

LONGEVITY DERIVATIVES AND FINANCIAL INSTRUMENTS

Report

August 2021



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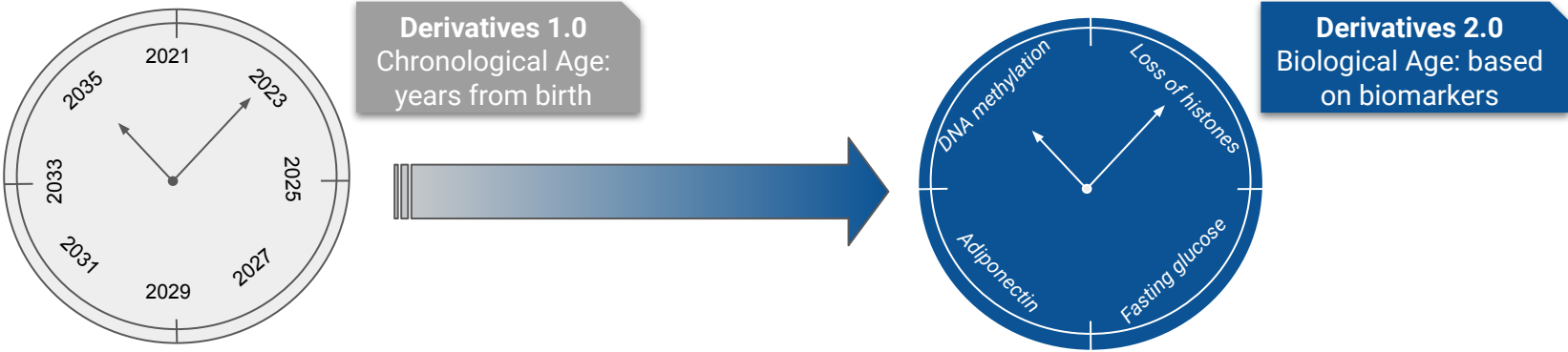
Humankind actively seeks to maximise its fleeting duration on Earth, and living a long healthy life is a natural desire, but it creates threats and opportunities. Traditional financial industries, especially pension funds, life insurance companies, and other investment firms are under pressure of the Silver Tsunami. Moreover, we are succeeding in extending the lifespan. Whilst this is to be celebrated, on the one hand it also raises challenges regarding how individuals manage their wealth, and on the other hand the current and future speed of expanding of lifetime expectancy is a new type of risk, so-called longevity risk which depends on individuals, the above-mentioned financial companies, and political issues.

Managing longevity risk requires an understanding of a wide range of issues, from the measurement of longevity risk for pricing, reserving and setting aside capital, to the management of risk through de-risking, reinsurance and capital markets solutions such as longevity-derived financial instruments. Such instruments are the main focus of this report. The report includes derivatives explanation and analysis, including the comparison to other financial instruments. A significant part of the text is dedicated to the so-called Longevity Derivatives 1.0, which underlying asset is chronological age.

Executive Summary

Although the longevity derivatives market has a large number of economical agents, the main ones are hedgers, speculators and arbitrageurs, who are given special attention in the report. New opportunities are opening up for all these agents in case of the high accuracy of risk assessment and forecasting, the selection of the correct risk management tool, and the valuation of a derivative are key challenges. To meet these requirements, the main types of longevity derivatives and financial instruments have been identified: different survival bonds, forwards, swaps, options, and swaptions etc. Although the first practical implementations of Longevity derivatives were introduced almost 20 years ago, they have not become a common hedging tool for financial companies. The reason is rooted in the fact that the chronological age does not have a sufficient correlation with longevity risk. In this report the possible solution is analysed – biological age-based financial instruments, Derivatives 2.0.

The rising age of human-validated biomarkers of aging generates a new form of financial instruments, which we believe are better not only for Longevity industry participants but also for traditional financial institutions because the correlation of biological age with age-related diseases is higher than the correlation of chronological age with age-related diseases. The implementation of Longevity derivatives based on biological age can also reduce costs of maintaining retirement living standards due to aging and Longevity shock.



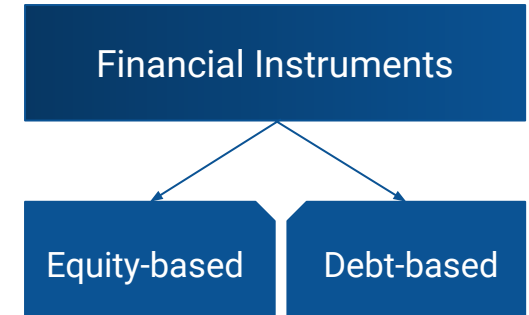
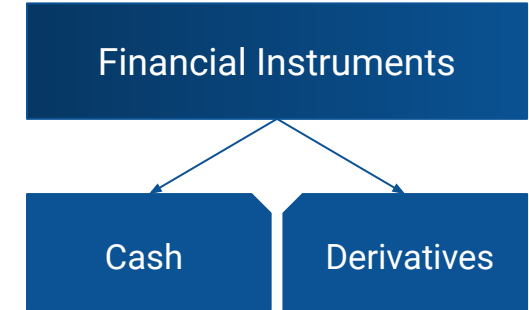
Financial instruments may be described as tradable assets or capital packages. One of the main goals of financial instruments is to **provide an efficient flow and transfer of capital all throughout the world's investors**. There is a variety of assets that may be used for financial instruments, namely cash, a contractual right to deliver or receive cash or another type of financial instrument, or evidence of one's ownership of an entity.

To sum up, a financial instrument is a real or virtual document representing a legal agreement involving any kind of monetary value.

According to their financial nature, financial instruments could be divided into two main categories: cash instruments and derivatives, where derivative is defined as financial security with a value that is derived from, an underlying asset or group of assets – the so-called benchmark.

On the other hand, the nature of the assets themselves might be analyzed. Based on that, we define equity-based and debt-based financial instruments. The common example of an equity-based financial instrument is stock.

As will be shown later, Longevity-derived financial instruments could be formulated in any of the aforementioned types.



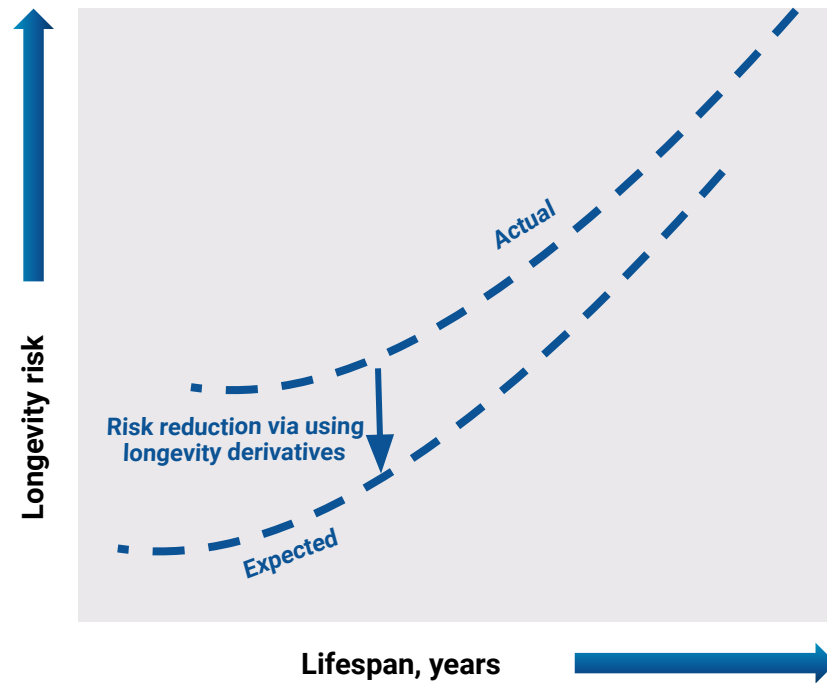
Longevity Risk / Longevity-derived Financial Instruments

A new global capital market, the Life Market, is developing and “longevity pools” are on their way to becoming the first major asset class of the twenty-first century.

