Longevity Risk and Capital Markets: The 2021-22 Update

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This Special Issue of the *Journal of Demographic Economics* contains 10 contributions to the academic literature all dealing with longevity risk and capital markets. Draft versions of the papers were presented at *Longevity 16: The Sixteenth International Longevity Risk and Capital Markets Solutions Conference* that was held in Helsingør near Copenhagen on 13-14 August 2021. It was hosted by PerCent at Copenhagen Business School and the Pensions Institute at City, University of London.

Longevity risk and related capital market solutions have grown increasingly important in recent years, both in academic research and in the markets we refer to as the Life Market, i.e., the capital market that trades longevity-linked assets and liabilities.[1] Mortality improvements around the world are putting more and more pressure on governments, pension funds, life insurance companies, as well as individuals, to deal with the longevity risk they face. At the same time, capital markets can, in principle, provide vehicles to hedge longevity risk effectively and transfer the risk from those unwilling or unable to manage it to those willing to invest in this risk in exchange for appropriate risk-adjusted returns or to those who have a counterpoising risk that longevity risk can hedge, e.g., life offices and reinsurers with mortality risk on their books. Many new investment products have been created both by the insurance/reinsurance industry and by the capital markets. Mortality catastrophe bonds are an early example of a successful insurance-linked security. Some new innovative capital market solutions for transferring longevity risk include longevity (or survivor) bonds, longevity (or survivor) swaps, mortality (or *q*-) forward contracts and reinsurance sidecars (also called strategic reinsurance vehicles). The aim of the *International Longevity Risk and Capital Markets Solutions Conferences* is to bring together academics and practitioners from all over the world to discuss and analyze these exciting new developments.

Longevity 1: 2005

The conferences have closely followed the developments in the market. The first conference (*L1*) was held at Bayes Business School[2] in London in February 2005. This conference was prompted by the announcement of the Swiss Re Vita mortality catastrophe bond in December

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[1] Blake et al. (2013).

[2] Formerly Cass Business School.

2003 and the European Investment Bank/BNP Paribas/PartnerRe longevity bond in November 2004.

Longevity 2: 2006

The second conference (*L2*) was held in April 2006 in Chicago and hosted by the Katie School at Illinois State University.[3] Since *L1*, there have been further issues of mortality catastrophe bonds, as well as the release of the Credit Suisse Longevity Index. In the UK, new life companies backed by global investment banks and private equity firms were setting up for the express purpose of buying out the defined benefit (DB) pension liabilities of UK corporations.[4] Goldman Sachs announced it was setting up such a buy-out company itself (Rothesay Life) because the issue of pension liabilities was beginning to impede its mergers and acquisitions activities. It decided that the best way of dealing with pension liabilities was to remove them altogether from the balance sheets of takeover targets. So there was firm evidence that a new global market in longevity risk transference had been established. However, as with many other economic activities, not all progress follows a smooth path. The EIB/BNP/PartnerRe longevity bond did not attract sufficient investor interest and was withdrawn in late 2005. A great deal, however, was learned from this failed issue about the conditions and requirements needed to launch a successful capital market instrument.

Longevity 3: 2007

The third conference (*L3*) was held in Taipei, Taiwan on 20-21 July 2007. It was hosted by National Chengchi University.[5] It was decided to hold *L3* in the Far East, not only to reflect the growing importance of Asia in the global economy, but also to recognize the fact that population aging and longevity risk are problems that affect all parts of the world and that what we need is a global approach to solving these problems.[6] Since the Chicago conference, there had been a number of new developments, including: the release of the LifeMetrics Indices covering England & Wales, the US, Holland and Germany in March 2007 by J.P. Morgan, the Pensions Institute and Towers Watson;[7] the world's first publicly announced longevity swap between Swiss Re and the UK life office Friends Provident in April 2007 (although this was structured as an insurance or indemnification contract rather than a capital market transaction).

Since the Taiwan conference, there were further developments in the capital markets. In December 2007, Goldman Sachs launched a monthly index suitable for trading life settlements.[8] The index, QxX.LS, was based on a pool of 46,290 anonymized US lives over

[3] The conference proceedings for *L2* were published in the December 2006 issue of the *Journal of Risk and Insurance*.

[4] With a buy-out, an insurance company buys out the liabilities of a pension scheme which is paid for with the pension scheme assets and a loan if the scheme is in deficit at the time. Both the pension scheme assets and liabilities are removed from the corporate sponsor's balance sheet. Each member has a personal annuity from the insurer who takes over responsibility for paying the pensions. This contrasts with a buy-in, where the liabilities remain on the sponsor's balance sheet, but the scheme buys a bulk purchase annuity (BPA) from an insurance company and pays members' pensions from the annuity payments it receives from the insurer. The BPA is an asset of the scheme, not the members. A BPA is more commonly known as a group annuity in other countries, such as the US and Canada.

[5] The conference proceedings for *L3* were published in the Fall 2008 issue of the *Asia-Pacific Journal of Risk and Insurance*.

[6] In fact, Asia has the world's largest and fastest growing aging population (United Nations, 2007).

[7] www.lifemetrics.com

[8] Life settlements are traded life policies. In April 2007, the Institutional Life Markets Association started in New York, as the dedicated institutional trade body for the life settlements industry.

the age of 65 from a database of life policy sellers assessed by the medical underwriter AVS. In 2008, Institutional Life Services (ILS) and Institutional Life Administration (ILA), a life settlements trading platform and clearing house, were launched by Goldman Sachs, Genworth Financial, and National Financial Partners. ILS and ILA were designed to modernize dealing in life settlements and meet the needs of consumers by ensuring permanent anonymity of the insured and of the capital markets by providing a central clearing house for onward distribution of life settlement assets, whether individually or in structured form.[9]

Longevity 4: 2008

The fourth conference (*L4*) was held in Amsterdam on 25-26 September 2008. It was hosted by the Netspar Network for Studies on Pensions, Aging and Retirement and the Pensions Institute.[10]

Xpect Age and Cohort Indices were launched in March 2008 by Deutsche Börse. These indices cover, respectively, life expectancy at different ages and survival rates for given cohorts of lives in Germany and its regions, Holland and England & Wales.

The world's first capital market derivative transaction, a *q*-forward contract[11] between J. P. Morgan and the UK pension fund buy-out company Lucida, took place in January 2008. The world's first capital market longevity swap was executed in July 2008. Canada Life hedged £500m of its UK-based annuity book (purchased from the defunct UK life insurer Equitable Life). This was a 40-year swap customized to the insurer's longevity exposure to 125,000 annuitants. The longevity risk was fully transferred to investors, which included hedge funds and insurance-linked securities (ILS) funds. J. P. Morgan acted as the intermediary and assumed counter-party credit risk. In August 2011, ITV, the UK's largest commercial TV producer, completed a £1.7bn bespoke longevity swap with Credit Suisse for its £2.2bn pension plan: the cost of the swap is reported as £50m (3% of the swap value). The largest to date in the UK, covering £16bn of pension liabilities, was the longevity swap for the British Telecom Pension Scheme, arranged by the Prudential Insurance Co of America (PICA)[12] in July 2014. In February 2010, Mercer launched a pension buy-out index for the UK to track the cost charged by insurance companies to buy out corporate pension liabilities: at the time of launch, the cost was some 44% higher than the accounting value of the liabilities which highlighted the attraction of using cheaper alternatives, such as longevity swaps.[13]
Also in 2008, Credit Suisse initiated a longevity swap with Centurion Fund Managers, whereby Centurion acquired a portfolio of synthetic (i.e., simulated) life policies, based on a longevity index built by Credit Suisse.

[9] In 2010, National Financial Partners became the sole owner of ILS/ILA.
[10] The conference proceedings for *L4* were published in the February 2010 issue of *Insurance: Mathematics and Economics*.
[11] Coughlan et al. (2007).
[12] We will use PICA to refer to the US-based insurer, which is a Prudential Financial Inc. company, as well as Prudential Retirement and Prudential Retirement Insurance and Annuity Company (PRIAC).
[13] The Index tracks the relationship between the accounting liability for retirees of a defined benefit pension plan and two cost measures: the estimated cost of transferring the pension liabilities to an insurance company (i.e., a buy-out) and the approximate total economic cost of retaining the pension obligations on the balance sheet.

Longevity 5: 2009

The fifth conference (*L5*) was held in New York on 25-26 September 2009.[14]

In 2009, survivor swaps began to be offered to the market based on Deutsche Börse's Xpect Cohort Indices.

Longevity 6: 2010

The sixth conference (*L6*) was held in Sydney on 9-10 September 2010.[15]

On 1 February 2010, the Life and Longevity Markets Association (LLMA) was established in London. Its members were Aviva, AXA, Deutsche Bank, J.P. Morgan, Morgan Stanley, Prudential (UK) PLC, and Swiss Re. LLMA was formed to promote the development of a liquid market in longevity- and mortality-related risks. This market is related to the ILS market and is also similar to other markets with trend risks, e.g., the market in inflation-linked securities and derivatives. LLMA aims to support the development of consistent standards, methodologies and benchmarks to help build a liquid trading market needed to support the future demand for longevity protection by insurers and pension funds. In April 2011, the LifeMetrics indices were transferred to LLMA with the aim of establishing a global benchmark for trading longevity and mortality risk.

In December 2010, building on its successful mortality catastrophe bonds and taking into account the lessons learned from the EIB bond, Swiss Re launched a series of eight-year longevity-based ILS notes valued at $50m. To do this, it used a special purpose vehicle, Kortis Capital, based in the Cayman Islands. As with the mortality bonds, the longevity notes are designed to hedge Swiss Re's own exposure to mortality and longevity risk. In particular, holders of the notes were exposed to an increase in the spread between mortality improvements in 75-85-year-old English & Welsh males and 55-65-year-old US males, indicating that Swiss Re has life insurance (mortality risk) exposure in the US and pension (longevity risk) exposure in the UK.

Longevity 7: 2011

The seventh conference (*L7*) was held at the House of Finance, Goethe University, Frankfurt, Germany on 8-9 September 2011.[16]

In January 2011, the Irish government announced that it would issue bonds that allow the creation of sovereign annuities.[17] This followed a request from the Irish Association of Pension Funds and the Society of Actuaries in Ireland. If the bonds are purchased by Irish

[14] The conference proceedings for *L5* were published in the *North American Actuarial Journal* (Volume 15, Number 2, 2011).

[15] The conference proceedings for *L6* were published in the October 2011 issue of *Geneva Papers on Risk and Insurance - Issues and Practice.*

[16] The conference proceedings for *L7* were published in the September 2013 issue of the *Journal of Risk and Insurance*.

[17] A sovereign annuity, introduced by the 2011 Social Welfare and Pensions Act, is an annuity contract issued by insurance companies where the annual income payment is linked directly to payments under bonds issued by Ireland or any other EU member state (known as reference bonds). The payments can be reduced if there is an event of non-performance in relation to the bonds to which the annuity is referenced. This contrasts with a standard annuity where the insurer guarantees to make the agreed payments for the lifetime of the annuitant.

pension funds, this will have a beneficial effect on the way in which the Irish funding standard values pension liabilities. On account of a statutory deadline to submit a deficit repair plan, 2013 was a record year for bulk annuity transactions in Ireland with sovereign annuities being used in a significant number of transactions.

The world's first longevity swap for non-pensioners (i.e., for active and deferred members of a pension plan) took place in January 2011, when J. P. Morgan executed a £70m 10-year *q*-forward contract with the Pall (UK) pension fund. This was a value swap designed to hedge the longevity risk in the value of Pall's pension liabilities, rather than the longevity risk in its pension payments as in the case of cash flow swaps which have been the majority of the swaps that have so far taken place. Longevity risk prior to retirement is all valuation risk: there is no cash flow risk and most of the risk lies in the forecasts of mortality improvements. Further, the longevity exposure of deferreds is not well defined as a result of the options that plan members have, e.g., lump sum commutation options, early retirement options, and the options to increase spouses' benefits at the expense of members' benefits.

In April 2011, the International Society of Life Settlement Professionals (ISLSP)[18] formed a life settlement and derivatives committee and announced that it was developing a life settlement index. The purpose of the index is to benchmark net asset values in life settlements trading. Investors need a reliable benchmark to measure performance and the index will help turn US life insurance policies into a tradable asset class according to ISLSP. The calculation agent for the index is AA Partners.

The first pension risk transfers deals outside the UK took place in 2009-11. The first buy-in deal outside the UK took place in 2009 in Canada; it was arranged by Sun Life Financial and valued at C$50m. The first buy-in deal in Europe took place in December 2010 between the Dutch food manufacturer Hero and the Dutch insurer Aegon (€44m). The first buy-in deal in the US took place in May 2011 between Hickory Springs Manufacturing Company and PICA ($75m). The first buy-out deal outside the UK was announced in May 2011 and involved the C$2.5bn Nortel pension plan in Canada. In September 2011, CAMRADATA Analytical Services launched a new pension risk transfer (PRT) database for US pension plans. The database provides insurance company organizational information, pension buy-in and buy-out product fact sheets and screening tools, pricing data, up-to-date information on each PRT provider's financial strength and relevant industry research. Users can request pension buy-in and buy-out quotes directly from providers, including American General Life Companies, MetLife, Pacific Life, Principal Financial Group, PICA, Transamerica and United of Omaha.

The first international longevity reinsurance[19] transaction took place in June 2011 between Rothesay Life (UK) and PICA and was valued at £100m. The first life book reinsurance swap since the 2007-08 Global Financial Crisis took place in June 2011 between Atlanticlux and institutional investors and was valued at €60m.

Longevity 8: 2012

The eighth conference (*L8*) was held at the University of Waterloo, Ontario, Canada on 7-8 September 2012.[20]

[18] www.islsp.org
[19] The insurance industry's name for a longevity swap.
[20] The conference proceedings for *L8* were published in the *North American Actuarial Journal* (Volume 18(1), 2014).

In February 2012, Deutsche Bank executed a massive €12 billion index-based longevity solution for Aegon in the Netherlands. This solution was based on Dutch population data and enabled Aegon to hedge the liabilities associated with a portion of its annuity book. Because the swap[21] was out of the money, the amount of longevity risk actually transferred was far less than that suggested by the €12 billion notional amount. Nonetheless, the key driver for this transaction from Aegon's point of view was the reduction in economic capital it hoped to achieve. Most of the longevity risk has been passed to investors in the form of private bonds and swaps.

In June 2012, General Motors Co. (GM) announced a huge deal to transfer up to $26 billion of pension obligations to PICA. This is by far the largest ever longevity risk transfer deal globally. The transaction is effectively a partial pension buy-out involving the purchase of a group annuity contract for GM's salaried retirees who retired before 1 December 2011 and refused a lump sum offer in 2012. To the extent retirees accepted a lump sum payment in lieu of future pension payments, the longevity risk was transferred directly to the retiree.[22] The deal was classified as a partial buy-out rather than a buy-in because it involved the settlement of the obligation. In other words, the portion of the liabilities associated with the annuity contract will no longer be GM's obligation. Moreover, in contrast to a buy-in, the annuity contract will not be an asset of the pension plan, but instead an asset of the retirees. In October 2012, GM did a $3.6 billion buy-out of the pension obligations of its white-collar retirees. Also in October 2012, Verizon Communications executed a $7.5 billion bulk annuity buy-in with PICA. The buy-out deals in the U.S. in 2012 amounted to $36 billion.

Longevity 9: 2013

The ninth conference (*L9*) was held in Beijing, China on 6-7 September 2013.[23]

The first £1bn+ PRT in the UK took place in July 2013, when Citigroup executed a £1.5bn buy-out for its EMI Group Pension Fund with Pension Insurance Corporation (PIC), a specialist UK buy-out insurer, covering all 20,000 members.[24]

In February 2013, the first medically underwritten bulk annuity (MUBA) transaction was executed in the UK by the UK insurer Partnership.[25] This involved each member filling in a medical questionnaire in order to get a more accurate assessment of their life expectancy based on their medical history or lifestyle. This was particularly useful in the case of 'top slicing', where scheme trustees insure the pensioners (who will typically be the company directors) with the largest liabilities and who therefore represent a disproportionate risk concentration for the scheme. In December 2014, Partnership executed a £206m medically underwritten bulk annuity transaction with a 'top slicing' arrangement for the £2bn Taylor Wimpey pension scheme. UK insurer Legal & General (L&G) transacted a £230m medically-underwritten buy-in in December 2015. The process of collecting medical information has been streamlined in recent years using third-party medical data collectors, such as MorganAsh, Age Partnership and Aon's AHEAD platform. It is expected that the share of medically underwritten de-risking

[21] It is structured as a bull call option spread – see Michaelson and Mullholland (2014).
[22] In fact, the lump sum was only being offered to limited cohorts of plan members.
[23] The conference proceedings for *L9* were published in *Insurance: Mathematics and Economics* (Volume 63, July, 2015).
[24] https://www.professionalpensions.com/news/2280322/emi-scheme-agrees-recordbreaking-gbp15bn-buyout
[25] Harrison and Blake (2013).

deals will increase significantly over the next few years in the UK, with new business more than doubling from £540m in 2014 to £1,200m in 2015.[26] In April 2016, the two largest UK medical underwriters, Partnership and Just Retirement merged to form the Just Group valued at £16bn.

In April 2013, L&G reported its first non-UK deal, the buy-out of a €136m annuity book from New Ireland Life. In June 2013, the Canadian Wheat Board executed a C$150m pension buy-in from Sun Life of Canada, involving inflation-linked annuities, while in March 2014, an unnamed Canadian company purchased C$500m of annuities from an insurer (reported to be Industrial Alliance), making it the largest ever Canadian pension risk transfer deal to date.
In August 2013, Numerix, a risk management and derivatives valuation company, introduced a new asset class called 'life' on its risk modeling platform (in addition to equities, bonds and commodities). In November 2013, SPX Corp. of Charlotte, NC, purchased a buy-out contract with Massachusetts Mutual Life Insurance Co. (MassMutual) as part of a deal that moved $800m in pension obligations off SPX's balance sheet.

In September 2013, UK consultant Barnett Waddingham launched an insurer financial strength review service which provides information on an insurer's structure, solvency position, credit rating, and key risks in their business model. This service was introduced in response to concerns about the financial strength of some buy-out insurers.

In November 2013, Deutsche Bank introduced the Longevity Experience Option (LEO). It is structured as an out-of-the-money call option spread on 10-year forward survival rates and has a 10-year maturity. The survival rates will be based on males and females in five-year age cohorts (between 50 to 79) derived from the England & Wales and Netherlands LLMA longevity indices. LEOs will be traded over-the-counter under a standard ISDA[27] contract. They allow longevity risk to be transferred between pension funds, insurance companies and investors. They are intended to provide a cheaper and more liquid alternative to bespoke longevity swaps which are generally costly and time consuming to implement. Purchasers of the option spread, such as a pension fund, will gain if realized survival rates are higher than the forward rates, but the gains will be limited, thereby providing some comfort to the investors providing the longevity hedge. The 10-year maturity is the maximum that Deutsche Bank believes investors will tolerate in the current stage in the development of a market in longevity risk transfers. It was reported that Deutsche Bank executed its first LEO transaction with an ILS fund in January 2014.

In December 2013, Aegon executed a second longevity risk transfer to capital markets investors and reinsurers, including SCOR. Société Générale was the intermediary in the €1.4 billion deal and Risk Management Solutions (RMS) was the modelling agent.

Also in December 2013, the Joint Forum reported on the results of its consultation on the longevity risk transfer market. It concluded that this market is not yet big enough to raise systemic concerns, but 'their massive potential size and growing interest from investment banks to mobilize this risk make it important to ensure that these markets are safe, both on a prudential and systemic level' (Joint Forum (2013, p.2)).

[26] Hunt and Blake (2016).
[27] International Swaps and Derivatives Association; https://www.isda.org/

Longevity 10: 2014

The tenth conference (*L10*) was held at Universidad Diego Portales in Santiago, Chile on 3-4 September 2014.[28]

In February 2014, the Mercer Global Pension Buy-out Index was introduced. It shows the benchmark prices of 18 independent third-party insurers in the four countries with the greatest interest in buying out DB liabilities: UK, US, Canada and Ireland. Costs were highest in the UK where the cost of insuring £100m of pension liabilities was 123% of the accounting value of the liabilities – equivalent to £32 per £1 p.a. of pension.[29] The comparable costs in Ireland, the U.S. and Canada were 117%, 108.5% and 105%, respectively. The higher cost in the UK is in part due to the greater degree of inflation uprating in the UK compared with the other countries. The difference between the US and Canada is explained by the use of different mortality tables. Rising interest rates and equity markets will lower funding deficits and hence lead to lower buy-out costs in future, especially in the US.

In July 2014, Mercer and Zurich launched Streamlined Longevity Solution, a longevity swap hedge for smaller pension schemes with liabilities above £50m. This is part of a new Mercer SmartDB service which provides bespoke longevity de-risking solutions and involves a panel of reinsurers led by Zurich. It reduces the costs by having standardized processes for quantifying the longevity risk in each pension scheme. The first deal, valued at £90m, was transacted with an unnamed UK pension scheme in December 2015.

In December 2014, Towers Watson launched Longevity Direct, an off-shore longevity swap hedging service that gives medium-sized pension schemes with liabilities between £1-3bn direct access to the reinsurance market, via its own cell (or captive) insurance company. This allows schemes to bypass insurers and investment banks, the traditional de-risking intermediaries, and significantly reduces transactions costs and completion times, while still getting the best possible reinsurance pricing. The first reported transaction on the Longevity Direct platform was the £1.5bn longevity swap executed by the Merchant Navy Officers Pension Fund (MNOPF) in January 2015 which was insured by MNOPF IC, a newly established cell insurance company based in the Channel Island of Guernsey, and then reinsured with Pacific Life Re. In February 2015, PwC launched a similar off-shore longevity swap service for pension schemes as small as £250m. It used a Guernsey-based incorporated cell company called Iccaria, established by Artex Risk Solutions, to pass longevity risk directly on to reinsurers. The arrangement is fully collateralized and each scheme owns a cell within Iccaria which again avoids the costs of dealing with insurer and investment bank intermediaries.

There is increasing demand from reinsurance companies for exposure to large books of pension annuity business to offset the risk in their books of life insurance. For example, in 2014, Warren Buffett's Berkshire Hathaway agreed to a £780m quota-reinsurance deal with PIC.[30] Similarly, in August 2014, AXA France executed a €750m longevity swap with Hannover Re.

In March 2014, L&G announced the biggest single buy-out in the UK to date when it took on £3bn of assets and liabilities from ICI's pension fund, a subsidiary of AkzoNobel. In December

[28] The conference proceedings for L10 were published in the *Journal of Risk and Insurance*, Volume 84, Number S1, April 2017, 273-532.
[29] Towers Watson (2015) *Corporate Briefing*, April.
[30] Reported in *Financial News*, 14 July 2014.

2014, L&G announced the largest ever UK buy-in valued at £2.5bn with US manufacturer TRW. Around £13bn of bulk annuity deals were executed in the UK in 2014, the largest volume of business since the de-risking market began in 2006 and beating the previous best year of 2008, just before the Global Financial Crisis, when £7.9bn of deals were completed. The total volume of de-risking deals in the UK in 2014 (covering buy-outs, buy-ins and longevity swaps) was £35bn, a significant proportion of which is accounted for by the £16bn BT longevity swap.

In November 2014, the Longevity Basis Risk Working Group (2014) of the Institute and Faculty of Actuaries (IFoA) and LLMA published 'Longevity Basis Risk: A Methodology for Assessing Basis Risk'. This study develops a new framework for insurers and pension schemes to assess longevity basis risk. This, in turn, will enable simpler, more standardized and easier to execute index-based longevity swaps to be implemented. Index-based longevity swaps allow insurers and pension schemes to offset the systematic risk of increased liabilities resulting from members living longer than expected. It had hitherto been difficult to assess how effectively an index-based longevity swap could reduce the longevity risk in a particular insurance book or pension scheme. The methodology developed in the report is applicable to both large schemes (which are able to use their own data in their models) and smaller schemes (by capturing demographic differences such as socio-economic class and deprivation).

Longevity 11: 2015

The eleventh conference (*L11*) was hosted by Université Lyon 1, Lyon, France on 7-8 September 2015.[31]

In March 2015, the UK government announced that it would introduce a new competitive corporate tax structure to allow ILS to be domiciled in the UK and the associated Risk Transformation Regulations 2017, creating a new regulated activity of insurance risk transformation, came into effect in December 2017. In May 2015, Rothesay Life, the insurance company owned by Goldman Sachs, bought out the liabilities of Lehman Brothers' UK pension scheme for £675m, thereby securing the pensions of former employees of the company associated with the beginning of the Global Financial Crisis. In April 2016, Rothesay bought two-thirds of Aegon's UK annuity book – representing 187,000 policy holders – for £6bn, bringing total assets under management to £20bn and total lives assured to over 400,000. This was the first substantial annuity transfer since the introduction of Solvency II[32] in January 2016. This new solvency regime for EU-based insurers increased capital requirements and has reduced the attractiveness of annuities as a business line for certain insurers and raised buy-out prices by 5-7%.[33]

In 2015, L&G entered both the US and European pension risk transfer markets. It executed a $450m transaction with the US subsidiary of Royal Philips covering 7,000 scheme members in October and a €200m deal with ASR Nederland NV, a Dutch insurer in December. The pension obligations were transferred to L&G Re in cooperation with Hannover Re. L&G said: 'The pension risk transfer market has become a global business…The potential market for pension risk transfer in the US, UK and Europe is huge, and will play out over many decades'. Two US insurers were also involved in the Royal Philips deal: PICA also acquired $450m of

[31] The conference proceedings for *L11* were published in *Insurance: Mathematics and Economics*, 78 (2018), 157–380.
[32] https://www.eiopa.europa.eu/browse/solvency-2_en and https://en.wikipedia.org/wiki/Solvency_II
[33] *Financial News*, 28 March–3 April 2016.

scheme liabilities covering another 7,000 members, while American United Life Insurance Company issued annuity contracts to 3,000 deferred scheme members, valued at $200m.

In January 2015, the Bell Canada Pension Plan executed a C$5bn longevity swap with Sun Life Financial,[34] SCOR, and Reinsurance Group of America (RGA Re); it was SCOR's first transaction in North America. In the process, Canada became the first country apart from the UK to have all three pension risk transfer solutions actively in use. In the same year, it completed its first inflation-linked buy-in annuity transaction, while in 2017, it completed its first buy-in annuity covering active future benefits.[35] In June 2015, Delta Lloyd did a second €12bn longevity swap with RGA Re: the swap was also index-based, with an 8-year duration and had a notional value of €350m.[36] In July 2015, Aegon executed one valued at €6bn with Canada Life Re, a new entrant to the de-risking market in 2015. Another new entrant was Scottish Widows.

In June 2015, the Mercer Pension Risk Exchange was launched. It gives clients in the US, UK and Canada up-to-date buy-in and buy-out pricing based on their plan's data. It collects prices provided monthly by insurers in the bulk market, based on plan benefit structures and member data. Mercer said: 'Many companies have the appetite to transfer pension risk off their balance sheet, but they face barriers: lack of clear information about the true cost of a buy-in or buy-out, limited transparency, the fluctuation of market rates and plan economics to name but a few. [The exchange will enable] sponsoring employers and trustees to be more strategic and sophisticated in their approach and to know that they are executing a buy-in or a buy-out at the best time for them and at a competitive price'.

Longevity 12: 2016

The twelfth conference (*L12*) was held in Chicago on 29-30 September 2016 and hosted by the Society of Actuaries and the Pensions Institute.[37]

In April 2016, Willis Towers Watson (WTW) released PulseModel which uses medical science and the opinions of medical experts to improve longevity predictions. For example, the model predicts that 16% of 50-year-old men in the UK will develop type-2 diabetes in the next 20 years, but this rises to 50% for those who are both obese and heavy smokers. Overall, the model predicts that longevity improvements in the future will be lower than currently predicted, at around 1% p.a. rather than 1.5%. If this turned out to be correct, then the current price of longevity of risk transfer products would be overestimated.

The largest buy-in in 2016 (in December) was Phoenix Life's £1.2bn buy-in for the 4,400 pensioners in the PGL Pension Scheme, which is sponsored by the Phoenix Group, Phoenix Life's parent company. This replaced a longevity swap that it had set up for the plan in 2014. This is the first example of a transaction which transforms a longevity swap into a bulk annuity. Phoenix Life saw this as an opportunity to bring £1.2bn of liquid assets (mostly UK government bonds) onto its balance sheet, which could then be swapped into a higher yielding, matching portfolio, structured to maximize the capital benefit under Solvency II. This, in turn,

[34] Sun Life Financial uses the RMS Longevity Risk Model, which RMS describes as a 'structural meta-model of geroscience advancement'.
[35] Eckler Consultants (2017) *Pension Risk Transfer Report*, November.
[36] http://www.artemis.bm/blog/2015/06/26/delta-lloyd-rga-in-second-e12-billion-longevity-swap-deal/
[37] The conference proceedings for *L12* were published in volume 25(S1) of the *North American Actuarial Journal* in 2021.

meant that Phoenix Life would be assuming the market risks associated with the PGL scheme pension liabilities in addition to the longevity risks – and already does this on its existing book of individual annuities which are backed by £12bn of assets. The timing was also critical. Phoenix wanted to ensure that its internal model under Solvency II had bedded down well and that the capital and balance sheet impacts of the transaction were well understood, and that Phoenix had elicited the full support of the UK Prudential Regulation Authority (PRA)[38] for the transaction, thereby ensuring execution certainty. Phoenix also provided comfort to the plan's trustees by giving them 'all-risks' cover from point of buy-in ('all-risks' cover is not usually provided until buy-out) and strong collateral protection.[39]

2016 saw the beginning of a trend towards consolidation amongst insurance companies involved in the longevity risk transfer business in the UK. For example, Aegon sold its £9bn UK annuity portfolio to Rothesay Life and L&G between April and May, as part of a strategy to free up capital from non-core businesses. Part of the reason for this is the additional capital requirements under Solvency II. Similarly, in September, Deutsche Bank sold its Abbey Life subsidiary to Phoenix Life – a consolidator of closed insurance books – for £935m, as part of a planned programme of disposals aimed at restoring its capital base. There is an estimated £100bn of UK individual annuities in back books and further consolidation of these back books is anticipated. In December 2017, L&G sold its £33bn closed book of traditional insurance-based pensions, savings and investment policies to the ReAssure division of Swiss Re for £650m.

Solvency II has also been blamed for some companies pulling out of the bulk annuities market altogether, a key example being Prudential (UK) in January 2016. Prudential (UK) announced it would be selling a portion of its £45bn UK annuity and pension liability businesses due to an inadequate return on capital and to transfer that capital to its growing businesses in Asia.[40] Reinsurance deals have also increased in response to Solvency II, involving non-EU reinsurers. For example, PIC executed a £1.6bn longevity reinsurance agreement with PICA in June 2016. 2016 also witnessed the increasing streamlining and standardization of contracts. This is particularly beneficial to small plans below £100m. Previously, smaller plans have been less attractive to insurers due to the higher costs of arranging such deals relative to the profit earned. To circumvent this, consultants have begun offering services that allow smaller plans to access improved pricing and better commercial terms using a standardized off-the-shelf process incorporating pre-negotiated legal contracts. Pricing is more competitive because the insurer's costs are kept low. An example is WTW's Streamlined Bulk Annuity Service. The increasing maturity of the market has meant that some larger plans have also been prepared to use pre-negotiated contracts.

2016 was also the tenth anniversary of the longevity transfer market. Since its beginning in the UK in 2006, £40bn of buy-outs and £31bn of buy-ins have taken place in the UK, covering one million people.[41] Yet this equates to just 5% of the £1.5trn of UK DB pension assets and 3% of the £2.7trn of DB pension liabilities on a buy-out basis in 2016. In addition, forty eight longevity swaps are known to have been completed in the United Kingdom between 2007 and 2016, valued at £75bn and covering 13 insurance companies' annuity and buy-out books, 22

[38] This is the regulatory authority for insurance companies in the UK.
[39] Stephanie Baxter (2017) How PGL's longevity swap was converted into a buy-in, *Professional Pensions*, 10 April.
[40] https://www.ftadviser.com/pensions/2016/12/05/prudential-seeks-buyers-for-45bn-annuity-business/
[41] LCP, *Professional Pensions* (15 December 2016 and 26 January 2017). Since 2007, some 92 buy-ins have been completed.

private sector pension funds, and one local authority pension fund (some of which executed more than one swap).[42]

Longevity 13: 2017

The thirteenth conference (*L13*) was held in Taipei, Taiwan on 21-22 September 2017. It was hosted by the Department of Risk Management and Insurance and the Risk and Insurance Research Center at National Chengchi University, and by the Pensions Institute.[43]

At the beginning of 2017, there were eight UK-domiciled insurers actively participating in the pension risk transfer market in the UK. The largest players were PIC and L&G, with market shares of 37% and 30%, respectively. The others were Rothesay Life, Canada Life, Zurich, Scottish Widows, Standard Life, and new entrant Phoenix (since August). Occasionally, the insurers co-operate in a transaction. To illustrate, in August 2017, L&G executed a longevity swap in respect of £800m of the pension liabilities of Scottish and Southern Energy (SSE), while PIC completed a £350m buy-in for the company. Consultant LCP estimated that £12bn buy-ins and buy-outs took place in 2017 and £19bn took place in 2018, with total insurer capacity at £25bn: 'There remains significant capacity and competition – even if a large back-book comes to market – providing attractive opportunities for pension plans to transfer longevity risk through a buy-in or buy-out'.[44]

One of the largest deals in 2017 (in September) involved a £3.4bn longevity swap between the Marsh & McLennan Companies (MMC) UK Pension Fund and both Canada Life Reinsurance and PICA, using Guernsey-based incorporated cell companies, Fission Alpha IC Limited and Fission Beta IC Limited. MMC subsidiary Mercer led the transaction as adviser to the pension fund trustee and the deal was the first to be completed using the Mercer Marsh longevity captive solution, with no upfront premium. The two reinsurers shared the risk equally and the use of the captive ICC vehicle meant that no insurer intermediary was required, making the deal more cost-effective for the pension fund.[45] Also in September, the British Airways' Airways Pension Scheme used a similar Guernsey-based captive insurer to set up a £1.7bn longevity swap. The longevity risk was then reinsured with Partner Re and Canada Life Re. The scheme had previously hedged £2.6bn of liabilities through two longevity swap transactions executed by Rothesay Life in 2010 and 2011.[46] In November 2017, PIC executed a £900m longevity swap with PICA, while in December 2017, L&G executed a £600m longevity swap with PICA.[47]

In December 2017, NN Life, part of the Nationale-Nederlanden Group, the largest Dutch insurance company, executed an index-based longevity hedge with reinsurer Hannover Re, in a deal covering the insurer against the longevity trend risk in €3bn of its liabilities. The structure is similar to the 2013 Aegon tail-risk deal arranged by Société Générale and builds on

[42] www.artemis.bm/library/longevity_swaps_risk_transfers.html.
[43] The conference proceedings for *L13* were published in volume 25(S1) of the *North American Actuarial Journal* in 2021.
[44] https://www.lcp.uk.com/media-centre/press-releases/2017/08/buy-in-and-buy-out-volumes-nearly-double; LCP (2018) *Pension De-risking 2018*.
[45]http://www.artemis.bm/blog/2017/09/14/mmc-pension-offloads-huge-3-4bn-of-longevity-risk-to-reinsurers. The counter to this cost-effectiveness is that the hedger takes on additional counterparty risk. If a reinsurer fails then there is no insurer to protect MMC's pension scheme.
[46] Nick Reeve (2017) BA scheme uses 'captive insurer' in £1.6bn longevity risk hedge, *IPE*, 13 September.
[47] https://www.pensioncorporation.com/media/press-releases/Prudential, PIC Reach $1.2 Billion Longevity Reinsurance Agreement; L&G reinsures £600m of longevity risk through Prudential, *Professional Pensions*, 21 December 2017.

subsequent work including Michaelson and Mulholland (2014) and Cairns and El Boukfaoui (2021). While the term of the transaction is 20 years, NN Life is protected over a longer time period via a commutation function[48] that applies at maturity. If longevity improvements have been much stronger than expected, this will be assumed to continue until the liabilities run-off and NN will receive a payment under the hedge. The transaction helped to reduce the solvency capital requirement of NN's Netherlands life business by €35m. The index attachment point for the hedge is close to NN's best estimate, which helps maintain the SCR (Solvency Capital Requirement)[49] relief and effective risk transfer over time.[50, 51]

In order to reduce the costs of de-risking, pension plans are encouraged to perform some liability reduction exercises, the key ones being:[52]

- Enhanced transfer values (ETVs) – allow deferred members to transfer an uplifted value of their benefits to an alternative arrangement. In August 2017, a 64-year old entitled to an index-linked pension starting at £10,000 from age 65 would be offered a transfer value of £237,000, according to the Xafinity Transfer Value Index.[53] In October 2019, the transfer value was £244,200. In 2019, around 50,000 members transferred out of their DB scheme, around 1% of eligible members.[54]
- Flexible retirement options (FROs) – allow deferred members aged 55 and over to retire early, or to take a transfer value and secure benefits in a different format from their plan benefits, or to use funds for drawdown purposes.
- Pension increase exchanges (PIEs) – allow pensioners to exchange non-statutory increases for a higher immediate pension with lower or even zero future increases (e.g., a £10,000 annual pension with inflation uplifting is replaced by a £12,000 annual pension with no further increases).
- Trivial commutations (TCs) – allow members with low value benefits to cash these in.

The most common exercises currently in the UK are PIEs and TCs – and these can be conducted either before or at the same time as a bulk purchase annuity broking exercise. Hymans Robertson has estimated that the use of these liability reduction exercises could reduce the buyout cost for UK DB schemes by around £100bn or 6% of total liabilities.[55]

Innovation is a continuing feature of this market. Some examples include (see, e.g., Legal & General and Engaged Investor, 2016):[56]

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[48] The role of the 'commutation function' is to 'compress' the risk period. As explained in Michaelson and Mulholland (2014, pp.32-33): 'This is accomplished by basing the final index calculations on the combination of two elements: (i) the actual mortality experience, as published by the national statistical reporting agency, applied to the exposure defined for the risk period; and (ii) the present value of the remaining exposure at the end of the risk period calculated using a 're-parameterized' longevity model that takes into account the realized mortality experience over the life of the transaction'.

[49] The SCR is the amount of funds that insurance and reinsurance companies are required to hold under Solvency II in order to have a 99.5% confidence they could survive the most extreme expected losses over the course of a year. The SCR incorporates market, credit, operational and counterparty risks, and must be recalculated at least once per year; https://www.risk.net/definition/solvency-capital-requirement

[50] http://www.artemis.bm/blog/2017/12/01/nn-life-gets-index-based-longevity-hedge-from-hannover-re/

[51] https://www.nn-group.com/Investors/Capital-Markets-Day-2017.htm

[52] *Professional Pensions* (2016) Risk reduction and the extent of trust in pension scheme advisers and providers, June, p.26.

[53] Hannah Godfrey (2017) DB transfer values back on the rise in August, *Professional Adviser*, 7 September.

[54] Sophie Smith (2019) DB transfer values in record fall – XPS, *Pensions Age*, 7 November.

[55] https://www.ipe.com/news/uk-roundup-clear-member-options-could-reduce-buyout-db-costs-by-100bn/10060598.article

[56] Legal & General and Engaged Investor (2016) *De-risking Journeys of Mid-sized Pension Schemes*, June.

- Buy-ins and buy-outs with deferred premium payments – to spread costs, schemes that cannot afford the upfront premium of a de-risking solution pay for it in instalments over a number of years.
- Buy-outs combined with a longevity hedge.[57]
- Phased buy-ins, where the largest risks or the lowest cost risks are insured first.
- Phased de-risking using a sequence of partial buy-ins with an 'umbrella' structure to avoid more than one set of contract negotiations – to spread costs.
- Accelerated buy-ins – the insurer provides a loan to the plan equal to the deficit (sometimes called a winding up lump sum (WULS)), so that a partial buy-in can take place immediately, with this converting to a full buy-in when the loan has been repaid, or with the option of a full buy-out at a later date.
- Forward start buy-ins – a standard buy-in with the start date delayed to reflect the level of funding available, with additional options, such as paying deferred members as and when they retire if this is prior to the start date, or the ability to bring forward the start date for an additional fee.
- Self-managed buy-ins – which allows pension schemes to run their own asset management strategy at lower cost and with a lighter regulatory burden than if an insurer was involved (introduced in 2018 by the UK asset manager Insight Investment). The strategy uses swaps to hedge interest, inflation and longevity risks and is estimated to be 10-15% cheaper than the equivalent insurance product.[58]
- Automated bulk plan transfers – to reduce risks (introduced in November 2017 by Scottish Widows and Standard Life).[59]
- Top-slice buy-ins – to target the highest value liabilities.
- Named-life longevity swap – if the named member lives longer than expected, the insurer pays out the difference (examples being the £400m Bentley plan and an unnamed plan with 90 named pensioners valued at £50m).
- Tranching by age – to reduce costs; according to consultant Punter Southall, a buy-in for pensioners up to age 70 will make a subsequent buy-out within the following 10 years cheaper than a buy-in for the over 70s.[60]
- Longevity swaps for small pension plans with liabilities of £50-100m – previously only available for medium (£100-500m) and large plans (above £500m).
- Novation – the ability to transfer a longevity hedge from one provider to another, thereby introducing some liquidity into what had previously been a completely illiquid market. An example would be the reinsurance of a small bulk annuity transaction. Contract simplicity is a desirable feature of such arrangements.
- Longevity swap to buy-in conversions – as pioneered by Phoenix Life in December 2016 for its parent company's pension plan. Solvency II incentivizes buy-in providers to hold longevity insurance, otherwise they pay an additional risk margin. This encourages buy-in providers to seek out plans which already have a longevity hedge and encourage them to do a buy-in. Another driver is longevity swap providers that are

[57] An example of this was the Philips Pension Fund which in 2015 completed a full buy-out valued at £2.4bn with PIC. The longevity risk was simultaneously reinsured with Hannover Re. Another interesting feature of this deal was that it covered both retired and deferred members.

[58] Angus Peters (2018) Insurers compete with fund managers for lucrative pension pots, FTfm, 15 January. The article points out that 'insurers and asset managers are engaged in a turf war for the £1.6tn sitting in the UK's defined benefit schemes'.

[59] Michael Klimes (2017) How the first automated bulk scheme transfers happened, *Professional Pensions*, 10 November.

[60] James Phillips (2017) DB schemes insuring wrong tranche of members in buy-ins, *Professional Pensions*, 14 August.

not currently active in the market – such as J.P. Morgan and Credit Suisse – but are still responsible for running off their existing swaps. They might have an incentive to encourage the associated pension plan to novate the swap to a buy-in provider and hence extinguish their liability.[61]

- Insuring away the extreme tail of liabilities in a closed plan after a specified term, such as 5 or 10 years – to reduce costs.
- Increasing optionality in contracts to improve flexibility – for example, the option to switch the indexation measure for pensions in payment from the Retail Price Index to the Consumer Price Index if government legislation changes; or the option to secure discretionary benefits, such as actual inflation above a 5% cap; or surrender options.
- Insuring the tail of the liabilities – whereby a closed scheme that cannot afford a full buy-out insures only the liabilities after a certain point in time, say, 10 years' ahead.
- Combining liability management solutions (such as interest rate and inflation swaps, and ETV, FRO and PIE exercises) and bulk annuities in a buy-out – so instead of completing liability management before considering a buy-out, plans do this in a single exercise.
- 'Buy-out aware' investment portfolios – used to reduce buy-out price volatility and close the funding shortfall, with the buy-out price locked to the value of the buy-out aware funds once a target shortfall has been reached and whilst the contract documentation for a buy-out is being completed.
- Improved arrangements for handling data errors that arise after a deal has been executed – to reduce pre-deal negotiation requirements and post-deal transaction uncertainty. Common data errors include member gender, date of birth, and benefit amounts for both member and partner. A simplified data error process could deal with these issues in the following way: locking down benefits, removing the need for re-pricing; mechanistically adjusting demographic errors; and using due diligence to check for systematic errors with the data.[62]
- Residual risk insurance, covering, e.g., benefit specification errors, data errors, and unidentified beneficiary cover.
- Arrangements to handle deferred members – to improve insurer appetite to assume the additional risk and cost involved. Deferred lives make up almost half (45%) of the membership of UK DB plans in the UK.[63] They are much more expensive to hedge for a number of reasons. First, there can be problems with their existence and identification. Second, they enjoy a large number of options which need to be priced.[64] Third, their longevity risk is greater, because the longevity improvement assumption used for pricing has greater reliance on the assumed long-run trend.[65] Fourth, as a direct consequence of the previous points, more capital is needed and this, in turn, increases the demand for reinsurance. These issues can be at least partially mitigated as follows:

[61] Stephanie Baxter (2017) Converting longevity swaps into bulk annuities: The next de-risking innovation?, *Professional Pensions*, 13 April.

[62] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference. Provided due diligence has been carried out at the outset, subsequent data errors tend to be unbiased in terms of their impact and so average out close to zero.

[63] That is 4.9m members (The Pension Regulator and the Pension Protection Fund, *Purple Book 2015*).

[64] For example, lump sum commutation, trivial commutation, early/late retirement, increasing a partner's benefits at the expense of the member's benefits, and pension increase exchanges.

[65] Valuation and risk assessment of a deferred annuity can be broken down into five overlapping components: survival to retirement; the socio-economic group of the pensioner at the date of retirement; the base mortality table at the time of retirement for that socio-economic group; general mortality improvements (e.g., age 65+) up to the date of retirement; and the mortality improvement rate after retirement. Uncertainty in the probability of survival to retirement will typically be quite small in relation to the other risks.

> a robust existence checking procedure is needed involving electronic tracing, assuming a fixed percentage of the pension is exchanged for tax-free cash, setting the assumed retirement date to the plan's normal retirement date, assuming no pension is exchanged for additional partner pension, restricting the age profile to older deferred members, and restricting the proportion of deferred members in the transaction.[66]

These are all innovations in the space linking pension plans and insurance companies designed to ease the transfer of pension liabilities (or at least the longevity risk in them) from pension plans to insurance companies.

The innovations have helped to encourage more business, but this, in turn, has exposed potential longer term capacity constraints within insurance companies. As one consultant said: 'Given the market has historically completed only 150-200 deals in any one year, there is a real risk of capacity constraints in the market, not just from an insurer capital perspective, but also from a resource and expertise perspective'.[67]

A total of £12.4bn in buy-ins and buy-outs and £.6.4bn in longevity swaps took place in the UK in 2017.

In April 2015, the UK government introduced 'Freedom and Choice' pension reforms which gave more flexibility to how individuals could draw down their defined contribution (DC) pension pots.[68] In particular, there was no longer a requirement to purchase an annuity.[69] This immediately led to a fall in annuity sales by around 75% (Cannon et al (2016)). The situation was not helped by the fall in gilt (UK government bond) yields (which led to a corresponding fall in annuity rates) arising from the government's quantitative easing programme introduced after the Global Financial Crisis. In August 2017, a 65-year old with a £100,000 pension pot, could get a level income for life of £4,894: two years before, the amount would have been £5,292.[70] By 2017, the following insurers had pulled out of the open market for annuities: Aegon, LV=, Partnership (before it merged with Just Retirement to form Just Group), Prudential (UK), Standard Life, Friends Life (merged with Aviva), Reliance Mutual, B&CE, and Retirement Advantage. This left just six providers in what was once the world's largest annuity market: Aviva (offering standard and enhanced (i.e., medically underwritten) annuities), Canada Life (standard and enhanced), Hodge Lifetime (standard only), Just Group (enhanced only), L&G (standard and enhanced) and Scottish Widows (standard and enhanced).[71]

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[66] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference.

[67] Martyn Phillips, Mercer (quoted in *Professional Pensions* (2016) Risk Reduction and the Extent of Trust in Pension Scheme Advisers and Providers, June, p.28). Hannover Re had previously warned about this: 'The number of risk-takers is limited and there is no unlimited capacity in the market for taking on longevity risk. The increasing worldwide demand for longevity cover will challenge the capacity for securing longevity risk' (quoted in Punter Southall (2015) *De-risking Bulletin*, March). At the time, there were significant human resource bottlenecks in some parts of the transaction chain, in particular, a shortage of qualified lawyers.

[68] The proposal was announced by the UK finance minister (George Osborne) in his Budget Speech on 19 April 2014.

[69] https://www.pensionsadvisoryservice.org.uk/about-pensions/pension-reform/freedom-and-choice

[70] Josephine Cumbo (2017), Pensioners hit as annuity rates drop 10% in two years, *Financial Times*, 1 September.

