watson, Hymans Robertson)

Rothesay Life, subsidiary of Goldman Sachs, pays the benefits of those pensioners to the trustees and receives predetermined returns from the pension scheme assets, which are still retained by the pension scheme. Basically, this transaction is an insurance policy for increasing life expectancy of the scheme members. After the announcement, some critics arose because of the small amount of liabilities which were covered (only 20%) and because of the fact that additional returns on the assets are reduced due to this type of arrangement.

5.2 Capital Market Transactions

Next, we give some examples of longevity transactions using capital market instruments. An overview is shown in Table 17, where we can see that the value of liabilities in some transaction is much higher than in traditional longevity transactions. So far, the BMW longevity swap[30] has been the largest longevity transaction with a liabilities' value of £3,000 million. It was a bespoke longevity swap between BMW (UK) Operations Pension Scheme and Abbey Life (subsidiary of Deutsche Bank), which was fully collateralized. This swap covered the liabilities of about 60,000 pensioners for the rest of their lives, i.e. the swap ends when the last pensioner or spouse dies. Part of the risk was transferred to

[30] See also http://www.ipe.com/news/bmw-uk-pension-completes-3bn-longevity-deal_34134.php

some reinsurers such as Hannover Re, Pacific Life Re and Partner Re. Furthermore, Deutsche Bank bears also a large part of the longevity risk.

Pension Fund / Annuity Provider (Hedger)	Date	Term	Value of liabilities in £m	Structurer/ Provider of Longevity Hedge
Lucida	January 2008	10 years	NA	JPMorgan
Canada Life	July 2008	40 years	500	JPMorgan
Babcock International	June 2009	50 years	1,200	Credit Swiss
RSA Insurance Group	July 2009	Run-off	1,900	Rothesay Life (Goldman Sachs*)
The Royal Borough of Windsor and Maidenhead	December 2009	NA	750	Windsor Life (Swiss Re*)
BMW	February 2010	Run-off	3,000	Abbey Life (Deutsche Bank*)
Pall Corporation	February 2011	10 years	70	JPMorgan

Table 17: Exemplary transfers of longevity risk to the capital market (Source: Lane Clark & Peacock). *: Parent company of the hedge provider.

The first index-based longevity swap was the deal between the Pall (UK) Pension Fund and JPMorgan in February 2011. This longevity swap[31] covered 1,800 scheme members with a 10-year term. It was the first swap including non-retired plan members that were former employees of Pall. This swap was based on the LifeMetrics Longevity Index. Pall receives money from JPMorgan if the life expectancy is higher than assumed in order to offset the additional retirement payments. However, there are also some disadvantages of the deal. The term is very short, which is not necessarily convenient for hedging longevity risk because it is rather a long-term risk. Besides that, only 1,800 scheme members are covered leading to significant basis risk. Therefore, it is not a full transfer of all longevity risks, but a risk management approach concerning longevity.

[31] See also http://www.risk.net/life-and-pension-risk/news/2024030/jp-morgan-completes-longevity-swap-retirees

The swaps of RSA Insurance Group with Rothesay Life and Goldman Sachs were the first Do-It-Yourself Buy-Ins[32]. As mentioned above, the Do-It-Yourself Buy-In is a combination of two different swaps. The value of liabilities covered by this transaction is £1,900 million, which represents 55% of the whole value of the pension liabilities. The structure of the deal can be seen from Figure 15. Consequently, it is a partial hedge (55%) of all liability risks including longevity, inflation, and interest rate risks. The longevity swap is funded with assets which are still owned by the pension scheme and which consist of UK government-backed securities. Moreover, the counterparty risk is reduced by collateralization.

As mentioned above, all large longevity transactions have only taken place in the UK. We will explain this in the next chapter and give an outlook about possible other longevity markets.