Longevity risks arrive due to inaccurate predictions of the level of mortality rate and numbers of retirees. Another reason why managing Longevity risks has become more important for the entities is new regulation requirements. **Solvency II** is the directive in European Union law and it requires that insurance companies measure and evaluate Longevity risk and as a result increase the capital level required for Longevity risk.

Thus, Longevity-derived financial instruments are used in order to hedge such risks. In general, these derivatives are designed to generate income for investors due to increased Longevity, as well as reduce the negative impact for companies suffering from Longevity risks. Longevity risks have weak correlation with other financial risks, therefore **small beta coefficient** (the measure of volatility of an individual stock compared to the systematic risk of the entire market) **attracts investors a lot**.

Hedging with Longevity Derivatives



Types of Longevity Derivatives Users



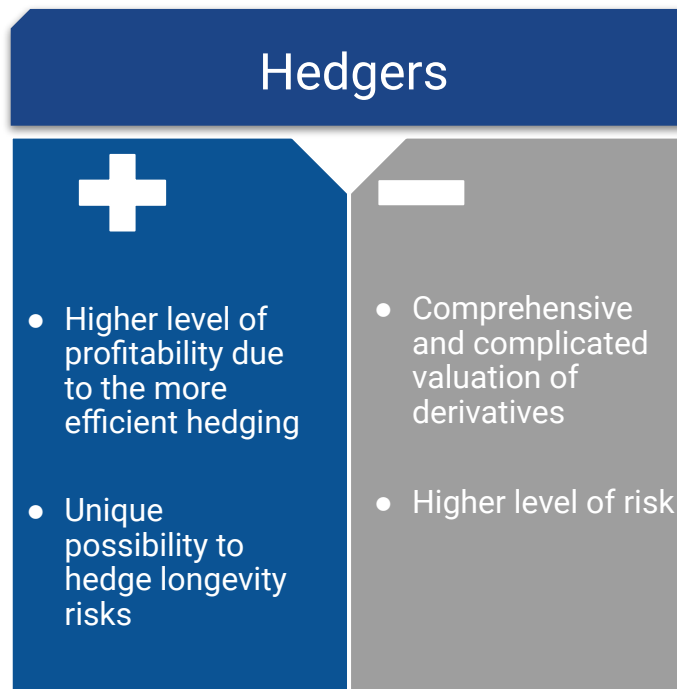
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Types of Longevity Derivatives Users: Hedgers

Main stakeholders who might be interested in the markets for longevity-linked securities are hedgers, arbitrageurs and speculators, who need derivatives as a response to longevity risks and speculations.

Hedgers have particular exposure to longevity risk and wish to lay off that risk: annuity providers lose if mortality improves by more than anticipated, whilst life assurers stand to gain, and vice versa. Pension funds and insurance companies, such as Towers Watson, Swiss Re have an incentive to transfer longevity risk off their books, especially since this risk exposure is potentially large.

For small pension funds, the case for longevity risk transfer may be relatively strong as they tend to have a larger longevity risk exposure as a result of undiversified idiosyncratic longevity risk. **All institutions**, that suffer from losses due to risks related to age-related diseases, **will be able to hedge more efficiently via bioage derivatives** than via chronological derivatives due to the higher correlation between biological age and risk of age-related disease. Defined benefit pension fund liabilities are exposed to longevity risk while their assets, typically equities, bonds and real estate, are not.



Types of Longevity Derivatives Users: Speculators

Many speculators are attracted by low correlations with traditional types of investment risks. Social security reforms and decline in growth of defined benefit schemes led to the transfer of longevity risk to individuals, boosting further demand for individual annuities and a possibility to speculate on the individuals market. As a result, insurance and reinsurance companies try to manage their longevity exposure optimally, passing some longevity risk to markets. Speculators can bet on technological progress advancements and thus predict future prices of derivatives and market moves better. However, there is a possibility of the reverse effect connected with the 'Silver Tsunami'. Demographic ageing could cause the appearance of additional factors that will be conducive for speculants' precise forecasts. Speculators that uses **HALE estimates can better predict future health service needs, evaluate the advantages and disadvantages of existing health programs, and identify trends in countries across the globe** which is a strong competitive advantage against existing chronological derivatives.

Speculators can profit from using longevity instruments predicting demographics trends in population ageing and profit from ageing in the following way: pension fund receives compensation for extra payments due to worse realized mortality rates and pays to the insurer when realized mortality rates are better than expected and speculators can be intermediaries between them and use swaps to propose both sides better hedge of payments risk and profiting on risk premiums and commissions.

Speculators



- Betting on technological progress advancements that influence lifespan
- Using derivatives as intermediaries between other market players



- Unstable deal flow
- Development of longevity technologies and markets leads to diminishing of ability to speculate

Types of Longevity Derivatives Users: Arbitrageurs

Investment banks and hedge funds are interested in acquiring exposure to longevity risk since it has a low correlation with classic market risk factors: inflation risk, liquidity risk, or currency risk. The combination of low beta and a potentially positive alpha makes longevity securities attractive investments in diversified portfolios.

As arbitrageurs seek to profit from any pricing anomalies in related securities there can be well-established pricing relationships between the related securities and longevity derivative is an effective choice for this. Difficulty with precise and correct pricing of longevity derivatives is a perspective mispricing potential for arbitrageurs to make a profit. **The active involvement of arbitrageurs and speculators** is very helpful for market liquidity, and **is**, in fact, **essential to the success of traded futures and options markets**.

Biological age is a non-tradeable asset, so the negative factor will appear in the form of impossibility to calculate accurate and precise effects.

Other stakeholders might include governments, securities managers and organised exchanges, all both of which would benefit from a new source of fee income and general financial and demographical stabilization.

Arbitrageurs



- More diversified investments and mispricing potential leads to high opportunity for getting up a profit



- Comprehensive and complicated valuation of derivatives
- Higher level of risk: purely estimated potential losses
- Additional investments to create market infrastructure and market making

Interest in Longevity Derivatives among Governments

Governments can be interested in longevity securities to assist financial institutions which are exposed to longevity risk. Such actions reduce the probability that large companies are bankrupted by their pension funds, with the result that society as a whole benefit from the greater stability of the economy.

Government is also interested in managing its own exposure to longevity risk as it is a significant holder of this risk: via the pay-as-you-go state pension system; via its obligations to provide health care for the elderly and for many other similar reasons.

Ensuring an efficient annuity market and efficient capital market for longevity risk transfers means that government can affect and reduce concentration risk and provide construction of national longevity indices. However, when we are considering issuing the longevity derivatives based on biological age, we can talk about the ability to consider the correlation with the actual health indicators.

Government helps to share longevity risk fairly across generations and provides a fair risk premium. When issuing longevity derivatives based on biological age, the government could insure age-related diseases and implement more advanced and actionable metrics for government pension programs. The government will earn the market longevity risk premium sufficient to compensate for the aggregate longevity risk it bears. The most positive effect of using these tangible and relevant metrics in short-term and long-term government planning is minimizing all spent resources.