[71] *Source: Hargreaves Lansdown, August 2017.* Scottish Widows introduced a standard annuity in September 2019.

In place of annuities, individuals took their pension pot either as a lump sum or they purchased an income drawdown product. In both cases, they bear their own longevity risk. Evidence shows that people systematically underestimate their life expectancy which implies that there is a significant probability that many people will spend their pension pot before they die. A study by Just Group found that UK men aged 40-54 expect to live until 78.9 years on average, whereas official estimates of their life expectancy is 87.5; the figures for women are 80.5 and 90.1.[72]

A number of UK insurers providing bulk annuities for buy-ins are also involved in the UK equity release mortgage (ERM, or reverse mortgage or lifetime mortgage) market which allows home owners to borrow against the equity in their homes. The modern form of the market began when the Equity Release Council (ERC) representing providers was established in 1991 with a voluntary code of conduct that offered a number of guarantees. Before this, users of the product could lose their homes when the value of the loan plus interest exceeded the value of the property. Since 1991, there is a guaranteed right to remain living in the property, either for life or until entry into long-term care. In addition, there is a 'no negative equity guarantee' (NNEG)[73] which means that the value of the loan plus interest can never exceed the value of the property, and so no debt can be passed on to the estate of the equity release borrower. The providers in the new market therefore face longevity risk in a way that those in the old market did not. In 2017, a total of £3bn in equity release loans were made with an average size loan of £102,000. In 2018, the UK Prudential Regulation Authority (2018) raised concerns that providers were not properly reflecting the cost of the NNEG in their capital reserving. Instead of valuing the NNEG using the Black (1976) model as a series of put options on the forward house price (which is lower than the current price to reflect the loss of rental income due to deferred possession) weighted by the probability of mortality, morbidity and pre-payment, it pointed out that most providers were using the expected future house price which required assumptions about property growth.

There were also important developments outside the UK in 2017, although many of these involve innovations adopted from the UK market. Apart from the US, Canada, and the Netherlands, new markets include Germany, Switzerland and Ireland. Examples of innovations in the US include: plan-specific mortality data – with $250m as the minimum transaction size; asset-in-kind premium funding – where bonds are used to fund the transaction. Insurer capacity has also increased, with 14 insurers engaged in pension buy-outs. Three new insurers joined: Athene,[74] Mutual of America, and CUNA Mutual. Athene wrote more than $2bn of business in 2017. A total of $24.7bn pension risk transfers were conducted in the US in 2017. In Canada, group annuity sales amounted to C$3.7bn, and a new group annuity provider, Brookfield Annuity, joined the market. In Germany, many schemes are considering using lump sum settlement payments to pensioners to transfer longevity risk. In Switzerland, insurers are now willing to consider transfers involving active members. In Ireland, Danske Bank transferred €335m of its Irish DB pension liabilities to Irish Life.[75]

In April 2017, the International Monetary Fund (IMF) released a new edition of its *Global Financial Stability Report*. Chapter 2 ('Low Growth, Low Interest Rates, And Financial

[72] Chris Seekings (2018) Millions of Brits underestimating their life expectancy by a decade, *The Actuary*, 3 May. There were similar findings in a study by the Institute for Fiscal Studies, see James Phillips (2018) New retirees overly pessimistic about life expectancy, *Professional Pensions*, 17 April.
[73] See Dowd et al. (2019).
[74] Athene is majority owned by private equity company Apollo Global Management, LLC.
[75] Navigating you through your de-risking journey: Overseas, *Aon Risk Settlement Market Review 2018*.

Intermediation') suggests that DB pension funds across the globe might have to cut benefits 'significantly' in the long term because of ultra-low interest rates. Attempts to increase returns by changing asset allocations 'appears feasible only by taking potentially unacceptable levels of risk'. In the face of such low rates, the IMF argues that 'life insurers and pension funds would face a long-lasting transitional challenge to profitability and solvency, which is likely to require additional capital' or would require a 'very high' level of volatility risk to meet their funding goals. However, a combination of risk aversion and regulatory constraints was likely to deter the vast majority from taking this second path. The IMF instead believes that the current situation might work to the benefit of insurers backing buy-ins and buy-outs. With investors increasingly monitoring the size of DB liabilities and the effects on company share prices, profits, and dividends, the IMF said offloading these liabilities to insurers 'is an attractive option' and 'may represent a market-efficient arrangement' and that 'regulation could play an important role in this area by facilitating such transactions'.

Longevity 14: 2018

The fourteenth conference (*L14*) was held in Amsterdam on 20-21 September 2018. It was hosted by the Pensions Institute and the Netspar Network for Studies on Pensions, Aging and Retirement.[76]

2018 saw the start of a trend towards consolidation amongst pension schemes in the UK. This was led by a group of private equity investors. One example is the Pension Superfund which was launched in March with £500m in seed capital provided by Disruptive Capital and Warburg Pincus. Another example is Clara-Pensions which has £500m in seed capital from TPG Sixth Street Partners. Both have set up as occupational pension scheme master trusts. Antony Barker of the Pension Superfund predicted that if the UK follows the experience of the Dutch and the Australian markets, consolidation could lead to the 5,500 UK DB schemes being reduced to 1,500 by the end of the decade. He argued that, while many will go into insurance buy-outs and another 50-100 insolvent schemes could end up in the Pension Protection Fund (PPF),[77] this leaves leaves potentially 2,000 that could end up with a superfund. That could represent £800bn in assets out of a total of £1.8trn in UK DB pension assets.[78]

The business models of the two consolidators are different, however. Clara-Pensions takes over the obligations and risks from pension scheme sponsors, but then becomes a 'bridge to a buy-out'. Its shareholders do not see a return on capital until every member has their full benefits secured in the insured market. In the meantime, it will need to hedge these risks, including longevity risk. By contrast, the Pension Superfund operates as a long-term run-off scheme. But instead of being supported by an operating company covenant, as in a standard occupational pension scheme trust, it is supported by a financial covenant in the form of a partnership holding material financial commitments from the former sponsor and new external capital providers, that should ensure members get at least 99% certainty of receiving their promised benefits in full. Any surplus of assets above 115% of liabilities 'on a prudent actuarial basis'

[76] The conference proceedings for *L14* were published in volume 14(2) of the *Annals of Actuarial Science* in 2020.

[77] The Pension Protection Fund is a statutory fund in the UK which takes on the assets and liabilities of the defined benefit schemes of UK companies that have become insolvent. Any member who is over their normal retirement age or who retired early due to ill health will receive 100% of their current pension. Other members will receive 90% of their pension entitlement at the time of insolvency up to a cap. The sponsors of all eligible schemes must pay a levy to the PPF. See https://www.ppf.co.uk/

[78] Quoted in Mona Dohle (2020) Superfunds - New entrants to the DB consolidation market, *Portfolio Institutional*, 17 August.

will be shared one-third to members and two-thirds to the investors. The liabilities would be hedged and the investment strategy would be 'fairly low risk'. The Pension Superfund intends to use reinsurance through a captive model in due course. It would be initially targeting schemes with assets between £200m-£1bn with a strong sponsor covenant.[79]

Insurers have expressed concerns that, since such pension consolidation vehicles come under the Pensions Regulator (TPR) (i.e., are classified as pension schemes), they do not have to satisfy the much stricter solvency requirements of insurers which are regulated by the Prudential Regulation Authority, which is part of the Bank of England.[80] Both the Pension Superfund and Clara-Pensions aim to undercut insurance buy-out pricing by up to 10-15%.[81] The two consolidators justify themselves as filling a gap between a full insurance buy-out and schemes entering into the PPF following the insolvency of their sponsor. Each year, around 2% of the UK's 5,500 schemes either buy-out or enter the PPF. The consolidators offer a solution to solvent companies that cannot afford a full buy-out. Insurers have responded to the challenge from the consolidators by offering these companies access to an investment and hedging strategy that moves them closer to the goal of a full buy-out or buy-in. The Pension Superfund agreed two deals in 2019, but these have been delayed due to an absence of regulatory approval and the government was at the time still considering an authorization, supervision and solvency regime.[82] An interim regime for superfunds was introduced in June 2020. In November 2021, Clara-Pensions became the first superfund to complete TPR's assessment process and meet its 'tough new standards' of governance and administration. It appointed Kempen Capital Management as fiduciary manager and Hymans Robertson as scheme administrator.[83]

The General Data Protection Regulation (GDPR) was introduced in all EU member states in May 2018 and will affect longevity risk transfers since they involve the exchange of personal data. There are fines for data protection breaches. The GDPR distinguishes between data controllers – people who determine how and why data should be used – and data processors – who process data on behalf of data controllers. Pension scheme trustees will be data controllers, as will insurers if they have received personal data in connection with a potential buy-out transaction (e.g., if they are conducting a data cleansing or medical underwriting exercise). In other cases, insurers might be classified as data processors. International data transfers, e.g., in the case where an insurer wants to transfer data to a reinsurer located outside the European Economic Area, can only take place if adequate data protections are in place. Care needs to be taken even if anonymized data is transferred, since it might still be possible to identify the individuals to whom the data relates, e.g., company directors might be identified from information about the size of their pension benefits and date of birth.

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[79] Adam Saron, Chief Executive Officer, Clara-Pensions, and Antony Barker, Managing Director, The Pension Superfund, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020. See also Willis Towers Watson *De-risking Report 2020*, January (p.24).

[80] James Phillips (2018) The Pension Superfund to split surplus with members and capital providers, *Professional Pensions*, 12 July.

[81] *Superfunds: New solutions for DB pension plans?*, KPMG, August 2018; https://assets.kpmg/content/dam/kpmg/uk/pdf/2018/08/kpmg-superfunds-solutions-for-db-pension-plans.PDF

[82] Nick Reeve (2019) Pension Super Fund signs up second client in £300m deal, *IPE*, 30 July; James Phillips (2019) Clara: 'Shadow market' is huge for DB consolidation, *Professional Pensions*, 22 October. The Government passed a Pension Schemes Act in February 2021, but it did not contain legislation for a DB consolidator regime.

[83] https://www.pensionsage.com/pa/BREAKING-Clara-Pensions-becomes-first-TPR-assessed-DB-superfund.php

For 2018, the key highlights in the UK longevity risk transfer market were:[84]

- PIC reinsured all its pensioner liabilities (73% of its total exposure) with Partner Re in January. It also helped to fund University Partnerships Programme acquisitions of student accommodation with index-linked bonds in February.
- Scottish Widows executed a £1.3bn longevity swap with PICA in February.[85] It was the last UK insurer to hedge at least some of its longevity risk. It did this to reduce its Solvency II capital requirements.
- Standard Life Aberdeen sold £2.93bn of its annuity back-book to Phoenix in February, with the rest of Standard Life Assurance sold to Phoenix in September.
- Prudential (UK) sold £12bn of its annuity back-book covering 400,000 policies to Rothesay Life in March, making Rothesay the UK's largest specialist annuity insurer with more than £37bn of assets and 750,000 lives insured.[86]
- In March, the Marks & Spencer Pension Scheme executed two buy-ins totalling £1.4bn with Aviva and Phoenix covering 15% of its pension liabilities. It was Aviva's largest buy-in to date (at £925m) and Phoenix's first external buy-in (at £475m).
- In March, PIC and PICA introduced a 'flow reinsurance' system which automates the longevity reinsurance element of buy-outs and buy-ins for schemes with liabilities below £200m. The system allows PIC to secure a commitment from PICA to assume the longevity risk early on in a transaction.
- In March, employee benefits consultant, JLT, launched a 'buy-out comparison service' and monitoring tool which allows schemes to upload their own data and receive regular bulk annuity quotations from eight insurers currently active in the market.
- In April, JLT became the first consultant to implement Club Vita's longevity analytics capabilities which have been incorporated into RiskFirst's PFaroe modelling system for DB plans. This will allow JLT clients to set best-estimate longevity assumptions.[87] Club Vita data shows that pension schemes can have a very different demographic composition compared with the national population, with liabilities that could be up to 10% higher or lower as a result of different mortality experience.
- PIC executed a £900m longevity swap with PICA in May, covering 7,500 pensioners.[88]

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[84] There were £24.2bn of transfers (buy-outs and buy-ins) in the UK in 2018 plus another £7bn in longevity swaps. The biggest insurers in the market were L&G, PIC, Zurich, Scottish Widows, Aviva, Canada Life, Just, Phoenix Life, and Rothesay Life (*LCP De-risking Report 2020*).

[85] Since 2011, PICA has completed more than £32bn in international reinsurance deals, including the £16bn deal with the BT Pension Scheme in 2014.

[86] In August 2019, the High Court in London blocked the Prudential-Rothesay transfer on the grounds that Rothesay was a 'relatively new entrant without an established reputation in the business' and although it had solvency ratios at least equal to Prudential's, 'it does not have the same capital management policies or the backing of a large group with the resources and a reputational imperative to support a company that carries its business name if the need were to arise over the lifetime of the annuity policies' (Susanna Rust (2019) High Court blocks £12bn Prudential-Rothesay annuities transfer, *IPE*, 19 August). In September 2019, Prudential and Rothesay announced that they would appeal against the decision on the basis that the judgement 'contains material errors of law' and should be reconsidered. On 2 December 2020, the Appeal Court granted an appeal against the High Court decision to block the Prudential to Rothesay Life transfer, on the grounds that the High Court had not given adequate weight to analysis by industry bodies and conclusions by the Prudential Regulation Authority and the Financial Conduct Authority, neither of which objected to the transfer. The issue of whether to sanction the scheme would be passed to the High Court for a second hearing. In November 2021, the High Court approved the transfer of the £12bn portfolio of annuities from Prudential (now a subsidiary of M&G) to Rothesay Life. The transfer was part of Prudential's demerging of its asset management and UK/European life insurance businesses under the M&G brand.

[87] Club Vita is a longevity data analytics company which pools data from over 220 UK DB schemes covering 2.8m pensioners, approximately one quarter of the total. RiskFirst is a fintech company which launched the PFaroe software in 2009 to enable pension funds to manage their asset and liability risks.

[88] This brought the total value of all the deals between the two companies to £4.4bn.

- In June, Canada Life sold its £2.7bn back book of 155,000 UK life and pension savings policies to Scottish Friendly. The company said it wanted to concentrate on developing new retirement products following its acquisition of Retirement Advantage, an annuity and retirement income specialist, in January.
- Siemans completed a £1.3bn buy-in of its UK pension liabilities covering 6,000 members with PIC in July.
- Aviva executed a £1bn longevity swap with PICA in August.
- National Grid Electricity Group completed a £2bn longevity swap with Zurich[89] for the Electricity Supply Pension Scheme also in August.
- In August, L&G entered the small scheme longevity insurance market after completing a £300m longevity swap with an unnamed pension fund. The deal had a 'streamlined structure' with simplified data requirements which helped to keep fixed costs down. The swap was later reinsured with SCOR. According to L&G, 'the transaction demonstrates that longevity reinsurance is a realistic option for most pension schemes, including for trustees whose schemes are not quite at the point they can enter into buy-in or buy-out, but want to manage their longevity risk'.
- In September, the British Airways' Airways Pension Scheme entered into the UK's largest buy-in agreement to date (at £4.4bn) with L&G, covering 60% of pensioner liabilities; taking account of the £1.7bn longevity swap agreed in 2017, the scheme has now hedged 90% of its longevity risk.
- The Automobile Association Pension Scheme completed a £351m buy-in with Canada Life also in September.
- In October, the UK pension scheme of Nortel, the Canadian telecoms company which became insolvent in 2009, agreed a £2.4bn buy-out deal with L&G, covering 15,000 pensioners and 7,200 deferred members, thereby avoiding entering the Pension Protection Fund.
- In December, PIC executed another longevity swap, this time with SCOR, covering 8,000 pensioners and valued at £1.2bn.[90]

In April 2018, the PRA said it was concerned that too much longevity risk was being transferred offshore through reinsurance arrangements, preferring that more of it be retained in the UK. It said it would consider amending Solvency II risk charges to encourage greater retention. While it said it understood the need for risk transfer, it said that it was concerned that pension assets were being transferred overseas, taking them outside of its regulation, so that if an offshore reinsurance firm failed, UK pensioners might not get their pensions.[91]

The first ever longevity swap in the US was executed by RGA in 2018. In Canada, the Life Insurance Capital Adequacy Test (LICAT) regulations came into effect at the start of 2018. RGA redesigned a longevity transaction structure to create two LICAT-compliant cash flow swaps which transferred longevity risk but not investment risk, and improved capital efficiency for both parties[92]

[89] Zurich reinsured a significant proportion of the longevity risk with Canada Life Re. It has executed £3.5bn longevity risk transfer deals since it entered the market in 2016.
[90] This brought the total value of the deals between the two companies to £2.2bn.
[91] Steve Evans (2018) Bank of England wants more longevity risk retained, less reinsured, *Reinsurance News*, 27 April; https://www.reinsurancene.ws/bank-of-england-wants-more-longevity-risk-retained-less-reinsured/
[92] https://www.rgare.com/docs/default-source/investor-relations/rga_ar18.pdf

Longevity 15: 2019

The fifteenth conference (*L15*) was held in Washington DC on 12-13 September 2019. It was hosted by the Pensions Institute at City, University of London.[93]

A total of £43.8bn longevity risk transfer deals were announced for the UK in 2019.[94] XPS reported that for a buy-out for a medium-sized scheme, pensioner member transfers used a 'gilts + 0.3% p.a.' discount rate to value the liabilities (i.e., technical provisions), while for deferred members the discount rate was 'gilts – 0.5% p.a.'.[95] Willis Towers Watson reported an average buy-in price at 0.15% p.a. above gilts.[96] Highlights included:

- In January, PIC invested £125m in Exeter University accommodation in order to generate index-linked cash flows to pay its pensioners.

[93] The conference proceedings for *L15* were published in *Insurance: Mathematics and Economics*, Volume 99, July 2021, Pages 130-508.

[94] *LCP De-risking Report 2020*. This compares with £1bn when the market started in 2006. The eight insurance companies involved were: Rothesay Life (37% market share), L&G (24%), PIC (16%), Aviva (9%), Phoenix Life (9%), Scottish Widows (5%), Just (3%), and Canada Life (1%). Their total assets and asset allocations are given below. In terms of transaction volumes, 65% of deals were over £1bn, 29% of deals were between £100m and £1bn, and 6% of deals were below £100m.

Total assets and asset allocations of the main UK PRT providers 2019

	L&G	Rothesay Life	Aviva	PIC	Scottish Widows	Just	Canada Life	Phoenix Life
Total assets (£bn)	75.9	53.7	46	40.9	22	21.6	18.7	11.7
Government bonds & cash (%)	72	47	14	44	30	57	61	28
Corporate bonds (%)		14	29	53	30			44
Equity release/lifetime mortgages (%)	6	5	16	3	40 (alternative credit investments)	37	6	23
Commercial mortgages and healthcare (%)	-	-	16	-		-	8	-
Secured Lending and residential mortgages (%)	-	25	-	-		-	-	-
Infrastructure (%)	-	9	17	-	-	4	-	-
Private placement and structured finance	-	-	4	-	-	2	-	5
Direct investments (%)	22	-	-	-	-	-	-	-
Real estate (%)	-	-	-	-	-	-	5	-
Other (%)	-	-	4	-	-	-	-	-

Source: LCP *De-Risking Report 2020*

[95] *XPS Risk Transfer News*, issue 10/19.

[96] Figure 2 in Willis Towers Watson *De-risking Report 2020*, January.

- In the same month, PIC completed a £425m buy-in with the Co-operative Group's Somerfield Pension Scheme.
- L&G executed buy-ins with the Pearson Pension Plan (£500m in February), Howden Group Pension Plan (£230m in March) and 3i Group (£95m in April).
- Rothesay completed a buy-in (amount undisclosed) with the Teachers Assurance Group Pension Scheme in February, and a £110m buy-out with the Laird Pension Scheme in April.
- Also in April, PIC completed a £1.2bn buy-in with Commerzbank in respect of the Dresdner Kleinwort Pension Plan of its UK subsidiary. This involved three transactions. The first was a £900m buy-in of the DB section. The second and third involved the DC section and gave members of the hybrid scheme the option of transferring their DC pension out or convert it into a DB equivalent for transfer to PIC.
- In May 2019, the British American Tobacco UK Pension Fund completed a £3.4bn buy-in with PIC, the second-largest buy-in to date.
- Also in May, PIC and Phoenix insured £900m and £460m, respectively, of the liabilities of Marks & Spencer's UK pension scheme.
- In June, Rolls Royce executed the biggest buy-out to date – at £4.6bn – with L&G, covering the benefits of 33,000 pensioners. As part of the deal, a longevity swap originally with Deutsche Bank was transferred to L&G – the first time a swap has been novated between counterparties.
- In July, Scottish Widows completed buy-ins totalling £830m with Peugeot and QinetiQ
- In August, PIC executed a £3.4bn de-risking deal with the British American Tobacco UK Pension Fund covering both 8,300 pensioners and 2,300 deferred members. It is the biggest deal to date covering both retired and non-retired members.
- In August, PICA completed a £7bn longevity swap with banking group HSBC's UK pension scheme – making it the second largest swap in the UK after the £16bn swap for the British Telecom Pension Scheme in 2014, also arranged by PICA. The transaction – which covers half of the scheme's pensioner liabilities – was structured as an insurance contract with a Bermuda-based, HSBC-owned captive insurer, which reinsured the longevity risk with PICA. It was the first captive longevity reinsurance transaction for a pension scheme associated with a major bank. Amy Kessler, PICA's head of longevity risk transfer, said: 'The captive approach has become the strategy of choice for large pension schemes seeking to hedge longevity risk'.[97]
- In August, Phoenix Life completed a £1.1bn buy-in of its own DB pension scheme, the PGL Pension Scheme. In the same month, it executed a longevity reinsurance arrangement with PICA.[98]
- In August, Rothesay Life executed a £520m buy-in with the Cadbury Mondelēz Pension Fund, covering 1,900 pensioner members.
- In August, L&G announced it had completed a buy-in transaction for the UK hybrid pension scheme of data and technology company Hitachi Vantara. The deal was described as 'innovative' since it also took into account the DC elements of the scheme. Each member's retirement benefit is based on the higher of the DB and DC pension over their career with Hitachi Vantara. The buy-in was structured to maintain this arrangement, allowing deferred members to 'consider their options' prior to a full buy-out.[99]

[97] Susanna Rust (2019) HSBC pension scheme strikes £7bn longevity risk transfer, *IPE*, 6 August.
[98] https://www.artemis.bm/news/prudential-in-longevity-reinsurance-deal-for-pension-insurer-phoenix/
[99] Nick Reeve (2019) L&G backs 'innovative' buy-in for Hitachi UK pension scheme, *IPE*, 14 August.

- In September, L&G arranged a £930m buy-in with the Tate & Lyle Pension Scheme, covering 4,800 members.
- In September, Rothesay Life executed an even larger buy-in than the Rolls Royce deal in June – at £4.7bn – with the GEC 1972 Plan, covering 39,000 members split 70-30 between pensioners and deferreds. There is an option for a buy-out at a later date. Hence this is known as a 'buy-in to buy-out deal'. The parent company of GEC is Telent.
- Also in September, Rothesay Life insured £3.8bn of members' benefits for the Allied Domecq Pension Fund in another buy-in covering around 27,000 pensioners and deferred members, spilt 63-37. The parent company of Allied Domecq is the Pernod Ricard Group.
- In October, Rothesay completed a £2.8bn buy-in with the National Grid Pension Scheme (Section A). The following month, L&G completed a £1.6bn buy-in with the National Grid Pension Scheme (Section B), covering 6,000 pensioner members.
- In October, Rothesay executed a full buy-in with retailer ASDA (owned by Walmart) for £3.8bn, covering 4,800 pensioners and 7,500 deferred members. This converted to a full buy-out in 2020-21 at an additional cost of £800m.
- In October, Aviva Life and Pensions UK completed a £1.7bn buy-in for the Aviva Staff Pension Scheme, covering 1,500 pensioners and 4,300 deferred members.
- In November, Phoenix completed a £144m buy-in with the Aegon UK Staff Retirement and Death Benefit Scheme.
- In December, Zurich and Hannover Re completed a £800m longevity swap with an unnamed FTSE100 company.

Other UK developments in 2019 included:

- In February, L&G launched Track My Apps, a tracking service provided by fintech company Origo, to enable advisers to track their clients pension transfers online.
- £936m of equity release deals in the first quarter with 20,000 households, taking out an average of £50,000 in housing wealth.
- In May, L&G announced the creation of a UK retirement housing business called Guild Living which plans to deliver 3,000 new homes over the next five years with a gross development value of £2bn.[100] The business will contribute the income it needs to pay the benefits on its longevity risk transfer business. In August, L&G announced it had acquired a site in Walton-on-Thames suitable for building 300 homes.
- In June, L&G launched the first pension risk transfer execution platform to be driven by blockchain technology. Known as 'Estua-Re', the technology provides a 'single ecosystem capable of driving every stage of the PRT reinsurance value chain', including pricing, claims handling, financial reporting, and collateral. It allows multiple parties to transact with each other without the need for an intermediary and there will be greater transparency since all parties will have access to the latest version of the ledger database.[101]
- In August, PICA and the Phoenix Group launched a reinsurance counterparty to provide longevity reinsurance for insurers in the UK pension risk transfer market, covering both their buy-out and buy-in transactions. Phoenix head of bulk annuities Justin Grainger said: 'Phoenix views longevity reinsurance as a key risk management tool. This transaction brings further depth to our reinsurer relationships and enhances our ability

[100] https://www.legalandgeneralgroup.com/media-centre/press-releases/legal-general-launches-guild-living-bringing-retirement-communities-to-uk-city-centres/

[101] https://www.professionalpensions.com/news/3077264/-deploys-blockchain-technology-streamline-pension-reinsurance

to offer competitive terms to pension schemes as we continue to develop our de-risking proposition'. Prudential Financial head of international transactions for longevity risk transfer Rohit Mathur said: '[PICA] has consistently focused on supporting the entire UK pension de-risking market. The addition of Phoenix is a culmination of our efforts over the past several years to do just that. We have invested in our pricing and transaction teams and …and we are happy to be in a position to support the robust pipeline of pension buy-ins and buy-outs seeking to be completed while market conditions hold'. PICA was advised in this deal by Willkie Farr & Gallagher, while Phoenix was advised by CMS and Eversheds Sutherland.[102]

- In September, Rothesay announced it would raise an additional £500m in shareholder capital to support its longevity risk transfer business – which in 2019 alone executed around £10bn in new deals.
- In November, L&G agreed to provide annuities to Prudential (UK) customers with guaranteed rates. As part of the deal, all guaranteed benefits will be honoured by Prudential and fulfilled by L&G. Prudential (UK), while remaining a UK-registered company, is closing down its UK operations in favour of growing its business in the Far East.
- In November, PIC converted a £800m longevity swap – originally executed in 2017 with L&G – for a £750m buy-in for Scottish & Southern Energy (SSE) on the back of improved funding for the pension scheme. This is the first example of a transfer of obligations between counterparties where the first counterparty (L&G) could have offered the buy-in itself. In novating the swap between counterparties, it is another important milestone in bringing an early form of liquidity to the longevity swaps market. The first conversion of a longevity swap to buy-in took place in 2016 (by Phoenix Life) and the SSE conversion is the fifth one to date. PIC said that a longevity swap provides a useful first step towards a buy-in.[103]
- In November, Scottish Friendly bought the back book of Canada Life's 127,000 life and pensions policies, with assets under management increasing by £2.4bn as a result.
- There was a modest recovery in annuity sales following the big fall in sales after the 'Freedom and Choice' reforms of 2015. There were 74,000 (internal and open market) annuity purchases in 2018/19. Annuity rates for 65-year olds were 4%, which although low by historical standards, exceeded the 3% that a lower-risk fund recommended as a sustainable withdrawal rate.[104]

There were a number of reasons explaining the strength of the UK longevity risk transfer market in 2018 and 2019. First, funding levels had improved as a result of deficit reduction contributions and strong equity returns, which increased asset values, and lower liability values due to a combination of higher interest rates and lower mortality improvements since 2011;[105] UK funds exhibited the first surplus in aggregate since 2011.[106] Second, there was an increase

[102] Holly Roach (2019) PICA launches reinsurance counterparty to back UK bulk annuities, *Professional Pensions*, 5 August.
[103] Susanna Rust (2019) Energy scheme completes rare longevity swap to buy-in conversion, *IPE*, 13 November.
[104] Greg Nielson (2019) Glimmers of an annuity market renaissance, *Retirement Planner*, 7 November.
[105] This is discussed later.
[106] At the end of November 2018, aggregate pension assets were £1.58trn, while aggregate pension liabilities were £1.57trn on a section 179 basis, according to the Pension Protection Fund's *Purple Book*. Some 3,008 schemes had a combined deficit of £137.6bn, while 2,442 schemes had a combined surplus of £151.9bn. During the previous 10 years, FTE100 companies had paid £82bn into their DB schemes in order to reduce their deficits (which equals one-eighth of the £636bn they paid out in dividends). If companies doubled their annual pension

in capital and competition from insurers which had recruited heavily and so had more staff to model pension scheme mortality, provide price quotations and implement transactions. Third, was an associated increase in reinsurance capacity, which is important since most of the longevity risk assumed by insurers is reinsured with global reinsurers. Fourth, there had been increasing standardization of the frameworks used to execute transfers, with three dominant examples: intermediated, pass through, and captive. Fifth, insurers had been increasing their investment in high yielding illiquid matching assets, such as infrastructure, housing and urban regeneration, and equity release, and had passed on the additional yield (including illiquidity premium) to schemes in the form of lower prices. Sixth, greater certainty over how Solvency II reserving requirements operate had helped to reduce margins for prudence. Finally, once a scheme closes to new entrants, its maturity increases rapidly: the proportion of the scheme's liabilities due to pensioners increases and the average age of non-pensioners also increases. Mature schemes tend to attract more favourable pricing because: scheme data for pensioners tends to be more reliable than for other types of member, there is less uncertainty over the timing and size of future cash flows, and the risk of the actual mortality experience deviating from that which was assumed is lower. All this helped to reduce the capital an insurer is required to hold.[107] Mercer has estimated that by 2030 more than £600bn of longevity risk transfers will have taken place in the UK, which represents around one-third of UK pension fund assets.[108]

Outside the UK, some significant developments took place in 2019, including:

- A longevity swap by RGA Life Reinsurance Company of Canada, covering 45,000 Manulife Canadian annuitants (February).
- A longevity swap by PartnerRe, covering 25,000 Manulife annuitants (March and May).
- A €5.5bn longevity swap by Canada Life Re, covering 150,000 in-payment and deferred pensioners liabilities of Dutch firm VIVAT (March).
- A €12bn longevity swap by Canada Life Re, for Dutch insurer Aegon, covering 200,000 in-payment and deferred pensioners (December).[109]
- There were also some significant buy-outs and buy-ins, e.g., PICA's $1.8bn buy-out of the Lockheed Martin pension scheme and a C$200m buy-in with an unnamed Canadian scheme executed by Brookfield Annuity Company and reinsured by L&G; this was L&G's first transaction in Canada.
- LifeXcel, a trading platform for mortality-linked contracts (MLCs), such as life settlements, was established in the US for institutions and hedge funds only. LifeXcel is a alternative assets administration company, specializing in structuring, distributing, and managing portfolios of MLCs. In 2021, the platform opened to 'accredited investors' in the US.

contributions to £16.6bn, 30% of schemes could buy-out their pension liabilities in 5 years, and 70% in 10 years (Kim Keveh (2019) Half of FTSE100 DB schemes could buy-out within 10 years, finds Barnett Waddingham, *Professional Pensions*, 1 July).

[107] Attractive pricing opportunities for buy-in/buy-out, XPS Pensions, Briefing Note No, 2, June 2018.

[108] Mark Cobley (2019) Pension insurance deals to top £600bn by 2030, says Mercer, *Financial News*, 16 December.

[109] https://www.artemis.bm/news/aegon-gets-e12bn-longevity-reinsurance-cover-from-canada-life-re/

We had mentioned earlier the problem of capacity constraints in the insurance and reinsurance industries. Our conference series is explicitly about capital markets solutions to the problem of transferring longevity risk. When the modern form of the longevity risk transfer market started in 2006, investment banks, such as J.P.Morgan, with their links to capital market investors, were active in the market along with insurers. However, the Global Financial Crisis in 2007-08 and the 2010 US Dodd-Frank (Restoring American Financial Stability) Act which followed led to the majority of investment banks withdrawing from the market. A few banks with insurance subsidiaries – such as Goldman Sachs, owner of Rothesay Life, and Deutsche Bank, owner of Abbey Life – remained for a while before they too sold their life businesses. So for the past few years, the market has been dominated by insurers and reinsurers. However, they are beginning to see that the current growth rates in the market are not sustainable without new sources of external (or third-party) capital.

One new solution to this problem that has emerged recently is the reinsurance sidecar – which is a way to share risks with new investors when the latter are concerned about the ceding reinsurer having an informational advantage. Formally, a reinsurance sidecar is a financial structure established to allow external investors to take on the risk and benefit from the return of specific books of insurance or reinsurance business. It is typically set up by existing (re)insurers that are looking to either partner with another source of capital or set up an entity to enable them to accept capital from third-party investors (Bugler et al. (2021)).

It is established as a special purpose vehicle (SPV), with a maturity of 2-3 years. It is capitalized by specialist insurance funds, usually by preference shares, though sometimes in the form of debt instruments. It reinsures a defined pre-agreed book of business or category of risk. Liability is limited to the assets of the SPV and the vehicle is unrated. The benefit to insurers is that sidecars can provide protection against exposure to peak longevity risks,[110] help with capital management by providing additional capacity without the need for permanent capital, and can provide an additional source of income by leveraging underwriting expertise. The benefit to investors is that they enjoy targeted non-correlated returns relating to specific short-horizon risks and have an agreed procedure for exiting; investors can also take advantage of temporary price hikes, but without facing legacy issues that could affect an investment in a typical insurer.

There are a number of challenges to the use of sidecars in the longevity risk transfer market. There is the tension between the long-term nature of longevity risk and investor preference for a short-term investment horizon. There are also regulatory requirements on cedants, affecting their ability to generate a return. These include: the posting of prudent collateral, the underlying assets in the SPV must generate matching cash flows, the risk transfer must be genuine, and the custodian/trustee must be financially strong. There is also a risk to cedants of losing capital relief if regulatory requirements are not met or they change.

Three reinsurance sidecars were established at the end of 2017 and the beginning of 2018, with investment capital provided by private equity investors and hedge funds, in addition to insurers and pension funds.

In December 2017, Athene entered into a reinsurance agreement with Voya Financial, covering $19bn of fixed, indexed and variable annuity liabilities. The matching assets will be managed by Athene Asset Management. By using an ‘enhanced asset management’ strategy and

[110] That is, specific individual cashflows that give rise to the greatest uncertainty in value terms.

positioning itself for 'incremental value creation in a more favorable credit spread environment', the company hopes to generate 'mid-teens returns'. The capital is supplied mainly by private equity investors, including Apollo, Athene's parent company, Crestview Partners and Reverence Capital Partners.[111]

In January 2018, RGA Re and RenaissanceRe, announced a new start-up named Langhorne Re, which will target in-force life and annuity business. The new company has secured $780m of equity capital from RGA, RenaissanceRe and third-party sidecar investors, including pension funds and other life companies.[112]

In February 2018, the $400m Leo Re Ltd 2018-1 collateralized reinsurance sidecar was established between Dutch pension fund manager PGGM and Munich Re as a private ILS deal. The agreement allows PGGM, which manages the pension assets of the Dutch healthcare workers' scheme, PFZW, to gain access to a share of Munich Re's portfolio. PGGM will enter into direct ILS trades with counterparties, via quota share arrangements with a reinsurer, for a proportion of the counterparties' underwriting book, thereby sharing in the cedents' risks and underwriting returns.[113]

By 2021, more than $20bn in third-party capital from sidecar investors had been deployed to support around $400bn worth of life and annuity book transfers. There are three categories of transactions. The first is standard spread business, like pension risk transfer, fixed annuities, or fixed indexed annuities. The second focus on mortality risk for inclusion in the same sidecar as annuity risk, thereby offsetting longevity and mortality risks in a capital-efficient way.[114] The third is variable annuities which is a more specialist category. The first category is the most common, while the third is the least. Sidecar platforms which cover all three categories include: Atlas Merchant Capital, Berkshire Hathaway, J. C. Flowers & Co, and Varge Agam. Sidecar investors include pension funds (e.g., APG, Canada Pension Plan, Ontario Teachers Pension Plan, PGGM), asset managers (e.g., Blackstone, Invesco, PIMCO), sovereign wealth funds (e.g., Abu Dhabi Investment Authority, NZ Super Fund), private equity and hedge funds (e.g., D. E. Shaw & Co, KKR), ILS funds (e.g., Leadenhall Capital Partners, Securis Investment Partners), endowments and family offices.[115]

In July, the Channel Island of Guernsey announced it would develop a simplified structure for the ILS market via an all-in-one legal entity that would combine insurance/reinsurance and investment activity in one vehicle – described as a 'Fund of One'. This would create a more transparent vehicle for investors which would promote 'true convergence' in ILS. Investors would establish both an unregulated investment fund and a reinsurance transformer cell. This would remove the need for multiple vehicles and allow a sidecar to have both the risks and the assets held in a single vehicle. This would help to reduce the challenges often associated with

[111] Athene & Apollo get long-term capital in $19bn annuity reinsurance deal, by Artemis on December 21, 2017; http://www.artemis.bm/blog/2017/12/21/athene-apollo-get-long-term-capital-in-19bn-annuity-reinsurance-deal/

[112] Steve Evans (2018) Langhorne Re launched by RGA and RenRe as in-force life and annuity reinsurer, *Reinsurance News*, 11 January,

[113] PGGM's $400m Leo Re is a private sidecar deal with Munich Re, by Artemis on February 5, 2018; http://www.artemis.bm/blog/2018/01/02/pggm-secures-140m-leo-re-sidecar-tranche-takes-2018-issue-to-400m/

[114] If there is a trend increase in life expectancy, the increase in longevity risk (from the annuity book) is offset by the reduction in mortality risk (in the life book).

[115] Kessler (2021, Table 14).

multiple vehicles, such as doing business in various jurisdictions, regulation, time zones, account rules, audit, and multiple layers of administration expenses.[116]

Another example of introducing new third-party capital is an initial public offer (IPO). This was the route Swiss Re considered in June 2019 when it proposed listing the shares of ReAssure – its UK closed book life consolidator business – on the London Stock Exchange. The idea was to provide working capital to put into new transactions and grow the UK life insurance book under the SwissRe brand. However, the idea was shelved due to weak demand and, in December 2019, ReAssure was sold to Phoenix for £3.2bn. In the process, Phoenix – which was valued at the time at £5.3bn – became Europe's biggest consolidator of life and pension businesses and justified the acquisition on the grounds that 'there are too many insurance companies in a market which is consolidating..[and the acquisition will] give us the opportunity to capture significant cost and capital synergies'.[117]

In September 2019, the European Life Settlement Association launched the ELSA Master Agreement for Tertiary Transactions (MATT). The aim was to develop an industry standard purchase and sale agreement to make tertiary transactions more cost and time efficient – in a similar manner as the ISDA Master Agreement.[118]

2020

Longevity risk transfers

2020 was a near record year for the longevity risk transfer market in the UK at £55.8bn. LCP and Mercer reported that £31.7bn of buy-ins and buy-outs and £24.1bn of longevity swaps were completed during the year. L&G had a 24% market share, followed by Rothesay with 22%, Aviva and PIC both on 19%.[119]

One explanation was that bulk annuity pricing fell slightly compared with 2019. Pensioner pricing was based on a 'gilts + 0.2% p.a.' discount rate to value liabilities, while the pricing of deferred pensioner liabilities was based on a 'gilts – 0.35% p.a.' liability. This implied that a buy-out for pensioners was cheaper than using gilts for pensioners in payment (equivalent to valuing liabilities on a gilts flat basis) – see Figure 1.[120]

[116] Guernsey targets "true convergence" via all in one ILS structure, by Artemis on July 24, 2018; http://www.artemis.bm/blog/2018/07/24/guernsey-targets-true-convergence-via-all-in-one-ils-structure/

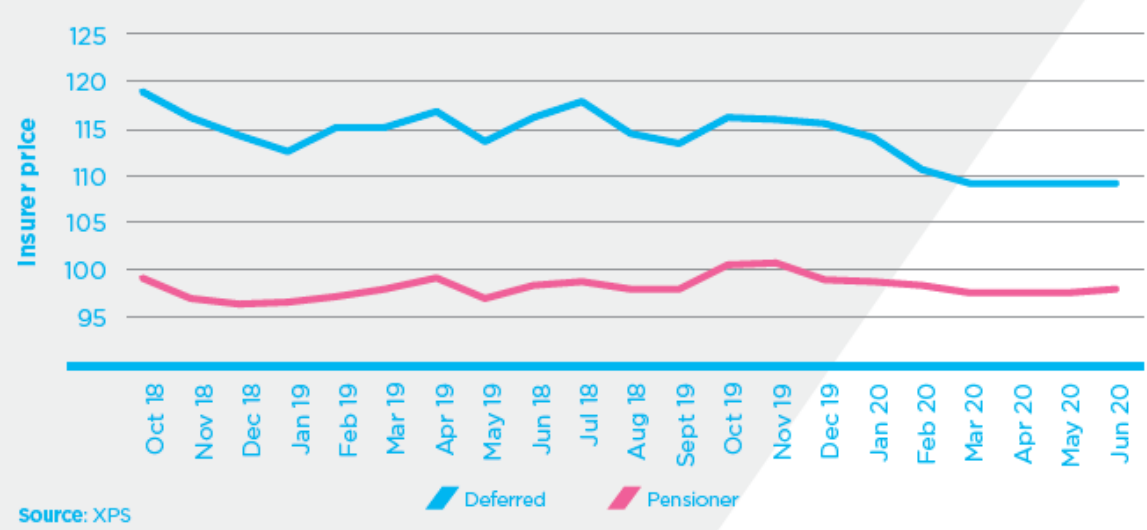
[117] Matt Sheehan (2019) Swiss Re confirms ReAssure IPO is set for July, *Reinsurance News*, 14 June; https://www.reinsurancene.ws/swiss-re-confirms-reassure-ipo-is-set-for-july/. Louis Ashworth and Michael O'Dwyer (2019) Phoenix boss bows out with £3.2bn takeover of insurance rival ReAssure, *Daily Telegraph*, 7 December.

[118] https://www.derivsdocu.com/services/consultancy/What-is-an-ISDA-Master-Agreement/

[119] UK. Pension longevity risk transfers reach record-breaking £55.8bn in 2020, *Pension Policy International*, 19 March 2021.

[120] Nick Reeve (2020), Longevity and risk transfer: A booming market, *IPE*, February; XPS Risk Transfer News 8/20.

Figure 1: Bulk annuity pricing 2018-2020 – buy-out price relative to £100 liability on a gilts flat basis



Highlights for 2020 in the UK included:

- In January, Securis Investment Partners announced that they had completed a capital market derisking deal – a longevity swaption – with a 'large well-known life risk carrier': 'we have taken structured longevity risk on a specific block of business. The transaction was structured as an indemnity derisking tool, i.e., without the use of any longevity indices, as a way to optimize the impact for our counterparty even further.. [It involved] a direct risk transfer to a Securis fund with no intermediary involved,…and was a first in terms of regulatory approval'.[121]
- In January, PIC said it would raise £750m in additional capital from existing investors to continue expanding its buy-out business. At the time, it managed £40.9bn on behalf of 225,000 pension scheme members.[122]
- Also in January, Pacific Life Re executed a £10bn longevity swap with three Lloyds Banking Group pension schemes – the second largest on record. The deal covers pensioner liabilities in the Lloyds Bank Pension Schemes No.1 and No.2 and the HBOS Final Salary Pension Scheme. The deal was structured as an insurance contract with Scottish Widows as the insurer and Pacific Life Re as the reinsurer.[123]
- In February, PIC agreed a £1.6bn buy-in with the Merchant Navy Officers' Pension Fund covering 14,000 members, in the process taking over a longevity swap that the fund initially executed with Pacific Life Re in 2014, using a Guernsey captive cell insurance company arrangement offered by Willis Towers Watson. This is another example of the novation of a swap to an annuity.[124]

[121] Email announcement from Luca Tres, 8 January 2020. See also Paul Fulcher and Luca Tres (2019) A capital management toolkit for life re/insurers, *InsuranceERM*, 14 March; https://www.insuranceerm.com/analysis/a-capital-management-toolkit-for-life-reinsurers.html

[122] Emily Horton (2020) Pension Insurance Corporation to raise £750m from backers, *Financial News*, 28 January.

[123] James Phillips (2020) Lloyds schemes agree £10bn longevity swap with Pacific Life Re, *Professional Pensions*, 29 January; Lloyds Banking Group pension schemes strike £10bn longevity swap, *IPE*, 29 January 2020.

[124] Susanna Rust (2020) Merchant navy fund converts longevity swap to £1.bn buy-in, *IPE*, 19 February.

- In February, Aviva and PIC each completed a £1bn buy-in with the Co-operative Pension Scheme. The deal was completed using a pre-agreed 'umbrella contract' designed to support a quick and efficient continuous process, each one covering 7,000 members. In May, Aviva completed a £350m buy-in transaction with the Co-operative Scheme covering an additional 2,300 members.[125]
- In February, PICA executed a $6bn reinsurance transaction with Rothesay Life.[126]
- In February, the AIB Group UK Pension Scheme completed a £1.1bn de-risking transaction with L&G, comprising a £850m buy-in combined with a £250m assured payment policy (APP).[127] The APP hedges the scheme's investment risk by protecting against changes in asset yields, interest rates and inflation, giving the scheme increased surety of being able to reach a full buy-out over a planned timeframe.[128]
- In March, the Xylem UK Pension Plan completed a £255m bulk annuity transaction with Rothesay Life, covering around 2,500 final salary section members.[129]
- In March, L&G announced that it executed eight PRT deals worth £261m, ranging in size between £2.2m and £80m.[130]
- In March, the General Healthcare Group (GHG) Pension & Life Assurance Plan secured a £150m buy-in contract with Aviva to cover all 700 of its defined benefit members.
- In May, L&G completed a £650m buy-in with the 3i Group Pension Plan.[131]

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[125] Susanna Rust (2020) Co-op pension scheme insures more liabilities as PIC deal disclosed, *IPE*, 19 February. Aviva in £350m bulk annuity deal with Co-operative Pension Scheme, *Reinsurance News*, 14 May 2020.

[126] Ditto.

[127] An assured payment policy is an insurance policy that provides the pension scheme with protection against investment-related risks, such as changes in asset returns, interest rates and inflation It was developed by L&G. APPs:

- Provide a pre-agreed series of future payments, which may be fixed or inflation-linked.
- Similar in nature to a buy-in, with the crucial difference being that APPs do not vary with longevity risk or other demographic experience. Compared with bulk annuities, they will be cheaper by around 15-20% for deferred pensioner members, but will be more expensive for pensioner members.
- Held as a pension scheme asset.
- Can apply to any sub-set of a pension scheme's liabilities.
- Can be used in combination with other de-risking solutions, such as pensioner buy-ins.

APPs can best be thought of as:

- Partial insurance: an APP locks down investment risk now, with a clear structure for adding the remaining pension-related risks in the future to 'complete the bulk annuity'; or
- An investment: an APP allows a pension scheme to 'build its own bond', with tailored inflation coverage and no exposure to market and reinvestment risk, while achieving a yield in excess of gilts.

APPs work as follows:

- An APP's fixed or inflation-linked pre-agreed payments are designed to match all or some of a pension scheme's liabilities.
- The trustees pay an upfront premium, as per a bulk annuity. In exchange, a payment schedule is agreed at outset, and payments are made by the provider to the trustees of the pension scheme as per that schedule.
- APPs can be structured to allow for conversion to buy-in or buyout, including through a series of partial conversions over time. This flexibility, and the effective and transparent conversion mechanics, create a more certain de-risking journey.

Source: https://www.legalandgeneral.com/institutional/pension-risk-transfer/what-we-offer/app/

[128] AIB UK scheme completes £1.1bn de-risking deal, *IPE*, 13 February 2020. In May 2021, £61m of the AIB Group's APP was converted into a buy-in policy, which L&G said shows 'how APPs facilitate the de-risking journey'.

[129] Xylem UK Pension Plan secures £255m bulk annuity deal, *Pensions Age,* 2 March 2020.