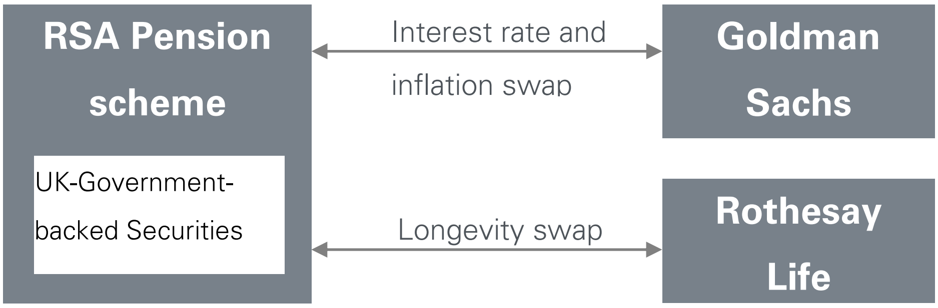

Figure 15: Structure of the RSA Insurance Group DIY Buy-In

[32] See also Lane Clark & Peacock: "Pension Buyouts 2010, Buy-Ins, Buy-Outs and Longevity hedging"

6 Further Evolution of the Longevity Market: Prerequisites and Possible Regulatory Support

As we have seen in the previous chapters, first steps towards a capital market for longevity risk have already been made. However, all large transactions have taken place in the UK so far. A global market for longevity risk does not yet exist. Moreover, the UK market is still in its infancy: The market structure is not yet efficient enough to generate a steady flow of transactions. Furthermore, transparency and standardization are rather low.

In order to establish a liquid global market for longevity risk, several issues need to be addressed as we will show in this chapter. We start with an explanation why longevity transactions have taken place in the UK in the first place as this indicates what needs to be done in other countries in order to develop longevity markets. Subsequently, we discuss possible market structures as well as requirements on regulation and accounting which would support the development of longevity markets.

6.1 The UK Longevity Market and other Possible Longevity Markets

The most important reasons for the development of a longevity market in the UK have been legislation and regulation. They have led to an assessment and an awareness of longevity risk which is more realistic than in other countries. In the 1995 UK pension act , two crucial requirements were introduced. First, members of pension plans have to nominate trustees who are personally liable and thus thought of as managing the plans in the best interest of their members. Companies are less involved in the management of their pension funds and merely act as sponsors. Secondly, mandatory indexation of pension benefits led to additional risk for pension plans and a steady increase in liabilities. In the 2004UK pension act , risk-based levies were introduced. Thus, trustees improved risk management and the assessment of all risks their funds are exposed to. Moreover, a new regulatory authority called Pension Regulator was introduced, which passed the responsibility for the pension plans again more to the managers and shareholders of the company. As a result of all these changes, the trustees as well as the sponsors of a pension plan are now more interested in risk mitigation, e.g. via longevity transactions.

Another issue which distinguishes the UK pension system from other pension systems is the mortality assumptions used for computing pension liabilities. In general, it can be said that, in the UK, a stronger and more realistic increase in future life expectancies is assumed than in other countries. This is a crucial factor in the development of a longevity market. If pension funds use overly optimistic mortality assumptions and thus consistently underestimate their liabilities longevity hedges are much more difficult to afford: The hedge provider typically uses more conservative mortality assumptions thus leading to a significant gap between his price demands and the price a pension fund is willing and able to pay for a longevity hedge. In case of significantly different mortality assumptions, a pension fund does not only have to pay a risk premium for the actual longevity risk but also a significant catch-up premium as described in subsection 4.2.1. The latter is needed to close the gap between the liabilities estimated by the pension fund and the hedge provider. If this catch-up premium is too large longevity transactions are hampered as a pension fund has to invest a significant amount of money at once to complete a hedge.

All developments outlined above have played a major role in preparing the ground for a longevity market in the UK. The next market is most likely to emerge in a country with similar prerequisites. These prerequisites include, in particular, a realistic valuation of pension liabilities based on up-to-date mortality assumptions and risk based capital requirements which reveal the significance of longevity risk. Only then pension funds will be willing to accept investors' price demands for taking over longevity risk. Other important factors will be the available data, the size, and the funding levels of pension funds. Before a longevity hedge can be implemented, the risk situation has to be analyzed thoroughly; for this, sufficient and reliable data are essential. Moreover, negotiations with hedge providers may take some time which can make longevity transactions rather expensive. Thus, they are an interesting risk mitigation tool only for sufficiently large pension funds. Finally, high funding levels are helpful as this reduces the catch-up premium. Moreover, in countries with rather low funding levels, trustees' focus will probably be more on increasing the funding level first instead of spending some of the little available capital on (partial) longevity hedges.