GOVERNMENT



Insuring age-related diseases



**Minimising of spended
resources**



**Using accurate and realistic
health indicators**

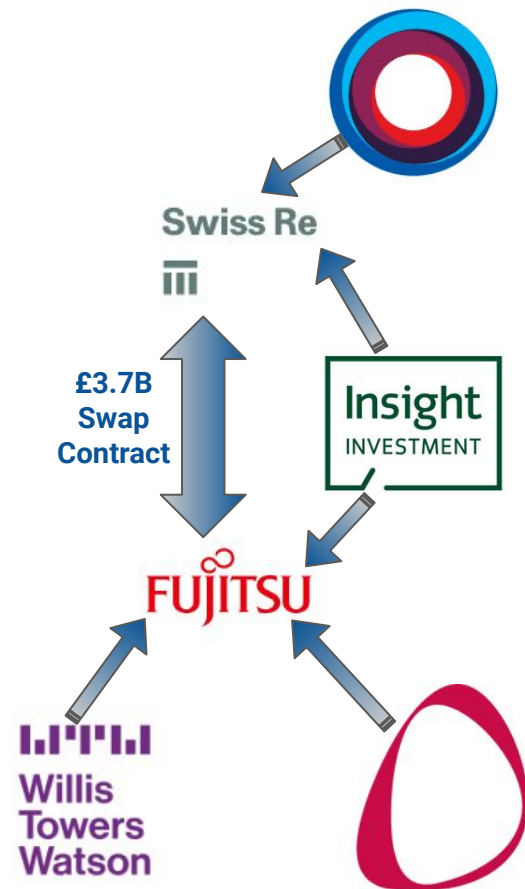
Examples of Longevity Derivatives Users' Activities

Financial institutions which wanted to make a profit from arbitrageurs fees have started to issue longevity derivatives in 2003. Global reinsurer **Swiss Re** offered a three-year mortality bond whose principal payment was tied to an international mortality index. During all these years Swiss Re continues making big deals on the longevity derivatives market.

The last deal using longevity swap was signed in May 2021 between **Swiss Re as an arbitrageur** and **The Trustee of the ICL Group Pension Plan**, a **Fujitsu** pension scheme, **as a hedger**. This longevity risk transfer insured **£ 3.7 billion of hedgers' liabilities** and covers pensions in payment for approximately 9,000 members. **Other institutions** of the swap deal infrastructure include:

- **Willis Towers Watson** as actuarial and transaction adviser to the hedger
- **Gowling WLG LLP and Momentum Investment Solutions and Consulting** as legal and investment adviser to the hedger
- **Pinsent Masons LLP** as legal adviser to the hedger
- **Insight Investment** as calculation agent, collateral manager, and collateral valuation agent.

Daniel Harrison, Global Head of Longevity Solutions at Swiss Re says: "There is a compelling rationale for pension plans and insurers to transfer their longevity risk to reinsurers. We have a natural offset with our mortality business, the capacity to write the business onto our balance sheet, and the expertise to tailor the transaction to meet our client's needs."



Infrastructure for Longevity Derivatives

Over 150 financial and, in particular, insurance companies are already developing innovative products and services which creates information infrastructure and provides data about healthy life expectancy (HALE), disability-adjusted life year (DALY) etc. Main players include pension funds that have a lot of liabilities to shift, insurers and reinsurers that are actively working with pension funds to hedge their risks, and investment banks along with major financial services companies that are also eager to provide insurance to pension funds and to trade the longevity risk itself:



Deutsche Bank

Deutsche Bank has launched a longevity risk index in hope it will increase liquidity within the market. The company said the Longevity Experience Options was meant to provide a standardised approach to further hedge longevity risk.

J.P.Morgan

JP Morgan developed LifeMetrics, a toolkit for measuring and managing longevity and mortality risk. LifeMetrics allow pension funds to calibrate and protect the longevity linked risk of their beneficiaries.

Due to the ecosystemic structure of the Longevity Industry, the interconnectedness and mutual influences of its sub-sectors make the growth of longevity infrastructure inevitable, since changes in one sector imply the developments in others. The most common examples technological multidimensional solutions for the Longevity Industry are: systems which hosts deep aging clocks, recommendations engines for longevity interventions and longevity databases, universal multifactorial tools that allows to measure human biological age, web and mobile apps for longevity, easy-to-use reporting system to provide a unique experience for tracking biological age and longevity. Here are some examples of such technologies:



Deep Longevity is developing explainable artificial intelligence systems to track the rate of aging at the molecular, cellular, tissue, organ, system, physiological, and psychological levels.

Haut.AI

Haut.AI provides an AI-powered SaaS platform for pharma companies. Their platform allows to collect, store, manage and analyse skin health-related data using machine learning algorithms.

Longevity-derived Instruments Market Size

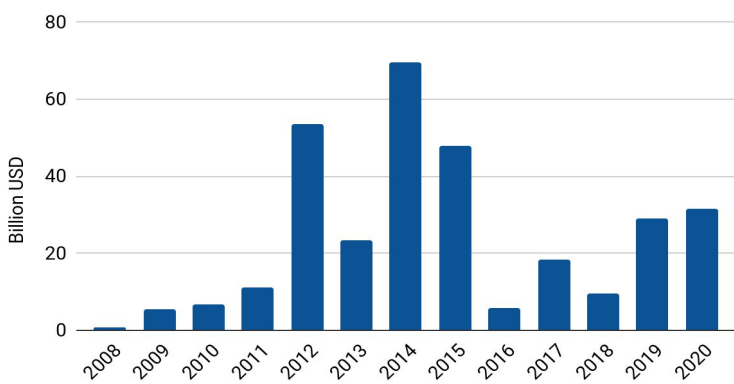
Longevity-derived Instruments' Market Size

The graph depicts the dynamics of longevity swaps' operations in period of 2008-2020 years. During this period, deals for amount of \$ 313 billion had been struck. Amount of new operations correlates with life insurance market size. For example, insurance market size in US also significantly dropped after 2015 year and slightly recovers during 2016-2020 years (IBISWorld, 2020).

Therefore, countries that may have potential demand for bioage derivatives are UK, the Netherlands, USA, Canada and France. Based on the fact that longevity swaps occupy the biggest part of longevity risk transfer market we assume that bioage swaps should be the most attractive longevity derivative. Similarly, bioage bonds will not be in demand.

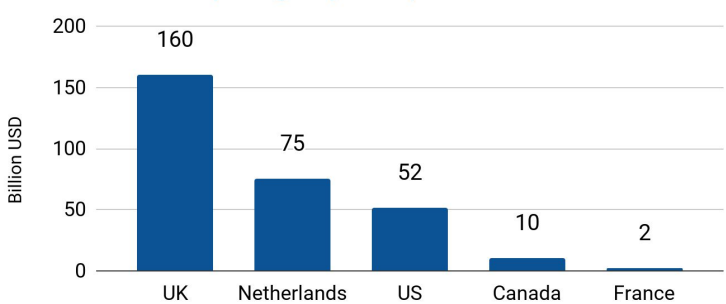
The longevity risk transfer activities mainly take place in the countries with a relatively large pension market size, such as UK, US, Australia, Netherlands and France (DNB, 2016). Main longevity instruments that are in demand in these countries are longevity swaps, longevity reinsurance, index-based longevity hedge, buy-ins and buy-outs. About 95,77 % of longevity deals belong to 3 countries: UK (53,49%), the Netherlands (25,09%) and USA (17,19%).