[130] L&G completes £261m of pension risk transfer deals in March, *Pension Policy International*, 3 April 2020.

[131] L&G agrees £650m buy-in with 3i scheme, *Professional Pensions*, 27 May 2020.

- Also in May, L&G completed a £70m buy-in for the ICI Pension Fund, the fund's 17th de-risking deal.[132]
- In June, the pension scheme of the Willis Group, now part of Willis Towers Watson, entered into a longevity swap with Munich Re. The swap covered £1bn pensioner liabilities of around 3,500 members. The longevity risk was transferred to the reinsurer via a Guernsey-based captive insurance company fully owned by the trustee of the scheme. It was established under Willis Towers Watson Guernsey ICC Limited, which is part of Willis Towers Watson's Longevity Direct solution allowing pension schemes to use a 'ready-made' incorporated cell company to access the reinsurance market.[133]
- In June, PIC executed a £280m longevity reinsurance deal with MetLife.[134]
- In July, the UBS (UK) Pension and Life Assurance Scheme executed a £1.4bn longevity swap with Zurich Assurance, covering around half the longevity risk in its £3bn DB scheme. Mercer, which acted as the adviser to the trustees, said the deal was structured as an 'innovative "pass through"' insurance contract, with 100% of the longevity risk reinsured by Canada Life Reinsurance.[135]
- In July, UBS executed a £1.4bn longevity swap with Zurich.[136]
- In July, the LV= Employee Pension Scheme converted a longevity swap held with ReAssure into a £800m buy-in with Phoenix Life. The buy-in covered the 4,100 pensioners and 200 deferred members who had been covered by the longevity swap, which had been agreed in 2012 and reinsured by Swiss Re. Swiss Re will continue to cover the longevity risk by providing reinsurance to Phoenix Life.[137]
- In July, the DB pension fund of Premaberg Holdings Limited, a UK manufacturer, completed a £5m bulk annuity transaction covering 50 members, of which around 80% are pensioners in payment. The buy-in was executed with Just Group and completed using Mercer's streamlined quotation service, which monitors buy-in pricing, demonstrating that 'smaller schemes can and do achieve successful bulk annuity transactions, despite continued high demand from much larger schemes'.[138]
- In July, the superannuation scheme for a farmers' cooperative secured the benefits of all its 120 members via a £13m buy-out with L&G.
- In July, the Countrywide Farmers Retirement Benefits Scheme agreed a £100m bulk annuity deal with L&G covering the benefits of 360 deferred members and 712 retirees. The scheme had entered the PPF assessment[139] in March 2018 following the insolvency of its sponsor, a rural retailer, livestock feed and energy supplier. However, it was overfunded on a PPF measure, and was therefore able to complete a so-called 'PPF+' transaction with L&G, which provided enhanced benefits compared with those available from the PPF, but less than those available from a full buy-out.[140]
- In August, the Littlewoods Pensions Scheme insured all its pension liabilities with a £930m buy-in covering deferred members with Rothesay Life, following a £880m buy-in covering pensioners with Scottish Widows in 2018.[141]

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[132] ICI fund teams up with Legal & General for 17th buy-in, *IPE*, 13 August 2020.
[133] Willis pension scheme strikes £1bn longevity hedge with Munich Re, *IPE*, 30 June 2020.
[134] https://www.artemis.bm/news/metlife-enters-uk-longevity-reinsurance-market-with-pic-transaction/
[135] UBS UK pension scheme enters into £1.4bn longevity hedge, *IPE*, 7 July 2020.
[136] *Aon's Risk Settlement Market Review 2020.*
[137] https://www.pensionsage.com/pa/LV-converts-longevity-swap-into-800m-Phoenix-Life-buy-in.php
[138] £5m deal shows small schemes' ability to access bulk annuity market, *IPE*, 22 July 2020.
[139] That is, being considered for inclusion in the PPF due to sponsor insolvency.
[140] Pension scheme of collapsed rural retailer agrees £100m bulk annuity, *IPE*, 30 July 2020.
[141] Littlewoods scheme completes de-risking with £930m buy-in, *IPE*, 12 August 2020.

- Also in August, Hitachi UK agreed a £275m buy-in transaction for the remaining deferred and pensioner members of its DB pension scheme with L&G. Hitachi's first buy-in was with Scottish Widows in 2018.[142]
- In October, the Old British Steel Pension Scheme agreed a £2bn buy-in covering 30,000 members with PIC, with a buy-out expected at a later date.[143]
- In October, Rothesay executed a $320m longevity reinsurance deal with MetLife.[144]
- In November, the Marks & Spencer Pension Scheme completed a third set of buy-ins with Aviva (for £390m) and Phoenix (for £360m), with 80% of the scheme's £3.7bn pensioner liabilities now insured. Both of the new transactions were carried out under 'umbrella contracts' entered into in 2018.[145]
- In November, the Prudential Staff Pension Scheme agreed a £3.7bn longevity swap covering 20,000 pensioners. The deal involved a Guernsey-based captive insurance company owned by the scheme trustees, which provided access to the reinsurance market. Artex Risk Solutions established the captive entity, with Pacific Life Re as the reinsurer.[146]
- In November, the £2.9bn Pearl Group Staff Pension Scheme, one of Phoenix Group's pension schemes, completed a £731m buy-in with the group's life assurance company, Phoenix Life.
- Also in November, the £1.4bn Baker Hughes UK pension plan completed a £100m buy-in with Just Group.
- Smiths Group completed a £290m buy-in with Aon as consultant in the August-December period.[147]
- In December, the Barclays Bank UK Retirement Fund completed a £5bn longevity swap transaction with RGA. Aon advised on all aspects of the transaction, including risk analytics, design and structuring, reinsurance selection and operational establishment. Tom Scott, principal consultant in Aon's risk settlement team, said: 'This transaction…demonstrates the capacity and appetite of the global reinsurance market to take on pension fund longevity risk, even in these challenging times'.[148]
- In December, the BBC Pension Scheme completed a longevity swap that covers more than £3bn of pensioner liabilities, Zurich Life was the insurer, while reinsurance was provided by Canada Life Reinsurance. The swap covers around one-third of the scheme's pensioner and dependant members.[149]
- In December, L&G executed a $2bn longevity reinsurance deal with MetLife.[150] It also completed a £400m APP with the L&G Group UK Senior Pension Scheme, covering 200 deferred members and 385 pensioner members.
- In December, the National Grid UK Pension Scheme completed an £800m buy-in with Rothesay.[151]
- In December, Maersk agreed £1.1bn buy-in with L&G.

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[142] Louron Pratt (2020) Hitachi UK completes £275 million pensions buy-in transaction, Employee Benefits, 26 August; https://employeebenefits.co.uk/hitachi-pensions-buy-in-transaction/

[143] Pension Insurance Corporation buys British Steel pension fund in £2bn deal, *Financial News,* 22 October 2020.

[144] https://www.artemis.bm/news/metlife-reinsures-320m-of-pension-longevity-risk-for-rothesay-life/

[145] M&S tops up de-risked pensioner liabilities with £750m set of buy-ins, *IPE*, 4 November 2020.

[146] Prudential Staff Pension Scheme agrees £3.7bn longevity swap, *IPE*, 11 November 2020.

[147] *Aon's Risk Settlement Market Review 2020.*

[148] Barclays Bank UK scheme agrees £5bn longevity swap transaction, *IPE*, 14 December 2020.

[149] https://www.artemis.bm/news/bbc-pension-gets-3bn-longevity-swap-from-zurich-canada-life-re/

[150] https://www.artemis.bm/news/metlife-reinsured-2bn-of-longevity-risk-for-lg-in-2020/

[151] National Grid completes £800m buy-in with Rothesay, *Professional Pensions*, 9 December 2020.

- Also in December, the Aon Retirement Plan completed a £510m pensioner buy-in with Scottish Widows.[152]
- Finally, Willis Towers Watson completed a £3.3bn buy-in with an unnamed company, the market's largest bulk annuity to date.[153]

A number of other key developments took place in the UK in 2020.

In June, Prudential Retirement, a subsidiary of PICA, introduced 'funded reinsurance' to the UK PRT market, with a deal involving UK insurer Aviva. Funded reinsurance allows an insurer to transfer both the asset risk and longevity risk associated with pension and annuity liabilities. It therefore protects the insurer not only from the financial risk of an unexpected increase in life expectancy, but also from unexpected losses in the invested assets. In return for a single premium, the reinsurer pays monthly benefits to the insurer for as long as the insured members live.[154] Before this, Prudential Retirement only reinsured the longevity risk of other insurers. As a consequence of the huge growth in the UK PRT market, insurers have been looking for reinsurance partners to bring in additional capital and asset management expertise in order to help manage the asset and longevity risk they have assumed. Amy Kessler, now head of International Reinsurance at Prudential Retirement, said: 'Our entry into the funded reinsurance business is a natural place for us to expand. The presence of reinsurers like us, with both longevity capacity and asset management capabilities, will allow the UK market to continue to grow in new ways in the years to come. …At least five reinsurers… closed funded reinsurance transactions, resulting in meaningful volume and capacity to support the growth in the UK'.[155]

In June, PIC announced that it had invested £75m in debt issued by a UK housing association, Trident Housing Association. PIC said the maturity profile of the debt has been tailored to match PIC's pension liabilities in years where it is difficult to source low-risk, long-term, secure cashflows in the public bond markets. It will also meet Trident's borrowing needs to develop more social housing stock. The debt is secured on a pool of housing assets owned by the association.[156] In November, PIC invested £65m in Welsh housing association Pobl in order to create 10,000 new homes over the next 10 years, with the debt secured on social housing assets. PIC said: 'This investment complements our portfolio providing low risk, long-term, secure cashflows that match our pension liabilities for decades into the future'.[157]

In July, a report by L&G – *The Power of Pensions: How pension savings can help to build the UK's infrastructure and drive growth in all regions* – suggested that pension risk transfer providers, such as insurers, were willing to invest up to £190bn of pension assets in UK infrastructure over the next decade. According to the report, this would provide 20% of the investment needed to 'to support our society's needs', since investment in infrastructure was the 'key' to maintaining the long-term competitiveness of the UK economy and was 'vital' to delivering the government's 'industrial strategy' and would bring the economic stimulation

[152] BBC scheme strikes £3bn longevity swap, Aon plan in £510m buy-in, *IPE*, 15 December 2020.
[153] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021
[154] https://www.pacificlifere.com/content/dam/plre/GFS-deal-signing-press-release-Final.pdf
[155] Prudential Retirement enters funded reinsurance business, 30 October 2020; https://news.prudential.com/prudential-retirement-enters-funded-reinsurance-business.htm#.X5wS1QIIOSE.linkedin; Kessler (2021).
[156] UK housing association Trident secures £75m funding from PIC, *IPE*, 19 June 2020.
[157] PIC invest a further £65m in Welsh housing association Pobl, *IPE*, 26 November 2020.

and employment opportunities needed following the covid-19 pandemic. Long-term infrastructure investments are 'very attractive' to insurers because of their security and ability to generate steady cash flows for paying pensions as they fall due.[158]

However, pension funds face barriers to infrastructure investing. There is a shortage of supply of suitable assets and those that are available face stiff competition from commercial fund managers and sovereign wealth funds which have significant amounts of capital to deploy and are often prepared to accept lower returns. Also while bigger schemes can acquire assets directly, smaller schemes have to invest via infrastructure funds which involve higher fees. Morten Nilsson, chief executive of the British Telecom Pension Scheme, argues that the government could help stimulate supply through the UK Infrastructure Bank which was set up in June 2021 to support infrastructure that drives local economic growth or helps tackle climate change through loans, credit enhancement and equity investments. It has a £22bn budget, split between £12bn of equity and debt capital, and the ability to issue £10bn of government guarantees.[159]

The most significant pension event of 2020 was the introduction in June by TPR of an interim regulatory regime for the superfund pension consolidation market.[160] This is the market where pension schemes are consolidated into a larger fund, while remaining legally classified as pension schemes.[161] Consolidators must be able to demonstrate that they are well-governed, run by fit and proper people and are backed by adequate capital, thereby reducing the chance that they later become insolvent and fall back on the PPF which bails out the pension schemes of insolvent sponsors.

Transferring to a consolidator might be a preferred option for a sponsoring company that wants to remove its pension liabilities, but cannot afford a full buy-out. The interim regime also explains how consolidators will be assessed and regulated. Capital adequacy is a key aspect of TPR's interim regime, since there will no longer be an employer covenant. TPR will require superfunds to hold sufficient assets to meet the promises to savers with a high degree of certainty. This will include the requirement for the scheme's liabilities (or technical provisions) to be calculated using specific assumptions set out in TPR's guidance and for additional assets to be held in a capital buffer. The interim regime sets a 1-in-100 risk of failure to pay benefits promised to scheme members in full, which is less stringent than the Solvency II regime for insurers which sets a 1-in-200 risk of failure. Superfunds must not extract any surplus from a scheme or its capital buffer until such time as either the pension liabilities are bought out with an insurer or final payments have been made. The interim regime will eventually be replaced by a legislative authorization and supervision framework.

Trustees need to be certain that a transfer to a superfund is in their members' interests. In October, TPR issued further guidance to trustees, setting out, three 'gateway principles' that transactions with superfunds must meet:

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[158] PRTs could help plug UK infrastructure 'mega-gap' – L&G, *Pension Policy International*, 9 July 2020.

[159] Val Cipriani (2021) Pension funds 'outcompeted' on UK green infrastructure investments, *Pensions Expert*, 29November 29; https://www.pensions-expert.com/Investment/Pension-funds-outcompeted-on-UK-green-infrastructure-investments

[160] https://www.thepensionsregulator.gov.uk/en/media-hub/press-releases/2020-press-releases/tpr-launches-tough-new-interim-regime-for-emerging-superfund-pension-market

[161] This contrasts with buy-outs where the liability for paying pensions is transferred to an insurance company.

- A transfer to a superfund should only be considered if the scheme cannot afford to buy out now;
- A transfer to a superfund should only be considered if a scheme has no realistic prospect of buy-out in the foreseeable future, given potential employer cash contributions and the insolvency risk of the employer; and
- A transfer to the chosen superfund must improve the likelihood of members receiving full benefits.

TPR said: 'We expect ceding employers to apply for clearance in relation to a transfer from their scheme to a superfund, and for trustees to demonstrate they have done their due diligence in respect of the transfer'. Marc Hommel, senior pensions adviser at EY, said the guidance 'further signals that the government and pensions regulator are backing employers to access superfunds as more affordable solutions to discharge their pension obligations and, in distressed situations, for trustees to have better options for their members relative to the Pension Protection Fund. In the near term, superfund transactions are likely to take place only where the employer is distressed or insolvent'.[162]

The introduction of the interim regime renewed the debate between the consolidators and insurers about which model of PRT was safer. Insurers complain that because superfunds operate as pension funds, there is no legislation which sets standards on their capital requirements or investment strategy. Hetty Hughes, policy adviser at the Association of British Insurers (ABI), argued: 'By underwriting superfunds with the PPF, you are potentially privatizing the gains and socializing the losses'.

However, superfunds counter that they must also hold a capital buffer, and, unlike insurers, they cannot distribute profits to investors for three years. Antony Barker of the Pension Superfund even argues that superfund capital requirements are more onerous than those of the insurers: 'If you do the maths on their one-year test versus our five year test, they have to hold less capital than us. For the schemes in PPF assessment, insurers can cut members' benefits unilaterally in securing them, but superfunds cannot'.

Nevertheless, Hughes believes that the interim guidance is insufficient. Her concern is that superfunds are targeting well-funded schemes: 'That is where the risk of regulatory arbitrage becomes more acute. The regime doesn't need to be Solvency II compliant as it is trying to serve a market that can't afford a buy-out, but that doesn't mean the regime doesn't need to have similar features to Solvency II. For example, the life insurance industry has undergone stress tests recently, where they have to measure the impact if half their assets' credit rating were downgraded. This was found to be manageable, whereas TPR guidance simply says that superfunds can do their own homework and come up with their own stress tests. The regulator imposing a three-year ban on passing profits to investors, is still insufficient. We might not see legislation for another five years and the guidance also says that the three-year rule is under review. What it doesn't say is that there are other ways of extracting value other than dividends. Performance fees and management fees are examples of the instructions private equity firms tend to put in place'. Andrew Bailey, the governor of the Bank of England, has also warned that the lack of firmer rules in TPR's interim guidance could pose a risk to financial stability.

It is certainly appears to be the case that superfunds have greater flexibility than insurers over investment strategy and can take on more investment risk. The Pension Superfund, for

[162] UK regulator delivers superfund guidance for trustees, sponsors, *IPE*, 21 October 2020.

example, has a target allocation of 80% in a liability-driven investment (LDI) strategy, with the rest in return-seeking assets. Barker accepts that, unlike insurers, superfunds have more freedom to adjust this target portfolio to the allocation that schemes already have in place: 'Our actual strategy will be driven to some extent by the schemes we inherit. One of our unique features is that we novate the schemes' existing portfolios. That ensures that our transaction costs are lower. So, if people already have private equity, we don't need them to sell it to provide us with cash and government bonds. The return seeking assets are going to be drawn from public and private markets, but will probably allow us to focus more on private markets and illiquid assets because we expect that our peak cash-flows are going to be in the late 2030s to early 2040s so that gives us a lot of time to invest in illiquids. We can look at infrastructure, private equity, insurance-linked securities, land, property and other real assets'.

Chris Clark, DB policy lead at TPR, says: 'We don't see superfunds as a replacement for insurance, they are not targeting an insurance level of guarantee, but there are many schemes out there that can't afford that level of guarantee. For trustees considering a transfer, it is vital that they are doing so because it is in the best interest of scheme members'. Yet, David Weeks, co-chair of the Association for Member Nominated Trustees, points out that currently superfunds do not allow for member nominated trustees with any say in scheme governance.[163] In October, a third superfund consolidator, Stoneport, joined the market. It was established by actuarial consultant Punter Southall with the aim of targeting the 4,350 DB schemes with fewer than 1,000 members. Punter Southall's own small DB scheme has joined up. Stoneport has the following aims: 'To address the growing number of problems facing trustees and sponsoring employers of small schemes, Stoneport [aims] to target running cost, investment management and end-game efficiencies, as well as improving governance standards'. Small schemes have running costs of £1,000 per member per year, compared with less than £100 for the largest schemes, leading to potential long-term savings of £40bn, comprising savings in lifetime running costs of £10bn, reduced investment management costs, the dividend from good governance, and the saving from joining together for an eventual buy-out.[164] In December 2021, Stoneport appointed Mobius Life as its investment platform provider. The platform will host Stoneport's investment funds which small schemes will be able to access without having to do their own market research.[165]

Another innovation in 2020 was the introduction of 'third-party capital solutions' (TPCSs).[166] These involve investors who provide a 'helping hand' to pensions schemes in the form of an additional capital buffer to schemes planning for a buy-out (or even just self-sufficiency) at a future target date if pre-agreed funding thresholds are not met. The link between the sponsor, the scheme and the trustees is maintained, so this model is different from the superfund model. It is also different from a buy-in which involves the bulk purchase of an annuity from an insurer. The model is most similar to the reinsurance sidecar discussed earlier, although with differences.

With a TPCS, the investors have a bigger influence on the investment strategy of the scheme. Indeed, the scheme trustees need to agree an investment strategy with the investors which will

[163] Quoted in Mona Dohle (2020) Superfunds – New entrants to the DB consolidation market, *Portfolio Institutional*, 17 August.
[164] New DB consolidator targets UK's small schemes, *IPE*, 20 October 2020.
[165] https://www.ipe.com/news/uk-db-consolidator-appoints-mobius-life/10056678.article
[166] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021

incorporate a return on the capital provided. The investment strategy can target higher returns and possibly enable lower sponsor contributions, since the capital buffer gives greater downside risk protection. However, once the investment strategy has been agreed, it cannot be changed without the consent of the investors, and the downside protection is limited to the size of the capital buffer. On the target date, if the scheme is sufficiently well funded to achieve a full buy-out, both the scheme and capital structure are wound up, with investors get back their capital in full; otherwise the scheme reverts to normal operations and the investors receive a partial return of capital. TPCS investors are looking at schemes with a strong sponsor covenant, with liabilities below £250m, which are at least 85% funded on a buy-out basis, and with a significant proportion of total liabilites in the form of deferred pensions.

International developments outside the UK in 2020 included:

- In May, NN Life, executed a €13.5bn longevity reinsurance and swap transaction covering a portfolio of annuity policies for over 200,000 pensioners and dependants. The deal was reinsured with Canada Life, Munich Re and Swiss Re, and NN Group said it would lower its required capital and strengthen its capital position, with a 25 percentage points increase to its Solvency II ratio, which at the end of April 2020 stood at 220%. There will be an immediate upfront capital benefit, as well as lower future operating capital generation of approximately €90m p.a., although the ongoing longevity reinsurance premiums will reduce the IFRS operating result before tax by approximately €30m p.a.[167]
- In June, actuarial consultant Milliman released the results of its new Milliman Pension Buy-out Index (MPBI) for the US. The MPBI uses the FTSE Above Median AA Curve, along with annuity purchase composite interest rates from a number of insurers, to estimate the average cost of a PRT annuity de-risking strategy. During May, the estimated cost to transfer retiree pension risk to an insurer dropped from 105.5% to 103.9% of a scheme's pension liabilities, as measured by its accumulated benefit obligation (ABO). The explanation for the fall is that discount rates in May dropped 27 basis points compared to a 10 basis point drop for annuity purchase rates, resulting in the relative cost of annuities decreasing by 1.6 percentage points.[168]
- The launch in August by Australian annuity provider Challenger – Australia's largest provider of annuities[169]– of a guaranteed floating rate lifetime annuity, with payments linked to the Reserve Bank of Australia (RBA) cash rate, so that annuitants would gain from any increase in interest rates.[170]
- In September, Mercer's US pension buy-out index indicated that the buy-out cost was only 97.7% of a US DB plan's accounting obligations, making buy-outs increasingly attractive. This followed a number of amendments to the US index which was originally launched in 2013 in response to changing to market conditions, including:
    - competition – the number of insurers who compete for annuity and buy-out transactions has doubled since 2012;
    - investments – insurer pricing is generally driven by the ability of insurers to source higher yielding, less liquid assets, such as private credit and commercial

[167] https://www.artemis.bm/news/nn-life-transfers-eur-13-5bn-of-pension-longevity-risk-to-reinsurers/; *Aon's Risk Settlement Market Review 2020.*

[168] Milliman analysis: Estimated cost of retiree pension risk transfer drops significantly, from 105.5% to 103.9% in May, *Pension Policy International*, 24 June 2020.

[169] https://www.challenger.com.au/about-us/challenger-group

[170] Australia. Challenger launches floating rate annuity, *Pension Policy International*, 24 August; https://pensionpolicyinternational.com/challenger-launches-floating-rate-annuity/

mortgages, which provide a good match for illiquid annuity buy-out liabilities; and

- mortality – insurers have evolved their mortality underwriting techniques to better assess mortality risk at the individual participant level. This may often lead to lower pricing especially for transactions with smaller benefits and/or where benefit accruals have been frozen for many years.

By contrast, the estimated long-term costs of maintaining pension liabilities on sponsor balance sheets was 105.2%, which reflects costs not included in accounting liabilities (i.e., ABOs), such as Pension Benefit Guaranty Corporation (PBGC) premiums, investment management and administration fees, and the risk associated with fixed-income defaults and downgrades.[171]

- In November, Milliman's US Pension Buy-out Index was modified to reflect the impact of competitive pricing on estimated buy-out cost and two new insurers were added to the index: Massachusetts Mutual Life Insurance Co. and Banner Life Insurance Company (Legal & General America). During September, the average estimated cost to transfer retiree pension risk to an insurer decreased by 60 basis points, from 102.9% of a plan's total liabilities to 102.3% of those liabilities, measured on a retiree ABO basis. Annuity purchase costs were even lower at 100.2% (down from 101.0% in August).[172]
- L& G completed its first two cross-country PRT transactions in 2020. The first, in May, covered IHS Markit's US and UK pension plans. The UK deal was for £37.8m and covered 150 members in the IHS (Global) Ltd. Pension and Life Assurance Scheme. The US deal was for $97.2m and covered 1,200 members in the IHS Retirement Income Plan.[173] In December, US chemicals company Evonik agreed a £544m full buy-in with L&G for its four UK pension schemes. This built on a $93m 'lift-out' completed by L&G for the US Evonik Corporation Retirement Plan in September. In a lift-out, a subset of pension scheme members are lifted out and transferred to an insurance company.[174]

For many PRT providers, 2020 was a record year with L&G, for example, completing more than 60 deals worth over £8bn across its US and UK businesses.[175] Actuarial consultant Hymans Robertson has pointed out that since the PRT market took off in 2007, UK buy-ins/buy-outs (£180bn) and longevity swaps (£110bn) have insured £300bn of risk from DB pension schemes and expects an additional £700bn by the end of 2031, resulting in £1trn of DB pension scheme risk – around 50% of the total – being insured by then.[176]

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[171] Revised Mercer U.S. Pension Buyout Index Methodology Shows That Costs of Annuity Buyouts Could Be Less Than Accounting Liability, *Pension Policy International,* 18 September 2020; https://pensionpolicyinternational.com/revised-mercer-u-s-pension-buyout-index-methodology-shows-that-costs-of-annuity-buyouts-could-be-less-than-accounting-liability/

[172] Milliman expands Pension Buyout Index to include competitive pricing rate, which drops to 100.2% in September, Pension Policy International, 4 November 2020; https://pensionpolicyinternational.com/milliman-expands-pension-buyout-index-to-include-competitive-pricing-rate-which-drops-to-100-2-in-september/

[173] https://www.ipe.com/news/uk-roundup-tpr-pipes-up-over-inter-dc-transfers-cross-country-prt-deal/10045567.article

[174] https://www.ipe.com/news/evonik-legal-and-general-add-544m-buy-in-to-us-de-risking-transaction/10050112.article

[175] *Insurance Asset Management*, 3 February 20121.

[176] https://www.pensionpolicy.net/uk-roundup-1trn-of-db-pension-risk-to-be-insured-by-2031-says-hymans/

The Covid-19 pandemic

The most significant global event of 2020 was, of course, the Covid-19 pandemic.[177] There was no longevity conference in 2020 as a result. Here we discuss the implications of the pandemic for pension schemes and the PRT market.

A study in May 2020 by Cairns et al (2020) of the UK predicted that if total Covid-19 deaths were capped at around 80,000, then this would have little overall effect on pension liabilities. By June 2022, total UK Covid-19 deaths were 200,000.[178] Liabilities fell since some pensioners would die, especially those in care homes, and that would be offset by a small increase in life expectancy of survivors. The UK government announced that it would save around £600m in state pension payments in 2020 as a result of an increase in excess deaths among the elderly. Given state spending on pensions of £100bn, this amounts to a reduction of 0.6%.[179] Given that pension scheme members are typically from higher socio-economic groups than the average, we should expect the liabilities of pension schemes to fall by less than this.

LCP's 2020 *Longevity Report* predicted that the value of a typical UK defined benefit (DB) scheme's net liabilities might fall by less than 0.25% as a direct result of the deaths of pensioners arising from Covid-19 in 2020. Since, total UK DB liabilities are around £2.2trn, excess deaths in 2020 due to Covid-19 could reduce liabilities by less than £5bn. However, this is dwarfed by the increase in liability values of over £50bn in 2020 as a result of falling stock markets and ultra low interest rates. The report concluded: 'The ultimate impact of deaths due to the coronavirus on the funding of DB pensions will be driven more by the economic and social consequences of the pandemic following 2020, in particular a severe recession.' The report also found that longevity insurers and reinsurers are making very little – if any – allowance for Covid-19 in their longevity assumptions at the moment: 'Any impact on the affordability of longevity hedging has therefore been dwarfed by the impact of changes to the financial markets due to the pandemic'.[180] XPS Pensions estimated a larger fall in UK pension liabilities of between 1.5% and 3.5%, equivalent to £25bn-£60bn.[181]

Willis Towers Watson found that UK bulk annuities and longevity swaps markets remained active all throughout the lockdown, implying that insurers' operating and financial models were robust enough to withstand the instability. Indeed, the widening of credit spreads created some exceptional pricing opportunities, which were taken advantage of by schemes already in the process of de-risking as well as schemes that had previously transacted and hence were in a position to execute a 'repeat deal' relatively quickly. WTW said it was involved in 20 buy-ins for 19 schemes, covering £8.6bn of liabilities, with most of these taking place during lockdown. It was also involved in five longevity swaps covering £14.7bn of liabilities. It noted: 'There is a significant appetite for reinsurers to take on new longevity swaps and this is producing very

[177] XPS COVID-19 Tracker for UK: https://www.xpsgroup.com/what-we-do/technology-and-trackers/xps-covid-19-tracker/

[178] https://ourworldindata.org/explorers/coronavirus-data-explorer?facet=none&Metric=Confirmed+deaths&Interval=7-day+rolling+average&Relative+to+Population=true&Color+by+test+positivity=false&country=~GBR (29 June 2022).

[179] *Daily Telegraph*, 25 November 2020; https://www.statista.com/statistics/283917/uk-state-pension-costs/

[180] UK roundup: LCP on COVID-19's direct, indirect liabilities hit, *IPE*, 23 June 2020, https://www.ipe.com/news/uk-roundup-lcp-on-covid-19s-direct-indirect-liabilities-hit/10046384.article

[181] https://www.professionaladviser.com/news/4028930/covid-19-leaves-schemes-overestimating-pension-liabilities-research

attractive pricing, and in several cases, schemes have been able to hedge at little or no cost, relative to their technical provisions'.[182]

WTW's *Emerging Trends in DB Pensions Survey 2020*[183] found that Covid-19 and the consequences for the wider economy are placing sponsors and schemes under strain, weakening the sponsor covenant: 1 in 3 say the sponsor's ability to support the scheme has weakened in the short term; 1 in 6 say it has in the long term. There is a trade-off between scheme security and business recovery: trustees aim to shorten the time to meet schemes' long term funding targets, while corporates expect to extend it. In the next 3 years, 4 in 10 schemes are looking to complete a bulk annuity transaction or longevity swap.

The economic impact of the Covid-19 pandemic following the lockdowns that most countries introduced to stop the virus spreading has affected the ability of workers and employers to contribute to private-sector pension schemes, according to the OECD's *Pensions Outlook 2020.*[184] It also points out that the liabilities of DB schemes are likely to grow. Although government wage support schemes meant that workers did not lose their entitlement to a state pension while they were furloughed, the huge cost of those schemes will inevitably impact the ability of governments to fund state pensions in the future.

Conducting an international comparison of mortality rates during 2020-21, Club Vita found that Canada's excess mortality rates versus the underlying trend were 6.3% and 2.9% in 2020 and 2021, while the US's were 14.3% and 14.4% and the UK's were 13.5% and 8.6%. Club Vita said 'Whether these levels of increased deaths continue and for how long will be vitally important for pension plans and insurers trying to understand future longevity trends in the UK, US and Canada'.[185]

2021

In 2021, UK DB schemes completed £44.8bn worth of PRT transactions covering buy-ins, buyouts, longevity swaps and assured payment policies. Excluding APPS (which do not hedge longevity risk), bulk annuity transactions were £27.7bn. Five longevity swaps were executed worth £17.1bn.[186] There were four bulk annuity deals of £1bn or more, compared with seven such jumbo deals in 2020, reflecting fewer multi-billion pound opportunities. However, buy-ins/outs between £100m and £1bn have trebled since 2015 and comprised one-third of all deals in 2021, while the number of deals below £100m fell by a third over the same period. The market was dominated by five insurers: Aviva (£6.2bn in deals, 22% market share), Standard Life (part of Phoenix Group, £5.5bn, 20%), L&G (£5.3bn, 19%), PIC (£4.7bn, 17%) and Rothesay Life (£3.0bn, 11%). Helped by rising yields on corporate bonds (a key investment

[182] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021

[183] https://www.willistowerswatson.com/en-GB/Insights/2020/10/emerging-trends-in-db-pensions-survey-2020; October 26, 2020.

[184] Published 7 December 2020; https://www.oecd-ilibrary.org/finance-and-investment/oecd-pensions-outlook-2020_67ede41b-en

[185] https://www.clubvita.us/news-and-insights/top-charts-22-03-2021-excess-deaths

[186] https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/

vehicle in de-risking strategies), competition between insurers was intense and this was reflected in keen pricing.[187]

In March 2020, the UK Institute and Faculty of Actuaries' Continuous Mortality Investigation (CMI) released the CMI_2020 Mortality Projections Model.[188] This is used by most DB schemes in the UK and it requires schemes to choose what allowance to make for the pandemic. By 2021, there was enough information for schemes to form a best estimate. For most schemes, an appropriate pandemic allowance was a reduction of 1.5% to 3.5% in liabilities. For a scheme that is 90% funded, this could mean a 25% reduction in the deficit.[189]

Highlights for 2021 in the UK included:

- In February, L&G agreed a £570m pensioner buy-in deal with Deutsche Bank's UK pension scheme; it was the £4.5bn scheme's first de-risking strategy.[190]
- In March, the AXA (UK) Pension Scheme executed a £3bn longevity swap with Hannover Re, covering a significant number of deferred members who comprise around 95% of the 16,000 members. This was helpful for the scheme's investment strategy as it provided increased cashflow certainty.[191]
- Also in March, an unnamed UK pension scheme executed a £6bn longevity swap with PICA and Zurich Assurance acting as an intermediary on a pass-through basis. The pass-through deal was the first used by PICA with a UK-based insurer, having previously used Guernsey- and Bermuda-based captive solutions. Rohit Mathur, the new head of international reinsurance at PICA, said 'We see the use of a third-party onshore UK-regulated insurer as a limited recourse intermediary as the logical next step in the de-risking solutions we can offer for clients in our evolving business model'.[192]
- In April, PIC made a £37.5m debt investment in Welsh housing association Wales and West Housing which will fund the building of 2,500 new homes over the next five years. PIC said: 'Sourcing long-dated, secure cash flows is important to PIC. The investment backs our long-term pension liabilities, while having the beneficial outcome of putting PIC's capital to use in parts of the economy where funds are vitally needed'.[193]
- In May, the AIB Group UK Pension Scheme agreed a £61m transaction with L&G to convert a tranche of its existing APP into a buy-in policy. Covering both deferred members and new retirees, the transaction is the first example of a APP being partially converted into a new buy-in policy. The conversion builds on the original £250m APP transaction with the AIB Group scheme, and follows a £400m APP transaction with the L&G Group UK Senior Pension Scheme.

[187] https://www.ipe.com/news/2021-uk-pension-risk-transfer-volumes-hit-439bn-with-record-core/10058708.article, https://www.pensions-expert.com/Investment/Derisking-activity-ramps-up-in-Q3
[188] https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-investigations/mortality-projections
[189] Updating life expectancy assumptions for the new CMI_2020 model, *XPS Express for Employers*, March 2021.
[190] https://www.pensionpolicy.net/deutsche-bank-inks-buy-in-deal-for-u-k-pension-fund-with-lg/
[191] https://www.ipe.com/news/axa-uk-scheme-signs-3bn-longevity-swap-for-mostly-deferred-liabilities/10051692.article
[192] https://www.professionalpensions.com/news/4030529/pica-reinsures-gbp6bn-longevity-risk-unnamed-scheme
[193] https://realassets.ipe.com/news/pension-insurance-corporation-lends-to-welsh-housing-association/10052418.article

- In May, the Wyeth Group Pension and Life Assurance Scheme, a Pfizer Group subsidiary, completed a £190m bulk purchase annuity buy-in, covering 2,000 members.[194]
- Also in May, the ICL Group Pension Plan (whose sponsor is Fujitsu) completed a £3.7bn longevity swap with Swiss Re.[195]
- In June, the pension scheme of travel agency company TUI agreed two buy-ins for £794m with L&G.[196]
- In June, PIC announced it was investing £200m in the development and operation of 10 new retirement living communities comprising around 2,000 older residents, via a partnership with Octopus Real Estate. PIC's aim is again to generate index-linked cash flows.[197] In the same month, it invested £175m in the senior secured debt funding of 18 Spanish solar parks owned by Q-Energy which in turn receives payments from the Spanish electricity system and so can guarantee an agreed level of return and predictable cashflows for PIC.[198]
- In July, L&G completed its third APP, another deal (valued at £925m) with its own DB pension scheme, covering 2,000 retired and 2,800 deferred members.[199]
- In July, the Pearl Group Staff Pension Scheme completed a second £998m buy-in with Phoenix Life.[200]
- In July, the Kingfisher Pension Scheme completed a £900m bulk purchase annuity transaction with Aviva, covering 8,000 of the £3.7bn scheme's members.[201]
- In September, Aviva completed a £320m bulk purchase annuity transaction with the John Laing Pension Fund, covering 1,850 pensioners.[202]
- In September, Just Group introduced medical underwriting for its equity release mortgage range, by taking account of the client's medical conditions and lifestyle factors in determining the borrowing rate and limit.[203]
- In September, Standard Life entered the equity release market with a range of lifetime mortgage products launched in partnership with Key Group, under the brand Standard Life Home Finance. Earlier in the month, Phoenix Group bought a portfolio of equity release mortgages worth £300m from Just Retirement. In 2020, the equity release market totalled £3.89bn, while £1.17bn of property wealth was unlocked by over-55 homeowners in the second quarter of this year, according to the Equity Release Council.[204]

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[194] https://www.ipe.com/news/251m-in-de-risking-deals-as-aib-converts-app-wyeth-seals-buy-in/10053116.article
[195] https://www.ipe.com/news/icl-group-scheme-strikes-37bn-longevity-hedge/10052771.article
[196] https://www.ipe.com/news/uk-roundup-tui-trust-strikes-800m-buy-in-pair-lothian-names-new-ceo/10053151.article
[197] https://realassets.ipe.com/news/pic-to-invest-up-to-200m-in-uk-retirement-communities-via-octopus-jv/10060819.article
[198] https://realassets.ipe.com/news/pic-increases-investment-in-renewable-energy/10053393.article
[199] https://www.ipe.com/news/legal-and-general-completes-925m-assured-payment-policy-transaction/10054195.article
[200] https://www.pensions-expert.com/DB-Derisking/Pearl-Group-pension-fund-completes-further-buy-in
[201] https://www.ipe.com/news/kingfisher-pension-scheme-inks-900m-bulk-annuity-with-aviva/10054147.article
[202] https://www.pensionpolicyinternational.com/aviva-announces-320m-bulk-annuity-deal-with-the-john-laing-pension-fund/
[203] https://www.professionaladviser.com/news/4037321/group-launches-medical-underwriting-equity-release
[204] https://www.professionaladviser.com/news/4037061/standard-life-launches-lifetime-mortgage-range-key-group

- In October, the Metal Box Pension Scheme agreed a £2.2bn buy-in, covering 10,300 pensioners and 2,200 non-pensioner members, with PIC as a step towards a full buy-out in November.[205]
- In October, the Sanofi Pension Scheme has signed a £760m buy-in policy with L&G, covering 2,900 retirees.[206]
- In December, the Imperial Tobacco Pension Fund completed a £1.8bn bulk purchase annuity transaction, covering 6,600 pensioner members, with Standard Life.[207]
- In December, the Gallaher Pension Scheme completed a £1.7bn BPA, covering 7,600 members, with Standard Life. Standard Life said the assets underlying the deal will be used to continue its investment into UK infrastructure and socially responsible projects that are vital to the UK's post-pandemic recovery.[208]
- In December, an unnamed pension scheme executed a £2.6bn longevity swap with Zurich and Metlife. It was MetLife's first pension scheme longevity swap transaction.[209]
- In December,the Phoenix Group completed a £1.8bn longevity swap covering its UK pension liabilities with Metlife.
- In December, the pension scheme of biochemical and food company CSM Limited completed a £86m buy-in with Just Group. The scheme received pricing from multiple insurers in three weeks using the PwC Insure service.[210]
- In December, Just Group also completed £345m buy-in transaction with the UK pension scheme of an unnamed global distribution company. The deal covered 1,000 deferred members and 900 pensioner members.[211]
- Also in December, the benefits in the pension plan of metal flow engineering company Vesuvius were fully insured with PIC following a seventh buy-in. The first buy-in with PIC was in 2012. With the latest deal, valued at £305m, over £600m of liabilities were insured with PIC.[212]

International developments outside the UK in 2021 included:

- Athora Netherlands executed two longevity swaps: the first was valued at €4.7bn with Canada Life Re in March and the second was valued at €3.3bn with RGA in September.
- Aegon executed a €7bn longevity swap with RGA in December. It had now reinsured 40% of the longevity risk of its Dutch pension insurance book. The deal improved the solvency ratio of Aegon's life business by 15 percentage points, releasing capital for new business growth.[213]
- NN Life executed a €4bn longevity swap with RGA also in December.[214]
- These transactions all involved Dutch insurers, but the larger Dutch pension plans have also been considering buy-outs as funding ratios have improved as a result of strong

[205] https://www.ipe.com/news/metal-box-scheme-in-wind-up-mode-after-striking-22bn-buyout/10055419.article
[206] https://www.ipe.com/news/sanofi-uk-pension-scheme-agrees-760m-buy-in-with-landg/10055597.article
[207] https://www.ipe.com/news/uk-roundup-tobacco-scheme-strikes-18bn-buy-in-deal/10057343.article
[208] https://www.ipe.com/news/de-risking-roundup-gallaher-pensions-17bn-buy-in-deal-with-standard-life/10057512.article
[209] https://www.ipe.com/news/metlife-zurich-complete-35bn-longevity-swap/10057535.article
[210] https://www.ipe.com/news/csm-limited-scheme-completes-86m-deferred-heavy-buy-in/10058660.article
[211] https://www.ipe.com/news/metlife-zurich-complete-35bn-longevity-swap/10057535.article
[212] https://www.ipe.com/news/vesuvius-seals-seventh-final-buy-in-with-pic/10057145.article
[213] https://www.ipe.com/news/aegon-reinsures-dutch-longevity-risk/10057149.article
[214] https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/

equity markets and higher interest rates. With funding ratios above 120%, accrued pension benefits can be transferred to an insurer with guaranteed indexation. In 2021, 44 plans out of a totalof 129 reached this threshold (e.g., ING and ABN AMRO Bank) compared with 15 in 2020. Competition from insurers has also increased, with NN Group, previously the only provider, joined by Aegon, Zwitserleven and Lifetri. It is however possible, under new Dutch legislation, for accrued DB benefits to be transferred to a DC plan and the Dutch regulator expected up to 70% of plans to do this.[215]

- In December, the Amsterdam School of Economics and Nationale-Nederlanden opened the Research Centre for Longevity Risk.[216] The research centre 'will study developments in survival rates and life expectancy and how these developments are affected by a variety of factors. This includes studying demographic trends and medical developments, as well as the impact of local socioeconomic conditions and the quality of our living environment. The research findings pertaining to expected developments in life expectancy will also provide a foundation for studying the financial and social impact of these trends'.
- US corporate pension plan buyout sales totaled $38bn in 2021, beating the previous record of $36bn set in 2012.[217] There were a number of large PRTs. For example, in August, Lockheed Martin Corp purchased group annuity contracts from Athene Holding to transfer $4.9bn pension plan liabilities, covering 18,000 retirees and beneficiaries.[218] In September, HP Inc agreed to purchase a group annuity contract from PICA to transfer $5.2bn in liabilities, covering 41,000 retirees and beneficiaries in the HP Pension Plan.[219]
- In November, State Street Global Advisors launched a deferred lifetime income annuity within the University of California's retirement plan. The deferred annuities are linked to target-date asset-allocation funds, which invest a portion of the plan member's assets in annuity contracts as the member approaches retirement age.[220]
- Canada introduced longevity funds which are mutual funds with mortality credits as a middle ground between pension funds and annuities. Purpose Investments launched the Longevity Pension Fund in 2021, while Guardian Capital launched GuardPath Longevity Solutions in 2022.[221]

[215] https://www.ipe.com/news/higher-funding-ratios-and-dc-transition-fuel-dutch-demand-for-buyouts/10056974.article
[216] https://rclr.nl
[217] https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-posts-record-breaking-2021/
[218] https://www.pionline.com/pension-risk-transfer/lockheed-martin-offloads-another-43-billion-pension-liabilities-insurer
[219] https://www.pensionpolicyinternational.com/hp-ships-off-5-2-billion-in-pension-liabilities/
[220] https://www.pensionpolicyinternational.com/us-new-lifetime-annuities-in-401k-plans-could-cut-advisors-out-of-the-picture/
[221] https://www.pensionpolicyinternational.com/canada-are-longevity-fund-solutions-going-to-change-the-retirement-income-game/

Figure 2 shows the growth of the global market in longevity risk transfer between 2007 and 2022. A total of $801bn in transactions have been completed during this period in the UK, the US and Canada (which comprises the vast majority of the global market).

2022

The effects of long Covid began to be observed in the UK in 2022. According to a study by the Institute for Fiscal Studies, there were 2m people with long Covid who have taken some time out of work, with 110,000 unable to work at any one time. Sufferers typically report long Covid for up to six months after they are first infected. Given that total unemployment and total vacancies both equal 1.3m, this 110,000 people had a 'meaningful effect' on the jobs market and the wider economy. The Office for National Statistics estimated that 8.75m people of working age were 'economically inactive', implying they were not in work or looking for work. This has risen by around 400,000 since the pandemic began. Of these, 2.3m were long-term sick (absent for more than four weeks), up by more than 200,000 since February 2020. Not only was this damaging for the economy, it also badly affected the finances of long Covid sufferers who experienced a reduction of income of around £1,100 per month on average.[222]

Douglas Anderson, Founder of Club Vita, reported that UK mortality rates for 2022 were below pre-Covid-19 levels. As social distancing measures were gradually relaxed at the start of 2022, Covid-19 cases increased, but the strain was less dangerous than at the beginning of the pandemic: 'Statistics show that there are many people in hospital *with Covid*, but *not because of Covid*. What we are seeing is the Covid has completed its journey …to now being a largely manageable endemic. When Covid first struck, the disease was materially more dangerous (a death rate of something like 10x flu). With vaccinations, changes to the way we live our lives, better treatments and the emergence of less deadly dominant variants, the risk of death has thankfully reduced. …The patterns in North America are following a similar trajectory to the UK. But the picture in China is very different with Shanghai in lockdown [in May 2022]. It's a good reminder that despite the improvement, we have not reached "herd immunity", and some experts argue that we probably never will'.

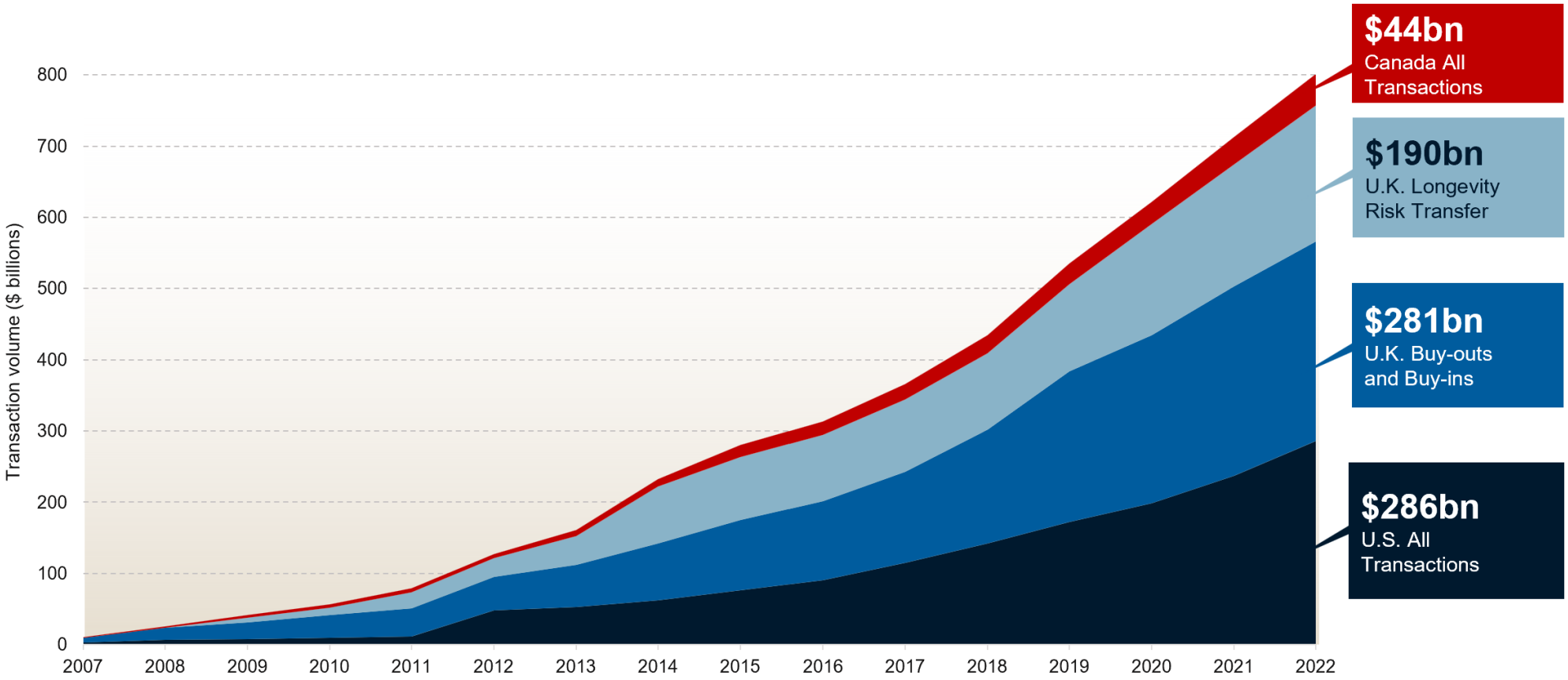
Looking to the long-term and the implications for projecting pension liabilities, Anderson identified four trends for the UK:

1. Waiting times for health treatments have lengthened: Since 2018 the number of people in England on a waiting list has risen from 4m to 6m, and the average wait time has almost doubled from 7 weeks to 13 weeks.[223]

[222] https://www.telegraph.co.uk/business/2022/07/27/long-covid-shrinks-workforce-110000/

[223] In the UK at the height of the pandemic in 2020, most cancer deaths occurred at home as hospitals prioritised Covid patients; https://www.telegraph.co.uk/news/2021/05/07/majority-cancer-deaths-occurred-home-last-year-hospitals-prioritised

Figure 2: Cumulative Pension Risk Transfers by Product and Country, $bn, 2007-2022



Data in USD billions. Cumulative totals. Sources: LIMRA, Hymans Robertson, LCP, WTW and SunLife Canada, 31 December 2022.