From this perspective, the next longevity market seems most likely to emerge in the Netherlands. Pension funds play a significant part in the provision of old age income in the Netherlands and are thus quite large in general. Moreover, mortality assumptions are updated on a regular basis with the last update having taken place in September 2010. This update led to an average increase in liabilities of almost 11% at once thus clearly highlighting the significance of longevity risk. Consequently, there is interest in longevity hedging and many experts think it is only a question of time when the first pure longevity transaction will be completed. A couple of Buy-Out transactions have already taken place.

Also in other countries, longevity transactions have been considered or, in fact, already completed. In the US, Prudential Financial took over longevity risk from the Hickory Springs Manufacturing Company's pension scheme via a Buy-In transaction in May 2011. In Chile, the World Bank and the local regulator attempted to issue longevity bonds in 2008 and 2009 in order to support a sustainable pension system. The bond issues were not successful mainly because of reservations of the domestic insurance companies. The interest in similar bond issues, e.g. in Mexico, shows that the attempts in Chile will probably not be the last of their kind. In Canada, longevity hedges have been discussed for quite a while and it seems that negotiations are coming to a successful close in the near future. Also in Israel longevity transactions have been considered.

Thus, there clearly is an increasing recognition of longevity risk globally and a desire to hedge this risk. In order to maintain and further improve the sustainability of worldwide pension systems, this development should be actively supported by governments, regulators, and international institutions. Capital market transactions seem to be a particularly effective risk mitigation tool as they allow for a wide spread of longevity risk in the global financial markets.

6.2 Possible Next Steps in Longevity Markets Development

The UK market has shown that longevity instruments can be a valuable risk mitigation tool for pension funds and annuity providers. In order to make them most effective, in the UK and especially in other countries, several issues need to be addressed:

- The significance of longevity risk and the benefits of a mitigation of this risk have to be made transparent to pension funds and annuity providers (benefit of longevity hedges).
- Longevity risk hedges via capital market instruments must result in an appropriate risk capital relief for pension funds (attractiveness of longevity hedges).
- Capacity for longevity risk in the capital market has to be increased by making investors feel comfortable with longevity risk.
- An efficient market structure has to be established which reflects the requirements of all market participants.
- Standardization, liquidity, and transparency have proven to be crucial for the development of any financial market and thus need to be addressed in the longevity case as well.
- Reference points for the pricing of longevity risk should be provided such that prices for longevity instruments can finally be derived from the market instead of negotiating them anew in each transaction.

In the following subsections, we discuss each of these points in more detail.

6.2.1 The Benefit of Longevity Hedges

In the UK, the application of realistic mortality assumptions as well as risk based capital requirements has shown pension funds their longevity risk exposure quite clearly. As a consequence, they have started securitizing this risk. In order to develop a longevity market also in other countries, similar regulatory requirements must be implemented.

In Europe, Solvency II is a big step in this direction. Its general concept of economic or "mark-to-market" valuation, i.e. valuation via market prices or, if no market prices are available, valuation according to market principles, will force annuity providers to assess their longevity risk on a realistic basis. In the case of mortality/longevity, this implies the use of best estimate mortality tables (company specific) in combination with a risk margin for uncertainty with respect to non-hedgeable risks. Even though pension funds will probably not be regulated under Solvency II, similar risk based rules may be implemented for them.[33] Note that once a deep and liquid longevity market has developed mark-to-market valuation of longevity risk will be possible. Thus, a longevity market could also be very helpful in determining appropriate capital requirements. Regulatory systems in non-European countries should also be adjusted such that they allow for a realistic assessment of longevity risk.

Besides the regulatory requirements, accounting rules are crucial for a realistic assessment of longevity risk. In some countries, certain mortality tables and fixed interest rates are prescribed for the computation of pension liabilities. Pension funds are obliged to use these specifications, e.g. for tax reasons, even if they know that they are not realistic for their specific case. Here, discussions with the International Accounting Standards Board (IASB) and governments are necessary to ensure that mortality and interest rate assumptions are always up-to-date and that realistic values for pension liabilities are disclosed. When this has been achieved there is a good chance that pension funds and annuity providers will address this risk and consider mitigating their longevity risk, possibly via capital market transactions.

6.2.2 The Attractiveness of Longevity Hedges

Once pension funds and annuity providers see the benefits of mitigating their longevity risk, respective tools have to be sufficiently attractive to them. Thus, longevity hedges must be adequately acknowledged in terms of capital requirements and accounting.