Longevity Swaps Operations, 2008-2020



Source: Artemis, Longevity Derivatives

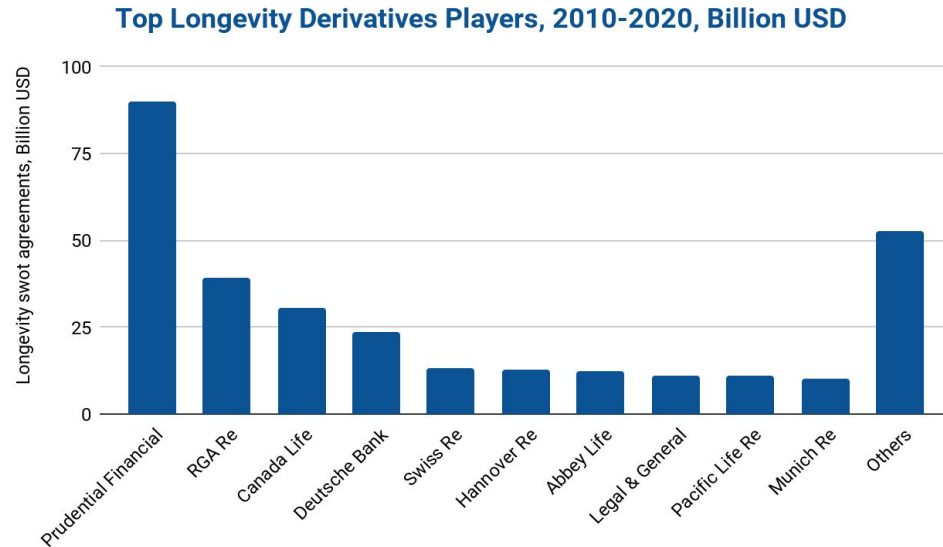
Top Longevity Deals, 2011-2020



Source: Artemis, 2019

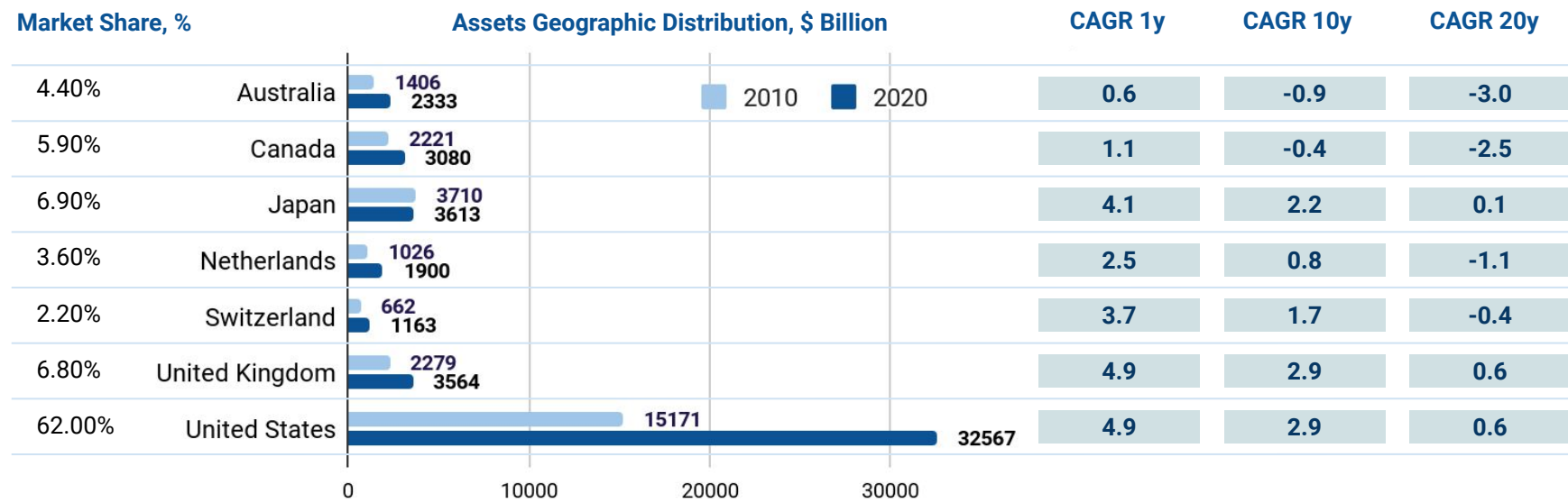
Top Longevity Derivatives Players

About 85% of longevity swaps and longevity risk transfers are provided by insurance companies (such as Prudential Financial Inc, Reinsurance Group of America, Canada Life etc.), remaining 15% are distributed between investment banking and finance services institutions (such as Deutsche Bank, Legal & General, Credit Suisse, Goldman Sachs). Since 2011, Prudential has completed approximately \$ 90 billion in international longevity reinsurance transactions. Prudential Financial's average longevity risk transfer or reinsurance arrangement equals \$ 4.1 billion. These transactions use a limited recourse, or pass-through structure, meaning the longevity and default risks are able to be passed through the insurer, onto the reinsurer.



Source: Artemis, Longevity Derivatives; Authors' calculations

Global Pension Funds Industry Outlook

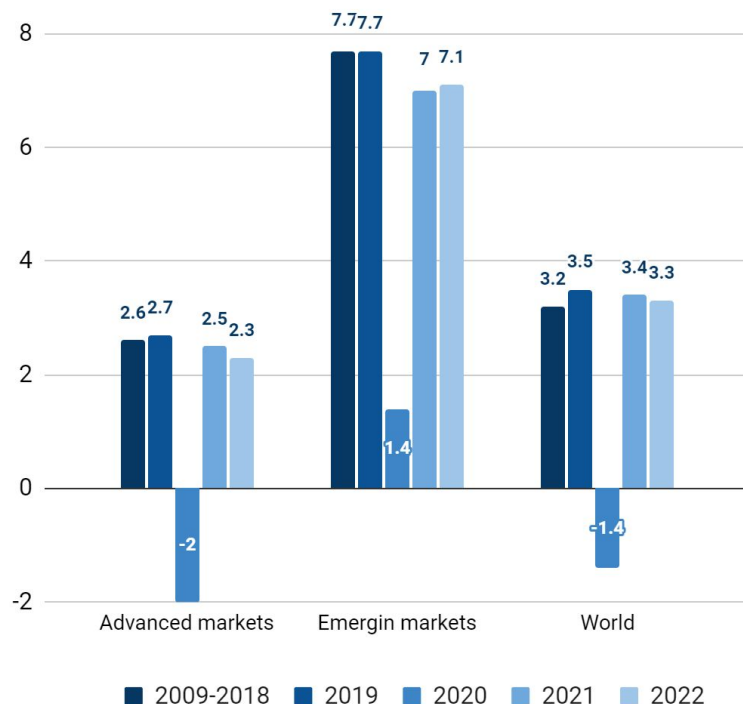


The US is the largest pension market accounting for **62%** of the global pension market according to 2020 figures. The global assets are estimated at **\$ 52,522 billion**. The **Japan and United Kingdom** follow the US with a significant difference – 6.8% and 6.9% respectively. Together, these three markets account for over 76% of all pension assets.

During the last 10 years, the fastest-growing pension markets have been the **US (215%), Netherlands (185%), and Switzerland (176%)** among observed, while the absolute leader in this rally was **China**, during the last decade it increased its assets by **6.8 times**.

Source: Thinking Ahead Institute, Global Pension Assets Study, 2021

Total Insurance Premium Growth, %



Source: Swiss Re sigma No 7, 2020

Non-life Insurance

Global non-life premium growth is expected to get recovered to 3.6% in 2021 and 2022, supported by strong rate hardening in commercial lines across countries. North America is the biggest contributor to the global non-life premium pool. The US will add over \$ 90 billion through 2022. China will add from \$ 40 to \$ 50 billion. China is still the fastest-growing non-life insurance market with 8% growth expected in 2022.

Life Insurance

Such a significant decline in the premiums in 2020 was due to increased unemployment in the Covid-19 recession and a corresponding reduction in demand, and business activity.

Following economic recovery we expect life premiums to get back to a growth trend after the 2020 crisis. Still, the growth was driven by emerging economies, primarily China, which is now the second-largest insurance market in the world after the United States. In advanced economies public pension systems faced difficulties coping with the shortfall in savings caused by low birth rates and longer life expectancies, opening new opportunities for the life insurance industry (Manzano, 2018). The COVID-19 pandemic also created a positive trend for insurance premiums growth (OECD, 2020).