2. More public money going into the UK National Health Service (NHS): To deal with this waiting list, in 2022, the government introduced a health and social care levy which will raise £12bn a year. Given that the NHS budget is around £150bn, 'that's useful money at the margin, but could be quickly used up by the continued aging of the population'.

3. Labour shortages are encouraging employers to prioritize employee well-being: **'**Covid continues to cause a big shake out in working practices. Trade unions highlight the loss of 200,000 older workers, reversing a previously healthy trend in employment levels in older people. Further, workers show little appetite to return to a daily commute to the office, after showing that the job can be done perfectly well from home: "hybrid working" – part office-based, part home-based looks like it will be the "new normal" for those whose jobs are suitable. Employers are increasingly appreciating that they will need to invest more in health and wellbeing to attract and retain older employees. This emphasis on prevention in middle aged workers is very welcome. By focussing on slowing down aging by improving lifestyle, it is possible to soften the demands of the aging population on future treatment in the NHS system'.

4. More private money going into genetic research: 'Covid showcased the first mass benefit of the genetics research industry (mRNA[224] vaccines), leading to sharp share price gains for the visionary investors. This stunning success is encouraging other investors to back the biotechnology sector. The increase in research capacity bodes well for the volume of future advances. Take a look at the Deep Knowledge Group to see the growing coalition of researchers and investors'.

Anderson concludes: 'My personal sample of emerging themes offers three positive, but slow, improvements from three different stakeholder groups: government, employers and investors. Collectively, these may turn out to be more significant for pensioner longevity – when the inevitable peaks and troughs from year to year are smoothed out - than today's spike in waiting lists for treatments'.[225]

In 2022, for the first time, all eight insurers in the UK market were in a position to offer full-scheme buyouts with member-facing administration services, 'a reaction to the

[224] Messenger RNA (mRNA) is a type of single-stranded RNA involved in protein synthesis; https://www.genome.gov/genetics-glossary/messenger-rna

[225] Douglas Anderson (2022) UK deaths now below pre COVID levels: what's the long-term COVID legacy for pensioner longevity?, Club Vita, 11 May; https://www.clubvita.co.uk/news-and-insights/uk-deaths-now-below-pre-covid-levels-whats-the-long-term-covid-legacy-for-pensioner-longevity

increasing maturity of final salary schemes and a growing conviction over targeting buyout'.[226]

The funding position of UK defined benefit schemes increased by 20% during 2022 to 104% of liabilities (with assets of £1,456bn and liabilities of £1,394bn). This was largely explained by gilt yields rising by 3% and a corresponding 35% reduction in the value of liabilities, moving many UK schemes into a surplus position for the first time for many years.[227]

WTW reported that 2022 was the biggest on record for pension scheme de-risking in the UK, with £60bn of bulk annuity and longevity swap transactions completed, comprising £40bn in buy-ins and buyouts and £20bn in longevity swaps. A key reason was higher gilt yields and widening corporate bond spreads which increased pension scheme funding levels and lowered buyout prices significantly. Around 30% of pension schemes anticipate de-risking their liabilities in the next three years.[228]

There was increasing automation of the pricing process which removed manual input and made use of interpretable machine learning, ensuring greater accuracy. This has improved workflows by making them more consistent, cost effective and reliable, which, in turn, has increased pricing agility and speed to market.

Despite this, some insurers were struggling to keep up with the current levels of demand, according to a report by Aon, especially the teams responsible for pricing transactions. This has made it harder for smaller schemes to attract the attention of insurance companies. Although transactions under £100m have increased in recent years due to insurer innovation, small schemes were now 'having to compete harder for insurer engagement and potentially show flexibility over their auction timing and form'.[229]

Legal & General Investment Management's (LGIM's) DB Health Tracker found that a typical DB scheme could meet 98.8% of accrued pension benefits as of 30 June 2022: 'The increase in both nominal and real interest rates benefited a typical scheme due to underhedged liabilities. This was largely offset by poor performance of growth assets

[226] https://www.ipe.com/news/2021-uk-pension-risk-transfer-volumes-hit-439bn-with-record-core/10058708.article
[227] https://www.professionaladviser.com/news/4062207/defined-benefit-pensions-gbp400bn-funding-improvement-2022
[228] Willis Towers Watson (2023) Shifting up a Gear – De-risking Report 2023; https://www.ipe.com/news/bulk-annuity-longevity-hedging-deals-set-to-reach-60bn-says-wtw/10064524.article
[229] https://www.ipe.com/news/insurers-stretched-as-uk-pension-de-risking-demand-rises/10061581.article

relative to expectations. Overall, however, our Expected Proportion of Benefits Met (EPBM) measure managed to …reach a new high'.[230] A PwC survey of UK DB pension plans in July 2022 found that 80% expected to reach their long-term funding target(of ensuring pensions are paid in full) within the next nine years: 85% of both the smallest plans with assets of less than £300m and the largest plans with assets above £5bn said they could achieve this, whereas only 75% of medium size plans felt they could. Asset returns were a key component of the strategy, with 92% of plans saying that they would rely in whole or in part on assets returns and 41% relying solely on asset returns; 8% had hedged their investment risk and were relying on sponsor contributions to reach their long-term funding target. PwC said that pension funding levels had improved dramatically over the last couple of years, with many schemes moving into a surplus position.[231] This will clearly increase the demand for buy-outs in the UK over the next decade.

In order to ensure they could meet their targets for buying out, pension funds were also increasing the inflation sensitivity of their portfolio in response to the increase in inflation following governments' pandemic quantitative easing programmes and the increase in commodity prices following the Russian invasion of Ukraine. A poll of global pension funds by investment consultancy bfinance indicated that the funds were planning to increase their exposure to infrastructure (48%), private debt (39%) and real estate (36%). Alternatives were more popular as an inflation hedge than equities (18%), inflation-linked bonds (12%) and commodities (8%).[232]

In the light of the UK's departure from the EU, the UK government announced revisions to Solvency II on 17 November 2022. According to Pelkiewicz et al. (2019)) the reason for this was as follows: 'Following the implementation of Solvency II, the risk margin[233] came under considerable criticism for being too large and too sensitive to interest rate

[230] https://www.ipe.com/news/uk-roundup-db-schemes-health-reaches-new-high/10061802.article? By 31 August 2022, the average UK pension fund was 100.2% funded on a long-term target basis for the first time since aggregated records began, according to XPS Pensions Group's DB:UK funding tracker; https://www.ipe.com/news/uk-roundup-pension-funds-achieve-100-funding-on-long-term-targets/10061950.article?

[231] https://www.ipe.com/news/uk-db-schemes-expected-to-reach-long-term-funding-target/10061323.article

[232] https://www.ipe.com/news/pension-funds-turn-to-alternatives-for-inflation-protection/10059146.article

[233] The risk margin represents the potential costs of transferring insurance obligations to a third party should an insurer fail. It is the difference between the technical provisions (the transfer value) and the Best Estimate Liabilities (BELs). It is calculated in Solvency II using the 'cost-of-capital method' as an insurer's baseline solvency capital requirement (SCR) for unhedgeable risks multiplied by the cost of capital at 6% and discounted at current interest rates. Unhedgeable risks are risks that cannot be hedged or easily transferred to a third party, due to the absence of a deep and liquid market. A current example is longevity risk. The risk margin does not include credit and market risks as compensation for uncertainty arising from those risks is considered to be already adequately reflected in the BELs; https://www.risk.net/definition/risk-margin

movements. These criticisms are particularly valid for annuity business in the United Kingdom. …A further criticism is that mitigation of the impact of the risk margin has led to an increase of reinsurance of longevity risks, particularly to overseas reinsurers'.

The new regime for UK insurers will be called 'Solvency UK' and will involve:

- a reduction in the 'risk margin', including a cut of 65% for long-term life insurers;[234]
- more sensitive treatment of credit risk in the 'matching adjustment',[235] such as allowing insurers to invest in assets with 'highly predictable' (rather than strictly 'fixed') cashflows and assets with prepayment risk, such as callable bonds;
- a significant increase in flexibility allowing insurers to invest in long-term assets such as infrastructure and other assets with a construction phase;
- a meaningful reduction in the current reporting and administrative burden on firms; and
- a new regime for start-up insurers, with adjusted entry requirements such as a lower capital floor, lower expectations for key personnel and governance structures, and exemptions from some reporting requirements, which is also aimed at developing the UK insurtech sector.[236]

The combined effect of these reforms is expected to release 10-15% of the capital currently held by life insurers.[237] They have been welcomed by UK insurers and are likely to lead to greater insurer capacity for schemes looking to de-risk through buy-ins and buyouts. John Baines, partner at Aon and head of its bulk purchase annuity team, said the reforms struck a good balance between capital relief and policyholder protection, with the PRA likely to be reassured that the level of capital requirement would still be a 'gold standard approach to ensuring insurers had a high chance of meeting pension benefit obligations.[238] Chris Anderson, head of BPA consulting at EY, said: 'Risk margin rules at the moment drive insurers to transact a huge amount of longevity reinsurance when they complete a PRT deal. Two potential consequences of the proposed changes are that first, it may encourage insurance companies to carry out slightly less reinsurance, which could be

[234] 30% for non-life insurers.
[235] The matching adjustment give insurers capital relief for holding specific long-term assets which match the cash flows of a designated portfolio of life or annuity insurance and reinsurance obligations. It permits insurers to discount their liability cash flows at a higher rate than the risk-free rate, resulting in a lower liability value and hence lower regulatory capital. The higher rate is intended to reflect the illiquidity premium in the return on the long-term assets held and is calculated as the difference between the spread on these assets above the risk-free rate and the 'fundamental spread' or credit risk premium (i.e., the expected cost of default and downgrade of these assets); https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/2022/solvency-ii-review-matching-adjustment-and-reforms-to-the-fundamental-spread
[236] https://www.skadden.com/insights/publications/2022/11/from-solvency-ii-to-solvency-uk
[237] https://ukfinancialservicesinsights.deloitte.com/post/102hnw5/the-uk-governments-consultation-on-solvency-ii-part-1-risk-margin-and-matchin
[238] https://www.ipe.com/news/analysis-uk-solvency-ii-reforms-and-the-pensions-buyout-market/10058506.article

beneficial on price for pension schemes, and secondly the risk margin on what remains will be lower, which also should be beneficial on price'. A key problem which slows down the pace of transactions is a shortage of qualified staff. According to Anderson: 'Everyone is trying to find people. Insurance companies need people to run the quotation process and to onboard schemes. Employee benefit consultants also need additional staff – everyone is resource constrained'.[239]

A report from PIC entitled *Investment Unleashed*[240] argued that appropriate reform to Solvency II could unlock 'tens of billions of pounds' to invest in infrastructure and social assets in the UK, including renewable energy and social housing. PIC estimated its planned investment of £30bn in productive finance by 2030 could increase to £50bn. According to the report, the ideal reform of Solvency II would:

- preserve insurer balance sheet resilience throughout the cycle – protecting policyholder pensions – whilst discouraging investment in relatively riskier assets in overvalued markets;
- encourage investment into productive finance throughout the cycle;
- ensure a competitive UK insurance industry – especially when compared to insurers operating under the EU Solvency II regime.[241]

However, Michael Luo, associate director at fiduciary manager Cardano, pointed out that in 2022 life insurers were facing geopolitical risks and a macroeconomic climate that had not been experienced in over 40 years, with the prospect that they could see the quality of their investments deteriorate through increased credit downgrades and defaults. In addition, any insurers looking to raise hybrid debt capital in the near-future may experience higher borrowing costs than in recent years, whilst any increase in volatility in interest rates and credit markets could create pressure on liquidity management. This implies that trustees and sponsors will need to put more focus on understanding insurers' financial strength, risk management and capital resilience when undergoing an insurer-led risk transfer exercise, to ensure the most appropriate insurer is selected to deliver benefits to their scheme members.[242]

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[239] Quoted in Greg Winterton (2022) Solvency II Reform Proposals Could Drive Increased Pension Risk Transfer Activity, *Life Risk News*, Volume 1, Issue 8, December; https://liferisk.news/solvency-ii-reform-proposals-could-drive-increased-pension-risk-transfer-activity/

[240] https://www.pensioncorporation.com/media/200562/investment-unleashed-2021-211223v1.pdf

[241] https://www.ipe.com/news/solvency-ii-reform-could-free-up-tens-of-billions-of-pounds-for-uk-infra-says-pic/10057177.article

[242] https://www.pensionsage.com/pa/Trustees-urged-to-consider-insurers-financial-strength-as-PRT-market-approaches-unique-juncture.php

In response to this, some pension plan trustees had become concerned about post-transaction protection. According to Alan Pickering, President of BESTrustees: 'If the trustees do not realize until the eleventh hour that once the scheme has no money, they will be depending on insurance or internal indemnities to guarantee that they will sleep at night for the rest of their lives, because ambulance chasing lawyers will not come after them claiming the benefit payments are wrong. You do not want to double bank external insurance and internal indemnities, but it is important to send trustees into retirement with peace of mind'.[243]

One of the most significant events of the year was the impact on UK pension funds' liability-driven investment (LDI) strategies – used by 73% of DB schemes according to Mercer[244] – following UK government's 'mini-Budget' of 23 September. The financial markets responded unfavourably to the unfunded tax cuts announced, predicting that the UK's national debt would increase substantially. The prices of gilts fell sharply and pension funds faced huge increases in collateral requirements as their hedging contracts for protecting against lower interest rates (principally in the form of interest rate swaps and gilt repurchase agreements[245]) moved out of the money. Pension funds were forced to sell gilts in an illiquid market to meet cash margin calls and this reduced gilt prices even further. The Bank of England was forced to step in and stabilize the market by agreeing to purchase gilts directly from pension funds. Although pension funds faced a severe liquidity crisis at the time, their solvency position actually improved, since the rise in gilt yields helped to reduce the value of their liabilities by more than the value of their assets.

This experience is expected to provide a further boost to buy-outs and buy-ins. It was also expected to be disappointing news for pension scheme consolidator companies that rely on LDI strategies to hedge their risks.[246] A survey by Russell Investments found that the volatility following the UK government's 'mini-Budget' had influenced asset allocation decisions, with moves away from developed markets (32% of respondents) and emerging markets equities (12%), as well as property (17%) exposure. Instead, investment grade credit (25%) and high yield credit (13%) were the key beneficiaries of this trend, as was infrastructure (16%) and private credit (12%), 'reflecting the perceived attractiveness of the risk/return opportunities available in these asset classes'.[247]

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[243] Quoted in Mark Dunne (2022, Editor) Endgame investing - pi roundtable, July; https://www.portfolio-institutional.co.uk/roundtables/endgame-investing/

[244] *Portfolio Institutional*, October 2022 (p.44).

[245] See, e.g., *An Introduction to Liability Driven Investment*, Insight Investment, November 2021.

[246] https://www.pensionpolicyinternational.com/uk-ldi-fallout-will-spur-pension-funds-to-seek-life-sector-arrangements/

[247] https://www.ipe.com/news/uk-mini-budget-accelerates-db-schemes-de-risking-says-russell-investments/10063686.article

In January 2023, the UK Prudential Regulation Authority wrote to UK insurance companies warning them that: 'In light of the multiple external uncertainties facing insurers, it is important that firms take proactive steps to assess the adequacy of their risk management and control frameworks. Firms should be able to respond to market and credit risk conditions different from those that prevailed for a long time. Firms need to be prepared for novel risks, changes in risk correlations and increases in distressed assets. We expect firms to assess their credit and counterparty credit risk management capabilities in light of widening credit spreads, rating downgrades, and defaults. … We are paying close attention to whether the continued high level of longevity reinsurance and the emergence of the more complex 'funded reinsurance' in the UK life market reduce the protection UK policyholders should have, beyond the risk tolerance. In particular, we see the potential for offshored counterparty concentration risk to arise from rapidly growing levels of reinsurance. These concentrations can arise for firms individually and for the sector as a whole. We expect UK authorized firms to consider their compliance with the Prudent Person Principle (PPP) for the risks associated with their reinsurance activities. Insurers need to consider the reinsurer's resilience over the whole duration of the exposures, as well as the potential impact from a mass recapture event where large concentrations to a small number of counterparties exist. Our own work on counterparty and concentration risk will examine the need for policy action on reinsurance structures and limits, to mitigate systemic risks to policyholders'.[248]

Another issue was currency movements. Sterling fell significantly against the US dollar during 2022 from $1.35 to $1.21. This reduced the costs for both US sponsors of UK pension plans and US insurers offering PRT solutions to UK plans.

A total of £44.7bn in buy-ins, buy-outs and longevity swaps were executed in 2022, of which £28.7bn were buy-ins.[249] The largest providers were Legal & General, Standard Life, Aviva, PIC and Rothesay, with Just Group having a record year with £2.6bn in transactions.

Highlights for 2022 in the UK included:

- In February, the Lloyds Banking Group Pensions Scheme executed a second longevity swap, covering £5.5bn of liabilities. It was structured as an insurance contract with Scottish Widows as the insurer and SCOR as the reinsurer, taking over the longevity risk.[250]

[248] https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2023/insurance-supervision-2023-priorities.pdf
[249] https://www.ipe.com/news/bulk-annuity-volumes-reach-278bn-according-to-aon/10065718.article?
[250] https://www.professionalpensions.com/news/4044972/lloyds-scheme-completes-gbp-5bn-longevity-swap

- In February, L&G agreed a £370 million buy-in with London Heathrow's BAA Pension Scheme, securing the benefits of more than 1,400 retirees.[251]
- In February, L&G announced it would invest £2.5bn of DB pension assets in UK build-to-rent (BTR) projects over the next five years, creating more than 7,000 new homes.[252] This was followed up in April with an announcement that it would invest a further £2bn in affordable UK homes over the next five years, creating 10,000 new homes.[253] In August, it invested £500m in 'later living' residential homes in a joint venture with the NatWest Bank pension fund.[254]
- In March, the Air Canada (UK) Pension Trust Fund completed a £380m buy-in deal with PIC, covering 1,400 members.[255]
- In March, the Royal Mencap Society completed a £61m bulk annuity transaction for its pension scheme, covering 710 members. Following a one-round appointment process, the scheme was able to benefit from Canada Life and Aon's streamlined internal legal process. These efficiencies secured competitive pricing for the scheme.[256]
- In March, the Newell Rubbermaid UK Pension Scheme has agreed to a £225m buy-in with L&G, covering 800 retirees and 900 deferred members.[257]
  In May, the £10.3bn British Steel Pension Scheme II agreed a second buy-in with L&G, insuring around 25% of its liabilities. The first buy-in was completed at the end of 2021 and covered 5% of the liabilities.[258] In December, the scheme completed a a further £2bn buy-in with L&G. This covered 30% of its liabilities, and brought the total liabilities insured to 60%.[259]
- In May, PIC made a £130m debt investment in UK social housing provider Raven Housing Trust to help fund the development of 630 homes by 2026.[260] In September, PIC invested £105m to forward fund a new 'net-zero in-operation office' in Manchester to be let to the Government Property Agency for 25 years. In

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[251] https://group.legalandgeneral.com/en/newsroom/press-releases/legal-general-agrees-c-370m-buy-in-with-heathrow-s-baa-pension-scheme
[252] https://realassets.ipe.com/news/landg-to-inject-25bn-of-pension-money-into-uk-build-to-rent-projects/10058092.article
[253] https://realassets.ipe.com/news/landg-to-invest-2bn-of-pension-money-into-affordable-uk-homes/10059125.article
[254] https://realassets.ipe.com/news/landg-and-natwest-pension-fund-to-invest-500m-in-uk-later-living-villages/10054341.article
[255] https://www.ipe.com/news/uk-pension-schemes-sign-buy-in-deals-with-pic-just-group/10058758.article
[256] https://www.ipe.com/news/uk-roundup-charity-completes-61m-bulk-annuity-transaction/10058643.article
[257] https://www.ipe.com/news/uk-roundup-rubbermaid-scheme-completes-buy-in-with-legal-and-general/10058607.article
[258] https://www.pensionsage.com/pa/BSPS-II-secures-two-buy-ins-with-L-G.php
[259] https://www.ipe.com/news/british-steel-pension-scheme-completes-2bn-buy-in-with-legal-and-general/10064456.article
[260] https://realassets.ipe.com/news/uk-social-housing-provider-raven-secures-130m-funding-from-pic/10059795.article

October, it invested £55m in Northern Ireland-based Clanmil Housing Association which will be used to build 1,400 new homes by 2026[261] and provided £102m of debt financing to Corelink Rail Infrastructure, a UK rolling-stock lessor.[262] Also in October, it invested £40m in the secured debt of UK social housing provider, Mhs, to fund the development of 600 new properties.[263] In November, it financed the construction of a £200m residential skyscraper in the West Midlands region of England.[264] Also in November, it created Senior Living Investment Partners with Octopus Real Estate which made its first £115m investment in a retirement community in St Albans.[265] In December, it invested £40m of debt in Housing Solutions, a housing association which owns and manages around 7,500 properties in the south-east of England.[266] In each case, the purpose was to secure long-dated index-linked cashflows for the purpose of paying the 'pensions of our current and future policyholders over coming decades'.[267]

- In June, the House of Fraser's Beatties & Jenners Pension Scheme insured £600m of liabilities via a buyout with PIC, covering 3,850 deferred members and 5,050 pensioners.[268]
- In June, the Phoenix Group provided £90m of long-term funding to regulated social housing provider, Alliance Homes, with the aim of generating index-linked cash flows.
- In July, the UBS (UK) Pension and Life Assurance Scheme extended its July 2020 longevity hedge by £500m to include 50% of its deferred members, those over 60. The combined hedge covered two-thirds of its DB liabilities. The deal involved Zurich Assurance as the insurer and Canada Life Assurance Company acting as the reinsurer.[269]
- In July, the Whitbread Group executed a £680m bulk purchase annuity covering approximately 8,000 members of its pension fund with Standard Life. Standard Life said: 'we receive a one-off premium from the scheme and then guarantee that member benefits will be paid into the future. This premium is invested across a

[261] https://realassets.ipe.com/news/pic-invests-55m-in-clanmil-housing-association/10062602.article
[262] https://realassets.ipe.com/news/uk-rolling-stock-lessor-corelink-gets-102m-pic-loan/10062627.article
[263][263] https://realassets.ipe.com/news/pic-invests-in-secured-debt-issued-by-uk-housing-association-mhs/10062935.article
[264] https://realassets.ipe.com/news/pic-funds-200m-residential-skyscraper-project-in-birmingham/10063144.article
[265] https://realassets.ipe.com/news/pic-and-octopus-real-estates-uk-retirement-living-venture-makes-first-investment/10063332
[266] https://realassets.ipe.com/news/pic-provides-40m-of-debt-for-uk-social-housing-provider/10063997.article
[267] https://realassets.ipe.com/news/pic-invests-105m-to-forward-fund-gpa-hub-office-project/10062435.article
[268] https://www.ipe.com/news/uk-roundup-house-of-fraser-plan-strikes-600m-buyout/10060379.article
[269] https://www.ipe.com/news/ubs-uk-scheme-extends-longevity-hedge-by-500m/10060899.article

broad range of assets to ensure we are able to meet the future liabilities. Given that member benefits will be paid out over decades we can afford to take a long-term view in the way we invest and make allocations to illiquid investments. We aim to invest 60% of our illiquid assets in sustainable investments including in areas like renewable energy, infrastructure, affordable housing and healthcare and education, …supporting some of society's most vulnerable people as well as …projects with a positive environmental impact, such as the provision of renewable electricity'.[270]

- In August, the Equity Release Council reported that 47,000 new and returning customers withdrew £3.13bn from their properties during the first half of 2022, an increase of 37% on the same period in 2021. The majority (54%) of the withdrawals were in the form of lump sum lifetime mortgages rather than drawdown lifetime mortgages. The Council believes that this is 'influenced by customers' continuing desire to gift money to younger family members and share their property wealth across generations'. Stephen Lowe, group communications director at Just Group, said the 'demand for equity release has recovered strongly from the pandemic wobbles. …Homeowners may be using equity release to generate lump sums, extra income or for estate-planning'.[271]
- In August, Phoenix Group announced it would acquire Sun Life Assurance Company of Canada (UK), a closed book UK life insurance company, from Sun Life Financial for £248m. The deal was expected to deliver £470m of incremental long-term cash generation, inclusive of cost and capital synergies. The insurer had about 480,000 in-force policies and £10bn of assets under administration, of which £2.5bn were annuities that would remain reinsured with Sun Life Financial.[272]
- In August, Standard Life completed a £1bn buy-in of the WH Smith Pension Trust, covering around 13,000 members. As with other insurers, the assets underlying the contract will be used to continue Standard Life's programme of investing into UK infrastructure and socially responsible projects, such as renewable energy, infrastructure, and affordable homes.[273]
- In August, L&G agreed a £50m full scheme buy-in with the Boots Supplementary Pension Plan, covering the benefits of more than 110 members. Lisa Varley, a senior consultant in Aon's risk settlement group, which advised the trustees, said: 'The successful outcome illustrates that there are excellent opportunities for

[270] https://www.ipe.com/whitbread-group-pension-fund-completes-680m-buy-in-with-standard-life/10061094.article
[271] https://www.professionaladviser.com/news/4054181/equity-release-activity-26?
[272] https://www.professionaladviser.com/news/4054283/phoenix-group-acquire-sun-life-uk-gbp248m
[273] https://www.ipe.com/news/standard-life-completes-1bn-buy-in-of-the-wh-smith-pension-trust/10061476.article

sub-£100m schemes, as long as insurers can see a clear line of sight to a successful transaction'.[274]

- In August, Railpen, the UK railways pension scheme, purchased a life-science business park in Oxford for £29m with plans to attract leading companies in scientific research as tenants and generate 'enhanced returns' for scheme members.[275] In October, Railpen agreed to fund the redevelopment of a mental health facility in Northern England in exchange for a 30-year lease on the site which will deliver inflation-linked returns for the scheme.[276]
- In September, the Barloworld UK Pension Scheme completed a £484m (€559m) full scheme buy-in with Just Group, insuring the benefits of around 3,000 pensioners and 1,800 deferred members.277
- In September, the Yell Pension Plan executed a full scheme buy-in with PIC, covering the remaining £370m of liabilities, having completed a £200m buy-in also with PIC in 2014. All 1,800 plan members became PIC policyholders.[278]
- In October, the Cobham Pension Plan has concluded a £530m buy-in with Standard Life, covering around 3,000 members.[279]
- In November, the Balfour Beatty Pension Fund completed a £1.7bn longevity reinsurance transaction (swap) covering 15,000 members with Zurich UK as the insurer and SCOR taking on 100% of the longevity risk using a 'pass-through' structure.[280]
- In November, an unnamed UK pension scheme sponsored by a Fortune 500 company completed a £1bn longevity swap with Zurich as insurer and PartnerRe as reinsurer. The deal covered both pensioner and non-pensioner members.[281]
- In November, the TT Group scheme executed a £400m buy-in deal with L&G, covering 5,000 members.[282]
- In December, the Barclays Bank UK Retirement Fund executed a £7bn reinsurance transaction (swap), with reinsurance provided by Prudential Financial.[283]

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[274] https://www.ipe.com/news/boots-supplementary-agrees-50m-pension-buy-in-with-landg/10061569.article
[275] https://realassets.ipe.com/news/railpen-buys-29m-life-science-business-park-from-aew/10061697.article
[276] https://realassets.ipe.com/news/railpen-to-fund-monkwearmouth-hospital-redevelopment/10062796.article
[277] https://www.ipe.com/news/barloworld-uk-scheme-completes-484m-buy-in-deal-with-just-group/10061961.article?
[278] https://www.ipe.com/news/uk-roundup-yell-pension-plan-completes-370m-buy-in-deal-with-pic/10062218.article?
[279] https://www.ipe.com/news/uk-roundup-cobham-scheme-completes-530m-buy-in/10062986.article
[280] https://www.ipe.com/news/uk-roundup-balfour-beatty-in-17bn-longevity-transaction/10063743.article
[281] https://www.professionalpensions.com/news/4060514/fortune-500-sponsored-scheme-completes-gbp1bn-longevity-swap
[282] https://www.ipe.com/news/partnerre-in-1bn-longevity-swap-deal-with-uk-fortune-500-scheme/10063540.article
[283] https://www.professionalpensions.com/news/4061710/barclays-uk-retirement-fund-seals-gbp7bn-longevity-deal

- In December, the Amey pension fund executed a £400m buy-in deal with PIC, covering 3,473 members, including 1,938 deferred members.[284]
- In December, The Interserve Pension Scheme completed a £400m buy-in with Aviva, covering around 7,000 members.[285]
- In December, the Tioxide Pension Fund agreed a £430m buy-in with L&G, securing the benefits of around 2,700 retirees and deferred members.[286]
- In December, the Co-operative Pension Scheme's £2.1bn Bank Section completed a full £1.2bn buy-in with Rothesay Life, covering all the liabilities of 2,474 pensioners and dependants and a further 6,531 deferred members.[287]
- Also in December, Rothesay Life executed a £762m buy-in for the Morrisons Retirement Saver Plan, covering 2,650 pensioners and dependants and 5,500 deferred members.[288]

There were a number of significant international developments outside the UK in 2022.

The US PRT market had its most successful year to date, with 568 transactions valued at $52bn, of which $48.3bn was accounted for by 562 single premium buy-outs, while the remainder were buy-ins.[289] This was largely due to improved funding ratios rising from 87.9% in 2020 to 95.8% in 2021 and to 100.7% in 2022, on the back of strong equity market performance and higher interest rates. With rising levels of inflation, a potential recession, and geopolitical uncertainty, plan sponsors wanted to protect themselves from market downturns. Some of the PRTs were lift-outs, with plans transferring some of their pension risk to an insurance company, but most followed plan terminations – and a consequential increase in annuity purchases – by plans that were over 100% funded. The market was also very competitive with 21 active insurers, including newcomers Global Atlantic, RGA and American National, compared with 10 in 2012.[290] As a result of this competition, the Milliman Pension Buyout Index was 98.9% of plans' retiree ABO, while the average annuity purchase cost across all insurers was 103.7%. This meant that the competitive bidding process was estimated to save plan sponsors on average around 4.8%

[284] https://www.ipe.com/news/british-steel-pension-scheme-completes-2bn-buy-in-with-legal-and-general/10064456.article
[285] https://www.pensionsage.com/pa/Interserve-Pension-Scheme-completes-400m-buy-in-with-Aviva.php
[286] https://www.ipe.com/news/uk-roundup-tioxide-pension-fund-in-430m-buy-in-deal-with-landg/10064566.article
[287] https://www.pensions-expert.com/DB-Derisking/Co-operative-Pension-Scheme-completes-1.2bn-full-section-buy-in
[288] https://www.pensionsage.com/pa/Morrisons-agrees-762-m-buy-in-with-Rothesay.php
[289] https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-keeps-setting-records/; https://www.pensionpolicyinternational.com/u-s-pension-plan-buyouts-reach-record-volume-in-2022/; https://www.pensionpolicyinternational.com/us-pension-risk-transfers-spiked-in-2022-due-to-higher-interest-rates-report-shows/
[290] https://www.institutionalinvestor.com/article/b1xzjngjkysg4t/Companies-Race-to-Offload-Pension-Risk-as-Market-Volatility-Rises

of PRT costs (as of February 28). By September 30, the cost savings had fallen to 3.0% of PRT costs due to 'insurers having less appetite for interest rate risk, or less assets available for transactions'.[291] Another development is the entry of reinsurers into the market, providing additional balance sheet capacity to insurers, but without being direct writers in the market. There is beginning to be some interest in buy-ins in the US market, but longevity-only transactions are still rare. A prediction for 2023 will be artificial intelligence enhanced modelling of mortality and longevity risks which could lead to more longevity risk-transfer deals.[292]

One of the largest disclosed US transactions of the year was completed in June by Lockheed Martin Corp. which purchased group annuity contracts from Athene Holding valued at $4.3bn.[293] An even bigger one was completed in September, when PICA and MetLife each agreed to reinsure 50% of the pension benefit payments of 100,000 IBM plan members. The total value of the PRT transaction was $16bn, making it the second-largest deal in the US market.[294]

In the Netherlands, there has been a movement away from longevity derivatives towards longevity swaps (or longevity reinsurance). According to Andre de Vries, vice president business development at RGA, longevity derivatives, which dominated the Dutch market between 2012 and 2017, 'are based on the mortality risk of the general Dutch population, as opposed to a specified portfolio of insured beneficiaries. In addition, these longevity derivatives are structured to transfer more remote (out-of-the-money) longevity risk over a limited term and the benefit (claim) under these longevity derivatives is capped at a pre-defined amount. Compared to longevity reinsurance, longevity derivatives require only a limited set of data to be shared with the risk takers and impose less due diligence requirements on the ceding company compared to a reinsurance transaction. On the other hand, it is more challenging to determine the reduction in Solvency Capital Requirement under Solvency II (SII) resulting from these derivatives because there is no perfect fit between the longevity risk transferred and the longevity risk of the insurance company'.

In 2018, the Dutch market switched to longevity reinsurance because if the introduction of SII in the EU in January 2016: 'As longevity swaps transfer all the longevity risk of a specified portfolio of pension obligations over their full remaining term (which can easily

[291] https://www.pensionpolicyinternational.com/milliman-analysis-competitive-pension-risk-transfer-buyout-rate-rises-320-basis-points-to-100-1-during-september/
[292] https://www.ipe.com/north-america/us-sponsors-back-pension-buyouts/10064707.article?
[293] https://www.pensionpolicyinternational.com/us-milliman-analysis-competitive-pension-risk-transfer-buyout-rate-hits-all-time-low-in-february-at-98-9/; https://www.pionline.com/pension-risk-transfer/us-corporate-pension-plan-buyouts-hit-record-123-billion-q2-limra-survey
[294] https://www.pensionpolicyinternational.com/prudential-and-metlife-entrusted-to-fulfill-16b-in-pension-obligations-for-100000-ibm-retirement-plan-participants-and-beneficiaries/

be more than a few decades), these transactions are more expensive than longevity derivatives. On the other hand, because these reinsurance transactions exactly match the underlying liabilities of the insurance companies, these instruments allow insurance companies to fully release the SCR for the corresponding longevity risk. …SII has an explicit SCR for longevity risk which resulted in clear capital relief from longevity risk transfer transactions. This was not the case under the prior regulatory regime'.

Dutch longevity swaps have introduced a number of new features:

- Recouponing (or rebalancing) longevity swaps. The objective of recouponing is to provide additional protection to the party that is facing a positive value of the longevity swap at a future moment during the term of the transaction. Under this mechanism, the fixed leg (the premiums) of the longevity swap is adjusted in case its present value has become materially different (either higher or lower) compared to the prevailing present value of the floating leg (the claims).

- Accommodating a bail-in. This is one of the resolution tools included in the 2019 Recovery and Resolution Act for insurers which might allow pension obligations to be reduced so that an insurer can continue in business.

- Extending longevity reinsurance with asset performance risk or 'asset intensive' (AI) reinsurance. This is a longevity swap whereby the present value of the fixed leg is paid at inception. To mitigate the counterparty credit exposure of the insurer on the reinsurer resulting from this initial settlement, a collateral arrangement forms part of AI reinsurance. Under this collateral arrangement, the reinsurer is responsible for maintaining a portfolio of assets within pre-agreed investment guidelines and restrictions. As asset performance risk is very capital intensive, Dutch insurers that are actively managing their capital position, are considering to also reinsure (some of the) asset performance risk resulting from these pension buy-outs. Such an approach might give them the opportunity to also offer very large pension buy-outs that they might otherwise not be comfortable executing because of the substantial capital implications.[295]

The Australian Prudential Regulation Authority (APRA) introduced a retirement income covenant in July 2022.[296] Regulated superannuation funds (or other registrable superannuation entities (RSEs)) are required to formulate a retirement income strategy (the strategy) for their members' decumulation phase which will improve their retirement

[295] Andre de Vries (2022) Update on Longevity Risk Transfer in the Netherlands, *de actuaris*, December, 18-20; https://www.ag-ai.nl/view/51882-DA-30-2-art-deVries.pdf
[296] https://www.apra.gov.au/implementation-of-retirement-income-covenant

outcomes and be in their best financial interests. Although not stated explicitly, the aim is to encourage greater use of lifetime annuities where that is appropriate for members. The A$220bn Australian Retirement Trust (ART) – formed from the merger of QSuper and Sunsuper in February 2022[297] – has introduced a lifetime pension product which is like an annuity. It offers a market-based income for life in a set-and-forget product in which the super funds are pooled with other investment funds to cover fees and costs and only a proportion of the assets are used to provide the pension. Other providers include Challenger Life and Generation Life which in May 2022 introduced an investment-linked lifetime annuity.[298] Previously, most retirees switched to an account-based pension which keeps their pension pot invested in the same pool of assets as in accumulation. Income from the account is tax free, but there is a minimum drawdown of 5% every year which increases as members get older.[299]

In July, AXA Germany announced the transfer of a portfolio of around 900,000 conventional life and annuity insurance contracts worth €19bn in assets under administration to Athora Germany for a purchase price of €610m. It will take five years to transfer the contracts, beginning in 2023.[300]

In May, the Bermuda Monetary Authority proposed amending the Insurance Act 1978 to introduce a new innovative class for long-term insurers (Class IILT). The BMA said it believed that market developments in the next decade will lead to a conflux of insurance, capital markets, artificial intelligence, and distributed ledger technology: 'The Class IILT is intended for, but not limited to, innovative business models, such as those insurers that utilize digital assets for their operations… [which] would enhance liquidity and risk transfer efficiency'.[301]

One of the most significant events of 2022 was the opening of the Longitude Exchange – as the first digital marketplace for trading longevity risk in index-based format – in Bermuda which is regulated by the Bermuda Monetary Authority (BMA), Bermuda's financial regulator.[302] It describes itself as the Longevity Risk Marketplace for connecting hedgers and investors on a platform optimized for trading longevity risk. Its mission is to build an efficient and deep market for trading longevity risk, helping ensure the stability of

[297] https://www.top1000funds.com/2022/03/super-and-sunsuper-merge-to-form-new-institutional-giant/. ART is the second largest super fund after the A$260bn AustralianSuper.
[298] https://frsltd.com/latest-news/generation-life-launches-australias-first-investment-linked-lifetime-annuity-solution-on-investpro-from-frs/
[299] https://www.ipe.com/asia-pacific/letter-from-australia-superfunds-focus-on-retirement-income/10057677.article
[300] https://www.ipe.com/news/axa-germany-transfers-19bn-insurance-portfolio-to-athora/10061129.article
[301] https://www.reinsurancene.ws/bma-introduces-new-innovative-class-for-long-term-insurers-class-iilt/
[302] https://www.longitude.exchange/

individuals retirement income and the global financial system by: helping pension funds and insurers manage liabilities at a lower cost; providing investors better access to an uncorrelated asset class; enhancing the efficiency of trading longevity risk; and improving the security of the financial system.

The Longitude Exchange platform handles documentation, trade set-up, primary issuance, valuations, and secondary trading. Its tools streamline the process of hedging and investing in longevity risk. For hedgers, there are tools for: hedge construction – construct trades optimized for risk and capital objectives; hedge analysis – measure hedges' impact on risk and capital positions; hedge placement – conduct auctions, negotiate terms and execute deals; hedge reporting – receive reporting, payment and collateral instructions; and hedge management – increase or decrease hedges through secondary trading. For investors, there are tools for: longevity modeling – models and datasets to generate longevity scenarios; investment analysis – price transactions using longevity scenarios; investment execution – place bids and negotiate terms with counterparties; on-going valuations – live quotes and historical trades to mark positions; and secondary trading – list positions, request bids, and buy listed transactions.[303]

In May, the Longitude Exchange linked up with Dedomainia to advance the techniques and processes for monitoring, administering, and valuing index-based longevity risk hedges. In December 2016, Dedomainia had launched a web-based platform designed for longevity swap calculations called LISA (Longevity Insurance Servicing and Administration).[304] In September, the Longitude Exchange announced it had raised seed funding from the Deep Knowledge Group, a consortium of commercial and non-profit organizations active in several technological domains including Longevity, AI, FinTech, and InvestTech.

Dr Erik Pickett, Chief Content Officer at Club Vita, argues that the key to developing a successful life market is the:

> *commoditization of longevity risk, i.e., the development of fungible, tradable financial instruments linked to longevity risk that increase the efficiency of each step of the risk transfer chain and ultimately the creation of a deep liquid market for longevity risk. Commoditization should attract more, much needed, capacity in longevity risk takers. This is expected largely to come from capital markets investors entering the market, attracted by returns diversified against key financial risks, with some extra capacity also released from existing players due to standardization and automation.*

[303] https://www.bayes.city.ac.uk/__data/assets/pdf_file/0012/701013/MICHAELSON-Avery.pdf
[304] https://www.artemis.bm/news/efficient-management-of-longevity-transactions-key-for-counterparts/

It is often not economical for small pension funds to enter into complicated indemnity contracts to remove longevity risk. Streamlining of contracts such as those implemented by Mercer and Zurich have opened up this market to smaller players to a certain extent, but complete commoditization would open it up further. By simplifying the process and increasing the supply of risk takers, commoditization should create competitive pricing for longevity risk transfers. The clearing price will of course be affected by any increase in demand, but price loadings due to market frictions should be reduced; a commoditized market could allow risks that have not traditionally attracted insurers or reinsurers, such as deferred annuity longevity risk contracts. A standardized risk classification system and index-based instruments will enable more efficient risk management solutions, in particular allowing more efficient balancing of longevity and mortality risk and reducing capital demands.

...For a commoditized market to develop, there needs to be a standardization of terms for the writing of financial instruments. Central to that will be the development of a set of widely accepted and accessible reference indices that would mimic the movements on the risk cedants' balance sheets. Index-linked instruments would be highly tradable and could protect cedants from extreme outcomes; they would also allow risk traders to act on their sentiment to future longevity risk. Innovative approaches to structuring financial instruments need to be developed that are attractive to both risk cedants and risk takers, in particular, instruments that reduce the time horizon of traditional indemnity swaps (such as those using commutation mechanisms) are needed to attract capital market investors. Shrinking the margins of dealers in a commoditized market could help to increase returns. Articulating the potential capital benefits of pairing longevity and mortality risk, or the diversification effect of longevity with key financial risks could help engage investors with the potential returns.

... Despite some previous false starts for the commoditized longevity market, it feels like the stars may finally be aligning. Over the last few years there has been real concern in the reinsurance community about a capacity crunch if the projected annual market demand materializes. Pension fund consolidators and the success of streamlined longevity swap contracts are bringing smaller pension funds into the de-risking market and new ideas about structuring financial instruments to address the key obstacle of shorter term contracts have now been developed. Players in the market such as Longitude Exchange and Club Vita are working to standardize models and index data to get everyone talking the same language.

> *For a market to develop, timing of many factors need to align. Maybe that is what's happening right now.*[305]

An additional factor is the aligned understanding of longevity risk, especially in the UK. As Song et al (2023) point out: 'The UK actuarial community has relatively easy access to credible mortality data and mortality improvement studies (e.g., the UK CMI model). Accessibility to quality population mortality data is crucial to balancing the information asymmetry between insurers (who have relatively smaller, more volatile portfolios) and global reinsurers (who have the capability to perform credible longevity studies with their large data repository and carry significant volumes of offsetting mortality risk from group life, catastrophe and other business). This free flow of information has created an unprecedented level of alignment of views on longevity risk among all UK PRT market participants, which in turn has helped the industry in setting an effective "market price" for that risk via longevity swaps'.[306]

Hedge funds (with assets of $4.13trn[307] in June 2022) and private equity (with assets of $7.97trn) could be attracted to this sector since the financial instruments being developed look like alternative fixed-income products with which they are already familiar. However, for them to commit capital, there needs to be much greater liquidity – which is where a trading platform like Longitude Exchange comes in.

Avery Michaelson, CEO of Longitude Exchange, argues that:[308]

> *In order for hedge funds and other institutional investors to get involved in the longevity market, they need a marketplace. Currently, transactions are brokered in an over-the-counter process using transaction formats that aren't well suited to the investment criteria of these players. These investors benefit from a certain level of commoditization of transactions, something which can be addressed with index-based transaction formats. By basing transaction pay outs on general-population mortality data, information asymmetries can be removed along with much of the analytical complexity involved in pricing and risk analysis.*

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[305] Erik Pickett (2022) If Longevity Risk is an Asset Class, How Do We Make It More Tradeable?, *Life Risk News*, 13 July; https://liferisk.news/if-longevity-risk-is-an-asset-class-how-do-we-make-it-more-tradeable/

[306] Paul Song, Patricia Nguyen, Rey Malile and Mark Spong (2023) Managing Longevity Risk: A Solution to Consider, *Reinsurance News*; https://www.soa.org/sections/reinsurance/reinsurance-newsletter/2023/february/rsn-2023-02-spong/

[307] According to data and analytics provider Preqin.

[308] Quoted in Greg Winterton (2023) Is a Digital Exchange the Solution to the Investor Participation in Longevity Risk Transfer Conundrum?, *Life Risk News*, Volume 2, Issue 2, February; https://liferisk.news/is-a-digital-exchange-the-solution-to-the-investor-participation-in-longevity-risk-transfer-conundrum/

Rising interest rates have further accelerated pension de-risking, fuelling greater than ever demand for capital. Fortunately, there are already a number of ILS Funds with experienced life risk teams prepared to commit capital to this space. They will be joined by a much broader range of institutional investors as deal flow and liquidity materialize.

There are around $100trn of longevity linked liabilities, globally. And every year of unanticipated life expectancy adds around 5% to liabilities. So, if estimates are off by three years, longevity risk could cause $15trn of unfunded liabilities. The enormous quantum of this risk points to the need for capital markets participation. It's only a matter of time before longevity risk is recognized as its own asset class.

Securitizing mortality risk

A number of insurers and reinsurers have used the capital markets to securitize some of the mortality risk on their book of business, in the form of what have become known as mortality-linked (or mortality catastrophe) bonds. Swiss Re has been the most active participant in the market, issuing the first security in 2003, known as Vita I.[309] Vita I was a $400m principal-at-risk variable rate note, where the investors' principal was at risk in certain extreme mortality risk scenarios in exchange for quarterly coupon payments of USD three-month Libor plus a spread of 135 basis points. The bond matured on 1 January 2007.