A pension fund or annuity provider will only hedge its longevity risk if the awarded risk capital relief is sufficiently large. If this capital relief is rather small, it will generally be cheaper for the pension fund to keep the risk and the fund will thus not seek longevity risk securitization. However, this does not mean that the capital relief for longevity risk only has to be attractive. When entering into a longevity hedge, a pension fund automatically takes on counterparty default risk and – in case of a standardized hedge – basis risk. Risk

[33] See e.g. EIOPA (2011): "Response to Call for Advice on the review of IORP Directive 2003/41/EC"

capital charges for these risks have to be appropriate such that, overall, a pension fund still perceives a significant capital relief when hedging its longevity risk

In the UK, the risk based levies introduced as part of the Pension Act in 2004 have seemingly implied capital reliefs which are sufficiently large to make longevity transactions attractive. Capital relief was also a crucial element in discussions surrounding the longevity bonds in Chile. There, the World Bank lobbied for significant capital relief as otherwise, failure of the bond issues would have been certain right from the start. For longevity markets outside the UK to emerge and for further development of the UK market, it is therefore crucial that regulatory systems worldwide allow for sufficient capital reliefs in case of longevity hedging. This holds for Solvency II and its equivalent for pension funds in Europe in particular. Discussions with the European Insurance and Occupational Pensions Authority (EIOPA) would be very helpful here to raise awareness of this issue.

At the same time, longevity instruments must be attractive from an accounting perspective. Accounting rules need to allow for an adequate valuation of longevity instruments on the balance sheet such that fluctuations in liability positions can be offset. Only if the longevity linked assets and the longevity prone liabilities move in line, the balance sheet volatility is reduced. As longevity transactions are usually collateralized in order to minimize counterparty default risk, also the collateral positions have to be taken into account adequately. Also on these issues, discussions with the IASB are desirable.

Finally, governments need to adjust legislation, local accounting rules and taxation such that the outlined prerequisites for successful longevity transactions are met. As an example, local accounting rules make longevity hedges rather unattractive for German insurance companies at the moment. The prudence principle does not allow insurance companies to value longevity instruments at a higher value than the purchase price. Thus, if longevity and consequently the fair value of a longevity hedge increase insurers will not be able to show this increase in value on their statutory balance sheets. Moreover, policyholders are entitled to a certain part of an insurer's unrealized gains every time they receive payments. Therefore, an increase in fair value of a longevity hedge can only partly be used to offset an increase in liabilities as some parts of the increase need to be realized for policyholder participation. Similar obstacles exist in other countries thus highlighting the need for adjustments in order to make longevity hedges work. Once these issues get addressed, it is quite likely that the demand for longevity transactions via the capital markets will increase substantially.

6.2.3 Market Capacity

In most existing transactions, the longevity risk has ended up with reinsurers. Thus, even though the longevity transactions may be structured as capital market instruments their effect is basically the same as of reinsurance contracts, i.e. the risk is transferred within the insurance sector. The reinsurers' demand for longevity risk is likely to maintain on the current level for a further couple of years as there are still opportunities for diversification of longevity risk with other risks. However, once reinsurers' longevity books exceed their books on other risks, their demand for longevity risk is likely to decrease. It is not clear when this will be the case exactly but compared to the global longevity exposure of pension funds, the overall reinsurance capacity appears rather small. To illustrate this, only 2% of the global life insurance premiums in 2009 have been ceded to reinsurers with the longevity exposure in the pension sector still being significantly larger than the combined mortality and longevity exposure in the life insurance sector (cf. Table 1: Longevity/mortality exposure in the US and the UK (Data from: OECD, UK Pensions Regulator, US Council of Insurers, Moody's, JPMorgan). Hence, if pension funds and annuity providers want to hedge their longevity risk on a larger scale additional capacity will have to be provided rather soon.

This capacity could come from capital market investors looking for alternative asset classes, e.g. insurance-linked securities (ILS) funds, hedge funds, private equity investors, or institutions which generally benefit from people living longer, e.g. pharmaceutical companies. However, for pharmaceutical companies, longevity risk does not seem to be an interesting investment yet. In the current state of the financial markets, the issuance of standard capital market instruments is more favorable for them in order to raise capital. However, this may change should their cost of capital increase at some point. In that case, they may be looking out for a risk premium on a risk which they can partially offset with their business concept.