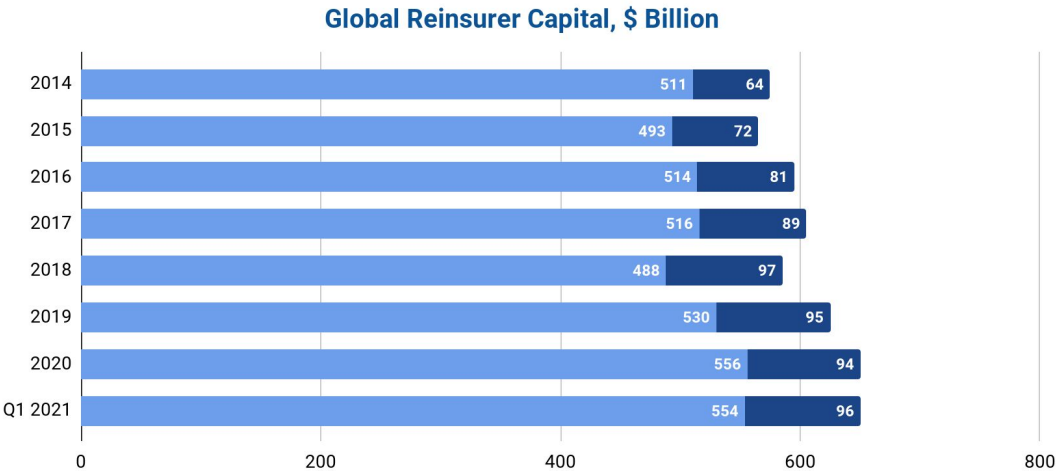
Reinsurance Industry Overview

Reinsurance pricing has been hardening since the COVID-19 has spread. But it is estimated that reinsurers capital has returned to pre-pandemic value of \$ 625 billion after 9 month of 2020.

Traditional capital grew by \$ 3 billion to a new level of \$ 533 billion in the third quarter of the previous year. New issues in the second and third quarters significantly replenished the capital. At the same time, reinsurers' incomes declined due to the effects of the Corona virus and natural catastrophes.

Alternative capital assets fell by \$ 3 billion during the same period to \$ 92 billion.

In the coming years, growing demand is expected, new capacity will appear in 2021. Risk-taking strategies will develop the impact of COVID-19 on the world economy.



Source: Aon Reinsurance Market Outlook, January 2021

Longevity-derived Swaps and Forwards

Longevity-derived Swaps and Forwards

By definition, swap is a financial instrument, namely – derivative contract through which two parties exchange the cash flows or liabilities from two different financial instruments. Swaps said to have two legs, where each cash flow comprises one leg of the swap.

As for Longevity swaps, Longevity swap is a reinsurance structure where the client pays a fixed pre-agreed annual premium to the reinsurer plus an annual fee. The premium comprises of the expected annuity payment and a margin. The annuity payment time is based on the Longevity of the given pensioner.

Longevity swaps have a number of features making them interesting for all parties involved, namely, they allow to deal with Longevity risks aside from the investment risks, this, in turn, allows trustees to diversify their risks and operate more efficiently. Longevity swaps also allows to exclude the upfront funding practice and hence to reduce counterparty risks. Probably, one of the most important things about Longevity swaps is their symmetry. **The risk distribution related to the Longevity swaps is much more fair** in comparison to some other financial instruments on the market.

The Advantages of the Longevity Swaps



**Investment and
longevity risks
separation**



**Symmetrical risk
distribution among
counterparties**



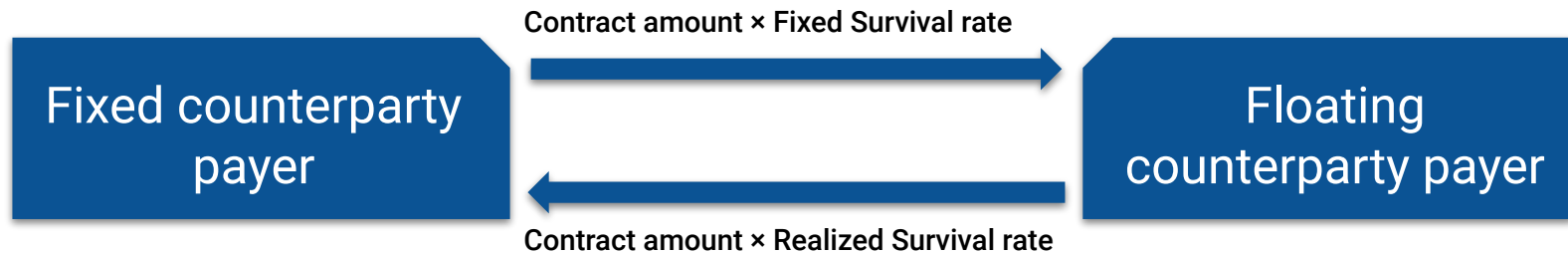
No upfront funding



**Counterparty risk
reduction**

Longevity-derived Swaps and Forwards

A survivor swap is an agreement to exchange cash flows in the future based on the outcome of at least one survivor index [Dawson, P. et al. "Survivor Derivatives: A Consistent Pricing Framework.", 2010]. It can be broken down into a collection of a more simple derivative – the survival-forwards. An S-forward is an agreement between two counterparties to exchange at a future date, an amount equal to the realized survival rate of a given population cohort (floating leg), in return for a fixed survival rate agreed at the inception of the contract (fixed rate payment). The use of the forward's structure is rooted in the fact that this financial instruments are well-known to be easily customizable, allowing tailor them to a specific commodity and date.



The payoff of the S-forward is then given by:

$$Payoff_{ff} (T) = p_x - \hat{p}_x$$

Where p_x is the realized survival rate (F_T measurable), and \hat{p}_x is a fixed probability of an individual aged x at time 0 to be alive at age $x + T$. At the same time, forward contracts (Longevity forwards included) are known "to bring" higher default risk, since they tend to become incoherent to the real market as time passes.

Longevity-derived Swaps and Forwards / Swaptions

Swaption itself is a over-the-counter, i.e. broker-dealer, financial instrument which allows its users to enter into an interest rate or other swap. In other words, the buyer of the swaption receives the right to enter into a specified swap agreement with the issuer on a specified future date. A good example of Longevity-related swaption is **survivor swaption**. In case when some pension fund, or other entity, has a payment liability for a cohort of a given age, it might expose itself to the survivorship risks. In this situation the aforementioned entity could use swap, forward swap or survivor forward in order to hedge its risks. Despite hedging, these strategies would not give any direct benefits to the entity, as was shown by Dawson, P. et al. This indicates a clear need for an additional financial instrument which will not only allow to hedge risks, but will give a benefit option to the entity. And this instrument is **survivor swaption**. The reason is rooted in the fact that swaption allows its users to decide whether they want to enter a pay-fixed swap on pre-agreed terms or not. The pricing model for this instrument proposed by Dawson, P. et al.:

$$P_{payer} = e^{-r\tau} ((\pi_{forwardswap} - \pi_{strike}) N(d) + \sigma \sqrt{\tau} N'(d))$$

$$P_{receiver} = e^{-r\tau} ((\pi_{strike} - \pi_{forwardswap}) N(-d) + \sigma \sqrt{\tau} N(d))$$

$$d = (\pi_{forwardswap} - \pi_{strike}) / \sigma \sqrt{\tau} .$$

Here σ is the annual volatility of the returns of $\pi_{forwardswap}$, τ is the time to option maturity, r is the interest rate, $N(d)$ is the standard normal cumulative distribution function of d , $N'(d)$ is the corresponding probability density function and π denotes the premium.