There has been some recent innovation in this market. An example of this is the La Vie Re Limited (Series 2020-1) mortality catastrophe bond issued by the Minnesota Life Insurance Company in October 2020. The bond covers the US and is the first indemnity 144A excess mortality bond that models the cedants' portfolio on a loss-ratio basis. The modelling was conducted by Risk Management Solutions which developed an indemnity trigger on loss ratios.[310]

Guy Carpenter (GC), the global risk and reinsurance specialist, argues that risk transfer, reinsurance and insurance-linked securities sectors are well-placed to assist in dealing with climate change.[311] The company highlights catastrophe bonds as a key risk transfer and resilience financing tool for governments and public sector entities. Climate change

[309] Swiss Re obtains USD 400 million of extreme mortality risk coverage its first life securitization, news release, 8 December 2003;
https://www.swissre.com/dam/jcr:edf6b706-4c0b-4fc1-85bf-46a338e36208/pr_20031208_en.pdf
[310] https://www.insurancebusinessmag.com/asia/news/breaking-news/rms-collaborates-on-new-mortality-catastrophe-bond-239994.aspx
[311] Climate change is discussed in more detail below.

increases the possibility of severe weather-related losses as well as demographic movements associated with rising sea levels, posing challenges to governments and entities exposed to these changes. GC calls for 'a rethink of how catastrophic events are funded and a greater use of public-private partnerships to manage risk'. According to the company, capital markets have the ability to absorb catastrophe and severe weather-related risks and diversify them away, allowing reinsurers and insurers to leverage its depth and liquidity and help make public sector entities more secure and better able to manage the financial exposure of climate-related risks.[312] Pension funds might consider diversifying into these catastrophe bonds.

Setbacks

As mentioned before, not all paths to progress are smooth. In recent years, this has been particularly true currently in the largest market dealing with micro-longevity risk, namely life settlements.[313] The life settlements market has been dogged by systematic underestimates of policy holders' life expectancies by certain medical underwriters, issues concerning premium financing, frauds, and ethical issues associated with 'profiting' from individuals dying and policies maturing. In December 2009, Goldman Sachs announced it was closing down its QxX.LS index. This was partly because of the reputational issues associated with life settlements, but mainly because of insufficient commercial activity in the index. While the ethical issues are no different in substance from those relating to the macro-longevity market (see, e.g., Blake and Harrison, 2008), the micro-longevity market needs to learn some important lessons from the macro-longevity (i.e., PRT) market. The macro-longevity market has been very successful at promoting good basic research on the analysis of the stochastic mortality forecasting models it uses and putting these models into the public domain and has also been much more transparent with the data it uses. This suggests a way forward for the life settlements micro-longevity market.

Another setback, this time to the macro-longevity market, occurred in April 2012 when a number of investment banks – Credit Suisse, Nomura and UBS – pulled out of the longevity risk transfer market as a result of additional capital requirements under Basel III. Investment banks had already been disadvantaged in this market by the Dodd-Frank Act which prevented US banks and their affiliates from entering longevity swaps and synthetic

[312] Steve Evans (2020) Risk transfer, reinsurance key to address reality of climate change: Guy Carpenter, *Artemis*, 11 March; https://www.artemis.bm/news/risk-transfer-reinsurance-key-to-address-reality-of-climate-change-guy-carpenter/

[313] The market for micro-longevity risk trades assets involving a small number of lives. In the case of life settlements, for example, the products involve individual lives and hence are subject to a significant degree of idiosyncratic mortality risk. This contrasts with the market for macro-longevity risk which deals with pension plans and annuity books and hence involves a large number of lives: here idiosyncratic mortality risk is much less important than systematic mortality risk which is essentially the trend risk of getting life expectancy projections wrong.

trades in life settlements. At around the same time, however, a number of insurers and reinsurers entered the market, e.g., PICA, SCOR and Munich Re. The following year witnessed the start of a process of consolidation in the insurance industry. In August 2013, Lucida was purchased by L&G for £150m; at the time, it had 31,000 pensioners on its books and £1.4bn in pension assets. In February 2014, the buy-out business of MetLife, which entered the market in 2007 and acquired the pension assets of 20,000 pensioners worth £3bn, was sold to Rothesay Life for an undisclosed sum, bringing its total assets to £10bn.

In December 2013, Goldman Sachs sold the majority of its stake in Rothesay Life to Blackstone (28.5%), Government of Singapore Investment Corporation (GIC) (28.5%), and MassMutual (7%), due to the new regulatory capital requirements faced by banks and insurers.[314] In October 2020, Blackstone sold its 36% stake in Rothesay Life to GIC and MassMutual for an undisclosed sum. This raised GIC and MassMutual's stakes to 49% each and values Rothesay Life at £5.8bn, with £56bn in assets under management.[315]

Academic contributions

At the same time as these practical developments in the capital markets were taking place, academics were continuing to make progress on theoretical developments, building on the original idea of using longevity bonds to hedge longevity risk in the capital markets (Blake and Burrows, 2001). These included:

- Design and pricing of longevity bonds and other longevity-linked products (e.g., Blake et al. (2006a,b, 2014), Bauer (2006), Bauer and Ruβ (2006), Antolin and Bloomestein (2007), Bauer and Kramer (2007), Denuit et al. (2007), Barbarin (2008), Bauer et al. (2010b), Chen and Cummins (2010), Kogure and Kurachi (2010), Bravo (2011), Dowd et al. (2011a), Mayhew and Smith (2011), Zhou et al. (2011, 2013, 2015), Chen et al. (2013), Shen and Siu (2013), Denuit et al. (2015), Hunt and Blake (2015), Milevsky and Salisbury (2015), Yang et al. (2015), Wang and Li (2016), Chen et al. (2017), Lin et al. (2017b), Blake (2018), D'Amato et al. (2018a), Leung et al. (2018), MacMinn and Richter (2018), Li and Tang (2019), Bahl and Sabanis (2021), Dagpunar (2021), Mayhew et al. (2021), Jevtić et al. (2021), Tang and Li (2021), Bozikas et al. (2022))

[314] In August 2017, Goldman Sachs sold its remaining stake in Rothesay Life to a consortium comprising US buy-out firm Blackstone, Singapore's sovereign wealth fund GIC, and US life insurer MassMutual in a deal valuing Rothesay Life at around £2bn; http://www.cityam.com/269996/goldman-sachs-sells-final-stake-2bn-rothesay-life

[315] Blackstone offloads stake in Rothesay Life, *Pionline*, 1 October; https://www.pionline.com/money-management/blackstone-offloads-stake-rothesay-life

- Design and pricing of longevity-linked derivatives (e.g., Shang et al. (2011), Lin et al. (2013), Wang and Yang (2013), Chuang and Brockett (2014), Bravo and Nunes (2021), Kung et al. (2021b)) and specifically survivor/longevity swaps (e.g., Dowd et al. (2006), Wang et al. (2013, 2015), Zhou and Li (2013), Li et al. (2019), Chen et al. (2022b)), survivor/longevity forwards and swaptions (e.g., Dawson et al. (2009, 2010), Zeddouk and Devolder (2020a)), *q*-forwards (e.g., Deng et. Al. (2012), Barrieu and Veraart (2016)), mortality options (e.g., Milevsky and Promislow (2001), Schmeck and Schmidli (2021), Zhou and Li (2021), Lin and Tsai (2022b)), guaranteed annuity options (e.g., Gao et al. (2015)) and longevity bond options (e.g., Xu et al. (2020))
- Pricing longevity and mortality risk (e.g., Olivieri and Pitacco (2008), Bayraktar et al. (2009), Chen et al. (2010), Li (2010), Li et al. (2022a))
- The pricing of longevity-related guarantees (e.g., Yang et al. (2008))
- The pricing and hedging of life settlements (e.g., Deng et al. (2011), Brockett et al. (2013), Zhu and Bauer (2013), MacMinn and Zhu (2017), Kung et al. (2021a))
- Longevity and mortality indices (e.g., Denuit (2009), Li et al. (2011), Chan et al. (2014), Tan et al. (2014))
- Securitization of longevity risk (e.g., Dahl (2004), Chen and Cox (2009), Cowley and Cummins (2005), Lin and Cox (2005), Cairns et al. (2006a), Cox and Lin (2007), Biffis and Blake (2010, 2013, 2014), Wills and Sherris (2010), Lane (2011), Mazonas et al. (2011), Blake et al. (2013), Yang and Wang (2013), Michaelson and Mulholland (2014), Li et al. (2017c), MacMinn and Brockett (2017), Bugler et al. (2021))
- Management and hedging of longevity risk (e.g., Dahl and Møller (2006), Friedberg and Webb (2007), Cocco and Gomes (2008), Tsai et al. (2010), Wang et al. (2010), Cairns (2011, 2013), Coughlan et al. (2011), Koijen et al. (2011), Li and Hardy (2011), and Tzeng et al. (2011), Wang et al. (2010, 2011b), Ngai and Sherris (2011), Barrieu et al. (2012), International Monetary Fund (2012), Li and Luo (2012), Cox et al. (2013a,b), Qiao and Sherris (2013), Cairns et al. (2014), Lin and Tsai (2014, 2020a,b), Zelenko (2014), Zhu and Bauer (2014), Liu and Li (2016, 2017, 2018, 2021), Blackburn et al. (2017), Li et al. (2017a), Wong et al. (2017), Zhou and Li (2017), D'Amato et al. (2018b), Li (2018), Tsai and Liang (2018), Hanbali et al. (2019), Zhou and Li (2019, 2020), Balasooriya et al. (2020), Sherris et al. (2020), Levantesi et al. (2020), Börger et al. (2021a), Broeders et al. (2021), Cairns and El Boukfaoui (2021), Hsieh et al. (2021), Kessler (2021), Li et al. (2021), MacMinn and Zhu (2021), Choulli et al. (2021), Siu and Liu (2021), Clemente et al. (2022), Feng et al. (2022), Tan et al. (2022), Chen et al. (2023a,b))

- Mortality data and modeling, mortality term structure[316] modeling, and mortality forecasting (e.g., Heligman and Pollard (1980), Hobcraft et al. (1982), Alho (1990), Lee and Carter (1992), Thatcher et al. (1998), Wilmoth and Horiuchi (1999), Booth et al. (2002a,b), Brouhns et al. (2002a,b, 2005), Renshaw and Haberman (2003a,b, 2006, 2008), Currie et al. (2004), Biffis (2005), Bongaarts (2005), Czado et al. (2005), Cairns et al. (2006b, 2008, 2009, 2011a), De Jong and Tickle (2006), Delwarde et al. (2007), Koissi et al (2006), Pedroza (2006), Bauer et al. (2008), Blake et al. (2008), Gourieroux and Monfort (2008), Hari et al. (2008), Kuang, et al. (2008), Haberman and Renshaw (2009, 2011, 2012, 2013), Hatzopoulos and Haberman (2009, 2011), Li et al. (2009, 2013, 2015a,b, 2017b), Plat (2009a,b), Wang and Preston (2009), Bauer et al. (2010a), Biffis and Blake (2010), Biffis et al. (2010), Cox et al. (2010), Debonneuil (2010), Dowd et al. (2010a,b, 2020), Lin and Tzeng (2010), Murphy (2010), Yang et al. (2010), Coelho and Nunes (2011), Currie (2011, 2016), D'Amato et al. (2011, 2012a,b), Ediev (2011, 2021), Gaille and Sherris (2011), Li and Chan (2011), Milidonis et al. (2011), Russo et al. (2011), Russolillo et al. (2011), Sweeting (2011), Wang et al. (2011a), Yue and Huang (2011), Zhu and Bauer (2011), Aleksic and Börger (2012), Hainaut (2012), O'Hare and Li (2012, 2017), Shang (2012, 2019), Wilmoth et al. (2012), Hyndman et al. (2013), Kleinow and Cairns (2013), Mitchell et al. (2013), Alai and Sherris (2014), Nielsen and Nielsen (2014), Hunt and Blake (2014, 2020a,b, 2021a,b,c,d), Villegas and Haberman (2014), Danesi at al. (2015), Tomas and Planchet (2015), Leng and Peng (2016), Li et al. (2016), Schinzinger et al. (2016), van Berkum et al. (2016), Beutner et al. (2017), Deprez et al. (2017), Gbari et al. (2017), Kleinow and Richards (2017), Li and Lu (2017), Li and O'Hare (2017), Mavros et al. (2017), Milidonis and Efthymiou (2017), Neves et al. (2017), Shang and Hyndman (2017), Tsai and Lin (2017a,b), Börger and Schupp (2018), Chen and Millossovich (2018), Debonneuil et al. (2018b), Hainaut (2018), Ludkovski et al. (2018), McCarthy (2018), Salhi, and Thérond (2018), Shang and Haberman (2018), Venter and Şahın (2018), Wong et al. (2018, 2023), Apicella et al. (2019), Guibert et al. (2019), Hilton et al. (2019), Liu et al. (2019), Yang et al. (2019), Zhou (2019), Balland et al. (2020), Basellini et al. (2020), Currie (2020), Li et al. (2020), Milevsky (2020), Njenga and Sherris (2020), Pascariu et al. (2020), Richards et al. (2020), Shang and Haberman (2020), Zeddouk and Devolder (2020b), Barigou et al. (2021, 2022), Börger et al. (2021b), Boumezoued (2021), Boumezoued and Elfassihi (2021), Diao et al. (2021), Guo and Bauer (2021), Gao and Shi (2021), Ghalehjooghi and Lyu (2021), He et al. (2021), Hilton et al. (2021), Kessy et al. (2021), Li and Kogure (2021), Li and Lyu (2021), Li et al. (2021a), Lin et al. (2021), McCarthy and Wang (2021a), Medford (2021), Odhiambo et al. (2021), Pavía and Lledó (2021), Perla et

[316] The mortality term structure is the two-dimensional surface showing projected mortality rates at different ages for different future years.

al. (2021), Rabbi and Mazzuco (2021), Rizzi et al. (2021), Ševčíková and Raftery (2021), Shimizu et al. (2021), Su and Yue (2021), Tsai and Cheng (2021), Yue et al. (2021), Wang et al. (2021a,b), Yan et al. (2021), Zhou and Ji (2021), Alonso-García (2022), Awad et al. (2022), Basellini et al. (2022), Beyaztas and Shang (2022), Bjerre (2022), Caraballo et al. (2022), Chandra and Abdullah (2022), Chen and Khaliq (2022), Huang et al. (2022), Hunt and Villegas (2022), Jallbjørn and Jarner (2022), Jones et al. (2022), Kularatne et al. (2022), Li (2022), Li and Chen (2022), Liu and Shi (2022), Lu and Zhu (2022), Marino et al. (2022), Miyata and Matsuyama (2022), Odhiambo et al. (2022), Schnürch and Korn (2022), Scognamiglio (2022a,b), Scognamiglio and Marino (2022), Sliwka and Socha (2022), Spreeuw et al. (2022), SriDaran et al. (2022), Tang et al. (2022a), Wang and Chan (2022), Zhou et al. (2022), Zhou and Li (2022), Zhu and Bauer (2022), Zhu and Zhou (2022), Diao et al. (2023), Haberman (2023), Rakhmawan et al. M. (2023))

- Multi-population mortality modeling (e.g., Darkiewicz and Hoedemakers (2004), Li and Lee (2005), Cairns et al. (2011b), Dowd et al. (2011b), Jarner and Kryger (2011), Njenga and Sherris (2011), Torri and Vaupel (2012), Li (2013), D'Amato et al. (2014), Raftery et al. (2014), Zhou et al. (2014), Antonio et al. (2015), Chen et al.(2015), Kleinow (2015), Shang (2016), Yang et al. (2016), Antonio et al. (2017), Biffis et al. (2017), Li et al. (2015c, 2017d), De Jong et al. (2016, 2020), Enchev et al. (2017), van Berkum et al. (2017), Villegas et al. (2017), Zhu et al. (2017), Hunt and Blake (2018), Kang et al. (2018), Pascariu et al. (2018), Pitt et al. (2018), Wang et al. (2018), Jevtić and Regis (2019), Jarner and Jallbjørn (2020, 2022), Shi et al. (2020), Chang et al. (2021), Li and Shi (2021a,b), Li et al. (2021b), Liu (2021), Lu et al. (2021), Richman and Wüthrich (2021), Schnürch et al. (2021), Shapovalov et al. (2021), Venter and Şahin (2021), Wen et al. (2021), Yang et al. (2021), Zhou and Ji (2021), Djeundje et al. (2022), Fokeer and Narsoo (2022), Gungah and Narsoo (2022), Jiao et al. (2022), Kung et al. (2022), Lin and Tsai (2022a), Perla and Scognamiglio (2022), Robben et al. (2022), Shang et al. (2022), Wang et al. (2022), Chang and Shi (2023))
- Mortality modeling by cause-of-death, educational attainment, social class, special patterns, Covid-19 etc (e.g., Beard (1971), McNown and Rogers (1992), Christensen and Vaupel (1996), Hanewald (2011), Murphy and Di Cesare (2012), Arnold and Sherris (2013, 2015, 2016), Janssen et al. (2013), Alai et al. (2014a), Gourieroux and Lu (2015), Alai et al. (2018), Boumezoued et al. (2018), Yue et al. (2018), Li et al. (2019), Dutton et al. (2019), Cupido et al. (2020), Kallestrup-Lamb et al. (2020), Lourés and Cairns (2020, 2021), Arnold and Glushko (2021), Lyu et al. (2021, 2022), Nusselder et al. (2022), Schnürch et al. (2022), Navarro and Requena (2023))

- Population, births and deaths data – and modeling (e.g., Richards (2008), Cairns et al. (2016), Boumezoued et al. (2019, 2020), Boumezoued (2021), Boumezoued and Elfassihi (2021), Cheng et al. (2022), Tang et al. (2022b), Hwang and Kim (2023))
- Longevity inequality (e.g., Mayhew and Smith (2014, 2021), Debón et al. (2017), Mayhew et al. (2020), Álvarez et al. (2021), Li and Hyndman (2021), Sanzenbacher et al. (2021), Katsiferis et al. (2023)).
- Longevity risk and financial innovation (improvements in the analysis and design of longevity-linked products) (e.g., Gong and Webb (2010), Stevens at al. (2010), Richter and Weber (2011), Cocco and Gomes (2012), Brown and Warshawsky (2013), Bernhardt and Donnelly (2019), Chen and Rach (2019), Chen et al. (2019), Weinert and Gründl (2021)).
- Reverse or equity release mortgages (e.g., Wang et al. (2008), Huang et al. (2011), Yang (2011), Alai et al. (2014b), Kogure et al. (2014), Shao et al. (2015), Lee et al. (2018), Dowd et al. (2019), Di Lorenzo et al. (2022))
- Longevity risk in investment portfolios and asset-liability management (e.g., Milevsky and Young (2007), Menoncin (2008), Horneff et al. (2008, 2009, 2010, 2015), Maurer et al. (2013), Aro and Pennanen (2017), Gemmo et al. (2020), Maffra et al. (2021), Rogalla (2021), Lin et al. (2022))
- Longevity risk in life insurance, pension plans, pension systems, annuities and long-term care, etc (e.g., Huang et al. (2012, 2017), Aro (2014), Bisetti and Favero (2014), Donnelly (2014), Lin et al. (2014, 2015, 2017a), Ai et al. (2015), Wan and Bertschi (2015), Ai et al. (2017), Hunt and Blake (2017), Bravo and El Mekkaoui de Freitas (2018), Bruszas et al. (2018), Cox et al. (2018), Debonneuil et al. (2018a), Hsieh et al. (2018), Ignatieva et al. (2018), Kurtbegu (2018), Mayhew et al. (2018), Balter et al. (2020), Chen et al. (2020), Olivieri and Pitacco (2020), Wen et al. (2020), Ayuso et al. (2021), Balter et al. (2021), Cox et al. (2021), De Rosa et al. (2021), Dowd et al. (2021), Kogure et al. (2021), Lee et al. (2021), Leung et al. (2021), McCarthy and Wang (2021b), Richards (2021), van Berkum et al. (2021), Bakar and Büyükyazıc (2022), Berstein and Morales (2021), Bravo et al. (2021), Bravo (2022), Cairns et al. (2022), Carannante et al. (2022), Chen et al. (2022a), Coppola et al. (2022), Feng et al. (2022), Li et al. (2022b), Li and Kara (2022), Mrad et al. (2022), Olivieri et al. (2022), Sharma et al. (2022), Rong et al. (2023), Agarwal et al. (2023), Lin et al. (2023)).

Looking into the future

There are a large number of factors that will influence the future of the PRT market. We now examine the key ones.

The volatility of life expectancy trends

In 2016, the UK Office for National Statistics (ONS) reported that longevity improvements rates at very high ages have slowed down since 2011. A number of reasons were put forward to explain this: short-term reasons, such as lower increases in health service[317] and long-term care spending as part of the government's 'austerity' spending cuts following the Global Financial Crisis; and longer term reasons, such as increasing deaths from neurodegenerative disorders, such as dementia and Alzheimer's disease,[318] and the fact that most of the improvement in life expectancy in the 1990s and 2000s was due to lower mortality from circulatory causes, such as heart disease, arising from the widespread use of statins and there was no longer scope for further improvements.[319] In 2018, the UK ONS reported that healthy life expectancy – the average number of years lived in 'very good' or 'good' general health – fell for women and rose for men, comparing 2015-17 and 2009-11 data. For men, healthy life expectancy at birth increased by five months to 63.1 years, while it fell by three months to 63.6 years for women. At birth, UK men and women can expect to live with a disability for 16.5 and 20.9 years, respectively.[320]

This prompted a debate in the UK about the volatility of life expectancy trends. Mortality improvements for England & Wales males aged 50-89 averaged 0.7% p.a. over the period 2011-16, compared with 3.1% p.a. between 2001-10, 1.8% between 1975-2000, and 0.7% between 1961-75.[321] At the time, the UK actuarial profession took the view that the sharp reduction in the trend improvement was permanent. The Mortality Projections Model of the Institute and Faculty of Actuaries' Continuous Mortality Investigation (CMI) – which covers England & Wales – published in March 2019 predicted that the average cohort life expectancy of a 65-year old man in 2018 was 19.8 years, down by five months (or 2.4%) compared with 2017; the corresponding figure for a 65-year old woman was 22.4 years,

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[317] A University of York study published in 2021 estimated that for every 1% real increase in healthcare spending there was a 0.5% improvement in population mortality (cited in Murray et al. (2022); https://bmjopen.bmj.com/content/bmjopen/11/10/e046417.full.pdf).

[318] Dementia is a syndrome, not a disease. A syndrome is a group of symptoms that does not have a definitive diagnosis. Dementia is a group of symptoms that affects mental cognitive tasks such as memory and reasoning. Dementia is an umbrella term that Alzheimer's disease can fall under. It can occur due to a variety of conditions, the most common of which, accounting for up to 70% of cases, is Alzheimer's disease. Other diseases which cause dementia are Parkinson's and Huntington's. See: Dementia and Alzheimer's: What Are the Differences?; https://www.healthline.com/health/alzheimers-disease/difference-dementia-alzheimers

[319] Anthony Hilton (2016) Life line, *Pensions World*, May; *Accounting for Pensions: Reflecting the cost of pension freedoms and life expectancy*, Xafinity Punter Southall, April 2018; page 12 of Willis Towers Watson *De-risking Report 2020*, January. See also www.bbc.com/news/health-4060825.

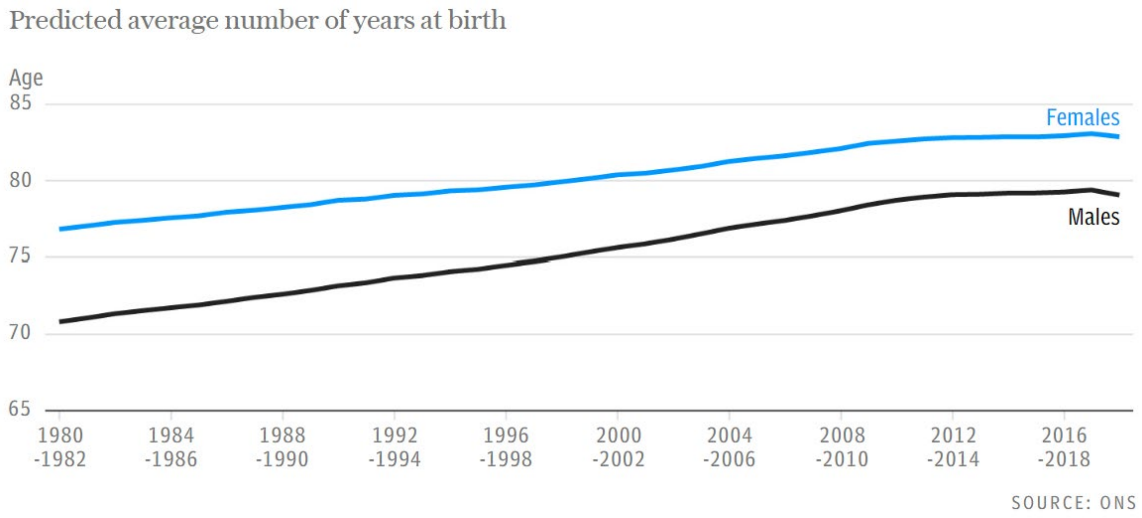
[320] Stephanie Baxter (2018) 'Healthy' life expectancy falls for women, but improves for men, *Professional Adviser*, 13 December.

[321] Page 6 of 'Mortality improvements in the next decade, Discussion hosted by SIAS and the CMI Mortality Projections Committee', 11 April 2017, Staple Inn Hall, London; https://www.actuaries.org.uk/system/files/field/document/CMI%20SIAS%20meeting%202017-04-11%20-%20Mortality%20imps%20in%20the%20next%20decade%20v04.pdf

also down by 5 months (or 2.1%).[322] The CMI's best estimate life expectancy growth for the next 40 years from 2022 is between 2.9 and 4.5 years, which is lower than the 6.8 years experienced over the previous 40 years.[323]

Figure 3 shows life expectancy from birth in the UK since 1980. The ONS found that between 2018 and 2020 there was 'virtually no improvement in life expectancy' for women which equalled 82.9 years in 2020. For men, life expectancy in 2020 was 79 years and had actually fallen back to 2012-14 levels. This is the first decline since the 1980s – and it could fall further following the pandemic.[324]

Figure 3: Life expectancy at birth in the UK



Source: https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70/

Particularly, striking is what has been happening in the US where the life expectancy of the average American fell from 78.85 years in 2019 to 76.98 years in 2020 and 76.44 years in 2021, a net reduction of 2.41 years, according to a study by Masters et al. (2022). The study said that most of the decline was due to the pandemic, with the rest explained by a rise in accidental deaths and deaths from drug overdoses, heart disease, chronic liver disease and cirrhosis. In contrast, 21 peer countries[325] averaged a smaller decrease in life expectancy between 2019 and 2020 (0.55 years) and a 0.26-year *increase* between 2020

[322] Rachel Fixen (2019) UK schemes set for 2.5% fall in liabilities after CMI model revamp, *IPE*, 8 March.
[323] Murray et al. (2022).
[324] Szu Ping Chan (2023) Why the state pension age may never again reach 70, *Daily Telegraph*, 3 December; https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70
[325] Australia, Austria, Belgium, Canada, Denmark, England and Wales, Finland, France, Germany, Israel, Italy, Netherlands, New Zealand, Northern Ireland, Norway, Portugal, Scotland, South Korea, Spain, Sweden, and Switzerland.

and 2021. This increased the gap in life expectancy between the US and the peer countries to around five years.[326]

Time will tell if there has been a permanent change in trend in these countries or if the trend will again reverse in response to advances in applied biotechnology and in regenerative medicine, as discussed below. In December 2018, the CMI published a new version of its SAPS (Self-Administered Pension Scheme) data set. This covers UK members of DB pension schemes and the data has been collected since 2000. The S3 series mortality tables for the period 2009-16 showed that life expectancy in this select group was still increasing when compared with the S2 series mortality tables for the period 2004-11.[327] One year's increase in life expectancy can raise a pension scheme's liabilities by 4%,[328] while if longevity risk is measured on a whole-of-life basis, the potential increase in pensions over 30-40 years could represent an increase in liabilities of 15-20%.[329] In March 2020, the CMI reported that mortality rates in England and Wales were on average 3.8% lower in 2019 than in 2018, the highest year-on-year reduction since 2011. This shows that mortality rates are volatile and confirms the point that longevity trends can go both ways.[330]

The long-term impact of Covid also needs to be taken into account. Analysis by consultancy Lane Clark & Peacock (LCP) predicted that there would be 30,000 excess deaths in the UK in 2022. Although winter and spring deaths were at their lowest level for a decade, mortality rates increased significantly in June, potentially linked to the fall-out from the pandemic, such as late diagnosis and treatment of diseases, and the growing NHS backlog of operations. LCP suggested that if the 2023 version of the Continuous Mortality Investigation model reflected these data, then life expectancies could reduce by around nine months, which would equate to a £100m lower funding requirement for a £3bn pension scheme.[331] Consultantcy Hymans Robertson conjecture that if Covid becomes another endemic disease, with similar severity to the flu, this would mean an additional $20{,}000 - 30{,}000$ death each year.[332]

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[326] https://www.nytimes.com/2022/08/31/health/life-expectancy-covid-pandemic.html
[327] XPS Pensions (2019), New 'SAPS3' mortality tables – a confusing message?, *Briefing Note No.3*, January.
[328] Mark Dunne (2020) Breaking free: Bulk annuities, *Portfolio Institutional*, 24 January; https://www.portfolio-institutional.co.uk/features/breaking-free/
[329] Willis Towers Watson *De-risking Report 2020*, January (p.9).
[330] Susanna Rust (2020) Highest reduction in mortality rates in England and Wales since 2011, *IPE*, 2 March.
[331] Jonathan Stapleton (2022) Mortality trend shift could cut funding requirements, *Professional Pensions*, 21 November; https://www.professionalpensions.com/news/4060538/mortality-trend-shift-cut-funding-requirements
[332] Murray et al. (2022).

All this makes it increasingly challenging for those operating in the PRT market to derive the best estimate of both the trend improvement in life expectancy and the volatility around the trend.

Peak cash flows

Pension funds not only need to have assets sufficient to meet liabilities (i.e., be fully funded), they need the cash flows on those assets to match pension payments as they fall due. Absent this, assets would have to be sold (possibly at unfavourable prices) in order to make the payments. It is especially significant for closed schemes which can no longer rely on contributions from active members to help to make pension payments. Further, once a scheme is closed, it matures rapidly and the duration of the liabilities falls. It is important therefore for such a scheme to work out the timing of peak cash flows and then insure that sufficient cash flow generating assets are in place during this period. In the UK, the Pensions Regulator requires schemes to set a long-term funding objective.

For a lot of UK schemes, research by TPR indicates that pension payments may already be close to their peak. Many of these schemes will have been preparing for this by switching out of growth assets, such as equities, into cash-flow generating assets, such as government (gilts) and high-quality high-yielding corporate bonds, as part of liability-driven investment (LDI) strategy which might also have involved hedging the purchase of these bonds against falling interest rates. As the peak approaches, then more precise cashflow matching is required.

It has been estimated that around £1trn out of a total of £2.2trn UK pension liabilities are exposed to (i.e., were not hedged against) changes in interest rates and inflation. In addition, there will be between £250-£300bn of additional exposure as schemes deleverage their LDI portfolios in prepartion for making cash payments.

Given the narrow range of suitable cash-flow generating assets, this is likely to drive up their prices. The total size of the sterling investment grade corporate bond market is only around £375bn. Although issuance has increased significantly with the fall the interest rates due to quantitative easing – £60bn of new sterling corporate bonds were issued in 2019, for example – quality and yields have also fallen. UK pension funds have been forced to increase their exposure to both BBB credit, the lowest class of investment grade bonds, and to sterling bonds issued by non-UK-based corporates (which account for around 50%

of sterling issuance). UK pension funds have also looked to source suitable bonds in the Eurozone and US corporate bond markets and then hedge the currency risk.[333]

In August 2020, LGIM launched a range of secure income asset funds aimed at small DB pension schemes following a cashflow-driven investment strategy. The funds have an open-ended pooled structure with a three-year lock-in period and target a return of gilts +2.5% per annum over a rolling three-year period. LGIM has also launched separate unit-linked life funds for senior real estate debt, investment grade infrastructure debt, investment grade private corporate debt, and sub-investment grade infrastructure debt and sub-investment grade private corporate debt, which are suitable for investment horizons of at least seven years.[334]

Population aging

There is an emerging global debate covering a wider set of demographic issues than just longevity risk. The debate has centred on population aging and its implications. One aspect of population aging is declining fertility which soon translates into an increase in the average age of the population. One reason for declining fertility is the choice made by women in developed countries to have fewer children than previous generations.

This has been exacerbated by the Covid-19 pandemic, according to the United Nations. Birth rates have fallen due to 'a postponement of childbearing in the face of the uncertainty regarding the disease and its economic impacts, disruptions in marriage patterns and family formation, and disruptions in the availability and access to sexual and reproductive health-care services, including family planning'.[335] Edward Stanley, an analyst at Morgan Stanley, comments that 'Prior financial crises suggest the suppressant on birth rates can last for three to four years. Moreover, using the 1917-20 Spanish Flu example as a loose proxy, the recovery in the birth rate in 2021 is unlikely to be linear. In 1917-20, with each new wave of virus came a renewed downturn in subsequent births'. The pandemic caused the fertility rate in the UK to plunge to a new low of 1.6 per woman in 2020. Stanley predicts that 70% of the world's population will be below the replacement rate within five years, adding significantly to population aging.[336]

Another explanation for declining fertility is male sperm counts falling so fast across the world that the human race could be infertile within 50 years. There has been a 60% decline

[333] Nikesh Patel and Arif Saad (2020) Viewpoint: The tipping point for UK pension schemes, *IPE*, 20 November; https://www.ipe.com/viewpoint-the-tipping-point-for-uk-pension-schemes/
[334] LGIM launches secure income range for DB plans, *IPE*, 3 August 2020.
[335] https://www.telegraph.co.uk/business/2022/07/13/europe-faces-ageing-population-nightmare-absolute-collapse
[336] https://www.telegraph.co.uk/business/2021/07/16/birth-rate-will-take-years-recover-covid-baby-bust/

in the sperm count of Western men between 1973 and 2011, with 15% of young Western men with a sperm count low enough to impair fertility. A variety of explanations have been put forward to explain this: lifestyle factors, such as alcohol, smoking, stress, obesity, antidepressants, and high doses of ibuprofen; pesticides and industrial pollutants getting into the food chain; sunscreen, containing endocrine-disrupting UV filters; non-stick frying pans, containing poly- and perfluoroalkyl substances; tight underpants; oestrogen in the water supply from the female contraceptive pill; and electromagnetic radiation from wi-fi routers.[337]

Figure 4 shows UN projections of fertility rates out to 2050. Prior to 1970, the average woman had five children. She now has 2.3 which is just above the 'replacement rate' of 2.1, the level which stabilizes the population. Globally, fertility rates are expected to fall to the replacement rate by 2050. Fertility rates in Europe, North America, Australia and New Zealand have been below replacement since the mid-1970s.

Figure 4: Fertility rates are slowing down globally

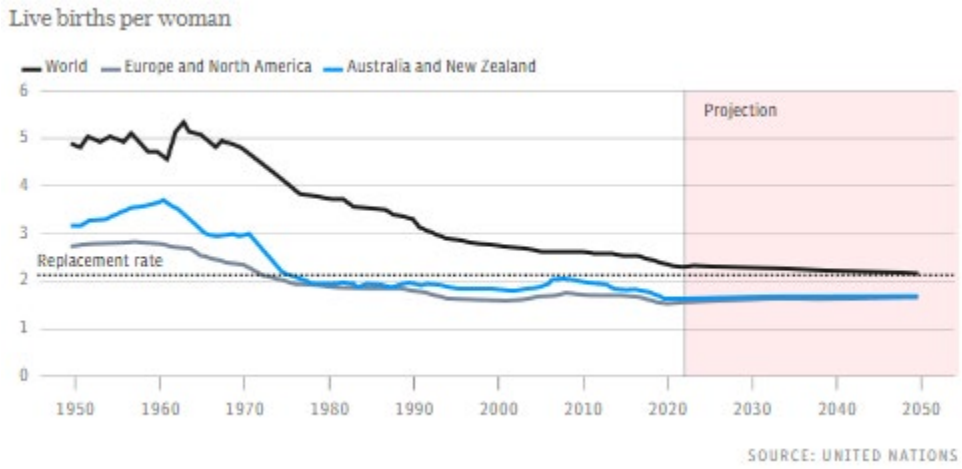


Figure 5 shows that global population growth has been on a downward trend since the mid-1960s from 2% to around 1% currently and is projected to be 0.5% by 2050. This is due mainly to the decline in fertility. The increase in deaths in 2020-21 caused by Covid-19 is also visible in the figure.

[337] India Sturgis (2018) Prepare for Spermageddon, *Daily Telegraph Magazine*, 27 January.

Figure 5: Global population growth is slowing

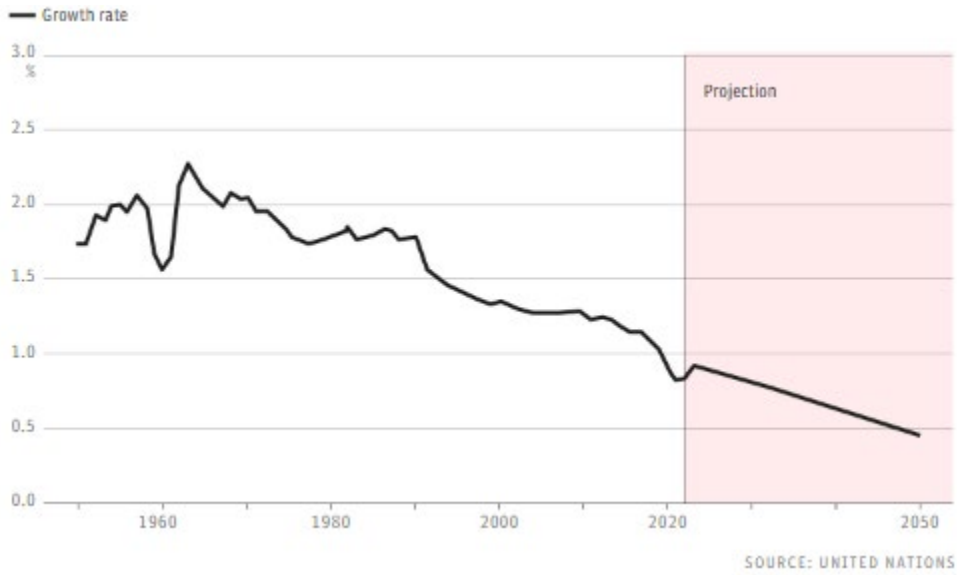
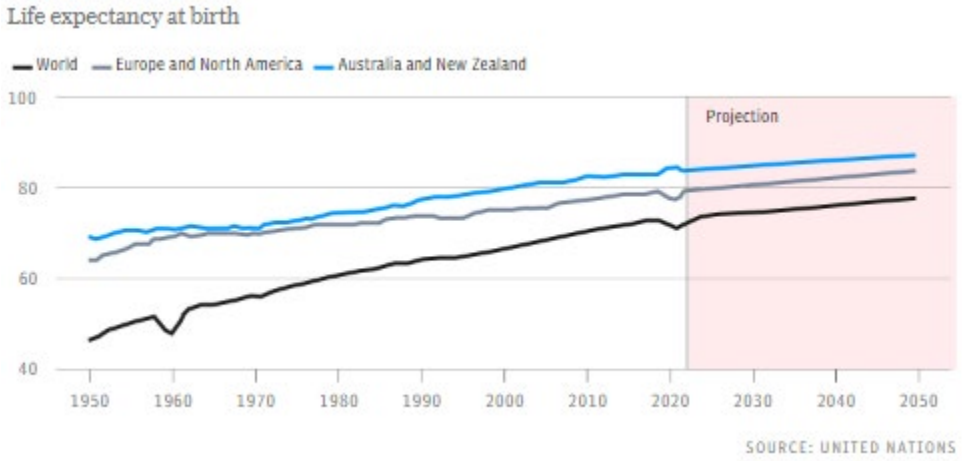


Figure 6 shows that while life expectancy is expected to increase, the rate of increase is expected to slow down a little. By 2050, the global population aged 60 and over is projected to exceed the population under 15. The global population – which reached 8bn on 15 November 2022 – is now expected to peak at 10.4bn in 2086 rather than in the 22nd century as previously predicted.

Figure 6: The increase in life expectancy is expected to slow



In July 2022, the International Longevity Centre (UK) released five reports on aging in Australia, China, Japan, Indonesia and South Korea. The main findings were:

- Japan's population is aging rapidly. In 2017, 40% of Japan's workers were over 50 – predicted to rise to 47% by 2035. In 2022, Japan recorded the lowest number of births (799,728, a fertility rate of 1.3) and the highest number of deaths (1.58m) since the Second World War.[338]
- Over 50s made up 29% of Australia's workforce in 2017 – rising to 35% by 2035. Over 2 in 5 of Australian dollars were spent by older households in 2015, around 18% of GDP.
- By 2035, 42% of China's population will be over 50. In China, people over 65 spent 5 more hours a year volunteering than people at other ages.
- In 2018, 37% of South Korea, population was over 50 - by 2035, 51% of people will be over 50. By 2035, more than 6 in 10 South Korean employees could be aged 50 and over.
- In Indonesia in 2018, 72% of people aged 50-64 were in employment and a quarter of Indonesia's population was over 50 - this is set to increase to 28% by 2035.

In May 2021, China announced it was ending its policy of limiting couples to two children and would now allow them to have three.[339] The government said the problem of an aging population was deepening and the change would help to improve the structure of China's population and maintain its advantage in human resources.[340] The Chinese population aged over 65 exceeded 14% of the total population in 2021 and, in 2022, there were expected to be more deaths than births – 12 years sooner than the UN had previously predicted.[341] Jilin province in northeast China is offering up to 200,000 yuan ($31,400) in 'marriage and birth consumer loans' to married couples to promote population growth; it has one of the fastest-shrinking populations in China.[342]

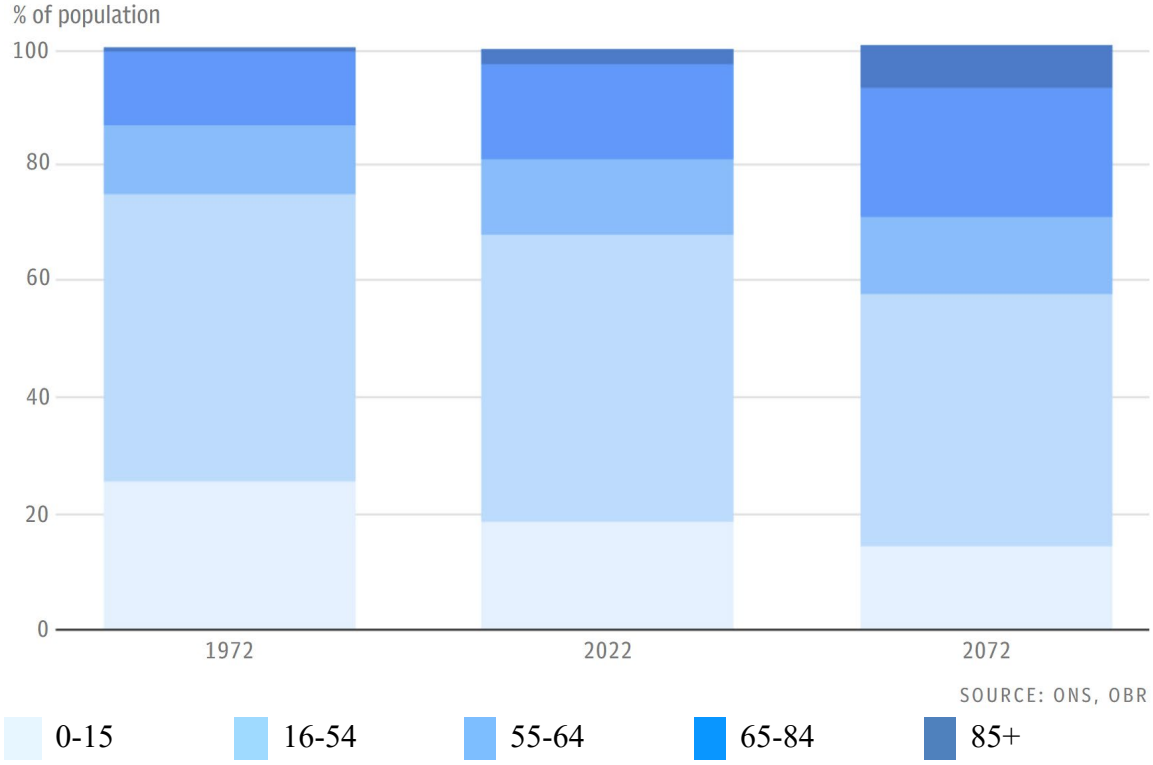
The ILC(UK) reports, while highlighting the global nature of population aging, also emphasize the crucial role of older workers and consumers for post-pandemic recovery in these and other countries – which it calls the 'global longevity dividend'.[343]

The world is also trying to cope with supply shortages, insufficient workers and the financial burden of the rising proportion of pensioners – which will all worsen as the global population switches from boom to bust. The UN estimates that in Italy, the population will fall from 59m to 55.3m by the 2040, while Germany's population will fall over the same

[338] https://www.pensionpolicyinternational.com/japan-births-fall-to-record-low-as-population-crisis-deepens/
[339] China introduced a one-child policy in 1979 and a two-child policy in 2016.
[340] https://www.pensionpolicyinternational.com/china-introduces-three-child-policy-to-alleviate-problem-of-ageing-population/
[341] https://www.pensionpolicyinternational.com/china-may-see-negative-population-growth-in-2022-12-years-earlier-than-un-prediction-experts/
[342] https://www.pensionpolicyinternational.com/chinese-province-offers-31000-baby-loans-to-counter-shrinking-population/
[343] https://ilcuk.org.uk/global-longevity-dividend/

period from 83.4m to 81.2m. Holger Schmieding, an economist at Berenberg Bank, says Germany can do more to get people to join the workforce which is below the participation rate of Scandinavia. Also 'There is room to increase the retirement age - it is going up to 67 already, it probably has to go up further'. Germany is also attractive to migrants which helps companies to keep growing despite the low domestic birth rate.[344]

Figure 7: Population age structure in the UK



Source: https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70/

Figure 7 shows the UK's population age structure according to calculations made by the Office for Budget Responsibility (OBR). In 1972, 60% of the population was aged between 16 and 64 and this rose to 62.2% in 2022 due to the baby boomers joining the workforce. Once they retire, the working age population will fall to 56.4% by 2072. By then, almost 30% of the British population will be over 65, more than double the proportion in 1972. The OBR predicts that age-related state spending will rise from 27% of GDP in 2023 to 36.1% in 2071. State pensions will rise from 4.8% to 8.1% of GDP or from £110bn[345] in 2022 to £185bn in today's prices.

[344] https://www.telegraph.co.uk/business/2022/07/13/europe-faces-ageing-population-nightmare-absolute-collapse

[345] https://obr.uk/forecasts-in-depth/tax-by-tax-spend-by-spend/welfare-spending-pensioner-benefits/

This rising cost could be ameliorated by increasing the state pension age. In 2018, the UK state pension age was increased to 66 and is set to rise to 67 by 2028 and to 68 by 2046. The government is considering bringing this forward to 2039. Each year that the pension is not paid saves £10bn and, in addition, people pay in-work taxes for another year. The Institute for Fiscal Studies found the rise in state pension age from 65 to 66 resulted in 25,000 men and 30,000 women aged 65 working for an extra year.

However, John Cridland, who chaired the UK's first state pension age review in 2017, while accepting that the implications for the public finances is 'really concerning', argues that there could be an upper limit to the state pension age: 'while the government may be able to justify bringing forward an increase to 68, telling people to work until they're 69 or even 70 is a much more difficult prospect. The UK has got a lot of people who started work at 16. Many do manual work in hard physical jobs, and expecting them to wait till the age of 70 for a pension is not a reasonable balance. One might need to increase the state pension age beyond 68 in years to come, but I'm talking decades, and only if longevity increases take off again. There has to be a reasonable balance to deliver intergenerational fairness. [Further,] it's not obvious that the working population will have as much healthy life expectancy because of multiple morbidity, where more people suffer from multiple conditions like dementia, obesity, diabetes, that can actually affect the quality of people's lives'. His report recommended that those with poor health or caring responsibilities should be able to access the state pension at 67.[346] This suggests that there could be limits to the longevity dividend identified by the ILC(UK).