In order to get new investors attracted to the asset class longevity risk, their knowledge about this risk is crucial. Longevity risk is significantly different in nature from the risks in more common asset classes like stocks or bonds and this nature has to be explained plainly and clearly to potential investors. So far, most of them know only little about longevity risk and they will only enter the longevity market on a larger scale if they fully understand what they are buying. However, the currently low returns on most asset classes and the demand for asset classes with low correlation to traditional asset classes could drive new investors to the longevity market. In their search for attractive returns they may well be interested in taking over, at an adequate price, a risk which is supposed to be lowly correlated with other (financial) risks. Thus, as soon as longevity risk is more widely understood and pension funds and annuity providers are willing to pay reasonable prices for longevity hedges, there is a good chance that the capital markets can and will provide the required capacity.

6.2.4 Market Structure

As we have already indicated in subsection 4.2.3, pension funds and annuity providers on the one hand and capital market investors on the other hand have different requirements on longevity instruments. Pension funds and annuity providers in general want to fully securitize their longevity risk. This means in particular that they look for instruments which are tailored to their specific portfolio and which possibly include the option to adjust the instrument if their portfolio changes, e.g. due to new members entering the pension scheme. Moreover, they prefer instruments which run until the last member in the pension plan or annuity portfolio dies which implies maturities of 30 years and more. Capital market investors, on the other hand, are typically interested in asset classes with maturities of at most 10 or 12 years. They do not accept longer maturities, in particular, if there is no liquid (secondary) market as it is the case for longevity risk. Moreover, they prefer standardized instruments, i.e. instruments based on mortality indices for which data is publicly available. These requirements of pension funds, annuity providers and capital market investors seem incompatible at first sight but, as the UK market has shown, transactions are possible nevertheless. In order to make the market deep and liquid, an efficient market structure is required though.

Reinsurers may be the crucial link between pension funds, annuity providers and capital market investors as they may be able to align the different requirements. They can assume portfolio specific longevity risk with long maturities thus providing pension funds and annuity providers with the desired hedge. This could be done via traditional reinsurance contracts which typically also cover other risks than longevity or capital market instruments for pure longevity transfers. If a reinsurer concludes several such transactions he can then bundle the longevity risk from several counterparties and diversify fund specific risk components or unsystematic longevity risk which capital market investors are not particularly interested in. This includes idiosyncratic risk, i.e. the risk of random fluctuations in small portfolios, but also basis risk, i.e. the risk that mortality of a particular (sub)population evolves differently from the general mortality trend. In general, reinsurers should be comfortable with taking over these kinds of risk as the pooling of different portfolios is part of their core business concept. In a second step, reinsurers can then use their knowledge on longevity risk in order to analyze the systematic risk in the portfolio they have acquired. Parts of this systematic risk can finally be transferred to capital market investors via index-based transactions with widely accepted maturities. Obviously, the population in a reinsurer's portfolio may still be somewhat different from the population underlying a certain mortality index. Due to the pooling the remaining basis risk should be rather small when compared to the systematic longevity risk. More importantly, the reinsurer would be left with some of the very long-term risk. Even if he enters a value hedge which securitizes changes in the liabilities over the next, say, 10 years it is not certain that the reinsurer will be able to buy a new hedge after those 10 years. On the other hand, taking over such very long-term risks for an appropriate risk premium is again part of reinsurers' business concept. Therefore, it is very likely that reinsurers will become more active in taking over longevity risk from the pension and annuity sector if they can transfer significant portions of the systematic longevity risk to the capital markets. This has also worked in other markets before, e.g. the market for hurricane risk in the US where risk is securitized via so-called CAT-bonds.

The depicted market structure with reinsurers as some kind of intermediaries who securitize only systematic longevity risk via index-based transactions would also help in the creation of a secondary market. The high degree of standardization and the moderate maturities would certainly facilitate the trading of longevity instruments between investors in case of an investor deciding to leave the market.