Payer Swaption

- ▶ Fixed-rate payer
- ▶ Floating-rate receiver

Bayer Swaption

- ▶ Floating-rate payer
- ▶ Fixed-rate receiver

Longevity-derived Swaps and Forwards / Caps and Floors

Mortality swaptions, as a part of Longevity-related swaptions, can be used for various risk management purposes. A good example of applicability of mortality swaptions in the insurance industry is proposed by D. Blake et al. He mentioned that, such swaptions might be useful for different insurance companies in managing the risks of positions in instruments such as guaranteed annuity options (GAOs), since such swaptions would presumably have long terms to maturity, because it is the longer-term longevity risk that, for example, annuity providers are most concerned about [D. Blake et al. "Living with mortality: Longevity bonds and other mortality-linked securities.", 2006].

Another approach that might help this one entity, we have mentioned before, to hedge its survivorship risks are **caps** and **floors**. In case when a swaption used, it determines a single fixed rate for all payments. Caps and floors might be treated as upper and, respectively, lower bounds of the rate's range. In terms of credit, cap (floor) is the maximum (minimum) value a borrower should pay to a creditor. In this case both parties obtain additional variability in course of their financial interactions. At the same time, such optionality is "charged" with a higher option premium. The reason is that cap and floors are tied with the strike rate, and the amount of the option premium is highly affected by the difference between the strike rate and the market interest rate. The pricing model for this instrument proposed by Dawson, P. et al.:

$$P_{payer} = e^{-r\tau} ((\pi_{SFC} - \pi_{strike}) N(d) + \sigma \sqrt{\tau} N'(d))$$

$$P_{receiver} = e^{-r\tau} ((\pi_{strike} - \pi_{SFC}) N(-d) + \sigma \sqrt{\tau} N(d))$$

As can be seen from the formulas above, the pricing approach does not vary significantly, the only difference is use of π_{SFC} instead of $\pi_{forwardswap}$ survivor forward contract, where SFC states for "survivor forward contract".

Longevity-derived Bonds

Longevity-derived Bonds

The evolution of financial market instruments has brought a number of new risk-diversification options to the attention of investors and new hedging options to companies that carry some specific risks like longevity risks for insurance companies and pension funds.

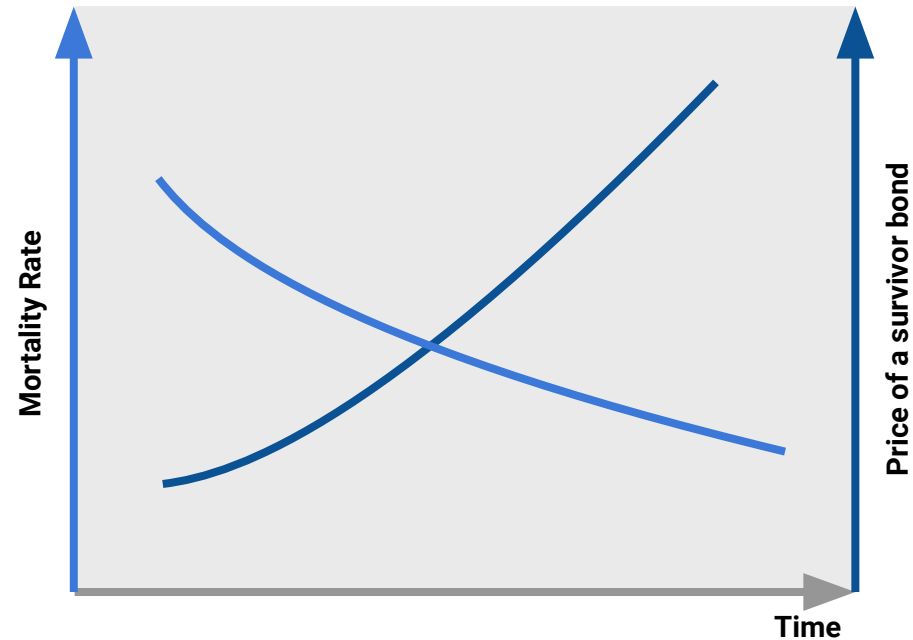
One of them is a survivor (longevity) bond which coupon payments are connected to the percentage of a defined population group especially retirees alive on the day of coupon payment. **The higher survivorship of aging population causes higher payouts to them and a more valuable S-bond is a suitable risk-managing instrument.**

There are also other types of longevity bonds with conditions which can meet different needs:

- Survivor bonds continue to pay until the last member of the reference population dies
- Principal-at-risk bonds with fixed or semi-floating coupons, principal repayments are connected to a survivor index
- Inverse bonds whose price behaviour are inversely proportional to traditional longevity bonds.

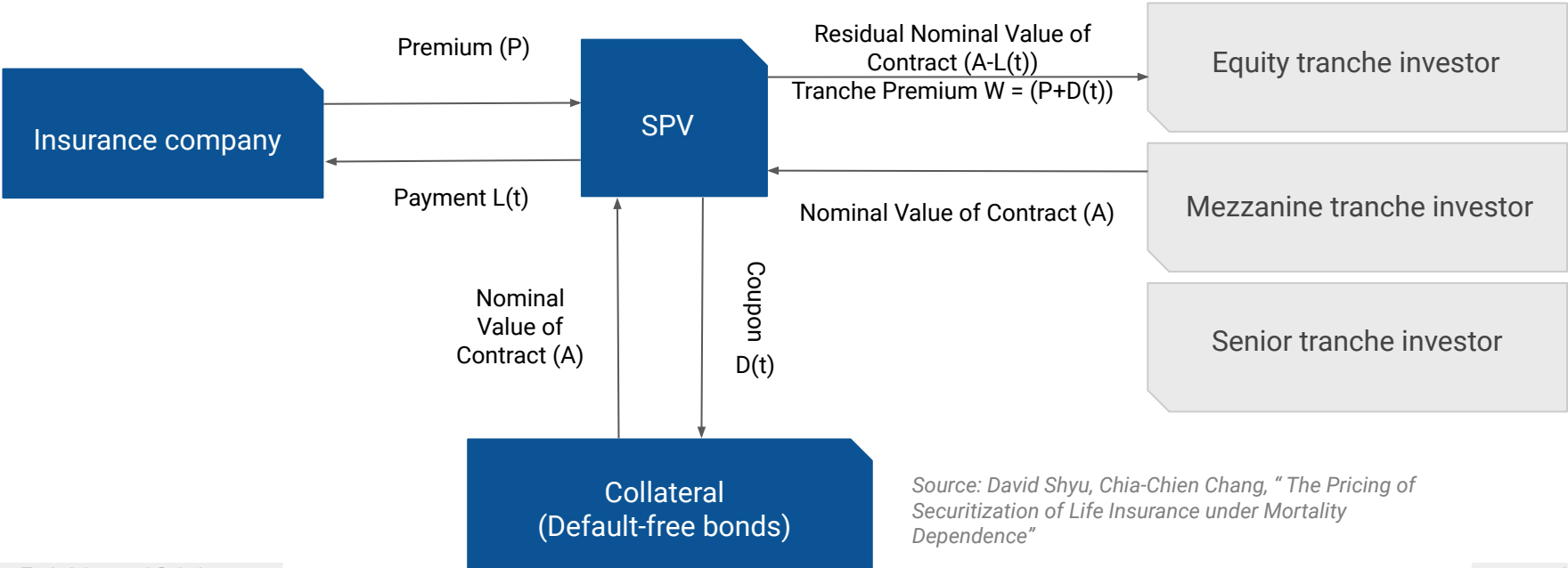
In 2003, for the first time in history, Swiss Re issued Longevity principal-at-risk bonds, with a coupon pegged to LIBOR, and a principal pegged to weighted index of mortality rates in its countries [Blake, David, et al. "Longevity bonds: financial engineering, valuation, and hedging.", 2006].