Another aspect of population aging is the differential impact on the rich and poor, i.e., health inequalities due to differences in wealth. A 2020 study by the Longevity Science Panel in the UK found that, while life expectancy had increased for all socio-economic groups between 2001 and 2015, it increased most for the richest cohort. The difference in life expectancy between rich and poor was 7.2 years in 2001, but this had increased to 8.4 years in 2015[347] and to 9 years in 2020.[348] Another study found that, while socio-economic status affects the incidence of multimorbidity (two or more of diabetes, coronary heart disease, stroke, chronic obstructive pulmonary disease (COPD), depression, arthritis, cancer, dementia, and Parkinson's disease), it did not affect the risk of mortality after the onset of these adverse health conditions, implying that primary prevention is key to reducing social inequalities in mortality (Dugravot et al (2019)). This is confirmed by a report written by the UK All-Party Parliamentary Group (APPG) for Longevity (*The*

[346] Szu Ping Chan (2022) Why the state pension age may never again reach 70, *Daily Telegraph*, 3 December; https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70
[347] Life expectancy gap between rich and poor widens, *BBC News*, 15 February 2018.
[348] Amelia Hill (2020) Being wealthy adds nine years to life expectancy, says study, *Guardian*, 15 January. The same 9-year difference holds in the US. The UK results come from the English Longitudinal Study of Ageing, while the US results come from the US Health and Retirement Study.

Health of the Nation: A Strategy for Healthier Longer Lives) which estimated that up to 75% of new cases of heart disease, stroke and type-2 diabetes, and 40% of cancer incidence and dementia risks could be reduced if individuals cut down on smoking and alcohol, increased physical activity and changed to a healthy diet. The report also found that a key reason for low productivity in certain parts of the country (e.g., the north of England) is that health is worse and reducing the health gap would keep people in work longer and hence increase national output.[349]

These findings will have implications for fairness between different cohorts of the same generation, for example, when governments raise the retirement age for all in line with increasing average life expectancy. In response to these inequalities, the government set up the UK Longevity Council to advise it on how best to use innovations in technology products and services to improve the lives of the older population. With the number of people in the UK over the age 65 to double to more than 20 million over the next half century, the government has set itself the Aging Society Grand Challenge which aims to ensure that people in the UK enjoy an extra 5 years of healthy and independent living by 2035, while narrowing the gap between the experience of the richest and poorest.[350]

Some of these issues – longer working lives, higher state pension ages, and narrowing the life expectancy gap – will clearly have consequences for the pricing of future PRT deals.

Climate change and sustainable development

The issue of climate change is clearly linked to population size and some scientists have begun to ask whether there are global limits to human habitability. For example, Dr Steven Running, emeritus professor of ecology at the University of Montana and a member of the NASA Earth Observing System, argues that a population cannot grow indefinitely in a finite ecosystem, such as the Earth. He explains: 'Systems ecology theory predicts when resource limits are exceeded, a progressive system feedback of starvation, predation, and disease limits uncontrolled population and consumption growth. The global human population has now nearly tripled since 1950, and economic activity increased tenfold, leading many to suggest that humanity is heading toward a population and consumption overshoot and correction this century. The global population, currently at [8]bn people, is projected to rise beyond 10bn by 2100. Future limits become an urgent policy issue when one considers the expansion in living standards aspired to by the underdeveloped world. Is humanity smart enough to anticipate global overshoot, and shift to sustainable policies before these morally unacceptable systems feedbacks take over?'.

[349] Amelia Hill (2020) Health inequality greater than previously thought, report finds, *Guardian*, 12 February.
[350] https://www.gov.uk/government/news/experts-to-help-uk-champion-ageing-society-opportunities

The core metric for quantifying total plant growth is net primary production (NPP), measured in kilograms per hectare of plant biomass. Land-based plants absorb around 30% of the carbon dioxide that human activity adds to the atmosphere. Increasing NPP slows down global warming. NASA has been monitoring global NPP for the last 20 years. Running points out that NPP depends on temperature and water availability: 'rising temperatures increase growing season length, but decrease water availability, and many of the NPP trends identified can be directly attributed to these effects. We showed how significant droughts between 2000 and 2009 caused the reduction in NPP in the Southern Hemisphere. Decreases in cloud cover increased sunlight over tropical areas causing the largest increases in NPP, particularly in the Amazon rainforest. It initially appeared that rising global temperatures were having a positive effect on the growth of plants, potentially increasing their ability to act as a sink for excess carbon dioxide produced by human activity. However, the reduction in NPP from 2000 to 2009 from drought effects raises serious issues. If rising global temperatures reduce plant growth, the ability of vegetation to act as a carbon sink will be reduced, accelerating climate change'. He concludes: 'As the Earth's population continues to increase, and climate continues to change, consistent monitoring of NPP will become an even more essential tool for understanding and mitigating damage caused to the biosphere. It is essential for humanity to not reach catastrophic planetary limits risking collapse. There is no better and available global dataset than NPP, the foundation of food, fibre, biofuel and climate stabilization, for this essential monitor of global habitability'.[351]

A report on climate change and health published in December 2020 by *The Lancet*[352] estimates that global warming has already caused a 50% increase in heat-related deaths of people older than 65, especially in Japan, China, India and parts of Europe. In the US, the report argues that rising temperatures, combined with pollution and wildfires, are endangering the health of Americans, with fatal consequences for many older people. The solution, according to the reports' authors is to aggressively curb planet-warming gases in the next five years: 'Climate action is a prescription for health'.

In 2022, the UK Longevity Science Panel published a report (*The Effects of Climate Change on Health in the UK*) assessing the impact of climate change on the UK's health.[353] The report suggests that climate change will be experienced unevenly across different sections of the UK population, and may deepen health inequalities in physical and mental health in the UK. The most economically deprived and those who are already frail through

[351] Steven Running (2019) The biosphere: Global limits of human habitability, 30 October; https://www.openaccessgovernment.org/biosphere-human-habitability/75469/
[352] Reported in the *New York Times*, 3 December 2020.
[353] https://www.pensionpolicyinternational.com/climate-change-poses-a-threat-to-health-equality-in-the-uk-the-longevity-science-panel-report/

age or having long-term health conditions will be the most vulnerable to high temperatures and shocks induced by adverse weather events. Compared with many other countries, the report found that the direct impacts of climate change such as heat waves, flooding and the increased spread of vector-borne diseases, are likely to be relatively modest. This is because of the UK's geographic location in the Northern hemisphere and its economic power to adapt houses, workplaces and infrastructure to reduce the negative impact of climate change.

However, the indirect impacts could worsen existing inequalities in health for the following reasons:

- Socio-economic. When economies are stressed the health of the most disadvantaged is disproportionately affected
- Climate change-related disruptions to global food production and supply chains will reduce food security, particularly for low-income families. Lower socio-economic households are more likely to be exposed to the damage caused by extreme weather events as poverty tends to force people to live in higher risk areas, but they often lack the disposable income to adequately prepare for the hazards associated with climate change. The build quality of certain lower income and private rental homes can make them more vulnerable to severe damage during adverse weather events
- Gender inequalities. Women are likely to be impacted more by climate effects than men. They are more often the primary caregivers, and these responsibilities can be considered an additional source of stress in times of adversity, particularly when infants and children in their care are threatened directly by displacement or food insecurity.
- Age inequalities. The young and the old are disproportionately affected by climate change compared to working age adults. This is due to differences in physiology, impacts on education, development, exposure, vulnerability to illness, lack of social support, declining health, and disruption to daily activities.
- Mental health. Climate change can negatively impact mental health in two main ways: by causing actual harm to people, family members, homes, livelihoods or culture, or by acting as a threat of harm and source of uncertainty.
- Disruptions to the UK economy, in part caused by climate-induced global economic stresses, are a key indirect pathway through which climate change may adversely impact on population health in the UK.

The World Economic Forum's *Global Risks Report 2019* warned of increasing naturally emerging infectious disease pandemics and risks posed by revolutionary new

biotechnologies, claiming that these could be as big a threat as climate change.[354] And within a year this came to pass.

A study by Carlson et al (2022) asserts that at least 10,000 virus species have the capacity to infect humans, but at present, the vast majority are circulating silently in wild mammals. However, climate and land use change will produce novel opportunities for viral sharing among previously geographically-isolated species of wildlife. In some cases, this will facilitate zoonotic spillover between species – a mechanistic link between global environmental change and disease emergence. The study uses a phylogeographic model of the mammal-virus network to simulate potential hotspots of future viral sharing and to make projections of geographic range shifts for 3,139 mammal species under climate change and land use scenarios for the year 2070. The model predicts that species will aggregate in new combinations at high elevations, in biodiversity hotspots, and in areas of high human population density in Asia and Africa, driving the novel cross-species transmission of their viruses an estimated 4,000 times. Because of their unique dispersal capacity, bats account for the majority of novel viral sharing, and are likely to share viruses along evolutionary pathways that will facilitate future emergence in humans. The study also conjectures that this ecological transition may already be under way, and holding warming under 2 °C within the century will not reduce future viral sharing. The authors conclude that 'Our findings highlight an urgent need to pair viral surveillance and discovery efforts with biodiversity surveys tracking species' range shifts, especially in tropical regions that harbor the most zoonoses and are experiencing rapid warming'. Vector-borne diseases (which are caused by the bite of infected insects, such as mosquitoes, ticks, and sandflies, which act as carriers or 'vectors') account for more than 17% of all infectious diseases, leading to more than 700,000 deaths annually.[355]

Some scientists predict a new 'pandemic age'. Professor Eddie Holmes, an evolutionary biologist and virologist at the University of Sydney, said: 'Climate change and pandemics go hand-in-hand….The more animals are forced to mix, the more viruses will jump species'.[356] A current example is the spread of dengue – or 'breakbone fever' because of the intense joint and muscle pain it causes – by mosquitos. It affected nine countries in the 1970s, but has spread to more than 100 and affects around 400 million people a year. The main causes are climate change and rapid urbanisation.[357]

[354] https://cirmagazine.com/cir/epidemic-risks-pose-as-big-a-business-threat-as-climate-change.php
[355] Nicola Oliver (2023) The Impacts of Climate Change on Mortality, *Life Risk News*, 8 March;https://liferisk.news/the-impacts-of-climate-change-on-mortality/
[356] https://www.telegraph.co.uk/global-health/science-and-disease/hotter-sicker-climate-crisis-will-trigger-surge-spillover-events
[357] https://www.telegraph.co.uk/global-health/science-and-disease/why-singapore-alert-record-breaking-year-disease

In November 2021, COP26, the 26th United Nations Climate Change Conference, took place in Glasgow, Scotland.[358] The outcome was the Glasgow Climate Pact which:

- Reaffirmed the 2015 Paris Agreement to limit global warming to below 2°C, preferably to 1.5°C, compared with pre-industrial levels and to achieve a climate-neutral ('net-zero') world by 2050.[359] However, it went further and expressed 'alarm and utmost concern that human activities have caused around 1.1°C of warming to date, that impacts are already being felt in every region, and that carbon budgets consistent with achieving the Paris Agreement temperature goal are now small and being rapidly depleted'.
- Seeks accelerated action to reduce carbon dioxide emissions by 45% in the 2020s**,** with countries producing stronger national action plans by 2022.
- Agreed to a provision calling for a phase-down of coal power and a phase-out of fossil fuel subsidies.
- Reaffirmed the pledge by developed countries to deliver $100bn a year for developing countries.
- Called for a doubling of finance to support developing countries in adapting to the impacts of climate change and building resilience.
- Agreed to complete the Paris rulebook, the operational details for the practical implementation of the Paris Agreement. An example is the norms relating to carbon markets, which will allow countries struggling to meet their emissions targets to purchase emissions reductions from other nations that have already exceeded their targets.
- Agreed to strengthen the Santiago Network that connects vulnerable countries with providers of technical assistance, knowledge and resources to address climate risks.
- Agreed new deals on:
    - Halting and reversing forest loss and land degradation by 2030.
    - Limiting methane emissions – one of the most potent greenhouse gases and responsible for a third of current warming from human activities – by 30% by 2030, compared with 2020 levels.
    - Restricting all new car and van sales to be zero-emission vehicles by 2040 globally and 2035 in leading markets, thereby accelerating the decarbonization of road transport, which currently accounts for about 10% of global greenhouse gas emissions.
    - Private financial institutions and central banks realigning trillions of dollars towards achieving global net zero emissions.

[358] https://www.un.org/en/climatechange/cop26
[359] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

In 2015, the United Nations adopted 17 global Sustainable Development Goals (SDGs), including ending poverty, fighting inequality and addressing climate change.[360]

According to Schroders' 2020 *Global Investment Survey*, 'increasingly clients are using the Sustainable Development Goals as a common language' and estimates global ESG (environmental, social, and corporate governance) assets under management in excess of $1trn.[361] Investment strategies consistent with SDG include: negative screening (excluding companies based on controversial business practices), socially responsible investing (SRI), thematic (pursuing specific sustainable themes based on a company's operations or sources of revenue) and impact investing (investing in a measurable sustainable outcome in addition to financial returns).[362]

The UK government has announced it would fund a new Green Finance Institute with the City of London 'to foster greater cooperation between the public and private sectors, create new opportunities for investors, and strengthen the UK's reputation as a global hub for green finance'. In September 2021, it issued its first 'green gilt' to investors in order to finance projects with clearly defined environmental benefits, thereby helping the UK achieve net-zero carbon emissions by 2050.[363] The bond satisfies the International Capital Market Association (ICMA) Green Bond Principles, a voluntary framework for issuers to follow and which promotes transparency and disclosure to reduce the risk of greenwashing.

The Government has set out 6 categories that will be financed by these gilts. Each category is also mapped to appropriate UN Sustainable SDGs:

1. Clean transportation, e.g., zero emission buses (consistent with the SDG: sustainable cities and communities)
2. Renewable energy, e.g., wind, solar and hydrogen (affordable and clean energy)
3. Energy efficiency e.g., support schemes for energy efficiency programmes for the commercial, public and industrial sectors and residential sector (including heating, retrofit and insulation) and research and development for new energy

[360] The Global Goals for Sustainable Development: Goal 1: No Poverty; Goal 2: Zero Hunger; Goal 3: Good Health and Well-being; Goal 4: Quality Education; Goal 5: Gender Equality; Goal 6: Clean Water and Sanitation; Goal 7: Affordable and Clean Energy; Goal 8: Decent Work and Economic Growth; Goal 9: Industry, Innovation and Infrastructure; Goal 10: Reduced Inequality; Goal 11: Sustainable Cities and Communities; Goal 12: Responsible Consumption and Production; Goal 13: Climate Action; Goal 14: Life Below Water; Goal 15: Life on Land; Goal 16: Peace and Justice Strong Institutions; Goal 17: Partnerships to achieve the Goal; https://www.globalgoals.org.
[361] The power of measurement: Schroders approach to sustainability, *funds-europe*, November 2020.
[362] Five reasons to choose indexing for sustainable, *portfolio institutional*, November 2020.
[363] XPS Investment Briefing, September 2021. In September 2021, the European Commission introduced a 'gold standard' for EU 'green bonds' where the proceeds are spent on environmentally friendly activities.

efficiency technologies (affordable and clean energy, industry, innovation and infrastructure)

4. Pollution prevention and control, e.g., reduction of air emissions and greenhouse gas control (responsible consumption and production)
5. Living and natural resources, e.g., protection and enhancement of terrestrial and marine biodiversity, ecosystems and natural capital;[364] sustainable land use and protection, including environmentally sustainable agriculture; environmentally sustainable clean water, water storage and wastewater management initiatives (zero hunger, clean water and sanitation, life below water, and life on land)
6. Climate change adaptation, e.g., flood protection, resilience and other risk mitigation programmes (climate action).

In March 2023, the UK government published its 2023 Green Finance Strategy, 'Mobilising Green Investment',[365] aimed at strengthening the rapidly growing global green finance market, while driving private investment to deliver its energy security, net-zero and environmental objectives.

While climate change has been in the news for around 30 years, only in the last couple of years has it begun to impact the pensions industry. For example, UK listed companies and asset managers, such as pension funds, were required to report on climate change risk by 2022, in line with recommendations made by the Financial Stability Board's Taskforce on Climate-related Financial Disclosures (TCFD).[366] The UK Pensions Regulator and

[364] Discussed in more detail below.

[365] https://www.gov.uk/government/publications/green-finance-strategy

[366] The corporate disclosure recommendations are based on a framework of:

- Governance: the organization's governance around climate-related risks and opportunities.
- Strategy: the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy and financial planning.
- Risk management: the processes used by the organization to identify, assess and manage climate-related risks.
- Metrics and targets: which metrics and targets are used to assess and manage relevant climate-related risks and opportunities.

Pension scheme trustees face similar obligations:

- Governance
  - Trustees must establish and maintain oversight of the climate-related risks and opportunities relevant to the scheme.
  - Trustees must establish and maintain processes to satisfy themselves that any person responsible for the scheme's governance activities takes adequate steps to identify, assess and manage climate-related risks and opportunities.
- Strategy
  - Trustees must, on an ongoing basis, identify climate-related risks and opportunities which they consider will have an effect over the short-, medium- and long-term on the scheme's investment and funding strategy.

Department for Work and Pensions has established the Pensions Climate Risk Industry Group (PCRIG) to produce guidance for pension schemes on 'climate-related practices', to ensure they are effectively governed in respect of the effects of climate change. Further, asset managers and other financial services firms are required to report publicly on how they manage climate risks.

Speaking at COP26, Thérèse Coffey, the UK Secretary of State for Work and Pensions, said that 'pensions can be a superpower that delivers prosperity for people and the planet in our race to net zero'. Her Department launched a consultation on proposals to require occupational pension schemes that already fall within the scope of climate disclosure regulations to publish a 'Paris alignment' metric to show the extent to which their investment portfolio is aligned with the 1.5°C Paris Agreement. The UK Government also published 'Greening Finance: A Roadmap to Sustainable Investing' which includes a new economy-wide Sustainability Disclosure Requirement (SDR) which would apply to occupational schemes. This aims to tackle 'greenwashing' (where investors are misled about how sustainable an investment is) via the implementation of a Green Taxonomy,

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    - Assess the impact of the above risks and opportunities.
    - As far as they are able, trustees must undertake scenario analysis, considering the impact on assets and liabilities of two scenarios under which global temperatures rise.
    - One scenario to be consistent with 1.5-2 degrees warming.
    - Analysis is to be carried out in the first year in which the regulations apply, and then every three years thereafter.
- Risk management
    - Trustees must establish and maintain processes for the purpose of enabling them to identify, assess and effectively manage climate-related risks.
- Metrics and targets
    - Trustees must select a minimum of three metrics, two of which are prescribed; one giving total greenhouse gas emissions of the scheme's assets ("absolute emissions metric"), and one giving total carbon dioxide emissions per pound of assets invested ("emissions intensity metric").
    - As far as they are able, trustees must obtain scope 1, scope 2 and scope 3* greenhouse gas emissions data for the scheme's assets, to calculate their metrics and to identify and assess climate related risks and opportunities. (In the first scheme year in which the requirements apply, trustees are not required to collect and report on scope 3 emissions).
    - Trustees must set a target for at least one of the metrics, and subsequently measure performance relative to that target on an annual basis.

*Scope 1: all direct emissions from the activities of an organization or under its control.
Scope 2: indirect emissions created from the production of electricity/energy purchased and used by the organization.
Scope 3: all other indirect emissions from activities of the organization (from sources the organization does not directly control).

Sources: https://www.fsb-tcfd.org/; https://www.willistowerswatson.com/en-GB/Insights/2021/09/reporting-pension-scheme-climate-risks-what-how-when

which will set out clear criteria for economic activities to meet in order to be considered sustainable. The Pension Schemes Act 2021 introduced new climate reporting obligations on UK schemes, together with annual implementation statements in respect of scheme assets.

The UK Pensions and Lifetime Savings Association (PLSA) which represents pension funds in the UK also supports the TCFD recommendations as well as measures to increase climate reporting and regulatory obligations throughout the investment chain, together with clarifying definitions of climate-aware investment. Related to this is ESG which are the three central factors in measuring the sustainability and societal impact of an investment in a company or business. In the UK, this is implemented via the Stewardship Code. The PLSA wants to work with the investment industry and regulators to develop principles for ESG asset management funds to adhere to on ESG generally, or specifically with regard to climate.[367] Ashley Hamilton Claxton, head of responsible investment at Royal London Asset Management argues that 'ESG is here to stay. Covid-19 has accelerated the trend towards greater awareness of sustainability and the interconnectedness between our economy, environment and society'. However, standards differ in different parts of the world. In the EU, for example, ESG is part of the fiduciary duty of fund managers, whereas in the US, the fiduciary duty is purely a financial duty.[368]

TPT Retirement Solutions, one of the UK's largest workplace pension plans, has introduced climate change considerations into its investment decisions. Cliff Speed, TPT's chief investment officer, said: 'Climate change has the potential to reduce the security of our members' retirement benefits and represents a systemic risk to the long-term value of our investment portfolio. At the same time, the investment required to transition to a net zero economy presents an opportunity to support the expansion of climate solutions. For us, this means taking an approach to managing our investment risks and opportunities on behalf of our members in line with our fiduciary duty'. In 2016, TPT made its first allocation to renewable energy generation and renewable supporting technologies. It also invested in two additional renewable energy strategies in 2021. It is on the global steering group of the Paris Aligned Investment Initiative, a global forum representing investors with $34trn in assets aligning their portfolios and activities to the goals of the Paris Agreement.[369]

The UK Pensions Regulator (TPR) published a climate adaptation report into the climate risks most relevant to occupational pension schemes which found that too few schemes

[367] Richard Butcher (2020) The PLSA is here to help overcome barriers as industry embraces climate-aware investment, *portfolio institutional*, November.
[368] Romil Patel (2020) Spinning on a sustainable axis, *funds-europe*, November 2020.
[369] https://www.ipe.com/news/uk-workplace-pension-scheme-plans-investment-in-climate-solutions/10065832.article?

were giving enough consideration to climate-related risks and opportunities. Only 43% of DC schemes surveyed took account of climate change when devising their investment strategy, while 51% of DB schemes had not spent any time or resources assessing financial risks and opportunities associated with climate change.[370] A pension consultant offered this advice to trustees considering a net-zero target:[371]

- Define your beliefs and priorities
- Set your overall net-zero objective
- Review your current portfolio
- Engage with your investment managers and define Net Zero pathway
- Consider sustainable funds
- Establish ongoing engagement and monitoring.

Charles Counsell, TPR's chief executive, said: 'Climate change is a risk to long-term sustainability [that] pension trustees need to consider when setting and implementing investment strategy, while many schemes are also supported by employers whose financial positions and prospects for growth are dependent on current and future policies and developments in relation to climate change'.[372]

In February 2022, the UK Employer Covenant Practitioners Association (ECPA) published a report which argued that climate change is 'progressively impacting' the covenant of a range of employers sponsoring DB defined benefit schemes, from affecting future cashflows to representing a 'fundamental risk' to scheme longevity. The report said that DB schemes should consider the impacts of climate change through sectoral analysis, including technological evolution, in order to identify 'red flags for their sponsor'. It added that covenant practitioners sit in the middle of the impact on the sponsor and the impact on other aspects of the scheme such as funding and investment. They will need to work with an increasing number of stakeholders and face a 'steep' regulatory trajectory.[373]

In June 2022, the UK Department for Work and Pensions, in collaboration with the Behavioural Insights Team, Aviva, Smart Pension and Hargreaves Lansdown, launched a 'green nudge' trial, designed to encourage pension scheme members to learn more about making greener pension choices. The trial will test the impact of behavioural nudges and

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[370] Further climate change disclosures in the offing as world leaders meet at COP26, *XPS Insights*, November 2021.

[371] Carbon Reduction Pathways: How your pension scheme investments can become Net Zero aligned now, *XPS*, July 2022

[372] Susanna Rust (2019) UK to explore mandatory climate reporting for pension funds, companies, *IPE*, 2 July; https://www.ipe.com/uk-to-explore-mandatory-climate-reporting-for-pension-funds-companies/10032058.article. Susanna Rust (2020) UK pension trustees presented with guide to climate-related risks, *IPE*, 12 March; https://www.ipe.com/news/uk-pension-trustees-presented-with-guide-to-climate-related-risks/10044243.article

[373] https://www.professionalpensions.com/news/4044614/climate-change-fundamental-risk-scheme-longevity

messages on increasing saver engagement with the sustainability of pension investments and how it could translate into greener pension decision-making. Around 160,000 pension scheme members will be involved. The DWP said: 'Through the productive long term investment power of pensions, we can help the UK get to net zero and deliver both investment returns and a sustainable planet'.[374]

The UN-convened Net-Zero Asset Owner Alliance[375] was established in 2019 by Allianz, Caisse des Dépôts, La Caisse de dépôt et placement du Québec (CDPQ), Folksam Group, PensionDanmark and Swiss Re – with Alecta, AMF, CalPERS, Nordea Life and Pension, Storebrand, and Zurich Insurance joining shortly after. Members commit to transitioning investment portfolios to net-zero greenhouse gas emissions by 2050. In May 2021, four UK pension asset owners joined the Alliance – Phoenix Group, L&G, Rothesay and Prudential (UK) – bringing the total membership to 42 and combined assets of $6.6trn.[376]

The Net Zero Asset Managers initiative (NZAMI)was launched in December 2020 and aims to galvanize the asset management industry to commit to a goal of net zero emissions.[377] At the time of COP26, NZAMI announced that 35% of their assets under management were being managed in line with net-zero emission targets.[378] Morningstar reported that in 2021 there were 860 mutual funds and exchange-traded funds (ETFs) with a climate-focused mandate with total assets of $408bn, double the previous year.[379] Climate Impact Consistent (CIC) Indices have been introduced for net-zero investors. They weight each company in proportion to its net-zero alignment, as measured through its carbon emissions intensity, its emissions disclosure/quality, its forward-looking emissions targets and their credibility, and its revenues from climate solutions.[380] At the end of 2022, NZAMI had 291 members with $66trn in assets under management.[381]

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[374] https://www.pensionpolicyinternational.com/new-uk-trial-seeks-to-nudge-people-into-making-greener-pension-choices/

[375] https://www.unepfi.org/net-zero-alliance/

[376] https://www.pensionpolicyinternational.com/uk-pension-asset-owners-join-net-zero-asset-owner-alliance/

[377] https://www.netzeroassetmanagers.org/

[378] https://www.ipe.com/news/average-35-of-assets-initially-in-scope-for-net-zero-manager-targets/10056078.article

[379] https://www.investmentweek.co.uk/news/4048291/assets-climate-focused-funds-soar-usd408bn-2021

[380] *IPE*, 17 May 2021.

[381] In December 2022, Vanguard, the world's second largest fund manager, announced: 'After a considerable period of review, we have decided to withdraw from NZAM so that we can provide the clarity our investors desire about the role of index funds and about how we think about material risks, including climate-related risks—and to make clear that Vanguard speaks independently on matters of importance to our investors. [The move] will not affect our commitment to helping our investors navigate the risks that climate change can pose to their long-term returns'
https://www.investmentweek.co.uk/news/4061376/vanguard-quits-net-zero-asset-managers-initiative

At the COP26 meeting, Blackrock announced that it had raised $673m in public and private sector money for a new infrastructure fund which would invest in climate-related projects in emerging markets.[382] The International Energy Agency estimates that investment in energy transition in emerging markets needs to rise to $1trn a year by 2030 if the world is to reach the net-zero target by 2050.[383]

The EU has introduced the European Green Deal with the aim of greening both the real economy, especially in agriculture, industry and transport, and its financing through the use of sustainable finance. One of key features of the deal is the Sustainable Finance Disclosures Regulation (SFDR) which requires asset managers to publish disclosure statements about which of their products fall into three distinct categories:

- Article 9 funds: those funds that specifically have sustainable goals as their objective (e.g., investing in companies whose goal is to reduce carbon emissions).
- Article 8 funds: those funds that promote E or S characteristics, but do not have them as the overarching objective (known as light green funds).
- Article 6 funds: funds that are not promoted as having ESG factors or objectives.

A survey by Morningstar (*SFDR – The First 20 Days*) found that Article 8 and 9 funds accounted for around 21% of total European funds and 25% of total European fund assets.[384]

The main ESG asset classes – which according to S&P Global account for 5% of the total global market – are sustainable investment funds ($500bn) and 'green'[385] or 'social'[386] bonds ($500bn). Many of these bonds are issued by inter-governmental organizations (e.g., the EU's SURE bonds) or local authorities with high credit ratings and they offer higher yields than conventional sovereign bonds. The bonds are used for socio-economic

[382] *Financial News*, 7 March 2022.
[383] *Financial News*, 7 March 2022.
[384] https://esgclarity.com/sfdr-which-groups-have-the-most-article-8-9-funds/
[385] Green bonds (also known as climate bonds or sustainable bonds) are designated fixed-income bonds intended to encourage sustainability and to support climate-related or other types of special environmental projects. More specifically, they finance projects aimed at energy efficiency, pollution prevention, sustainable agriculture, fishery and forestry, the protection of aquatic and terrestrial ecosystems, clean transportation, clean water, and sustainable water management. They also finance the cultivation of environmentally friendly technologies and the mitigation of climate change; https://www.investopedia.com/terms/g/green-bond.asp
[386] Social bonds are used to fund projects with positive social outcomes, such as economic development by financing small businesses, affordable housing and transportation, promoting access to education and healthcare in low-income areas, and food supply protection. Traditionally, they have been issued by supranationals and governments. But corporate social bonds are also now being issued by companies wishing to demonstrate their corporate social responsibility to their employees, customers and local communities; https://inews.co.uk/inews-lifestyle/money/ethical-money/social-bonds-what-how-work-available-who-invest-explained-1012606

enhancement (30%), housing (21%), education (20%), essential infrastructure (13%) and healthcare (11%).[387]

Another key feature is the Corporate Sustainability Reporting Directive (CSRD) which requires companies to include sustainability-related information in their annual reports that must meet European Sustainability Reporting Standards (ESRS). Investment funds also have to make disclosures under SFDR which will allow investors to compare investment funds and their sustainability performance. An additional key feature is the European Taxonomy Regulation which companies to report on the percentage of their economic activities that are environmentally sustainable.[388]

In December 2020, the European Insurance and Occupational Pensions Authority (EIOPA) published a discussion paper on a methodology for including climate change in the Solvency II standard formula when calculating natural catastrophe underwriting risk.[389] The frequency and severity of natural catastrophes and extreme weather, such as heat waves, heavy precipitation, droughts, top wind speeds and storm surges, is expected to increase due to climate change. EIOPA wants to ensure the financial resilience of (re)insurers covering natural catastrophes, implying that the solvency capital requirements for natural catastrophe underwriting risk need to be appropriate in light of climate change.

In April 2022, EIOPA launched its first stress test of the impact of climate change on European pension scheme investments. It would include not only an assessment of the effects of a rise in inflation, but also a climate risk stress which will test schemes' resilience against a climate change scenario developed with the European Systemic Risk Board and the European Central Bank. The scenario involves a disorderly transition to climate neutrality due to delayed policy action, specifically, that new climate policies are not introduced until 2030 and this leads to an abrupt carbon price increase which affects the entire economy. The stress test will focus on both the impact on pension fund investments and the financial situation of scheme sponsors.[390]

In December 2022, EIOPA reported the findings from this stress test. The test covered 187 pension funds from 18 EU member states with €2 trn of assets (65% of total assets in defined benefit and defined contribution schemes). The funds were tested for resilience to a sharp rise in carbon prices caused by a sudden disorderly transition to carbon neutrality

[387] ESG News, *portfolio institutional*, November 2020 (p26).
[388] https://www.sustainable-investment.com/opinion/4077463/european-green-deals-framework
[389] EIOPA launches discussion paper on a methodology for integrating climate change in the standard formula, *Pensions Policy International*, 4 December 2020; https://pensionpolicyinternational.com/eiopa-launches-discussion-paper-on-a-methodology-for-integrating-climate-change-in-the-standard-formula
[390] https://www.ipe.com/news/eiopa-launches-climate-risk-focussed-2022-pension-fund-stress-test/10059031.article

resulting from delayed policy actions. The funds held 6% of their share and 10% of their corporate bond investments in carbon intensive industries such as mining, electricity, gas and land transport. The stress test resulted in a fall in asset values of 12.9%. EIOPA concluded that the funds were 'materially exposed' to transition risks.[391]

We end this sub-section by considering three sustainability issues attracting the attention of pension schemes: biodiversity, natural capital and the circular economy.

Mark Thompson (2023),[392] a pension scheme trustee, argues that pension funds should consider biodiversity on their investment strategy:

> *Biodiversity is the variety of animals, plants, fungi and micro-organisms that make up the natural world. These species and organisms work together in ecosystems to maintain balance and support life. The planet's biodiversity is being seriously depleted, threating the viability of human existence. Since 1970 the Earth's wildlife populations have fallen by almost 70% – a result of deforestation, excessive human consumption and industrial scale pollution. Mother Nature's cupboard cannot be raided forever without serious consequences. ...It is estimated that around half of the world's GDP is dependent on nature.*
>
> *Against this background, there are four possible risks supporting why trustees should incorporate biodiversity considerations into their investment processes:*
>
> - *Companies that rely on threatened ecosystems will suffer from increased financial risk, with negative effects on their share prices and credit ratings.*
> - *Like climate change, there is transition risk, as governments legislate to mitigate the systemic risk of biodiversity loss.*
> - *Companies that exploit unpriced biodiversity externalities run the risk of reputational risk as media and public opinion turns against them with the resultant impacts on shareholder value.*
> - *Finally, schemes are unlikely to reach their climate net-zero objective without significant improvements in biodiversity loss. This is because marine and terrestrial ecosystems are the sole sinks of anthropogenic carbon emissions.*

[391] https://www.pensionpolicyinternational.com/climate-change-could-cost-pension-funds-billions-eu-watchdog-says/

[392] Mark Thompson (2023) Biodiversity: What trustees need to know, *portfolio institutional*, 17 January; https://www.portfolio-institutional.co.uk/opinion/biodiversity-what-trustees-need-to-know/

In December 2022, almost 200 countries signed up to the UN Biodiversity accord. The accord commits to halting and reversing biodiversity loss by 2030. Implementation will be key to the accord's success and that will need increased legislation around the globe.

However, in doing this, unlike climate change (which is essentially a case of controlling carbon emissions) biodiversity has many facets, and they are location-specific. This makes constructing a framework to manage biodiversity risks, and develop disclosure requirements, more complicated. This is the challenge the Taskforce on Nature-related Financial Disclosures (TNFD) has taken up. It is sensibly adopting the framework pioneered by the TCFD to build on.

Assets managed by funds focused on biodiversity increased from $525m to $1.3bn between 2020 and 2022.

Natural capital is a new asset class in which land is used to generate an investment return. There are three sub-categories: food production (the traditional use of land), afforestation (for carbon sequestration) and timber (as an alternative to steel and concrete in real estate construction). But with total productive land in scarce supply, there is an increasing competition over these uses.

The outcome in any particular country will depend on the price of carbon generated by the country's emission trading scheme. If demand from companies for carbon offsets increases the price of carbon credits, this makes carbon farming more attractive.

For example, in New Zealand, which is one of the world's highest per-capita carbon emitters (because of its red meat industry), carbon credits are above US$50 per tonne. This has resulted in prime farmland being sold to forestry investors for NZ$20,000 per hectare, up from NZ$4,000 per hectare, reflecting the higher net present value of the cash flows that can now be generated from it. This, in turn, has led to criticism from the red meat industry (Beef + Lamb New Zealand) which is forecasting significant economic damage to the sector and its rural communities.

The University of Melbourne's *Land Gap Report*, published in November 2022, has the following warning: 'Governments' over-reliance on carbon removal could push ecosystems, land rights and food security to the brink – with new land area equivalent to 50% of the world's croplands currently being required to meet [climate pledge] targets. Climate pledges should focus on protecting and restoring existing ecosystems with carbon benefits'.

Asset manager Gresham House has produced a Forest Charter, outlining six core pillars for investment managers, which include biodiversity and integration with the community.[393] It argues that a long-term sustainable supply of timber is 'enabling the world to transition to a lower carbon, sustainable model, through the continued replacement of concrete and steel as building materials'.[394]

A key feature of a sustainable future is the Circular Economy. This has been defined as an economy which 'allows [the production of] sustainable consumer goods, while protecting nature – by giving it time to regenerate – and ensuring the well-being of individuals. There is an urgent need to promote a society in which natural resources are protected, in which nature has the time to regenerate, where consumption is reasoned, where the life of goods is extended to the maximum and where waste is treated to be recycled in new products… We therefore need to move from a linear economic model to a circular economic model that will limit the damage to the environment, giving it time to regenerate by promoting the extension of the life span of produced goods – notably through eco-design, reparability, durability, and the second-hand market. It must also include better treatment of waste allowing raw materials to be reused to create new goods... thus closing the loop'.[395]

SDG/ESG considerations have begun to impact the investments held by PRT providers in the UK. For example, they are investing in social housing. Not only does this meet one of the SDGs, it also provides a regular income stream to pay pension annuitants from an investment that generates higher returns than UK government bonds. Similarly, in March 2022, the Aon MasterTrust and Aon's Group Personal Pension Plan seeded the UBS Global Equity Climate Transition Fund with £700m. The fund offers cost-efficient and broad-based exposure to global equity markets, providing investors with the ability to mitigate climate-related investment risks while aiming to have a positive effect on society.[396] As another example, in July 2022, Railpen, the UK railways pension scheme, and the Alberta Investment Management Corporation (AIMCo) bought a grid-scale battery energy storage platform in the UK from investment firm Constantine for £400m. Railpen said: 'This acquisition marks Railpen's first direct investment into battery storage and reflects our ambition to drive positive change through our portfolio, working with management to develop the critical infrastructure needed to support the UK's transition to net zero'.[397]

[393] https://greshamhouse.com/forest-charter/
[394] https://greshamhouse.com/news-media/global-timber-outlook/
[395] The wheels of a Circular Economy go round and round, Amundi Asset Management, 26 January 2022; https://research-center.amundi.com/article/wheels-circular-economy-go-round-and-round
[396] https://www.ipe.com/news/aon-mastertrust-pension-plan-seed-ubs-climate-fund/10058957.article
[397] https://realassets.ipe.com/news/railpen-aimco-to-pump-400m-into-uk-battery-energy-storage-projects/10061353.article

There are other global developments that could affect life expectancy – some positively, others negatively.

The aging process and anti-aging treatments

Life expectancy is strongly linked to the aging process.[398] Aging results in a progressive deterioration in physiological integrity, leading to impaired function and increased vulnerability to death. This deterioration is the primary risk factor for cancer, diabetes, cardiovascular disorders, and neurodegenerative diseases. López-Otín et al. (2013) show that there are nine candidate hallmarks of aging:[399] genomic instability,[400] telomere attrition,[401] epigenetic alterations,[402] loss of proteostasis,[403] deregulated nutrient

[398] See, e.g., Andrew Steele (2020) *The New Science of Getting Older Without Getting Old*, Bloomsbury, London; https://www.bloomsbury.com/uk/ageless-9781526608277/

[399] Carlos López-Otín, Maria A. Blasco, Linda Partridge, Manuel Serrano, and Guido Kroemer (2013) The Hallmarks of Aging, *Cell*, 153(6):1194-1217; https://doi.org/10.1016/j.cell.2013.05.039

[400] A high frequency of mutations within a cell's genome.

[401] The telomere ends of chromosomes get shorter as cells divide and eventually become too short for cells to divide further. Shortened telomeres are associated with aging cells that are senescent.

[402] Non-genetic (i.e., heritable) changes in gene expression that do not affect the DNA sequence. Epigenetics is the study of how your behaviours and environment can cause changes that affect the way your genes work. Unlike genetic changes, epigenetic changes are reversible and do not change your DNA sequence, but they can change how your body reads a DNA sequence; https://www.cdc.gov/genomics/disease/epigenetics.htm

[403] Proteostasis is a balanced state in which the body's production of proteins is stable and without defects. Proteins are molecules that do most of the work in cells and are needed for the structure, function, and regulation of the body's tissues and organs. They are composed of amino acids and are categorised according to their function: antibody, enzyme (carries out most of the chemical reactions that take place in cells), messenger (transmits signals to coordinate biological processes between different cells, tissues, and organs), structural component, and transport/storage. A loss of proteostasis is associated with the production of excess, insufficient or misshapen proteins that send incorrect signals. See: Steve Hill (2018) Hallmarks of Aging: Loss of Proteostasis, 23 May; https://www.lifespan.io/news/hallmarks-of-aging-loss-of-proteostasis/

sensing,[404] mitochondrial dysfunction,[405] cellular senescence,[406] stem cell exhaustion,[407] and altered intercellular communication.[408]

López-Otín et al. (op cit) continue: 'Aging research has experienced an unprecedented advance over recent years, particularly with the discovery that the rate of aging is controlled, at least to some extent, by genetic pathways and biochemical processes conserved in evolution. … A major challenge is to dissect the interconnectedness between the candidate hallmarks and their relative contributions to aging, with the final goal of identifying pharmaceutical targets to improve human health during aging, with minimal side effects'.

Dr Eric Verdin, President and CEO of the Buck Institute for Research on Aging[409] explains the origins of aging research: 'The initial discoveries by several groups between 1985 and

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[404] Metabolism is the balance between anabolism (building up body tissues and energy stores) and catabolism (breaking down body tissues and energy stores to get fuel for body functions). The body has multiple nutrient sensing pathways to ensure that it takes in the right amount of nutrition – not too much, not too little. Excess metabolic activity, e.g., anabolic signalling, together with changes in nutrient availability and composition, damage cells and cause them to age faster. These damaging events also deregulate the nutrient-sensing molecules and downstream pathways, for example, signalling greater food intake when the body does not need it. Age-related obesity, diabetes and other metabolic syndromes result. Decreased nutrient signalling, achieved with caloric restricted diets or by stimulation of proteins called sirtuins, promotes healthspan and longevity. See: Deregulated Nutrient Sensing; https://www.merckmillipore.com/GB/en/life-science-research/genomic-analysis/Epigenetics-and-Nuclear-Function/Deregulated-Nutrient-Sensing/FsCb.qB.u04AAAFQ6t52i0ib,nav

[405] Mitochondria are organelles – specialised subunits within cells with a specific function – found in most cells, in which the biochemical processes of respiration and energy production occur. Mitochondrial dysfunction occurs when the mitochondria do not work as they should due to damage, mutation or conditions such as progressive inefficiency of electron transport chain complexes resulting from destabilization or oxidative stress owing to excessive production of reactive oxygen species (ROS). This can affect other diseases, such as Alzheimer's, diabetes and cancer. See: Joshua N. Farr and Maria Almeida (2018) The Spectrum of Fundamental Basic Science Discoveries Contributing to Organismal Aging, *J Bone Miner Res*, 33(9): 1568–1584; doi: 10.1002/jbmr.3564

[406] Irreversible cell cycle arrest driven by a variety of mechanisms, including telomere shortening, other forms of genotoxic stress, or mitogens or inflammatory cytokine. Senescent cells have stopped dividing and hence renewing themselves and so have lost their purpose, but can neverthless destabilise neighbouring cells and promote inflammation. See: Edward J. Masoro and Steven N. Austad (eds) *Handbook of the Biology of Aging* (seventh edition, 2011); https://www.sciencedirect.com/book/9780123786388/handbook-of-the-biology-of-aging

[407] A reduction in stem cell activity which can lead to diseases and other issues, such as immunosuppression through reduced production of bacteria-killing and virus-killing white blood cells, muscle loss, frailty, and the weakening of bones. See: Patrick Deane (2018) Hallmarks of Aging: Stem Cell Exhaustion, 18 September; https://www.lifespan.io/news/hallmarks-of-aging-stem-cell-exhaustion/

[408] Cells, as they age, show an increase in self-preserving signals that result in damage elsewhere. Altered intercellular communication with aging contributes to a decline in tissue health. In particular, senescent cells trigger chronic inflammation that can further damage aging tissues. See: Altered Intercellular Communication; https://www.merckmillipore.com/GB/en/life-science-research/antibodies-assays/antibodies-overview/Research-Areas/cell-signaling/Altered-Intercellular-Communication/C.qb.qB.O48AAAFQe592i0hr,nav

[409] https://www.buckinstitute.org/

1995 suggested that there are genes that can mitigate the aging process. If these genes are mutated to either gain or lose function, one can dramatically impact healthspan and lifespan. …We've learned a number of key lessons. Firstly, we've learned that there are genetic pathways that interact together and appear to control aging. Secondly, these pathways seem to be conserved across different species. So, we find the same pathways in yeast, in worms and in humans. Thirdly, we can speak to these pathways via small molecule drugs to have the same effect as mutating the gene, and subsequently impacting the aging process. Finally, these genes that control aging don't just control lifespan, they also control healthspan'.[410]

There have been a number of significant positive innovations that help to identify and treat noncommunicable diseases associated with aging, such as dementia and cancer. Examples include:

- Professor Steve Horvath (UCLA) and Ken Raj (Public Health England) have demonstrated that rapamycin[411] retards the epigenetic aging of human cells – using an epigenetic clock (called the Skin and Blood Clock) which is an accurate biomarker for aging that relies on the mathematical precision of the relationship between chemical modifications on DNA called methylation and changes in age[412]
- The finding that rapamycin, administered to middle aged mice, increased survival significantly in both male and female mice.[413]
- Potential reversal of aging using a younger person's blood, following successful experiments with mice.[414]
- Professor Tony Wyss-Coray (Stanford) has identified circulating factors in plasma that can rejuvenate or restore function in the aging brain, leading to the development of anti-aging therapies based on the plasma proteome, suitable for treating age-related macular degeneration and neurodegenerative disorders.[415]
- Development of inhibitors for the protein complex TORC1 which extend lifespan and healthspan by, for example, reducing the incidence of respiratory tract

[410] Interview in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[411] A bacterial antifungal compound discovered in the soil of Easter Island in the 1970s.
[412] http://mypharmacynews.com/health-problems/rapamycin-retards-epigenetic-ageing-of-keratinocytes/
[413] Randy Strong, Richard A. Miller, Molly Bogue, Elizabeth Fernandez, Martin A. Javors, Sergiy Libert, Paul Anthony Marinez, Michael P. Murphy, Nicolas Musi, James F. Nelson, Michael Petrascheck, Peter Reifsnyder, Arlan Richardson, Adam B. Salmon, Francesca Macchiarini, and David E. Harrison (2020) Rapamycin-mediated mouse lifespan extension: Late-life dosage regimes with sex-specific effects, *Aging Cell*. 2020;00:e13269. https://doi.org/10.1111/acel.13269
[414] Undulating changes in human plasma proteome profiles across the lifespan, *Nature Medicine*, 5 December 2019.
[415] Steven Braithwaite, Chief Scientific Officer, Alkahest, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

infections or treating neurodegenerative diseases by inducing autophagy, a process which by which cells clear out toxic protein aggregates.[416]

- Scientists have converted the cells of a deceased 114-year-old into young pluripotent stem cells, thereby reversing the telomere aging clock in a supercentenarian's cells and providing support for the hypothesis of no upper age limit for reprogramming cellular aging.[417]
- Identification of an inflammatory marker called sCD14 which is linked to cognitive decline and dementia, allowing early intervention.[418]
- Randall J. Bateman (Washington University School of Medicine in St. Louis) has developed a simple blood test that can detect Alzheimer's disease in its earliest stages by measuring levels of the protein amyloid beta which begin to collect in the brain 15 to 20 years before symptoms arise and play a key role in the development of Alzheimer's.[419]
- The development of protein-destroying drugs, capable of degrading the MYC cancer-fuelling protein or the tau protein responsible for Alzheimer's.[420]
- The identification of two natural compounds – CMS121 and J147 – that can reverse age-related cognitive impairment and potentially treat Alzheimer's by restoring mitochondrial function, such as cell respiration and energy production, in the aging brain.[421]
- The discovery that higher levels of humanin, a peptide[422] encoded in the small genome of mitochondria, are associated with longer lifespans, better health, and a lower risk for diseases such as Alzheimer's.[423]

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[416] Joan Mannick, Chief Medical Officer, resTORbio, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[417] Phil Newman (2020) 114 year-old cells converted to pluripotent stem cells, *Longevity Technology*, 28 February; https://www.longevity.technology/114-year-old-cells-converted-to-pluripotent-stem-cells.See also: Old human cells rejuvenated with stem cell technology, *Science News*, 24 March 2020.

[418] Inflammatory marker linked to dementia, *EurakAlert! Science News*, 9 December 2019.

[419] https://medicine.wustl.edu/news/bateman-receives-potamkin-award-for-alzheimers-research/; https://www.labmedica.com/clinical-chem./articles/294789678/blood-based-biomarker-predicts-onset-of-symptomatic-alzheimers-disease.html; https://www.labmedica.com/hematology/articles/294792023/unique-diagnostic-test-based-on-mass-spectrometry-technique-accurately-identifies-early-stage-alzheimers-disease.html; https://www.labmedica.com/molecular-diagnostics/articles/294793970/blood-test-could-detect-alzheimers-up-to-17-years-in-advance.html

[420] Protein-slaying drugs could be the next blockbuster therapies, *Nature Feature*, 20 March 2019.