Unfortunately, a market structure where reinsurers assume portfolio specific risk and subsequently hand the systematic risk over to the capital markets has not developed yet. So far, pension funds and annuity providers have transferred their longevity risk to the capital markets directly in most transactions. This does not appear to be the most effective approach. Direct transactions only work for pension funds of a certain size, in particular due to costs in setting up such transactions. Moreover, as we have outlined above, the demands of pension funds and capital market investors with respect to the underlying populations and the maturities in particular are difficult to align in direct transactions. Thus, it is quite likely that, compared to the number of deals negotiated, only few have actually been concluded. This clearly affects market liquidity. Nevertheless, such direct transactions from pension funds and annuity providers to the capital markets are important steps on the way to a more standardized and liquid longevity market. Therefore, the conclusion of such transactions should be supported in order to provide valuable reference points for the valuation of future deals and to thus promote longevity risk as a new asset class. This particularly holds for index-based transactions and transactions with rather short maturities which offer pension funds and annuity providers a partial hedge of their longevity risk. Such transactions seem to be most promising in the further development of the market. Therefore, sufficient capital relief should be awarded in order to promote such transactions. For example, under Solvency II clear principles for the valuation of basis risk in index-based transactions are required (cf. subsection 6.2.2).

6.2.5 Standardization, Liquidity, and Transparency

A prerequisite for any financial market to be efficient is a high degree of standardization. This needs to be achieved, in general and also for the specific case of longevity, with respect to the structure of the financial instruments, the process of setting up transactions, their pricing and their documentation in particular. Once standardization is sufficiently high on each of these aspects, longevity transactions can be negotiated and concluded significantly faster than today thus making them also cheaper and more attractive.

Regarding the structure of the hedging instruments, the concept of reinsurers pooling portfolio specific longevity risk and transferring only the systematic risk component to the capital markets (as explained in the previous subsection) should be very helpful. For the transfer of the systematic risk, index-based transactions could be used and thus, most transactions would be concluded based on the same reference population. It may even be possible to concentrate longevity transactions in Europe on just one index for the whole European population. The general trend in the mortality evolution of different European countries has been shown to be closely correlated.[34] Therefore, a longevity hedge for a large pool of pensioners or annuitants in a certain European country based on a European index may be almost as effective as a hedge via the general population of that country. Differences, e.g., in the level of mortality between the population in a certain country and the European population could be accounted for by an adequate calibration of the longevity hedge, i.e., by combining instruments with different maturities in an optimal way. The remaining basis risk should be rather small and reinsurers should be fine with accepting it. The concentration of longevity transactions on a single index would not only make transactions cheaper but would also increase liquidity thus making the asset class longevity risk again more attractive to investors. Once trading on this European index is sufficiently liquid, more specific indices could be developed, not necessarily for populations from individual countries but also for different socio-economic groups.

The LLMA[35] also looks to improve standardization and transparency in the longevity market. Regarding longevity indices, it pursues several goals: It develops indices based on up-to-date mortality data and tries to concentrate as many transactions as possible on as few indices as possible. Whether this turns out to be one index for each country or indices for even larger reference populations remains to be seen. Moreover, it works on standards for the creation and computation of indices so that indices on different reference populations are as similar as possible in terms of statistics computed and

[34] See, e.g., Li and Lee: "Coherent Mortality Forecasts for a Group of Populations: An Extension of the Lee-Carter Method" (2005), or Aleksic and Börger: "Coherent Projections of Age, Period, and Cohort Dependent Mortality Improvements" (2012).

[35] For details on the LLMA, see Annotation 1.

information provided. The idea behind is that investors shall be able to easily conclude transactions on different index populations once they are familiar with the index for a single population.

Besides the indices, the LLMA works on standards on all issues surrounding the transaction of longevity risk. This includes generally accepted methods for the analysis, quantification, and pricing of longevity risk (and therefore addresses model risk) as well as the documentation and collateralization of longevity transactions. These efforts could, at some stage, result in a kind of "best practice" for longevity transactions.

The efforts of the LLMA in developing a longevity market could possibly be enhanced by a collaboration of the LLMA and public institutions like the OECD and Eurostat. In such a cooperation, Eurostat, as an independent and reliable source of data, could compute longevity indices, or just a single index on the European population. The LLMA could provide templates for efficient longevity transactions and their documentation, similar to the ISDA Master Agreement for other financial derivatives. Moreover, the LLMA may be able to set up some kind of market place where transactions can be concluded following a standardized routine. The role of the OECD could be similar to the World Bank's role in the longevity bond issues in Chile. As already described in detail above, the OECD could help to make longevity hedges attractive to pension funds, annuity providers, and capital market investors, in particular by raising awareness for longevity risk and its hedging in discussions with the IASB, regulators and governments.