Correlation between the Mortality Rate and the Price (Coupon) of a S-Bond



Longevity-derived Bonds / Collateralized Insurance Obligation

Longevity-related bonds (and swaps) is good example of how both risk-averse and risk-loving investors ended up facing the same mortality risk. Realizing that, there are some attempts to bring more “optionality” in this situation. Thus, a Collateralized Insurance Obligation (CIO) was created. This financial instrument has some significant advantages in terms of risk optimization or “optionality”. The CIO links to a portfolio of life insurance with different insurance amount and different degree of mortality risk. In this situation, parties do not have any built-in risks and the investor can decide on the various tranches of the CIO which have different mortality risks. This, in turn, allows the participation in investment activities with different levels of risk.

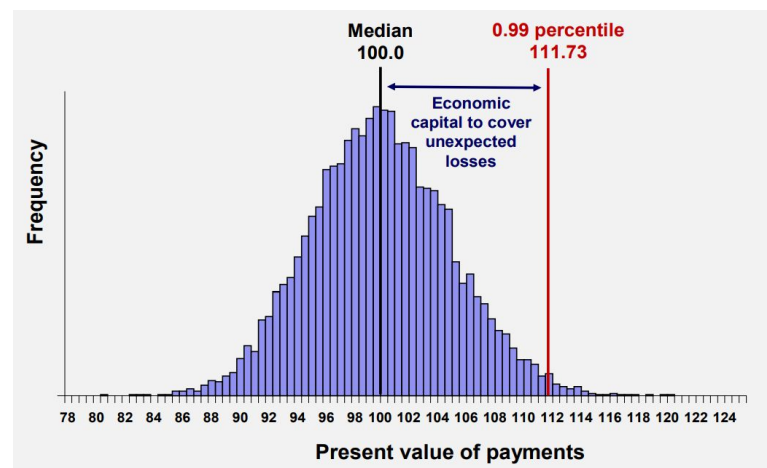


Longevity-derived Bonds / Zeros and Deferred Bonds

Deferred Longevity Bonds

A deferred interest bond, also called a deferred coupon bond, is a debt instrument that pays all accrued interest in a one-time payment at a later date, rather than in periodic increments. The classical longevity bond can have a very low longevity risk attached to early payments, because of the speed of lifetime expectancy expanding with time. But first coupon payments are also the most expensive part of the bond. Financial institutions can deal with this problem using deferred longevity bonds. The deferments would save a large amount of capital, and so increase the gearing. This, in turn, would make such longevity bonds much more attractive as hedging instruments. These deferred longevity bonds can also be regarded as a form of mortality forward contract. As with conventional forwards, one can envisage that they might take a large number of different forms

The graph depicts Cairns-Blake-Dowd model output which shows the distribution of 10,000 scenarios of the present values of 10-year deferred longevity bond payments for males aged 65. Longevity bond with coupon of £19.15 adjusted for survivorship of age 65 cohort [D. Blake et al. "Sharing Longevity Risk: Why Governments Should Issue Longevity Bonds", 2006]. This example regards government longevity bonds and defines the distribution of risk premium. Although this results in a narrowing funnel of doubt as each year passes, the mean term of the expected cash payments also reduces and this requires higher quantiles of the distribution to be used each year to maintain the desired AAA credit rating for the Bond. The present value of payments should be set on a level 111.73 to cover unexpected losses from longevity risk.



Source: D. Blake et al. "Sharing Longevity Risk: Why Governments Should Issue Longevity Bonds"

Longevity Financial Instruments 2.0 / Biological vs. Chronological Age



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Solutions

Biological vs. Chronological Age

The financial instruments described above are based on chronological age, which means that underlying assets are related to chronological age, for instance, mortality indexes. **Chronological age is the amount of time that has passed from birth of organism to the given date.** Biological age (physiological age) – physiological integrity of organism at the moment of research evaluated and based on measurement of biomarkers. The term "biological age" reveals progress of the biological aging process as opposed to the simple passage of time.

The basic idea behind biological aging is that aging occurs as damage to various cells and tissues is gradually accumulated in our bodies. Also known as physiological or functional age, biological age differs from chronological age because it takes into consideration a number of factors other than just birthdate.

	CRONOLOGILAL AGE
▶	The number of years that have passed since birth
▶	Cannot be influenced by lifestyle and socioeconomic conditions
▶	Has little relevance to how you feel and function

	BIOLOGICAL AGE
▶	How old our cells really are therefore, our real age
▶	Can be reversed by attending to your health
▶	The most important component to the aging process

Biomarkers of Aging

In general, biomarkers of aging are used to objectively gauge true biological age that could differ from chronological and depends on biological condition of person [G.Baker 1998]. They reveal physiological processes that change with age, diseases linked to aging and aging itself [Eil. Crimmins et al. 2008].

The main goals biomarkers of ageing aims to attain:



Assay the biological process of aging itself and not only the predisposition to disease, since the vast majority of the aging process occurs without pathological manifestation



Cause a minimal amount of trauma to assay in the organism, thus enabling continuous measurement and analysis that do not cause morphofunctional damage, which ultimately results in aging



Be measurable with high reproducibility during extremely short intervals compared to the lifespan of the organism

There are several types of aging biomarkers:

- ▶ Omics biomarkers (from genomics, epigenomics, transcriptomics, proteomics, metabolomics, lipidomics, glycomics, etc.)
- ▶ Functional tests (cognitive function, cardiovascular and respiratory system, etc.)
- ▶ Blood based biomarkers
- ▶ Imaging (MRI, CT)
- ▶ Microbiome
- ▶ Nutrition

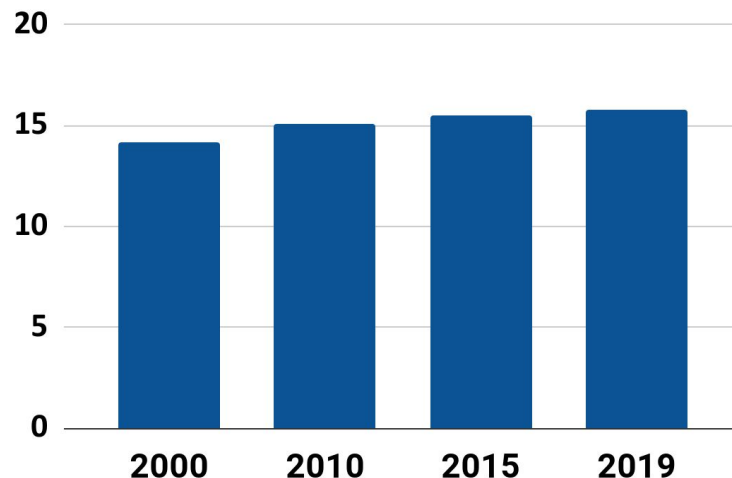
Relation Between HALE, QALE, DALE and Biological Age

It is hard to find universal methods and biomarkers for biological age assessment. Nevertheless, we can still use well established metrics that, we assume, have high correlation with biological age. Good candidates for such metrics are HALE (healthy life expectancy), DALE (disability-adjusted life year), and QALE (quality-adjusted life-year). HALE, DALE, and QALE don't depend on any particular biomarker, but are measured empirically for high group of people all over the world.

Healthy life expectancy (HALE) is a form of health expectancy that applies disability weights to health states to compute the equivalent number of years of good health that a newborn can expect. First estimations were based on the incidence, prevalence, and disability distributions for 100+ diseases and injury causes by age group, sex, and region of the world [Colin Mathers et al. World Health Report 2000].

HALE estimates are used to predict future health service needs, evaluate existing health programs, and identify trends in countries across the globe. The data is used by public health officials in creating policies to address inequalities in health programs and services across different regions. A standard summary measure of population health at both the international and national levels, HALE is used by the WHO to measure a country's effectiveness in reducing the burden of diseases.