[421] Carla Heyworth (2020) Targeting mitochondria to fight aging, *Longevity Technology*, 22 January; https://www.longevity.technology/targeting-mitochondria-to-fight-aging/

[422] A peptide is a 'short chain of amino acids. The amino acids in a peptide are connected to one another in a sequence by bonds called peptide bonds. Typically, peptides are distinguished from proteins by their shorter length, although the cut-off number of amino acids for defining a peptide and protein can be arbitrary'; https://www.nature.com/scitable/definition/peptide-317/

[423] Protein in mitochondria appears to regulate health and longevity, *Science Daily*, 24 June 2020; https://www.sciencedaily.com/releases/2020/06/200624151613.htm

- The development of an antibody that stimulates microglia, the brain's immune cells, in such a way that they live longer, divide more quickly and detect aberrant substances more easily, thus helping to prevent the progression of Alzheimer's.[424]
- The discovery that Alzheimer's establishes itself independently at various points in the brain from an early stage and it is the rate at which these clusters grow that determines the speed of a patient's deterioration, not the speed at which they spread. Previously, it was was believed that it started at one specific point in the brain and then spread to other parts in a chain reaction.[425]
- The Institute of Ageing at Newcastle University and the Mayo Clinic in the US have demonstrated that senescent cells can be selectively killed (using a process known as senolytics) and this helps to postpone multiple age-related disabilities and disease.[426]
- The introduction of rejuvenation medicine that turns back biological age, rather than just slowing it down, by the restoration of the molecular and cellular structure and composition of tissues and organs. One example is the removal of 'zombie' cells, senescent cells that no longer divide, but remain alive, creating difficulties for their environment.[427] Another example is organ regeneration using lymph nodes to regrow functioning organs within a patient's own body, eradicating the problem of organ rejection in transplant patients and solving the problem of organ supply scarcity.[428, 429]
- The use of hyperbaric oxygen therapy to reverse two key indicators of biological aging: telomere length and senescent cells accumulation. In a clinical study, 35 adults over 64 years were placed in a pressurized chamber and given pure oxygen for 90 minutes a day, five days a week for three months. At the end of the trial, the participants' telomeres had increased in length by an average of 20%, while their senescent cells had been reduced by up to 37%.[430]

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[424] Stimulating immune cells to protect against Alzheimer's, *Neuroscience News*, 10 March 2020.
[425] https://www.telegraph.co.uk/news/2021/10/29/scientists-pinpoint-exactly-alzheimers-grows-brain-breakthrough
[426] Danny Buckland (2019) We're living much longer, but are we healthier?, Raconteur.net, 23 May. Ellie Dolgin (2020) Send in the senolytics, *Nature Biotechnology*, 12 November,
[427] Aubrey de Grey, Co-Founder and Chief Scientific Officer,SENS Research Foundation, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[428] *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[429] Some scientists question whether it is currently possible to measure biological age accurately. One example is Jay Olshansky, Chief Scientific Officer, Lapetus Solutions. Nevertheless, he has developed a metric based on face age 'which illustrates the documented relationship between how young or old you look relative to your chronological age. It's not a statement that you're this many years younger or older, but it seems to be a reasonable biomarker giving you a clue that you might be aging more slowly or more rapidly'. Interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[430] Anthony Cuthbertson (2020) Human aging reversed in 'Holy Grail' study, *Independent*, 30 November; https://www.independent.co.uk/life-style/gadgets-and-tech/anti-ageing-reverse-treatment-telomeres-b1748067.html

- Demonstration in an animal model that age-related frailty and immune decline can be halted and even partially reversed using a novel cell-based therapeutic approach. It is known that visceral adipose tissue or belly fat contributes to the development of chronic low-grade inflammation. Researchers at the University of Bern report that certain immune cells in the belly fat play an essential role in regulating chronic low-grade inflammation and downstream aging processes. They show that these immune cells may be used to reverse such processes.[431]
- The identification of 10 genomic loci which influence three key phenotypes[432] (years lived in good health (healthspan), total years lived (lifespan), and survival until an exceptional old age (longevity)). Of these five (FOXO3, SLC4A7, LINC02513, ZW10, and FGD6) have not been reported previously as of genome-wide significance. The majority of these 10 loci are associated with cardiovascular disease and some affect the expression of genes known to change their activity with age. The study also showed the importance of gene sets linked to how the body metabolizes iron, with too much iron in the blood appearing to increase risk of dying earlier. Professor Timmers, one of the authors of the study, said: 'We speculate that our findings on iron metabolism might also start to explain why very high levels of iron-rich red meat in the diet has been linked to age-related conditions such as heart disease'.[433]
- The identification of proteins associated with aging and increased frailty.[434] A study of 4265 proteins measured in plasma found that 55 were positively associated with fraility, in particular, fatty acid-binding protein FABP and ANTR2.[435]
- The development by biotech company Elevian of drugs based on GDF11 (growth differentiation factor 11), a Harvard University-discovered protein linked to age-related diseases. The work on GDF11—which involved a technique called

[431] Daniel Brigger, Carsten Riether, Robin van Brummelen, Kira I. Mosher, Alicia Shiu, Zhaoqing Ding, Noemi Zbären, Pascal Gasser, Pascal Guntern, Hanadie Yousef, Joseph M. Castellano, Federico Storni, Neill Graff-Radford, Markus Britschgi, Denis Grandgirard, Magdalena Hinterbrandner, Mark Siegrist, Norman Moullan, Willy Hofstetter, Stephen L. Leib, Peter M. Villiger, Johan Auwerx, Saul A. Villeda, Tony Wyss-Coray, Mario Noti, Alexander Eggel (2020) Eosinophils regulate adipose tissue inflammation and sustain physical and immunological fitness in old age, *Nature Metabolism*; DOI: 10.1038/s42255-020-0228-3

[432] Phenotypes are the observable characteristics of an organism that result from the interaction of its genotype (total genetic inheritance) with the environment. For individuals, this includes characteristics such as height, eye colour and blood type (https://www.britannica.com/science/phenotype; https://www.genome.gov/genetics-glossary/Phenotype).

[433] Paul R. H. J. Timmers, James F. Wilson, Peter K. Joshi, and Joris Deelen (2020) Multivariate genomic scan implicates novel loci and haem metabolism in human aging, *Nature Communications* volume 11, Article number: 3570 (2020); https://doi.org/10.1038/s41467-020-17312-3. David Nield (2020) Study of Over 1 Million People Finds Intriguing Link Between Iron Levels And Lifespan, *Science Alert*, 17 July; https://www.sciencealert.com/a-study-of-1m-people-finds-a-strange-link-between-iron-levels-and-long-life

[434] Frailty is a state of decreased physiological reserve and increased vulnerability to adverse outcomes in aging, and is characterized by dysregulation across various biological pathways.

[435] Sanish Sathyan, Tina Gao, Sofiya Milman, Nir Barzilai, Joe Verghese, Sanish Sathyan and Emmeline Ayers (2020) Plasma proteomic profile of frailty, *Aging Cell,* https://doi.org/10.1111/acel.13193

parabiosis in which the circulatory systems of young and old mice were combined to allow blood to flow between the animals—suggested that injecting the protein into old mice regenerated cardiac, brain and muscle tissue.[436]

- By increasing the amount of the protein sestrin in fruit flies, researchers have been able to extend their lifespan and at the same time these flies were protected against the lifespan-shortening effects of a protein-rich diet. The researchers could further show that sestrin plays a key role in stem cells in the fly gut thereby improving the health of the fly.[437]
- The discovery that pro-inflammatory cytokines[438] induce cellular senescence and hence aging by activating EGFR (Epidermal Growth Factor Receptor) signaling. The activity of five senescence-inducing cytokines (IL-1β, IL-13, MCP-2, MIP-3α, and SDF-1α) could be significantly inhibited by treatment with cetuximab (an antibody targeting EGFR), gefitinib (a small molecule inhibitor of EGFR), and EGFR knockdown (the targeted reduction rather than inhibition of the EGFR peptide).[439]
- The discovery that lysine glycation in collagen appears to contribute to tendon stiffening with age and in diabetes.[440]
- A study led by University College London suggests that weight management could play a significant role in reducing the risk of developing dementia, after finding that obesity increases the risk of dementia up to 15 years later. The study showed that people who are obese in late adulthood face a 31% increased risk of dementia compared with those whose body mass index is normal. The risk is particularly high for women.[441]
- Researchers at the University of Bonn have discovered a receptor in mice that regulates both increasing abdominal girth and shrinking muscles, two common

[436] Ben Adams (2020) Anti-aging biotech Elevian raises $15M as it looks to the clinic, *Fierce biotech,* 24 November; https://www.fiercebiotech.com/biotech/anti-ageing-biotech-elevian-raises-15m-as-it-looks-to-clinic

[437] Jiongming Lu, Ulrike Temp, Andrea Müller-Hartmann, Jacqueline Esser, Sebastian Grönke, Linda Partridge. Sestrin is a key regulator of stem cell function and lifespan in response to dietary amino acids. *Nature Aging*, 2020; DOI: 10.1038/s43587-020-00001-7

[438] Cytokines are a broad category of small proteins or peptides – such as chemokines, interferons, interleukins, lymphokines, and growth factors – which are secreted by certain cells of the immune system and have an effect on – by sending signals to – other cells; https://en.wikipedia.org/wiki/Cytokine

[439] Dongsheng Shang, Danlin Sun, Chunyan Shi, Jun Xu, Mingxiang Shen, Xing Hu and Hanqing Liu (2020) Activation of epidermal growth factor receptor signaling mediates cellular senescence induced by certain pro-inflammatory cytokines, *Aging Cell*, 22 April; https://doi.org/10.1111/acel.13145

[440] Melanie Stammers, Irina M Ivanova , Izabella S Niewczas, Anne Segonds-Pichon , Matthew Streeter , David A Spiegel , and Jonathan Clark (2020) Age-related changes in the physical properties, cross-linking, and glycation of collagen from mouse tail tendon, J Biol Chem, doi: 10.1074/jbc.RA119.011031

[441] Obesity linked to higher risk of dementia, Pharma Times, 29 June 2020; http://www.pharmatimes.com/news/obesity_linked_to_higher_risk_of_dementia_1343249

side effects of aging. Experiments with human cell cultures suggest that the corresponding signaling pathways might also exist in humans.[442]

- Adoptive cell therapies (ACTs) which involve the use of immune cells as anti-cancer agents and hold promise for the treatment of adult and paediatric cancer, ranging from liquid to solid tumors. One type of ACT involves chimeric antigen receptor (CAR)-engineered immune cells, with two CAR T-cell-based therapies recently approved by the US Food and Drug Administration, paving the way for the development of additional ACT therapies.[443]
- Identification of a biomarker for tumour initiating (or cancer stem) cells.[444]
- Early diagnosis of certain cancers (e.g., ovarian and brain) by identifying genetic errors in DNA.[445]
- A new DNA test evaluates biomarkers in 517 cancer-relevant genes across 30 types of solid tumours.[446]
- A new metabolism-based blood test detects multiple cancer types prior to symptoms.[447]
- The development of a sterilizable nanowire-based device that can extract urinary microRNAs and use it as a liquid biopsy to detect cancers of the central nervous system.[448]
- Researchers at the Georgia Institute of Technology in the US have invented a microfluidic chip called the Cluster-Well which can precisely locate each cell in a blood sample and determine if it is cancerous. This could lead to earlier and more targeted treatment.[449]

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[442] University of Bonn. "Receptor makes mice strong and slim: Molecule that regulates two side effects of aging identified." ScienceDaily. ScienceDaily, 25 June 2020; www.sciencedaily.com/releases/2020/06/200625115916.htm

[443] Katy Rezvani, Marco Ruella, and Robbie Majzner (2020) Advances in Adoptive Cell Therapies, Cell Press webinar, 16 July.

[444] Labmedica.com, 28 November 2019.

[445] Rhys Blakely (2020) Cancer code offers hope of treatment decades early, *The Times*, 6 February.

[446] https://www.labmedica.com/molecular-diagnostics/articles/294792025/groundbreaking-dna-test-evaluates-biomarkers-in-517-cancer-relevant-genes-across-30-types-of-solid-tumors.html

[447] https://www.labmedica.com/molecular-diagnostics/articles/294793553/index.php; https://www.labmedica.com/molecular-diagnostics/articles/294788864/blood-based-liquid-biopsy-test-accurately-detects-more-than-fifty-types-of-cancer.html;

[448] https://www.labmedica.com/molecular-diagnostics/articles/294788818/a-nanowire-based-liquid-biopsy-method-for-detection-of-tumors-of-the-central-nervous-system.html

[449] https://www.labmedica.com/molecular-diagnostics/articles/294794252/index.php: 'Cancer spreads via circulating tumor cells (CTCs) that travel through the blood to other organs, and they are nearly impossible to track. When a tumor starts metastasizing, it sheds its cell into the blood. An individual cell often doesn't survive the bloodstream on its own, but clusters of cells are much more robust and can travel to other organs, effectively pushing the cancer to a metastatic state. CTCs have proven difficult to study, let alone treat. Blood contains billions of cells per milliliter, and only a handful of those cells would be CTCs in a patient with metastatic cancer'.

- A new liquid biopsy blood test can detect brain tumours where a conventional biopsy is not possible.[450]
- Immunotherapy – the re-education of an individual's own immune cells to fight diseases such as cancer.[451] An immunotherapy drug, AFM24, has been shown to work in patients with advanced cancers that had stopped responding to treatment, including bowel, lung and pancreatic cancers.[452]
- The development of tests that can transform cancer treatments. For example, a blood test developed by the Vancouver Prostate Centre and BC Cancer (British Columbia, Canada) analyzes the DNA that metastatic cancers shed into the bloodstream, known as circulating tumor DNA. By sequencing the entire genome of this ctDNA, the test reveals characteristics that are unique to each patient's cancer, giving physicians new tools to develop more personalized treatment plans.[453]
- The development by Moderna and Merck of a personalized cancer vaccine, designed to prime the immune system so the body can generate a response based on a person's specific type of cancer tumour, using the same mRNA technology as in Covid-19 vaccines.[454]
- The levels of antibodies against ALDOA and FH provide novel predictors of ischemic stroke, including transient ischemic attack (TIA) and cerebral infarction (CI), which are induced by atherosclerosis.[455]
- A new blood-based cardiovascular risk test for more accurate risk prediction (of heart disease and sudden cardiac arrest) and patient management.[456]
- The importance of selenium in antioxidant mixtures designed to reduce all-cause mortality, in particular, from cardiovascular disease and cancer.[457]

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[450] https://www.labmedica.com/molecular-diagnostics/articles/294795854/blood-test-helps-diagnose-inaccessible-brain-tumors.html

[451] Siddhartha Mukherjee (2022) *The Song of the Cell: An Exploration of Medicine and the New Human*, Simon & Schuster; https://www.simonandschuster.com/books/The-Song-of-the-Cell/Siddhartha-Mukherjee/9781982117351

[452] https://www.telegraph.co.uk/news/2022/04/08/new-killer-cancer-treatment-stops-one-three-tumours-growing

[453] https://www.labmedica.com/molecular-diagnostics/articles/294793945/first-of-its-kind-blood-test-could-transform-cancer-treatment.html

[454] https://www.telegraph.co.uk/news/2022/12/13/skin-cancer-vaccine-based-covid-jab-technology-hailed-game-changer

[455] https://www.labmedica.com/clinical-chem./articles/294789093/aldoa-and-fh4-antibodies-associated-with-cerebrovascular-disease.html

[456] https://www.labmedica.com/hematology/articles/294792002/elisa-blood-test-uses-innovative-biomarker-to-detect-heart-disease-and-sudden-cardiac-arrest.html; https://www.labmedica.com/hematology/articles/294789202/novel-ai-driven-cardiac-blood-test-provides-highly-accurate-prediction-of-one-year-risk-for-heart-attack-stroke-or-cardiac-death.html

[457] David J A Jenkins, David Kitts, Edward L Giovannucci, Sandhya Sahye-Pudaruth, Melanie Paquette, Sonia Blanco Mejia, Darshna Patel, Meaghan Kavanagh, Tom Tsirakis, Cyril W C Kendall, Sathish C Pichika, John L Sievenpiper, Selenium, antioxidants, cardiovascular disease, and all-cause mortality: a

- The development of technology by Bit.Bio to reprogram stem cells to make any human cell desired.[458]

Huge advances are expected to follow the final decoding of the entire human genome in March 2022.[459] Cost and speed have fallen dramatically. A whole genome cost $100m in 2001, but in 2022 it was $400 and is anticipated to be just $100 by 2024. The development of CRISPR technology for editing genomes allows scientists to change DNA sequences and modify gene function, so that, for example, genetic defects can be corrected and the spread of diseases can be prevented.[460] Scientists claim that this will open the way to precision medicine for everybody. Professor Sir Mark Caulfield, former chief scientist at Genomics England, said: 'We have got a fabulous future. We have only scratched the surface of what the whole genome can offer'. The first benefit will be the early diagnosis of illness and personalized medicine. This will be followed by the correction of faulty genes via gene therapy. As an early example of gene therapy, scientists, using a technique called optogenetics, have added light-sensitive proteins to the man's retina, partially restoring his sight.[461] All this will help to reduce working age sickness and extend the working life, with knock-on benefits for the sustainability of the pension system.[462]

Dr Verdin expects the first anti-aging drugs to become available on the market in the next 5-10 years, following the completion of successful clinical trials. He also believes the new drugs will revolutionize the whole process of medical intervention which have traditionally focused on treating a specific disease, like heart or lung disease: 'Aging biology presents a different way of organizing medicine and of treating disease. Aging affects every single organ, so if your intervention targets an aging pathway, you will affect the development of

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systematic review and meta-analysis of randomized controlled trials, *The American Journal of Clinical Nutrition*, nqaa245, https://doi.org/10.1093/ajcn/nqaa245

[458] Tom Whipple (2020) Bit.Bio: British firm cracks code for stem cells, *The Times*, 27 October.

[459] Timeline - Genetic breakthroughs:

- December 1999 - First human chromosome is sequenced
- April 2003 - Heads of government of Britain, the US, Japan, France, Germany, and China announce the successful sequencing of the entire human genome
- September 2005 - The chimpanzee genome is sequenced
- December 2009 - The first comprehensive analysis of cancer genomes is published, including lung cancer and malignant melanoma
- May 2010 - The Neanderthal genome is sequenced
- December 2018 - The 100,000 genomes project is completed, sequencing 100,000 genomes from patients affected by a rare disease or cancer
- March 2022 - Scientists finally decode the entire human genome

Source: https://www.telegraph.co.uk/business/2022/08/19/britains-path-economic-national-renewal-genome-revolution

[460] Su Bin Moon, Do Yon Kim, Jeong-Heon Ko and Yong-Sam Kim (2019) Recent Advances in the CRISPR Genome Editing Tool Set, *Experimental & Molecular Medicine*, 51: 1–11.

[461] https://www.nytimes.com/2021/05/24/science/blindness-therapy-optogenetics.html

[462] https://www.telegraph.co.uk/business/2022/08/19/britains-path-economic-national-renewal-genome-revolution

diseases in different organs. That doesn't fit in the traditional field of medicine. So, one of the biggest challenges we face… is convincing people that we should be studying disease in the context of pathways that are universal across different organs. We need to change the way that we practice medicine to aim for a preventative approach'.[463] This point is reinforced by Steven Braithwaite, Chief Scientific Officer of Alkahest: 'Our long-term goal is that we will develop therapeutics that modulate the biology of aging and will have impact across multiple disorders'.[464] Joan Mannick, Chief Medical Officer of resTORbio, goes further: 'In the future we may be able to personalize aging-related therapeutics. For instance, it would be useful to develop biomarkers of aging-related biochemical pathways and then use therapeutics targeting specific biochemical pathways in …specific patients', similar to how cholesterol became a biomarker for the use of statins.[465] A huge investment is being made in healthcare innovation to slow the aging process by organizations like the Deep Knowledge Group.[466]

Governments are also setting up life science strategies. For example, the UK government introduced one in 2017 and updated it in 2021, building on the knowledge gained from the Covid-19 pandemic to tackle future disease missions, such as dementia research, the early-stage diagnosis and treatment of diseases such as cancer, and prevention of cardiovascular diseases. There will be greater use of genomics and health data to provide much deeper, real world evidence about the safety of new medicines and health technologies.[467] There will also be greater use of oncology medicines, such as AstraZenica's Enhurtu (for treating breast cancer), Tagrisso (lung cancer) and Lynparza (ovarian cancer). Dave Frederickson, head of oncology at AZ, believes it will soon be possible 'to eliminate cancer as a cause of death'.[468]

In April 2022, leading life sciences companies and Innovate UK called for the development of a national vision on cell and gene therapies (CGTs) in the UK.[469] CGTs are treatments based on human cells or genes and a form of advanced therapy medicinal product (ATMPs). Compared to small molecules and protein-based treatments, such as monoclonal antibodies, which require repeated administration to treat the underlying conditions, CGT treatments offer a solution in which a single dose can provide a durable therapeutic

[463] Interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[464] Steven Braithwaite, Chief Scientific Officer, Alkahest, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[465] Joan Mannick, Chief Medical Officer, resTORbio, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[466][466] https://www.dkv.global/
[467] https://www.pinsentmasons.com/out-law/news/genomics-and-health-data-central-to-uk-life-sciences-vision
[468] https://www.telegraph.co.uk/business/2023/01/27/meet-scientist-working-eliminate-terminal-cancer/
[469] https://ct.catapult.org.uk/sites/default/files/publication/National%20Cell%20and%20Gene%20Therapy%20Vision%20for%20the%20UK.pdf

effect. Nearly 300 new CGTs were currently in development, but the UK needed to scale-up its manufacturing capacity to meet demand for CGTs in future. There was also a compliance challenge, since CGTs often have a very short shelf life.

Amongst these positive developments, there have been some negative ones. A key example in 2022 was the exposure by the journal *Science* in July that the study by Lesné et al (2006) published in the journal *Nature* on the causes of Alzheimer's disease may have been based on evidence tampering using 'manipulated' data.[470] The 2006 study concluded that Alzheimer's is triggered by a build-up of amyloid beta plaques in the brain following experiments in which amyloid beta injected into young mice brought on dementia. However, the *Science* investigation claims to have found evidence that the images of amyloid beta in mice had been doctored by combining photos from different experiments. German psychiatrist Alois Alzheimer first identified plaques in the brains of dementia patients in 1906 and in 1984 amyloid beta was found to be their main component. Hundreds of different therapies targeting amyloid in the brain were trialled, but since they all failed, futher experimentation was abandoned until the 2006 paper. Since then billions of dollars have been spent trialling new therapies to remove amyloid from the brain – again without success. Yet in June 2022, the US Food and Drug Administration approved the drug aducanumab (marketed as Aduhelm) to slow cognitive decline in people with mild memory and thinking problems. It was the first approved treatment to attack the disease process of Alzheimer's instead of just addressing dementia symptoms. This was despite the fact that the FDA's own independent advisory committee argued that there was insufficient evidence that the drug – which costs $56,000 a year – can help patients.[471] The authors of the 2006 paper responded by saying they 'still have faith' that amyloid is a cause of Alzheimer's. Alzheimer's Research UK said: 'the research that has been called into question is focused on a very specific type of amyloid, and these allegations do not compromise the vast majority of knowledge built up during decades of research into the role of this protein in the disease'.[472]

Another negative development is the finding by Binghamton University in the US that early retirement can accelerate cognitive decline at older ages. The finding was based on an examination of China's New Rural Pension Scheme (NRPS) and the Chinese Health and Retirement Longitudinal Survey (CHARLS). The most significant indicator of cognitive decline was delayed recall which is an important predictor of dementia and was

[470] https://www.science.org/content/article/potential-fabrication-research-images-threatens-key-theory-alzheimers-disease
[471] https://www.nytimes.com/2021/06/07/health/aduhelm-fda-alzheimers-drug.html
[472] https://www.telegraph.co.uk/news/2022/07/21/manipulated-alzheimers-data-may-have-misled-research-16-years/

associated with increased social isolation. The findings were similar to those in higher income countries, such as the US, UK, and EU.[473]

Preventative health care and later life wellness

The previous subsection highlights the importance of preventative health care – given how expensive it is to treat noncommunicable diseases, such as heart disease, cancer, diabetes, and dementia, which account for around 70% of deaths globally.

The OECD estimates that around 40% of cancer cases are preventable and mortality can be reduced through earlier diagnosis and the provision of more timely and effective treatments. Confirmation of this comes from the UK. Lung cancer is the most legal form and in the UK it causes an average of 35,000 deaths per year, where the average stage of diagnosis is Stage 3. There was no nationwide screening programme, but in 2019, the NHS introduced a lung cancer screening pilot scheme using low dose CT scanning for current and ex-smokers aged between 55 and 75, with 77% of patients being diagnosed with lung cancer at Stages 1 or 2 (compared with 33% previously). In October 2022, the NHS began to roll out of the programme nationally.[474]

Professor Andrew Scott points out: 'The dominant cause of many noncommunicable diseases is age itself. This suggests that efforts to slow the aging process should play a more prominent role in treatments rather than targeting particular diseases, such as cancer. A growing research programme is focusing on understanding why we age and developing treatments that, if successful, could lead to dramatic changes in the malleability of age'[475]

Examples of these developments include:

- Periodic fasting or caloric restriction has been shown to be one of the most effective ways of preventing age-related disorders and promoting life expectancy and health span. The first study to examine caloric restriction in humans was the Comprehensive Assessment of Long-Term Effects of Reducing Intake of Energy (CALERIE) at Duke University.[476] It showed that two years of caloric restriction could slow biological aging and reduce age-related markers, such as oxidative stress.[477]

[473] https://www.pensionpolicyinternational.com/early-retirement-can-accelerate-cognitive-decline-among-the-elderly-research-shows/
[474] Murray et al. (2022).
[475] Andrew Scott (2020) The Long, Good Life: Longer, more productive lives will mean big changes to the old rules of aging, *Finance and Development*, March.
[476] https://calerie.duke.edu/
[477] Carla Heyworth (2020) Metabolic aging, fasting and metformin, *Longevity Technology*, 10 March; https://www.longevity.technology/metabolic-aging-fasting-and-metformin/

- Diets and food supplements designed to treat age-related disorders. The Buck Institute's Dr Eric Verdin reports the development of fasting-mimicking diets. There are also caloric restriction mimetics, supplements that offer the health-promoting effects of fasting, without the need for fasting. Metformin (previously used in the treatment of type-2 diabetes) is being examined as a drug for increasing healthspan by Dr Nir Barzilai, Professor of Medicine and Genetics and Director of the Institute for Aging Research at the Albert Einstein College of Medicine in New York, in his TAME (Targeting Aging with Metformin) trial.[478] Similarly, methionine, an amino acid that plays an important role in the metabolism, is being considered for the treatment of age-related disorders. Singapore-based Senescence Life Sciences aims to use nutraceuticals – ingredients and raw materials for dietary supplements – to combat natural brain aging by targeting an enzymatic process that has been shown to restore classical neuronal indicators of age – including learning, memory and decision-making performance.[479] Food companies are promoting 'future food' which combines healthier eating and leveraging agricultural gene editing.[480]
- Recognition that low concentrations of circulating 25-hydroxyvitamin D (25[OH]D), a metabolite used as a clinical indicator of vitamin D status, are associated with an increased risk of cardiovascular disease and all-cause mortality, as well as other chronic diseases.[481]
- Developing a wearable device to detect early signs of Alzheimer's disease as part of the Early Detection of Neurodegenerative diseases (EDON) project run by Alzheimer's Research UK. EDON will analyse data from existing studies using artificial intelligence and use the results to design a prototype device within three years. The wearable will then collect data on gait, heart rate and sleep patterns etc which can be used to identify signs of the disease years before symptoms develop.[482]

Equally important are measures that contribute to later life wellness, which, in turn, are likely to increase both lifespan and healthspan. Examples include:

- Exercise together with sleep and stress management (in addition to nutrition). But much more work needs to be done to understand the link to life expectancy, as Dr

[478] Carla Heyworth (2020) Metabolic aging, fasting and metformin, *Longevity Technology*, 10 March; https://www.longevity.technology/metabolic-aging-fasting-and-metformin/
[479] Danny Sullivan (2020) Nutraceuticals to beat cognitive decline before it starts, *Longevity Technology*, 16 March; https://www.longevity.technology/nutraceuticals-to-beat-cognitive-decline-before-it-starts
[480] Aging Analytics Agency, *Advancing Financial Industry: Longevity/AgeTech /WealthTech*
[481] https://www.labmedica.com/clinical-chem./articles/294790627/vitamin-d-deficiency-has-greater-risk-for-all-cause-mortality.html
[482] Jane Wakefield (2020) Wearable to spot Alzheimer's being developed, *BBC News*, 13 February.

Verdin points out: 'How exactly does exercise impact longevity? We know it does, but we don't know what forms of exercise are effective – endurance vs high intensity interval training? 10,000 steps vs 4,000 steps? We need molecular-level data to increase our knowledge'.[483]

- Reducing non-adherence to medication. The World Health Organization has estimated that adherence to medication for chronic conditions is as low as 50% in developed countries and even lower in developing countries. The annual costs of medication non-adherence range from $100bn to $290bn in the USA, €125bn in Europe and AU$7bn in Australia. Around 10% of hospitalizations in older people are attributed to non-adherence. The typical non-adherent patient requires three extra medical visits per year, leading to increased treatment costs of $2,000 per annum. The International Longevity Centre (UK) said: 'We could see a considerable improvement in health outcomes (and consequently longevity), not only by developing new drugs, but by helping people adhere to existing treatment regimens that have already been researched, tested and prescribed for them'.[484]
- The living environment. Where you live can have a significant impact on the likelihood that you will reach centenarian age, according a study from Washington State University's Elson S. Floyd College of Medicine. Washingtonians who live in highly walkable, mixed-age communities may be more likely to live to their 100th birthday. The study also found socioeconomic status to be correlated, and an additional analysis showed that geographic clusters where the probability of reaching centenarian age is high are located in urban areas and smaller towns with higher socioeconomic status. Existing research estimates that heritable factors such as genes only explain about 20% to 35% of an individual's chances of reaching centenarian age.[485]
- Targeting products and services at older people with the intention of improving their well-being and indirectly their life and healthspans. Companies doing this are not being altruistic. Rather they recognize the financial resources available to this demographic in developed countries. In the US, for example, people over 50 control 75% of net wealth and 50% of disposable income and will spend around $4trn over the next twenty years. Tech companies like Amazon, Apple and Google are looking at designing new products and services for this group. Agetech[486] in the form of digital health platforms and telemedicine is providing access to cost-effective

[483] Interview in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[484] https://ilcuk.org.uk/doctors-orders/
[485] Centenarian study suggests living environment may be key to longevity, Washington State University, 17 June 2020; https://news.wsu.edu/2020/06/17/centenarian-study-suggests-living-environment-may-key-longevity/
[486] Defined as the digital-enabled market of consumers over 50. It relies on this age group being willing and able to access the market digitally.

healthcare, in combination with medical software and apps.[487] Agetech also targets other aspects of well-being, such as education and financial wellness.[488]

- The promotion of a 'positive outlook' to reduce memory decline. A study finds that people who feel enthusiastic and cheerful – what psychologists call 'positive affect' – are less likely to experience memory decline as they age, controlling for age, gender, education, depression, negative affect, and extraversion. This result adds to a growing body of research on positive affect's role in healthy aging.[489]

These developments led Bank of America to conclude that the human lifespan could soon pass 100 years, with one of the biggest investment opportunities over the next decade being in companies working to delay human death, a market expected to be worth at least $600bn by 2025.[490] To illustrate, in June 2021, M&G Investments launched the Better Health Solutions fund which will invest in companies whose products or services are designed to promote better health and wellbeing.[491] Investment in the biotech sector reached $5.2bn globally according to analysts at Longevity.Technology, with 130 deals in 2022.[492] This compares with $6.2bn (190 deals) in 2021 and $3.0bn (148 deals) in 2020. The largest investment in 2022 was Jeff Bezos's $3bn financing for Altos Labs which focuses on cellular reprogramming. The Hevolution Foundation was also established. This is a Saudi-backed non-profit organization with an annual budget of up to $1 billon to spend on 'independent research and entrepreneurship in the emerging field of healthspan science'.[493] The leading longevity domains are 'Longevity discovery platforms', 'Longevity drugs',

[487] Angela Tyrrell (2020) Eight sectors to be disrupted by longevity, *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[488] Angela Tyrrell, SVP, Longevity Leaders, identifies ten consumer trends driving the preventative wellness market: 1) digital tracking tools (e.g., for counting steps, logging calories, tracking ovulation or recording sleep patterns), 2) consumer biological testing (e.g., personalized DNA testing to improve lifetime health management), 3) personalization (of, e.g., nutrition and skincare), 4) responding to climate change (e.g., by driving less and walking or cycling more), 5) meat alternatives, 6) alcohol alternatives, 7) natural products (without preservatives, sugar and salt), 8) mental health awareness (leading to diagnoses and treatments that reduce cognitive decline in later life), 9) meditation and mindfulness programmes (to reduce stress, improve sleep quality or breathing, or accompany a physical activity such as yoga), and 10) Ethical leadership (e.g., via a corporate and social responsibility policy that enhances a company's reputation with its customers and, as a consequence, has long-term benefits for the health of its employees). See *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[489] Emily F. Hittner, Jacquelyn E. Stephens, Nicholas A. Turiano, Denis Gerstorf, Margie E. Lachman, Claudia M. Haase (2020). Positive Affect Is Associated With Less Memory Decline: Evidence From a 9-Year Longitudinal Study. *Psychological Science*, 2020; 095679762095388 DOI: 10.1177/0956797620953883

[490] https://www.cnbc.com/2019/05/08/techs-next-big-disruption-could-be-delaying-death.html

[491] https://www.professionaladviser.com/news/4033150/unveils-impact-fund-focusing-health-wellbeing

[492] https://longevity.technology/news/global-longevity-investment-hit-5-2-billion-in-2022/

[493] https://longevity.technology/news/hevolution-ceo-on-how-to-spend-1-billion-a-year-on-longevity/

renewal therapies ('Regeneration', 'Rejuvenation', 'Cellular reprogramming') and 'Gene therapies'.[494]

In order to take advantage of this increase in human lifespan, companies should exploit the longevity dividend, i.e., recognize the value of their older workforce and do not force them into retirement before they are ready to leave. Forced early retirement can have the effect of harming health and reducing life expectancy because of depression and loss of self-worth which can, in turn, lead to alcoholism, excessive drug use and suicide.[495] Mercer's Next Stage research programme, for example, showed that age and experience enhance business performance. Companies that use data analytics and business impact modelling to examine their own organizational demographic data have discovered some key drivers of business performance. To illustrate:

- Experienced workers lower costs because they – and the people they supervise – are less likely to leave. A 5% reduction in turnover saved one of Mercer's clients $66m in cost per unit.
- Experienced workers increase productivity. Branch revenue at one US bank increased by $40m per year for each year of extra service/age of its sales team.

An important aspect of this is life-long learning in order to increase later-life productivity. This is being promoted, for example, as part of a project called 'Living, Learning and Earning Longer'[496] by the OECD, the World Economic Forum, and the American Association of Retired Persons (AARP). Another aspect of the longevity dividend to companies from their employees working longer is potentially lower pension liabilities since additional pensions contributions are made and the pension, when it is paid, is drawn for a shorter period on average.[497] Society also benefits from the increase in healthspan associated with the longevity dividend as a result of lower later-life healthcare costs.[498]

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[494][494] https://longevity.technology/investment/report/annual-longevity-investment-report/

[495] There is some evidence for this in the US. See, for example, Kate W. Strully (2009) Job Loss and Health in the U.S. Labor Market, *Demography*, 46(2): 221–246; Clemens Noelke and Jason Beckfield (2014) Recessions, Job Loss, and Mortality Among Older US Adults, *Am J Public Health*, 104(11): e126–e134; and Anne Case and Angus Deaton (2015) Rising Morbidity and Mortality in Midlife Among White Non-Hispanic Americans in the 21st Century, *Proceedings of the National Academy of Sciences of the United States of America*, December 8, 2015 112 (49) 15078-15083.

[496] https://www.aarpinternational.org/initiatives/future-of-work/living-learning-and-earning-longer

[497] Yvonne Sonsino, Global Co-Leader of Next Stage, Mercer, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[498] For a typical individual, around 70% lifetime healthcare costs occur in the last 3 years of their life. This is the sum of 47.1% for long-term care costs (average across 5 countries: Denmark, Germany, Netherlands, Taiwan and US) and 22.9% for hospital costs (average across 9 countries: Denmark, Germany, Netherlands, Taiwan, US, England, France, Japan and Quebec). See: Eric B. French et al. (2017) End-of-Life Medical Spending in Last Twelve Months of Life is Lower than Previously Reported, *Health Affairs*, 36(7): *Advanced Illness & End-Of-Life Care*; https://doi.org/10.1377/hlthaff.2017.0174

Another important aspect is financial wellbeing. The US Consumer Financial Protection Bureau argues that: 'A person's financial wellbeing comes from their sense of financial security and freedom of choice – both in the present and when considering the future. …[A]dults' financial well-being [is influenced by]: income and employment; savings and safety nets; past financial experiences; and financial behaviours, skills, and attitudes'.[499] A survey by WTW found that following the pandemic, employers in the UK had become more concerned about the financial wellbeing of their employees, with 80% saying that they were planning to introduce a financial wellbeing strategy. In addition to retirement savings, this could cover debt solutions, emergency savings and saving for housing. The main reasons given were that it supported broader welfare initiatives (including employee health), it enhanced employee benefits at a time of acute labour shortages, and it recognized employer duty of care.[500] Pension schemes have also begun to offer financial wellness services to their members. On example in the UK is the Royal Mail Defined Contribution Pension Scheme which has chosen Destination Retirement from HUB Financial Solutions as a service to support scheme members making key financial choices in the run-up to retirement and beyond.[501]

A report[502] from the Geneva Association and the Global Aging Institute, while accepting that ensuring financial wellbeing was the core purpose of life insurance, argued that 'traditional business models have come under stress as socio-economic, demographic, health and technological developments, [and] combined with a protracted period of low interest rates, have dented the appeal of savings-oriented life insurance globally'. To counteract this, the report made four recommendations for insurers:

- *Step up efforts to directly affect the determinants of savings and risk protection.* Inherent in the concept of financial wellbeing is an ecosystem of consumer needs that transcends the traditional products offered by life insurers. If life insurers wish to position themselves more strategically, they will have to redefine their role to include directly affecting the determinants of retirement savings and risk protection through pathways such as education, advisory services, mentoring and financial incentives in partnership with government, financial advisers and wealth and asset managers. Doing so will require insurers to either create or buy new capabilities, or else partner to bring them in.
- *Promote financial literacy in young age.* The lack of attention to financial education leaves the young ill-prepared to navigate the insecurities of the current labour market and successfully prepare for their eventual retirement. It also overlooks the

[499] https://www.consumerfinance.gov/data-research/financial-well-being-survey-data/
[500] https://www.wtwco.com/en-GB/Insights/2021/05/future-of-financial-wellbeing-survey-2021
[501] https://www.ipe.com/news/uk-roundup-house-of-fraser-plan-strikes-600m-buyout/10060379.article
[502] Financial Wellbeing: Is it the key to reinventing life insurance?, May 2022; https://www.genevaassociation.org/financial-wellbeing-report

opportunity to cement the role of life insurance at an early age. With a relatively modest investment, insurers can partner with national educational agencies, schools, communities and digital platforms to develop innovative ways of propagating financial knowledge, including by gamifying it, using social media and leveraging word of mouth and 'influencers'.

- *Improve risk exposure through preventive measures.* Very few life insurers cited limiting risk exposure as a primary motivation for developing new financial wellbeing products. Yet there are strong connections between financial wellbeing, general wellbeing and risky behaviours. Altering these behaviours will require insurers to embed data science at the heart of their products and indeed to see it as a key to understanding needs, shifting the paradigm from repair/replace to predict/prevent. Similarly, using data science to better integrate health and wellness products could have significant benefits.
- *Tap into the longevity economy.* Life insurers' efforts to tap into the burgeoning longevity sector are currently modest. There is also little to suggest that their products address changing retirement patterns, such as unretirement, phased retirement and new careers post-retirement, or changing family structures, including shifts in multigenerational living arrangements. New solutions such as silver sabbaticals to enable middle-aged adults to re-skill and to encourage longer working lives as well as supplementary health and care benefits that take over where government leaves off could help insurers unlock the potential of the silver economy and increase their relevance to aging societies.

There have also been significant negative developments. Examples include:

- An increase in deaths from heart and circulatory diseases in the UK for the first time in 50 years – as a result of an increase in obesity and type-2 diabetes.[503]
- Deaths of despair. The 'longevity economy' has not benefited older workers in jobs with low, unstable incomes without employee benefits. Such workers typically accumulate little wealth and savings over their working lives and face a retirement of poverty.[504]
- Increasing antibiotic resistance. The World Health Organization points out that a growing number of infections – such as pneumonia, tuberculosis, gonorrhoea, and salmonellosis – are becoming harder to treat as the antibiotics used to treat them become less effective. Antibiotic resistance occurs naturally, but misuse of

[503] Haroon Siddique (2019) UK heart disease fatalities rise for first time in 50 years, *Guardian*, 13 May.
[504] U.S. Deaths of despair - Not everyone benefits from the 'longevity economy', *Pension Policy International*, 14 October 2020; https://pensionpolicyinternational.com/us-deaths-of-despair-not-everyone-benefits-from-the-longevity-economy/

antibiotics in humans and animals is accelerating the process. It is one of the biggest threats to global health, food security, and development. It leads to longer hospital stays, higher medical costs and increased mortality.[505]

- The return of illnesses that had been eradicated. For example, the UK has been polio-free since 2003, with the last wild case detected in 1984. However, a polio virus mutation was detected in sewage system in London in early 2022, with tests indicating that it had been imported from a country where polio was still present.[506] In July 2022, a case of polio was reported in New York state, the first in the US since 1993; again, it is believed that the person caught it from someone outside of the US.
- The development and spread of new viruses. For example, the Ebola virus was first discovered in 1976. There was a major outbreak in West Africa in 2014–2016 and in Uganda in 2022.[507]
- Long Covid. Michael Fasano (2023)[508] points out that 'Most patients totally recover from acute Covid within 3 to 4 weeks after onset of infection. Long Covid has been reported in 10% to 30% of those with Covid-19,[509]and in some studies, even more. It is more common in women, non-whites, hospitalized patients and those with a Chronic obstructive pulmonary disease and/or smoking history. The World Health Organization characterizes Long Covid, or Post Covid-19 Syndrome, as being associated with:
    - Individuals with a history of probable or confirmed SARS-CoV-2 infection (the virus that causes Covid-19) who experience symptoms impacting everyday life, such as fatigue, shortness of breath and cognitive dysfunction; and
    - Symptoms that usually are present 3 months from the onset of acute Covid-19, that last for at least 2 months and can't be explained by an alternative diagnosis. … Approximately 25% of Americans with long Covid report significant activity limitations'.[510]
- Covid reinfection risk. There is currently conflicting evidence. On the one hand, Michael Fasano (2023)[511] considers a number of studies which show that 'those infected more than once with SARS-CoV-2 have a higher risk of experiencing diseases associated with long Covid. …However, the severity of the reinfection related impairments is less than that associated with primary infection'. On the

[505] Antibiotic resistance, World Health Organization, 5 February 2018; https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance
[506] https://www.telegraph.co.uk/news/2022/06/22/polio-back-national-incident-declared-uk-disease-spreads-first
[507] https://www.who.int/health-topics/ebola#tab=tab_1
[508] Michael Fasano (2023) Long COVID and Reinfection Risk, Fasano eNewsletter, February.
[509] Nashville Chest, October 16-19, 2022.
[510] CDC Survey, September 14-26, 2022.
[511] Michael Fasano (2023) Long COVID and Reinfection Risk, Fasano eNewsletter, February.

other hand, a study published in *Nature Medicine* by Washington University researchers found that people who caught Covid more than once were twice as likely to die and three times more likely to be hospitalized than people only infected once. They were also likely to experience more damage to their lungs, heart, brain, blood, muscles and digestive system. The study was based on data from 500,000 US veterans.[512]

Yet even here, there have been some potentially positive developments. For example, scientists at the University of Exeter have developed a technique which can be used to assess whether a bacterium is likely to respond to antibiotics. It works by examining whether fluorescent qualities of the antibiotics are taken up by bacteria. If so, the bacteria glow brighter under the microscope, revealing that the antibiotic has infiltrated the membrane and could be effective. The research could contribute to efforts to reduce prescribing, and also enable the development of more effective antibiotics, to help fight the global threat of antibiotic resistance.[513]

Dr Nir Barzilai argues that 'Death is inevitable but aging is not'.[514] This is a key message that needs to be taken into account when quantifying longevity risk and projecting healthy life expectancy going forward.

Artificial intelligence, machine learning and robotics

There have been a number of significant developments:

- Combining natural-language processing (NLP) and artificial intelligence (AI) could reveal clinical insights buried in existing medical records and scans.[515]
- Using AI for many health-related purposes, such as the early detection of heart disease and breast and prostate cancer,[516] diagnosis of leukemia, reading retinal scans with as much accuracy as experienced junior doctors (using Google's DeepMind), the use of minimally invasive procedures in hospitals to improve the quality of patient care, correcting faults in the human nervous system (e.g., robotic

[512] https://www.telegraph.co.uk/news/2022/11/10/catching-covid-doubles-risk-death
[513] Glowing bacteria to help tackle antibiotic resistance, Open Access Government, 3 July 2020; https://www.openaccessgovernment.org/glowing-bacteria/89771/
[514] Amelia Hill (2019) Scientists harness AI to reverse aging in billion-dollar industry, *Guardian*, 21 December; https://www.theguardian.com/science/2019/dec/21/scientists-harness-ai-to-reverse-ageing-in-billion-dollar-industry
[515] Investment Week (2022) Healthcare is on the cusp of a digital revolution, 30 November.
[516] https://www.nytimes.com/2023/03/05/technology/artificial-intelligence-breast-cancer-detection.html; https://www.labmedica.com/pathology/articles/294796508/ai-powered-prostate-cancer-diagnosis-tool-accurately-identifies-and-classifies-tumors.html

arms controlled by brain signals replacing lost human arms) and reducing false results in Covid-19 lateral flow tests.[517]

- The development of an AI tool called AlphaFold (by DeepMind) which has predicted the structure of almost (98.5% of) the entire human proteome (the full complement of proteins expressed by an organism).[518]
- AI has designed proteins with anti-microbial properties which could be incorporated into new medicines.[519]
- Using microchips to repair motor function in human organs. Elon Musk set up Neuralink in 2016 to explore how to connect the human brain to a computer using the N1 microchip. Musk claims the N1 microchip can repair motor function in the paralysed, restore eyesight and hearing and help those suffering from memory loss through dementia and Alzheimer's. The technology could also allow humans to compete with AI by controlling machines with the power of thought. The N1 microchip is a 4mm square. Each person could have up to 4 implanted in the skull. Attached to the chip are superfine wires. They are placed close to important parts of the brain, recording neuron impulses. The chips connect wirelessly to a device behind the ear containing a Bluetooth radio. This sends signals to control a smartphone or computer.[520]
- Machine learning (ML) can radically reduce the workload of cell counting for disease diagnosis. Researchers at Benihang University (Beijing, China) have developed the new scheme for training a convolutional neural network (CNN) – a type of ML that mirrors the connection structure of the human visual cortex. The number and type of cells in the blood often play a crucial role in disease diagnosis, but the cell analysis techniques currently used to perform such counting of blood cells – involving the detection and measurement of physical and chemical characteristics of cells suspended in fluid – are expensive and require complex preparations. Worse still, the accuracy of cell analyzer machines is only about 90%.[521]

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[517] Christine Chow (2020) Artificial intelligence in healthcare, Investment Week, 4 December; https://www.investmentweek.co.uk/feature/4023966/artificial-intelligence-in-healthcare-the-do-no-harm-ethos-must-be-extended-to-its-application-in-the-sector/. Startups.co.uk Newsletter, 30 June 2019; https://www.labmedica.com/industry/articles/294787904/artificial-intelligence-ai-in-medical-diagnostics-market-to-reach-usd-386-billion-by-2025.html; https://www.labmedica.com/hematology/articles/294789897/artificial-intelligence-helps-diagnose-leukemia.html; https://www.labmedica.com/covid-19/articles/294795002/ai-takes-guesswork-out-of-lateral-flow-testing.html

[518] https://www.nature.com/articles/d41586-021-02025-4

[519519] https://www.newscientist.com/article/2356597-ai-has-designed-bacteria-killing-proteins-from-scratch-and-they-work/

[520] Emin Shinmaz (2020) Could Musk 's microchip really boost brainpower, *Daily Mail*, 29 August.