In terms of standardization and transparency in the pricing of longevity risk, the inclusion of independent pricing agents would certainly be beneficial. These agents would determine the fair price of a longevity derivative and thus limit the effect of any information inequality between the sellers of longevity risk (pension funds, insurance companies, and reinsurance companies) and the investors. This would make investors more comfortable with the asset class longevity risk and could therefore significantly increase market capacity.

6.2.6 Reference Points for Pricing Longevity Risk

In any capital market, potential investors look for reference prices in this market when setting up their initial pricing. Thus, in order to attract new investors to the longevity market, some publicly available pricing information would be very helpful. However, so far, all longevity transactions have been over-the-counter deals between just two or three parties and no prices have been publicly announced on these transactions. This situation could be improved by setting up a "price index" or "price range" for longevity risk which would be very likely to increase both liquidity and transparency in the market.

Such a price index would be of help to everybody involved in the market. New investors would feel more comfortable with their own pricing and could enter the market more easily thus increasing liquidity. Existing investors could check their pricing against a benchmark and would benefit from the increased liquidity. For pension funds and annuity providers or, more generally speaking, the sustainability of global old-age income provision, the advantage of having as many buyers of longevity risk as possible is obvious.

Given these advantages for all market participants, they should provide data on concluded transactions on a voluntary basis. Should this not work out as desired, regulators might be able to enforce the provision of data. Pricing information would not have to be made publicly available for each transaction separately but could be used to compute the price index or the price range as an aggregated statistic based on all data provided. The actual computations could be carried out by some independent party, e.g. a public institution like Eurostat, an academic institution, an independent consultant or a market association like the LLMA. Here, market participants should decide, possibly in cooperation with regulators, who may be most suitable for providing the price index. The same holds for the statistic and its details to be computed as price index.

6.2.7 Government-issued Longevity Bonds

In subsection 2.3.2, we already indicated that government-issued longevity bonds could be very helpful in supporting the further development of longevity markets. Moreover, we outlined how these bonds could be structured. In this subsection, we focus on the way governments could issue longevity bonds and what the likely effects would be.

Government-issued longevity bonds should always be index-based with the reference population most obviously being the population in the respective country. Thus, reinsurers could use these bonds to hedge the systematic longevity risk in a market structure as described in subsection 6.2.4. As such a market structure has not yet developed, government bonds could be particularly helpful in setting up an efficient market. Moreover, governments could sell their bonds in auctions thus making offers and final prices publicly available as reference points for other transactions.

The primary goal of government-issued bonds should definitely not be the settlement of the whole demand for longevity hedges. This would squeeze private investors out of the market who are supposed to assume longevity risk in the future. Instead, governments should aim for a steady stream of bond issues which market participants can rely on. Annual issues, for instance, could be a massive boost for the longevity market even if these issues were only 5-10 billion Euros in face value with maturities of only 10-15 years. The likely effect of such bonds can best be seen in the market for inflation risk. Inflation-linked government bonds were pivotal in the development of the inflation risk market as we see it today.

Obviously, there are lots of aspects to consider surrounding the question whether governments should issue longevity bonds. Besides political and economic issues, there is the issue that governments are already largely exposed to longevity risk via public pension schemes. Thus, it needs to be discussed thoroughly how much additional longevity risk could and should be assumed to support the development of a longevity market. Nevertheless, longevity bonds may be an acceptable venture given the rather small amount of bonds required compared to the overall amount of sovereign debt and the risk premium which can be earned on longevity bonds. Also the fact that government-issued longevity bonds would push a market which increases stability and sustainability in the private and occupational pension sectors makes these bonds an option to consider.