[521] https://www.labmedica.com/hematology/articles/294793039/machine-learning-radically-reduces-workload-of-cell-counting-for-disease-diagnosis.html

- The use of ML to grow artificial organs, especially to tackle blindness. Researchers from the Moscow Institute of Physics and Technology, Ivannikov Institute for System Programming, and the Harvard Medical School-affiliated Schepens Eye Research Institute have developed a neural network capable of recognizing retinal tissues. Unlike humans, the algorithm achieves this without the need to modify cells, making the method suitable for growing retinal tissue for developing cell replacement therapies to treat blindness and conducting research into new drugs. The method could be adapted to create other human artificial organs.[522]
- The use of ML, matrix factorization, deep learning, and topological data analysis, to improve understanding of the complex relationships between diseases or multimorbidities.[523]
- Combining ML, epigenetics, and next-generation sequencing (NGS) in a blood test for multi-cancer early detection[524]
- Combining AI and ML, e.g., in a blood test to identify cancer before it is visible or symptomatic.[525]
- The use of digital technologies, such as predictive analytics, by life companies for product innovation.[526] Predictive analytics makes use of data mining, predictive modelling and ML to analyze current and historical data in order to make predictions about the future. An example is a joint venture between Longevitytech.fund and Vesttoo to harness the power of AI and machine learning to forecast and price long-tail risks such as longevity, excess mortality, lapse, as well as Value-in-Force (VIF) monetization and excess mortality Industry Loss Warranties (ILW) and transfer them to the capital markets.[527]
- Combining AI and robotics to improve healthcare for the elderly. For example, Taiwan has created an AI robot which can interact with and accompany elderly when they are outside the hospital. This robot analyses the elderly's medical records, reminds them to take their medication, and measures their blood sugar levels. The robot also helps doctors give more timely diagnosis and monitor patients. It is able to combine the physiological data of patients and upload it to the cloud, where doctors can view it remotely. This allows them to detect any

[522] Machine learning will help to grow artificial organs, Open Access Government, 7 July 2020; https://www.openaccessgovernment.org/grow-artificial-organs/89945/

[523] Abdelaali Hassaine, Gholamreza Salimi-Khorshidi, Dexter Canoy, and Kazem Rahimi (2020) Untangling the complexity of multimorbidity with machine learning, *Mechanisms of Ageing and Development*,Volume 190, September 2020, 111325; https://doi.org/10.1016/j.mad.2020.111325

[524] https://www.labmedica.com/molecular-diagnostics/articles/294793279/index.php

[525] https://www.labmedica.com/hematology/articles/294791085/blood-test-combines-ai-and-machine-learning-to-detect-cancer-before-it-becomes-visible-or-symptomatic.html

[526] Demand for predictive analytics rises among life insurers, *The Actuary*, 26 November 2020.

[527] PRNewswire, 7 January 2021.

> abnormalities and immediately give a diagnosis. AI also helps doctors better communicate with their elderly patients. Most of the elderly in Taiwan speak only Hokkien. But an AI programme has been developed that automatically translates Mandarin to Hokkien, and vice versa, to assist doctor-patient communication.[528]

Clearly these developments are going to have a significant effect on diagnosing illnesses and improving health care and, in turn, on projections of future life expectancy.

Implications of global aging for financial markets and economic growth

Aging populations – as a consequence of both declining fertility and mortality – could have a big influence on the future returns and the volatility of returns on the assets in which pension funds and PRT providers invest, in addition to their impact on government spending on pensions and the sustainability of pension systems, as well as on the rate of economic growth.

Long-term real interest rates in developed countries have been falling since the mid-1980s. Before that they averaged around 3% back to the 1950s. They reached 0% in around 2012 and have fallen to as low as -2% in some European countries. The European Systemic Risk Board (2021) explains this new low interest rate environment (LIRE) in terms of:

- demographic developments including rising life expectancy and falling population growth rates (Acemoglu and Johnson (2007), Backus et al. (2014), Aksoy et al. (2019), Ferrero et al. (2019));
- falling (relative) price of investment goods and rising share of intangible investment (Karabarbounis and Neiman (2014), Thwaites (2015));
- slowing pace of technological innovation (Gordon (2016));
- falling marginal product of capital (related to demography and technical progress) (Cochrane (2021));
- rising wealth and income inequality (Summers (2014), Rachel and Summers (2019))
- rising savings rates in developing countries and the consequent increasing demand for assets issued by advanced economies (Bernanke (2005)); and
- declines in the consumption/wealth ratio which predict depressed real rates for an extended period of time (Gourinchas and Rey (2019)).

Summers (2013) describes the LIRE as 'secular stagnation' and some expect it to last for an extended period of time (e.g., Blanchard et al. (2014), Gourinchas and Rey (2019) and Kiley (2020)). The European Systemic Risk Board (2021) identifies four key areas of concern in the LIRE:

[528] https://govinsider.asia/health/how-ai-and-robots-are-caring-for-the-elderly-in-taiwans-ageing-society-dr-jenny-su-ncku/

- the profitability and resilience of banks: as net interest margins have trended downwards, banks have responded by increasing interest-earning assets and shifting the composition of their assets towards riskier market segments – including towards commercial real estate, consumer lending and SMEs;

- the indebtedness and viability of borrowers, as the LIRE facilitates higher leverage and encourages search-for-yield behaviour;

- systemic liquidity risk, as the LIRE have made the financial system more sensitive to market shocks;

- the sustainability of the business models of insurers and pension funds offering longer-term return guarantees, as they experience increasing pressures in the LIRE.[529]

Focusing on the demographic developments, Jen (2007)[530] argues that there are four important economic and financial implications:

- The level of real long-term interest rates will be affected by the changing fiscal outlook of countries. Potential economic growth rates vary with these demographic trends. Potential economic growth in countries with high dependency ratios will likely slow.[531] Not only will the growth of labour supply slow, but justifications for capital accumulation will be less compelling in an aging country. Further, as the population of a country ages, ceteris paribus, the aggregate wage bill may shrink, reducing tax receipts. At the same time, medical expenditures and other healthcare-related spending may crowd out the education expenses needed to enhance the productivity of the shrinking work force.[532] The end result is a shrinking tax base and rising budgetary demands. Without changes in the retirement age or female

[529] See also John Fell, Tuomas Peltonen and Richard Portes (2021) Lower for longer – macroprudential policy issues arising from the low interest rate environment, 2 June; https://voxeu.org/article/macroprudential-policy-issues-arising-low-interest-rate-environment

[530] Drawn from Jen (2007) – with updated data. See also Bohl et al. (2016).

[531] One study estimated that in Europe, a 1% increase in the old age dependency ratio (of those aged 65+ to those in work) decreased real per capita GDP by 0.4% (A 'back of the envelope' evidence on aging and growth in Europe, www.reforming.it, 30 March 2018). Key European countries are attracting headlines like this: 'Aging Germany Is Running Out of Workers, Putting Europe's Largest Economy at Risk'; https://www.pensionpolicyinternational.com/aging-germany-is-running-out-of-workers-putting-europes-largest-economy-at-risk/. In 2022, the German government announced that it wanted to attract 400,000 qualified workers from abroad each year to tackle both the demographic imbalance and labour shortages in key sectors that risk undermining the recovery from the coronavirus pandemic; https://www.pensionpolicyinternational.com/germany-wants-to-attract-400000-skilled-workers-from-abroad-each-year/

[532] In theory, investment to enhance total factor productivity could keep output growth high, even with a shrinking population.

participation in the labour force, what this means is that the levels of real interest rates in countries with aging populations may rise above what could be justified by their potential growth rates, as public borrowing needs grow and the private sector starts to dis-save during retirement, both of which drive up interest rates.

Aksoy et al. (2019) provide empirical evidence from OECD countries which confirm that population aging leads to subdued output growth, higher net savings and lower interest rates. In particular, an increase in the share of the dependent population and a decline in the share of the working age population lead to a statistically significant decline in real interest rates. However, these rates would be even lower without the impact of increased public borrowing and retiree dissaving.

- Yield curves should flatten in countries with aging populations and steepen in countries with younger populations. The shapes of the yield curves may change as well. With the monetary policy of most central banks driven by formal or informal inflation targeting, demographic trends could distort the shapes of the yield curves.

  In a country with an aging population (such as the US), in the short term, the Fed would need to have higher policy rates to stabilize inflation as potential growth decelerates. In other words, it should be more sensitive to lingering inflationary pressures at every given level of growth rate of aggregate demand. However, the long-term interest rate should be commensurate with the new, lower, potential growth rate and therefore should be lower, notwithstanding the possibility of a rise in the borrowing cost and retiree dissaving. This implies a flatter yield curve in the US and similar countries with aging populations.

  Similar logic suggests that the accelerating potential growth rates in younger countries tend to steepen their yield curves.

- Aging may affect the preferred structure of financial portfolios. Different generations have different risk preferences. There are two competing theories. On the one hand, it is thought that global aging may raise the equity premium, as aging households become less willing to warehouse risk. As a result, aging could benefit bond markets relative to equity markets. Most academics would agree with this.

  However, recent experience in Japan suggests an interesting alternative hypothesis. A fixed retirement age, coupled with ever improving life expectancy, has created a ‘longevity risk’, whereby retirees can no longer be confident of their ability to defend their lifestyle if they end up living much longer than they expect at the time of their retirement. In the case of Japan, this has led to more risk-taking, not less,

as retirees try to enhance their expected investment returns by diversifying away from assets with low credit risk. In contrast to the first hypothesis, this alternative hypothesis suggests that retirees should have a bigger appetite for equities.

- Asynchronous aging patterns in different parts of the world have implications for current account (C/A) imbalances. C/A imbalances are essentially savings-investment gaps.[533] If demographic trends drive the savings patterns in countries, then C/A imbalances should also be affected. The permanent income (or life cycle) hypothesis suggests that very 'young' and very 'old' countries tend to dis-save, while those with low dependency ratios should be saving. However, the constellations of the C/A imbalances in the world are not consistent with this pattern.

Jen (2007) continues: 'What this may imply is that, as Japan ages, its savings rate should decline, as retirees start to draw down their savings. This may very well start to happen. With a high C/A surplus position [4% of GDP in 2021], this prospective trend should not pose a problem for Japan. However, the same argument applies to the US, but with a high C/A deficit [3.8% of GDP in 2022], the US does not seem to have a great deal of scope to dis-save further. [Two other countries with large C/A surpluses (Germany and China)] are themselves facing aging pressures, and therefore downward pressures on savings. The implications for the dollar will be a function of how fast the US savings rate changes relative to that of the rest of the world'.

More recently, Goodhart and Pradhan (2020) argue that 'the underlying forces of demography and globalization will shortly reverse three multi-decade global trends – it will raise inflation and interest rates. …Deflationary headwinds over the last three decades have been primarily due to an enormous surge in the world's available labour supply, owing to very favourable demographic trends and the entry of China and Eastern Europe into the world's trading system. …These demographic trends are on the point of reversing sharply, coinciding with a retreat from globalization. The result? Aging can be expected to raise inflation and interest rates, bringing a slew of problems for an over-indebted world economy, but is also anticipated to increase the share of labour [in national income], so that inequality falls'. However, while nominal interest rates might rise, this does not necessarily mean that real interest rates will rise.

There are differing views on whether population aging leads to price volatility in asset markets, which would be the case if, for example, a relatively large old generation attempted to sell its asset holding to a relatively smaller younger generation to finance its

[533] This follows from the national income accounting identity: savings – investment = exports – imports (if government expenditure = taxation). If savings are low relative to investment, this will be associated with a current account deficit.

retirement. Mankiw and Weil (1989) argue that it does – at least in the housing market. However, Poterba (2001) could find no strong cohort effect. He estimated a flat financial asset profile in old age, indicating that there was little evidence of a mass disposal of assets in old age – at least in the US – and conjectured that this might be for precautionary or bequest motives. Similarly, Börsch-Supan (2006), using an open-economy model, predicts that capital outflows will restrict asset price reductions in the domestic economy, suggesting that open economies can avoid some of the demographic effects that depress saving rates and the rate of return on capital. On the other hand, it is possible that imperfections in international capital and traded goods markets could well contribute to international asset price volatility arising from differential aging across countries.[534]

The bottom line, according to Jen (2007) is that 'demographic trends have important economic and financial implications'.

What pension funds need is, as Ferrero et al. (2019, p275) point out: 'structural reforms and fiscal policies that encourage later retirement and promote innovation and investment in research and development. These policies would also reduce the negative impact of aging on potential output growth, although their effects would materialize only gradually. An acceleration in technological innovation (Brynjolfsson and McAfee, 2014), arising from the unfolding of the "the second machine age" could offset the impact of adverse demographic developments and raise potential output growth'.

Indeed, Acemoglu and Restrepo (2021) have found evidence that aging, because it creates a shortage of middle-aged workers specializing in manual production tasks, leads to greater industrial automation. Aging is associated with the greater adoption of robots and other automation technologies and that more automation innovation occurs in countries undergoing faster aging. Further, productivity improves relatively in industries that are more amenable to automation.

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[534] This is an implication of Borio and Disyatat's (2015), Ford and Horioka's (2016, 2017), and Horioka and Ford's (2017) explanation of two of the so-called macroeconomic puzzles identified by Obstfeld and Rogoff (2000), in particular, the Feldstein-Horioka puzzle and the purchasing power and exchange rate disconnect puzzle. The former puzzle, identified by Feldstein and Horioka (1980), is the high correlation between domestic savings and investment rates when there should be no correlation if capital mobility is perfect. The second puzzle, identified by Meese and Rogoff (1983), is that real exchange rates can deviate from purchasing power parity exchange rates for considerable periods which should not be possible if there was a high degree of mobility in internationally traded goods. However, Borio and Disyatat (2015), Ford and Horioka (2016, 2017) and Horioka and Ford (2017) argue that these are not real puzzles at all. The first study argues that the puzzles are a consequence of the 'failure to maintain a clear distinction between net resource flows [i.e, the gap between savings and investment] and financing flows'. The latter two studies make the same point in a different way: 'financial markets alone cannot achieve net transfers of financial capital and cannot equalize real interest rates across countries – [and this] also helps explain why previous attempts to connect changes in the exchange rate to economic fundamentals have not been successful'. It is clear that, given the slow response of the global economic and financial system to savings, investment and trade imbalances, then differential population aging will add an additional source of asset price volatility.

At the same time, a report by the American Association of Retired Persons found that the 50-year-plus population accounts for a large portion of global GDP and recommends that policies should be implemented that enable older citizens to be as productive as possible. This would require governments and companies to abandon ageist stereotypes and make the kind of investments that harness the opportunities unleashed by increased longevity, such as policies to promote lifetime training and initiatives to boost late-life entrepreneurship. The report looked at the 50-plus population across 79 countries between 2020 and 2050, and predicts that their contribution to global GDP could increase between 2020 and 2050 from $45 trillion to $118 trillion. Much of that would be driven by people working longer and continuing to contribute in their 50s, their 60s, and even their 70s, depending on their health.[535]

Workers are also taking a more flexible attitude to retirement in some countries. For example, a survey by abrdn for its *Class of 2022* study of 2,000 UK workers due to retire in 2022 found that 66% planned to remain employed in some form compared to 56% in 2021 and 34% in 2020. The survey found that 24% will go part-time with either the same job or a new one, 15% will continue to work for their own business, and 12% plan to become entrepreneurs and start their own business. The main reasons cited for 'flexi-retirement' include needing the income (31%) and wanting to keep busy (32%).[536]

It is clear from this look into the future that longevity risk is likely to increase going forward – even the direction of the trend change in life expectancy will be more uncertain than it has been in recent decades. In addition, there is likely to be increasing uncertainty about the real level and volatility of the returns on the assets which pension funds and PRT providers need to hold to achieve their objectives. Technological developments and changing retirement patterns will also influence outcomes.

Longevity 16: 2021

As with the previous conferences, *Longevity 16 (L16)* consisted of both academic papers and more practical and policy-oriented presentations. There were four plenary sessions and the following keynote speakers and panellists contributed to these sessions:

[535] https://www.pensionpolicyinternational.com/why-an-aging-population-doesnt-spell-economic-doom/
[536] https://www.professionaladviser.com/news/4047456/flexi-retirement-trend-emerges-thirds-plan-research

- Plenary Session 1

  - Stephen Kramer (Swiss Re Institute) opened the conference with a presentation entitled 'Modelling the Covid-19 pandemic'. He explained that the standard infectious disease model is the SIR model.[537] There are three aspects to the model:
    - timing, duration and severity of illness (asymptomatic, mild, hospital, intensive care unit (ICU), dead) – determines the burden on the health system
    - timing, duration and level of infectiousness – determines the next generation of infections
    - rate of lethality (death-per-infection) / IFR (infection fatality rate) – this was age-specific (the vast majority of fatalities were elderly) and country-specific.

    The model can give a sense of possible attack rates and mortality under various scenarios, but, more importantly, is useful in developing strategies for determining whether containment is possible and which interventions would be most effective, such as: rapid self-identification, isolation and contact tracing versus social distancing and closures of schools and workplaces.

- Nicola Oliver (Medical Intelligence) discussed 'The Covid-19 vaccine landscape: Progress, challenges, and the road ahead'. She pointed out that most vaccines take years to develop, but scientists – such as Drs. Ugur Sahin and Ozlem Tureci, co-founders of BioNTech – developed multiple vaccines for Covid-19 (SARS-CoV-2) within one year. This included the first three phases of clinical trials – phase I: trials to test the safety of a new treatment; phase II: trials to test the efficacy of the new treatment on a small sample of patients; phase III: trials to test the efficacy of the new treatment on a large sample of patients.[538] The vaccine works by creating an immune response in the form of antigen presenting cells which ingest the virus and display proportions of it to activate T helper cells. These enable other immune responses: B cells make antibodies that can block the virus from infecting cells, as well as mark the virus for destruction. Cytotoxic T cells identify and destoy virus-infected cells. Long-lived 'memory' T and B cells that recognize the virus can patrol the body for months and years, providing immunity. The vaccines have an efficacy of 90% which means that 90% fewer people contract the disease when they come into contact with the virus, significantly reducing hospitalization and death.

[537] Where S is the number of susceptible individuals, I is the number of infected individuals, and R is the number of recovered individuals; https://www.maa.org/press/periodicals/loci/joma/the-sir-model-for-spread-of-disease-the-differential-equation-model

[538] Phase IV trials – which find out more about efficacy, side effects and safety – are ongoing.

The optimal efficacy was reached after the second dose. Challenges ahead relate the supply chain (in particular manufacturing and storage), variants (e.g., the omicron variant was more transmissible but had lower severity of illness, compared with earlier variants), equity (economic recovery depends on securing equal access to vaccines in all countries) and misinformation (spread by social media). Finally, it looks as though the virus will transition from being pandemic to being epidemic, like flu.

- Josephine Robertson (Health & Care / Risk Actuary) discussed 'Long Covid'.

- Plenary Session 2

- Hamish Galloway (RGA Re) gave a presentation on 'Counterparty risk and the effects of regulation in structuring transactions'. He pointed out that the longevity risk transfer market is now a very large market – individual transactions of £3-10bn are not uncommon – with potential counterparty risk. The primary market transfers longevity risk from pension funds to insurers. The insurance market is backed by capital, but capital is expensive. The secondary markets are the reinsurance and retrocession[539] markets. For insurers based in Europe, longevity risk is migrating offshore to the most capital efficient location and reinsurance is the conduit. This is because of the size of the risk margin in Solvency II. In the US, there is no offset to capital requirements and risk stays onshore with little or no secondary market activity to date. Reinsurance swaps longevity risk for counterparty risk which is low since counterparties are generally well-rated and the required capital generated is small; also counterparty risk diversifies. Nevertheless, insurers must consider the failure of their largest counterparty at an inconvenient moment: the risk will fall back onto their own balance sheet, there will be current losses plus the need to re-establish their capital position in a distressed environment, and a recovery and resolution plan will need to be established. Various tools exist to minimize the impact of reinsurer failure, such as collateral, diversification of reinsurance, external guarantees (e.g., credit default swaps), cut-through clauses which allow reinsurers to modify the original reinsurance agreement in certain conditions, and recouponing (if a swap gets out of line, collateral is paid down and terms are reset to something closer to what is now expected). Counterparty calculation is now a common negotiating point in reinsurance treaties.

- Amy Kessler (Head of International Reinsurance Strategic Initiatives, Prudential Financial) gave a presentation entitled 'Resilient in a crisis: How pandemic insights supported a rock solid longevity risk transfer market in 2020'. She

[539] Retrocession is reinsurance for reinsurers.

explained the following related markets turned out to be very resilient during the Covid-19 pandemic: pension/longevity risk transfer, funded reinsurance, and life reinsurance capital raising and sidecars. In the pension/longevity risk transfer market, the volatility of funded status and the unpredictability of mortality rates during the pandemic increased the incentive for well-funded plans to exit the risk – and in 2020, the UK and US buy-in and buy-out market volumes were the second- and third-highest on record. The arrival of funded reinsurance supported the continued growth in the UK pension de-risking market, since insurers were able to bring in reinsurance partners with capital and asset management expertise. In these transactions, insurers transfer asset and longevity risk and receive indirect access to the reinsurer's asset management capabilities and illiquid asset origination. Finally, life reinsurers are raising new third-party capital through sidecars where the risk is co-shared. Private equity companies, such as KKR, Blackstone and Apollo Global, are acquiring insurance platforms or investing in insurance blocks through sidecars and thereby facilitating a traded longevity market. Since 2018, there has been over $20bn in investor capital leveraged for the life and annuity markets, supporting nearly $400bn in liabilities.

- This session ended with a panel discussion called 'The challenges of valuing future pension liabilities post Covid-19'. The panel members were Amy Kessler, Douglas Anderson (ClubVita) and Tim Gordon (Aon) It was chaired by Guy Coughlan (Universities Superannuation Scheme).

- Plenary Session 3

- Cord-Roland Rinke (Hannover Re) spoke about 'Creating opportunities beyond longevity risk transfer'. He accepted that standard longevity reinsurance was a comprehensive, intuitive and field-proven solution. But he then discussed some examples of new tailor-made structures:

  Bespoke Regular Premium Annuity Treaty (RPAT) with cash flow optimization. This is a proportional reassurance agreement – typically a quota share. The reinsurer pays the actual annuity benefits for the reassured business and receives regular reinsurance premiums equal to the expected annuity payments plus a fee, fixed at inception, based on best estimate mortality and mortality improvements. There is a net settlement of cash flows.

  Home reversion RPAT. This is a reinsurance agreement involving a quota share swap of actual and expected annuity payments. The aim is the stabilization of cash flows and longevity cover.

Limited term cover for longevity in pension and annuity payments. This provides reinsurance cover only for the initial years, together with a) a structured fee, b) forced termination/recapture, and c) a fee after year *x* depending on experience.

Corridor solution for longevity in pension and annuity payments. This provides carve out cover with symmetric up- and down-sides. Three corridors for the payments are specified. If the actual payments (floating rate) lie in the central corridor, the reinsurer receives a reinsurance fee only; mortality deviations from the fixed rate of +/- x% are retained by the insurer. If the actual payments lie in the upper corridor, the insurer receives the difference (within the corridor), but this is restricted to the upper bound. If the actual payments lie in the lower corridor, the reinsurer receives the difference (within the corridor), but this is restricted to to the lower bound.

Longevity index cover provides longevity trend protection and capital relief. The positives are: no experience data required, no data cleansing, and limited duration at a level acceptable for the capital markets. The negatives are: the challenge of the termination assumptions, gaining regulatory approval, and the recognition that there is no perfect portfolio hedging. There are three steps: step 1 – rebuild the actual portfolio via a simplified artificial portfolio; step 2 – use an officially published population mortality index instead of the portfolio mortality, so that the present value of the liabilities 'equals' past and future annuity exposure for the artificial portfolio based on the realized past and projected future official mortality index; step 3 – the final payment has an excess of loss (equivalent to a bull call spread[540]) structure, with a claim payment if the present value of liabilities exceeds the attachment point (of the official index value at the transaction end) capped at the detachment point.

- Avery Michaelson (Longitude Solutions and Longitude Exchange) gave a presentation called 'Constructing a longevity market that works for all stakeholders: Exploring market inefficiencies in managing longevity risk on a global basis, and suggestions for regulatory and market-based way to correct them'. He began by accepting that insurers and reinsurers have so far been very successful in transferring longevity risk from pension plans, but there were some key issues emerging, such as capacity constraints, concentration and counterparty risks, the size of the risk margin, and uncertainty surrounding the capital benefit from index hedges. The solution is to bring in new investors via the capital markets. The attractions are that longevity risk is uncorrelated with other asset classes, index

[540] See, e.g., Figure 19 in Blake (2018).

longevity risk can be modelled by financial quants, and taking trend risk with a fixed downside and maturity is like an alternative fixed income asset with which the financial markets are familiar. However, there is currently insufficient deal flow to dedicate resources and there needs to be options for secondary liquidity to develop. To overcome this, Michaelson helped to set up the Longitude Exchange as a marketplace for longevity risk. It brings hedgers and investors together on a digital platform designed for transacting longevity risk. By providing a marketplace, Longitude Exchange will drive down frictional costs and timelines, leading to more transaction volume and presenting an option for secondary liquidity. LE's tools streamline the process of hedging and investing in longevity risk:

- For hedgers: hedge reporting – receive reporting, payment and collateral instructions; hedge placement – conduct auctions, negotiate terms and execute deals; hedge construction – construct trades optimized for risk and capital objectives; hedge analysis – measure hedges impact on risk and capital positions; hedge management – increase or decrease hedges through secondary trading.

- For investors: longevity modeling – models and datasets to generate longevity scenarios; secondary trading – list positions, request bids, and buy listed transactions; on-going valuations – live quotes and historical trades to mark positions; investment analysis – price transactions using longevity scenarios; investment execution – place bids and negotiate terms with counterparties.

- Luca Tres (Head of EMEA Strategic Risk and Capital Life Solutions at Guy Carpenter) gave a talk called 'Capital market investors and longevity risk: the past – and more importantly – the future'. He began by considering some old myths about capital markets and longevity:

  'The duration cannot be longer than 10 years'. This is only partially true. Most of the recent structures have long final maturities and a much shorter expected one, i.e., the focus has partially shifted to the expected maturity. Still most capital market investors cannot take transactions with a final maturity of 20+ years.

  'It needs to be remote risk'. This is only partially true. The out-of-the-money structuring has been mostly driven by Solvency II on the cedant's

side. Still, it is true that capital markets investors tend to have a preference for remote risk hedges.

'It needs to be population index based'. This is not true. Most of the recent transactions have been indemnity based. Sophisticated investors do not have a strong preference and index transaction are suboptimal for cedants (due to basis risk). Population index transactions might make sense for new entrants and can be relevant to expand the potential investor universe.

He then considered some capital market structures that he thought would be successful:

'Hedge Fund Re' model. The insurer enters into a standard longevity reinsurance contract with a reinsurance vehicle. The vehicle is typically owned by private equity, a hedge fund or more generally capital market investors. The only difference compared to the traditional structure is the mindset of the reinsurer. Unlike most traditional reinsurers, the reinsurer will strongly focus on the asset return as its key source of return on equity. Since this type of reinsurer is mostly focused on the asset management component, it often wants to hedge out longevity. Pros: simple reinsurance structure; flexible structuring. Cons: complexity in finding the asset mix that complies with local regulation plus gives the insurer comfort on counterparty risk and gives the reinsurer the intended expected return (will require switching into less liquid assets); counterparty risk and collateral considerations; high regulatory complexity in Europe. A number of players active in the space operate from a balance sheet outside Solvency II (often in Bermuda). While it depends on the specific structure and asset mix, generally moving long dated risks outside Europe might often find pushback from the EU regulators. A number of players in these areas have weaker rating levels compared to most of the 'traditional' reinsurers – although this is not necessarily linked to their financial strength but simply to the shorter track record. A longer (and strong) track record helping on the regulatory front, the hedge fund re model is expected to play a major role in the future longevity.

Capital market investors longevity swap (typically life ILS funds). The insurer enters into a longevity reinsurance contract with a reinsurance cell. This is typically done with an attachment and detachment point to cap the maximum counterparty exposure. The reinsurance cell passes all the risk to a capital market investor with a longevity swap. If the insurer does not

require a reinsurance treaty from a legal standpoint, the same result can be achieved with capital market investors transacting a longevity swap directly with the insurer. Pros: flexible structuring; quick(er) execution. Cons: counterparty risk/collateral structuring required; likely to attract higher regulatory scrutiny as it is more innovative than traditional solutions; it requires an attachment and detachment point to set a maximum counterparty risk limit (bringing additional regulatory checks). Counterparty risk is a key factor, since almost all capital market investors are unrated, hence additional structuring is required to tackle this challenge. Investment banks used to intermediate these transactions, providing a rated counterparty to insurers. However, the changing regulatory landscape (e.g., the Dodd-Frank Act) has made this intermediation expensive. Instead, reinsurers are sometimes acting as fronter: their more sophisticated internal credit system can apply an internal rating to the counterparty risk. There are possible alternative structuring solutions. For example, large asset managers could pledge available assets; however, because of investors' right to redeem, this might be an option only for a minority of the funds. More and more capital market investors are looking at rated solutions, either directly or through a fronter. This format is expected to play a key role in longevity derisking in the future.

Future new investors include sovereign wealth funds and very large asset managers. Tres concluded that we are close to making longevity a sustainable risk for our financial industry and our society. If not now, when?

- Plenary Session 4

Douglas Anderson, Chief Visionary Officer of Club Vita and Steven Baxter, Club Vita's Chief Data Scientist gave a joint talk entitled 'Necessary remaining steps to encourage more transactions'. They began by summarizing today's insurance market: bespoke private contracts, typically between two parties; a small group of risk takers with deep specialism; long duration commitments (with penalties on early exit); tracks a named group of lives – the market is illiquid and physical. They then offered a vision of tomorrow's capital market: standardized contracts; a larger pool of investors (e.g., thematic hedge funds); penalty-free early exit (at the prevailing market price); tracks published proxy index – the market is liquid and synthetic. The aim is to give ILS mass appeal for longevity cedants. The current perceptions of the ILS market is that it is short time horizon (c.10 years) and more expensive (since an illiquidity premium is included in the price). The keys to

unlocking the market are to make secondary trading easier and to help market sentiment to develop – and the common criterion for achieving both is better data.

Secondary trading can be made easier through the use of timely, reliable and relevant proxy indices. The liquity 'battle' needs to recognize that the capital markets need timeliness, while risk cedants need relevance and reliability. Relevance means dealing with 'basis risk', the socio-economic differences (including mortality trend differences) between a particular pension plan and the national population. This can be estimated using member postcodes and pension amount. Reliability relates to the accuracy of national statistics - national population indices tend to rely on estimated populations and actual deaths. Population estimates can involve significant biases.[541] Timely, relevant and reliant data can be achieved using life existence checking (LEC) service providers. This involves non-invasive identification of deaths in advance of formal confirmation with pension plan updates, and reduces the lead time for robust insights from c.18 months to c.3 months.

Developing market sentiment requires an understanding of the key factors that could lead to either higher or lower future life expectancy. First, the Covid legacy could lead to both longer lives for survivors (due to improved hygiene, reduced infectious disease deaths, immunity of survivors) and shorter lives (due to the impaired health of some survivors and delayed treatments, e.g., for cancer). Second, there is an acceleration in technology innovations. The mRNA vaccine revolution is just beginning. mRNA brought us a Covid-19 vaccine in record speed. Next it could tackle flu, malaria or HIV. Third, investor pressure for health improvements. For example, Business for Health is a business-led coalition supporting long-term sustainable innovation and investment in preventative health and care. Its aim is to enhance the health and economic resilience of the UK, catalysing and facilitating business contributions to achieve Mission 7 of the UK's Levelling Up ambition: to reduce health inequalities and add five years to healthy life expectancy ('HLE+5').[542]

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[541] As shown by Cairns et al (2016). See also the article in *The Economist* dated 17 December 2016 entitled 'The curious case of Britain's missing nonagenarians' which begins: 'Anyone who comes across 50,000 missing nonagenarians should notify the Office for National Statistics (ONS) at once. "There is no definitive count of the population aged 90 and over in England and Wales," the statisticians acknowledged in a little-noticed report on December 12th. The ONS compared three estimates, which varied by more than 46,000, or nearly a tenth of the official total. Why is it so hard to measure the number of oldies? The official count of the population is the census, taken every ten years. On an annual basis, estimates are produced by rolling forward the census figures and allowing for deaths and migration. By this measure, in 2015 there were 504,030 people aged 90 or over'; https://www.economist.com/britain/2016/12/17/the-curious-case-of-britains-missing-nonagenarians

[542] https://www.businessforhealth.org/

Different investors will take different views on how these key factors will pan out in future – and this diversity of investor opinion is essential for a market to develop. There will be both longevity bears (equivalent to mortality bulls) and longevity bulls (equivalent to mortality bears) and the balance between the two will drive market prices up or down. Diversity of view is essential for a liquid market to develop. By equipping a new breed of traders with the tools to express their longevity/mortality sentiment, longevity swaps can evolve into liquid and tradeable capital market instruments, providing a new investment opportunity. One such tool is a dashboard of leading longevity indicators. It will have three phases: observed mortality (short duration phase), observed morbidity (medium duration phase), future interventions (long duration phase). The innovations required for success in the three phase are respectively, 'quicker' (i.e.faster insights), 'translation', and 'visibility'. By making it easier for a larger pool of professional investors to take different thematic health views, we can increase the appetite for longer durations and enable better pricing.

- Roshan Tajapra (SCOR Life) gave a talk called 'Why smooth the past? How to deal with abnormal years of mortality experience'. The exceptional Covid-19 mortality experience in 2020-21 posed a problem for setting base mortality rates. Many actuaries ignored or applied limited credibility to 2020-21 data for future experience analyses. However, Tajapra offered a framework to allow the inclusion of such outliers. It involved adjusting the improvement rate in the first year of projection to get back to trend (denoted a 'bounce back' adjustment) and then adjusting the base mortality table to avoid double-counting.

- Razvan Ionescu (SCOR Life) gave a presentation called 'The end of life tables? Mortality modelling history and outlook'. Life tables were originally developed by people such as Johan de Witt, Edmond Halley and Pierre-Joseph Cambon to improve the pricing of life annuities – which originally was not based on age. Over time, the pricing became more sophisticated by including factors such as gender and social class. Recently, with the advent of machine learning and big data, computational power has significantly increased, allowing much wider information sets to be analysed. An example is the random survival forests algorithm which generalizes the survival tree algorithm. The survival tree algorithm segments the population based on mortality. For each final segment, mortality is estimated. This is equivalent to dividing a population in several groups and constructing a life table for each group. It is close to current actuarial practice. By contrast, the random survival forests algorithm performs data sampling, ands then for each sample, a survival tree is constructed. The final prediction is obtained by averaging the

prediction of each constructed tree. It is equivalent to constructing thousands of life tables and averaging them. Ionescu ended by asking whether this means the end of standard life tables.

- Guy Coughlan (Universities Superannuation Scheme, USS) considered 'The implications of Covid-19 for pension scheme longevity'. He first asked how the impact of Covid-19 at a national level is reflected in pension plan mortality. The answer depended on two key observations. First, pension plans have very different member profiles which vary by gender, age, socio-economic group, location, etc, so the impact of Covid-19 on a particular pension plan's mortality will reflect its particular member profile which in general will not be the same as the impact on the national population. Second, following the research of Cairns et al. (2020), Covid-19 mortality in adults appears to be proportional to all-cause mortality (at higher ages), i.e, Covid-19 mortality rate = [All-cause mortality rate] × [infection rate] × [relative frailty].[543] Hence, Covid-19 mortality for a particular pension plan can be estimated from the all-cause mortality appropriate for its profile of members. Using USS to illustrate, the member profile suggests Covid-19 mortality should be lower than for the national population, since most members (> 60%) live in the higher socio-economic areas in South and Central England which have the lowest mortality rates. In fact, USS all-cause mortality is much lower than even the least deprived decile (IMD-10)[544] of the English population. A closer look at IMD centiles, shows USS male life expectancy in the top 1% of the national population. Because Covid-19 mortality is proportional to all-cause mortality, the impact of Covid-19 on USS was expected to be very low. This is what happened: excess deaths for USS over 2020-21 followed a similar cumulative profile to the total for England, but at a lower level, with cumulative percentage excess deaths for USS about half that of the national population during the first Covid-19 peak (during April-May 2020) about 40% lower during the second peak (January-February 2021). Coughlan concluded:' While not impossible, it seems unlikely that Covid-19 will have a significant long-term impact on pension plans'.

The academic papers that were selected by us as the editors of this Special Issue went through a refereeing process subject to the usual high standards of the *Journal of Demographic Economics.* They cover the following themes: the implications of Covid-19 for the longevity risk transfer market; longevity-linked transactions, such as buy-ins, buy-

[543] Relative frailty is measured as the ratio of the death rate at age x from Covid-19 (conditional on being infected) to the death rate at age x from all causes in the absence of Covid-19. It recognizes, for example, that older males are more frail than females, and that more deprived people are more frail than less deprived people at a given age.

[544] Index of Multiple Deprivations; https://www.gov.uk/government/collections/english-indices-of-deprivation

outs, longevity bonds and equity release mortgages; the impact on life expectancy on marriage, economic disadvantage, and disabilities and diseases such as cancer; the financial burden of cancer insurance; and mortality models that take account of Covid-19 shocks, Covid-19 frailty heterogeneity, and mortality differentials between different populations using long memory processes. We briefly discuss each of the 10 papers selected.

In 'Resilience in a Time of Crisis: How Covid-19 Pandemic Insights are Supporting a Vibrant Longevity Risk Transfer Market', Amy Kessler explains that pension risk transfer and longevity risk transfer are now growing secular trends. From North America to Europe, companies are de-risking pension plans in near-record volumes and have continued to do so throughout the pandemic—at or near the most favourable pricing experienced in years. The arrival of funded reinsurance on both sides of the Atlantic is bringing reinsurer capital and private assets to support the steady growth in the pension risk transfer market. Additionally, the enduring low interest-rate environment and quest for uncorrelated risk has seen the world's largest investors directing billions into life reinsurance sidecars. Kessler investigates how these markets thrived during the worst global pandemic in a century. The answer is that key research on the pandemic's impact on pensioner life expectancy allowed prices to be set and transactions to proceed through a time of significant uncertainty.

In 'Buy-ins, Buy-outs, Longevity Bonds, and the Creation of Value', Richard MacMinn, Yijia Lin, and Tianxiang Shi argue that unanticipated increases in life expectancy expose corporations and pension funds to the risk of insufficient funds to pay a more extended stream of annuity benefits. Buy-ins, buy-outs, and longevity bonds provide pension funds with insurance and financial market instruments designed to hedge longevity risk. The most straightforward instruments and the most robust markets are currently for buy-ins and buy-outs. A model developed by the authors shows that these instruments transfer value to pension holders and, other things being equal, would not be used by firms since shareholder value is reduced. The analysis, however, also shows that these instruments can be used to solve the under-investment problem created by underfunded pension plans and so increase not only the pension fund value but also the corporate stock value.

Dean Buckner and Kevin Dowd contributed a paper entitled 'A Market Consistent Approach to the Valuation of No Negative Equity Guarantees and Equity Release Mortgages'. In addition to providing a new market consistent approach to the valuation of 'no negative equity guarantees' and 'equity release mortgages', the paper also provides a new approach to the estimation of the volatility inputs. The proposed approach to volatility produces a volatility term structure that is dependent on the age and gender of the borrower. Illustrative valuations are provided based on the Black '76 put pricing formula and

mortality projections based on the M5 Cairns-Blake-Dowd (CBD) mortality model. Results have interesting ramifications for industry practice and prudential regulation.

In 'The Effect of Marital Status on Life Expectancy: Is Cohabitation as Protective as Marriage?', Anne G. Balter, Dorethe S. Bjerre, and Malene Kallestrup-Lamb argue that marital status is an important predictor for life expectancy. However, non-married individuals are often misclassified as singles which ignores the heterogeneity within the group. The paper shows the importance of distinguishing between types of singles, and in particular whether they are cohabiting, when predicting life expectancies. The authors use unique and detailed longitudinal register data to track marital status throughout the individual's lifetime. They find that all types of singles consistently benefit from living with a partner, i.e., after divorce, becoming widowed or never being married. This result holds for both men and women. For certain types of cohabiting singles, the authors reject significant differences in life expectancy compared to married individuals. Finally, they use a case study to show that, like married individuals, all types of singles that cohabit also serve as informal caregivers and have the potential to limit end-of-life long-term care expenditure levels.

In 'Counting the Cost of Inequality', Les Mayhew argues that an aging population increases pressure on health and social care, on welfare payments and on pensions – and hence on taxes, especially in public funded systems. There is no simple measure linking health, on the one hand, to economic disadvantage, on the other– and hence the tax burden that would be needed to pay for health and welfare services. The author imagines a situation in which each local area is responsible for financing its own public services out of earnings. He classifies all local authorities in England according to their health, life and work span. He hypothesizes that a local tax is levied to cover health care costs, welfare benefits for those sick and unable to work, and state pension payments. He uses a model to partition life time costs to the public purse based on years spent in ill health, disability and pensionable years over the life course using the average costs per person per year for each district. He argues that differences in these hypothetical tax rates between districts provide a summary measure of inequality since a higher tax burden would fall on those who can least afford it. He shows that a one-year improvement in healthy life expectancy would add around 4.5 months to life expectancy and 3.4 months to working lives in England whilst reducing the tax burden by around 0.5%. He casts doubt on current UK government targets to increase health expectancy by five years by 2035; however, were it to be achieved it would add an estimated 23 months to life expectancy and 17 months to work expectancy and reduce taxes by 2.4%.

Marjan Qazvini contributed a paper entitled 'Survival Analysis of Longitudinal Data: The Case of the English Population Aged 50 and Over'. The paper analyses data from 5 waves

of the English Longitudinal Study of Aging (ELSA). The aim is to study the impact of demographic and self-rated health variables, including disability and diseases, on the survival of the population aged 50+. The disability variables considered are mobility impairment, difficulties in performing Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL). One of the problems with the survey is missing observations. This may happen for different reasons, such as errors, nonresponses and temporary withdrawals. The author addresses this problem by applying single and multiple imputation methods and then fitting a Generalized Linear Model (GLM) and a Generalized Linear Mixed Model (GLMM) to the data. The results indicate that a GLMM performs better than a GLM in terms of information criteria. The paper also looks at the predictability of the model in terms of the receiver operating characteristic (ROC) and the area of ROC. The author concludes that among the disability factors, IADL, and among the diseases, cancer, significantly affect the survival of the English population aged 50 and older.

Hsin-Chung Wang, Jack C. Yue, Ting-Chung Chang, and Ting-Chen Chang contributed a paper entitled 'Morbidity Compression and Cancer Insurance'. Cancer is among the leading causes of death in the world, with about 10 million deaths, one in every six deaths, related to cancer in 2020. Asian countries suffer even more from cancer. For example, in Japan and the Four Asian Tigers (Hong Kong, Japan, South Korea, and Taiwan), cancer is the leading cause of death. In Taiwan, cancer insurance is the most popular commercial health product. However, the loss ratio of cancer products increases with policy year and exceeds 100% in many insurance companies. In addition, almost all cancer benefits are significantly limited in order to avoid financial insolvency. In this study, the authors evaluate the risk to the provider from offering cancer insurance from the perspective of morbidity compression. They obtain age-specific survival rates and medical expenditures for those diagnosed with cancer, as well as mortality rates and cancer incidence rates, using the data from Taiwan's National Health Insurance Research Database. Also, they apply the standardized mortality ratio (SMR) and the Lee-Carter model to estimate the trend of cancer-related values. They find that cancer incidence rates gradually increase with time, which indicates that the assumption of morbidity compression is violated. On the other hand, the mortality rates and survival rates of cancer patients decrease significantly annually. Thus, length of life with cancer increases, and so does the cancer insurance premium. The authors recommend that cancer insurance covers only the first five years of medical expenditure after the insured is diagnosed with cancer. This can greatly reduce the burden on insurers and provide a possibility to deal with the cancer longevity risk.

In 'Accounting for Covid-19-Type Shocks in Mortality Modeling: A Comparative Study', Simon Schnürch, Torsten Kleinow and Andreas Wagner point out that mortality shocks such as the one induced by the Covid-19 pandemic have a substantial impact on mortality models. They describe how to deal with this in the period effect of the Lee-Carter model.

The main idea is to not rely on the usual normal distribution assumption as it is not always justified. Instead, the authors consider a mixture distribution model based on the peaks-over-threshold method, a jump model and a regime switching model and introduce a modified calibration procedure to account for the fact that varying amounts of data are necessary for calibrating different parts of these models. They perform an extensive empirical study for nine European countries, comparing the models with respect to their parameters, quality of fit and forecasting performance. They define five exemplary scenarios regarding the future development of pandemic-related mortality. As a result of their evaluations, the authors recommend the peaks-over-threshold approach for applications with a possibility of extreme mortality events.

In 'Effect of the Covid-19 Frailty Heterogeneity on the Future Evolution of Mortality by Stratified Weighting', Maria Carannante, Valeria D'Amato, and Steven Haberman start by pointing out the inadequacy of assuming, in the construction of a model of mortality, that frailty is constant for the individuals comprising a demographic population. This assumption is implicitly made by standard life table techniques. The substantial differences in the individual susceptibility to specific causes of death lead to heterogeneity in frailty, and this can have a material effect on mortality models and projections – specifically a bias due to the underestimation of longevity improvements. Given these considerations, the authors develop a stochastic model based on a stratification weighting mechanism, which takes into account heterogeneity in frailty. Furthermore, the stratified stochastic model has been adapted also to capture Covid-19 frailty heterogeneity, that is a frailty worsening due to the Covid-19 virus. Based on different frailty levels characterizing a population, which affect mortality differentials, the analysis allows for forecasting the temporary excess of deaths by the stratification schemes in a stochastic environment.

Finally, in 'The Impact of Long Memory in Mortality Differentials on Index-based Longevity Hedges', Kenneth Q. Zhou and Johnny Siu-Hang Li point out that in multi-population mortality modeling, autoregressive moving average (ARMA) processes are typically used to model the evolution of mortality differentials between different populations over time. While such processes capture only short-term serial dependence, it is found in their empirical work that mortality differentials often exhibit statistically significant long-term serial dependence, suggesting the necessity for using long memory processes instead. In this paper, the authors model mortality differentials between different populations with long memory processes, while preserving coherence in the resulting mortality forecasts. The results indicate that if the dynamics of mortality differentials are modeled by long memory processes, mean reversion would be much slower, and forecast uncertainty over the long run would be higher. These results imply that the true level of population basis risk in index-based longevity hedges may be larger than what we would expect when ARMA processes are assumed. The authors also study how index-based

longevity hedges should be calibrated if mortality differentials follow long memory processes. It is found that delta hedges are more robust than variance-minimizing hedges, in the sense that the former remain effective even if the true processes for mortality differentials are long memory ones.

Longevity 17 took place place on 12-13 September 2022. The plan was to hold a physical conference in Toronto in Canada. Unfortunately, during the early planning stage in December 2021, the Canadian government decided, in response to a surge in Covid-19 cases, to impose an international travel ban and, following discussions with our conference sponsors, we decided to hold L17 online. We also decided to call the conference the Waterloo conference to acknowledge all the ground work Johnny Li had expended in trying to get a physical conference for 2022. We did not want to call it the Toronto conference because we are determined to hold a physical conference in Toronto at a future date and will not be put off by a 'little critter'[545] called SARS-CoV-2. *Geneva Papers on Risk and Insurance* will publish a special issue. *Longevity 18* will take place on 7-8 September 2023 at Bayes Business School in London. The *European Actuarial Journal* will publish a special issue.

Finally, we would like to express our deep sadness on hearing of the tragically early death of Professor Ken Seng Tan in 2022. He was a long-time supporter of our conference series and organized *Longevity 9* in Beijing in September 2013. We offer our sincere condolences to his family and friends.

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[545] So named by the immunologist and geneticist Sir John Bell, Regius Professor of Medicine at Oxford University.

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