7 Appendix

7.1 Comparison of Longevity Instruments

	q-forward	s-forward	Longevity bond	Longevity swap
Basic payment structure	Exchange of an amount proportional to the realized mortality rate and to a fixed mortality rate	Exchange of an amount proportional to the realized survival rate and to a fixed survival rate	Issue price Coupon payments	Exchange of a predefined cash flow and the actual pension payments
Payment frequency	Only one cash flow at maturity −	Only one cash flow at maturity −	Monthly/ yearly +	Monthly/ yearly +
Underlying mortality rate	One-year death probability −	Survival rate +	Survival rate +	Survival rate +
Reference population	General population (index population)	General population (index population)	General population (possibly also population of the pension plan)	General population or pension plan population +
Funding	No funding +	No funding +	Funding necessary −	No funding +
Completed transactions	Not many completed transaction so far	No completed transaction so far	Only mortality catastrophe bonds so far	Most attractive capital market instrument at the moment

Table 18: Comparison of the capital market instruments related to longevity

7.2 Full Do-It-Yourself Buy-In („DIY Buy-In") or Full Synthetic Buy-In

This section provides some details on DIY Buy-Ins as describe in section 4.3.

The full synthetic Buy-In is characterized by a ring-fenced portfolio of assets (asset classes, rating, etc.). At first, the composition of this portfolio has to be defined. The investment bank determines the value of the assets, which should be in the ring-portfolio, in order to take over the longevity exposure of the pension plan. Note, that the value of the assets is calculated such that the fixed leg of the longevity swap and the fixed leg of the total return swap are the same. Thereafter, the pension plan provides the liquid assets in the ring-fenced portfolio, whereas the assets remain in the pension plan. Additional assets are placed by the Investment bank in the portfolio regarding a haircut.[36] The complete structure of such a synthetic Buy-In can be found in Figure 16.

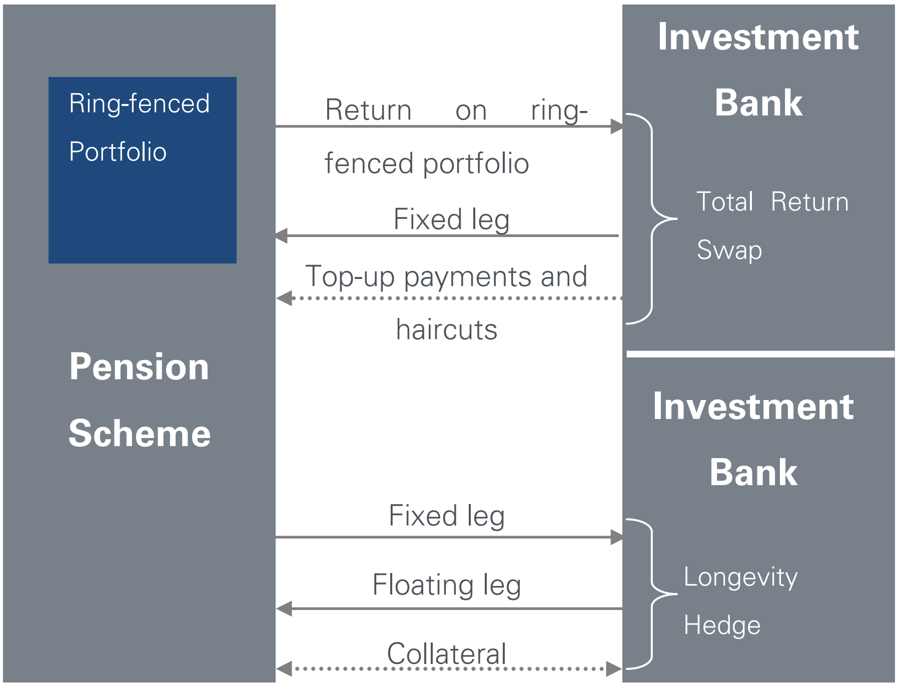

Figure 16: Structure of a Full Do-It-Yourself Buy-In (Source: Credit Suisse)

There is a significant economic impact of such a hedge. First, the pension scheme's exposure to longevity risk, at least for the pensioners of the pension scheme, and the investment risk on the assets in the ring-fenced portfolio is removed. Furthermore, it has considerable security in the event of a default of the investment bank because the ring-fenced portfolio is retained by the pension plan and the longevity swap is collateralized. A detailed description of this full DIY-Buy In can be found in "De-Risking UK Pension Schemes" (2010) by Credit Suisse.

[36] Here a haircut is defined as the reduction of value to securities used as collateral in a margin loan. That is, when one places securities as collateral, the brokerage making the loan treats them as being worth less than they actually are, so as to give itself a cushion in case its market price decreases.