Dynamics of Health Life Expectancy at Age 60, Years

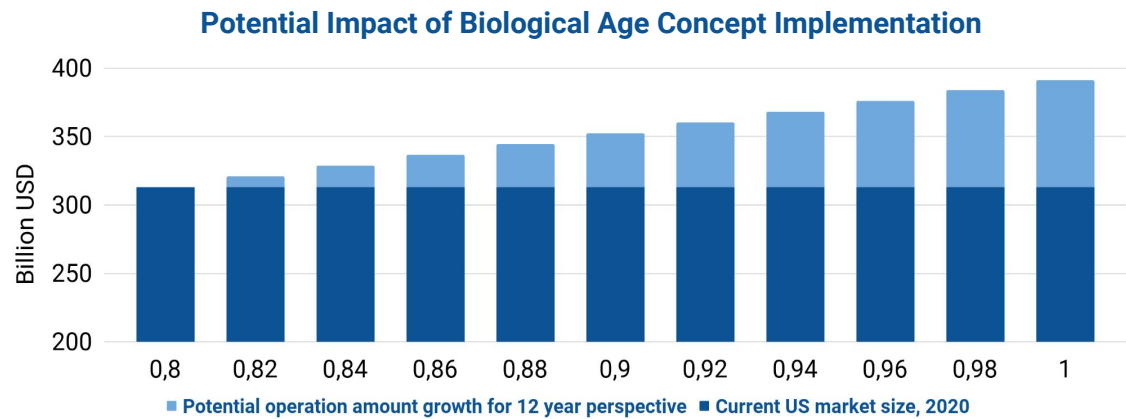


Source: The World Health Organization

Biological Age Derivatives vs Chronological Age Derivatives

Assuming that biological and chronological age derivatives variations are not roughly equal, we can imply that biological age derivatives enable more efficient hedging when the correlation of **biological age with age-related diseases is higher than the correlation of chronological age with age-related diseases**.

Potential impact of different value of correlation between biological age and human disease, on Longevity derivatives operation amount for 12 year perspective is represented in the graph. This approach can lead to increase of market operation amount when the relationship between the biological age and the underlying asset of the financial derivative becomes stronger. Usage of Longevity derivatives with usage of biological age also can reduce costs of maintaining retirement living standards due to aging and to Longevity shock [International Monetary Fund, 2012]. Over 150 financial and, in particular, insurance companies are already developing innovative products and services which creates information infrastructure and provides data about healthy life expectancy (HALE).



Source: Artemis, Longevity Derivatives; Authors' calculations

Market's Point of View

Blackrock Capital and Vanguard on the Rising Longevity Industry



"Longevity is a blessing. And as an investor, it provides you opportunities to benefit from compounding and to have a longer investment horizon. But if you don't prepare for it, you are left with two options: Work longer in life, perhaps much longer than you'd like, or hope you've been good to your children and that they'll be willing to care for you in your old age. And, second, I hope you'll speak out. Longevity is an issue of social justice that will have a more profound impact on your generation than on any generation before. If we don't start to address it – not just in this country but globally – we're going to see fewer job prospects for young people, higher unemployment, lower growth and many older people – maybe your parents – left without the means to support themselves."

– Larry Fink, Chairman of Blackrock Capital



"I'm actually pretty optimistic about the U.S. economy. But Europe's got real challenges. A lot of that is due to the demographics in Europe. China has been the engine of growth for the world for the last 20 years, or the last 10 years in particular, but that's not sustainable. So you're looking at a world where growth is going to be more challenged than it's been, unless you see some really big jumps in productivity."

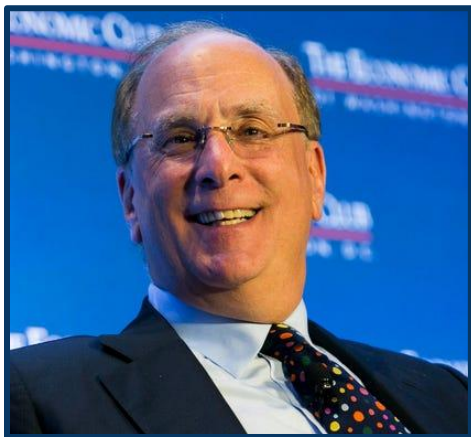
– Bill McNabb, Chair of Vanguard

Larry Fink and Rob Kapito on the Rising Longevity Industry



"People are living longer than ever before, dramatically altering the financial challenges of retirement. Increased longevity is a blessing, but it's an expensive one because that translates into the need for a bigger retirement nest egg and access to secure, retirement-long income. As our survey suggests, many Americans simply won't have the money they need to enjoy their longer lives if they don't start investing differently."

– Rob Kapito, President of Blackrock Capital



"The entire system is now wired toward the short term. Banks and securities firms grow revenue from the velocity of money. So they have a short-term incentive. Media, especially in the online age of the 24/7 news cycle, draw traffic from hyper-focusing on the latest developments... But they should do just the opposite, taking advantage of their longer investment horizon to keep their money working for them. Because let's face it – if you have 25, 30 or 40 years to save for retirement and 20 or 30 years to fund in retirement, you should not be worrying about what's happening this second, today, this week – even this quarter."

– Larry Fink, Chairman of Blackrock Capital



"As data-driven health intelligence becomes more accessible and affordable, we see an opportunity to improve the health and well-being of policyholders by offering services that can help extend life expectancy"

"As a reinsurer, we are eager to contribute to innovation that identifies health risks early and provides win-win outcomes."

— Michael Colannino, Chief Strategy Officer of SCOR Global Life



"More and more people are living to 65 and over, and for a long time this has fueled general concerns about associated financial issues. The thinking is that, at this age, people generally stop being net contributors and instead become net receivers of benefits. Moreover, people who live longer tend to see a deterioration in their health, which increases the global cost of care. However, that vision is no longer completely true. Nowadays people tend to reach retirement age in better health and to be more active – they create companies, they continue to work, they consume."

— Daria Ossipova, Head of Health and Longevity R&D of SCOR Global Life

Klaus Schwab on Biotech, 4th Industrial Revolution and Fundamental Differentiations from Previous Industrial Revolutions



"The new technology wave is changing who we are. There is research going on in biology, regeneration of body parts, enzymes and so on. If we make progress in what we are doing in treating cancer, it will prolong life expectancy by a number of years. Now, in Switzerland, every second baby is expected to have a life of more than 100 years."

"We have to change our whole education systems. The UAE could be one of the first to adopt lifelong learning systems in a systematic way."

"Similarly, the revolutions occurring in biotechnology and AI, which are redefining what it means to be human by pushing back the current thresholds of life span, health, cognition, and capabilities, will compel us to redefine our moral and ethical boundaries."

"The Fourth Industrial Revolution, finally, will change not only what we do but also who we are. It is already changing our health and leading to a "quantified" self, and sooner than we think it may lead to human augmentation."

– Klaus Schwab, Founder and Executive Chairman of the World Economic Forum

Conclusions

As a result of aging and the upcoming Silver Tsunami, **there has been an increase in interest in the Longevity industry**. Currently, the **size of the market** is estimated at **\$ 25 trillion**, and Longevity derivatives are an important part of its financial infrastructure. The main players in the markets for Longevity-linked securities are hedgers, arbitrageurs, speculators and governments.

A new global capital market, the Life Market, is developing and “Longevity pools” are on their way to becoming the first major asset class of the twenty-first century. Longevity risks arrive due to inaccurate predictions of the level of mortality rate and numbers of retirees. Another reason why managing Longevity risks has become more important for the entities is new regulation requirements.

The Longevity risk transfer activities mainly take place in the countries with a relatively large pension market size, such as UK, US, Australia, Netherlands and France. Since 2011, Prudential Financial Inc, the leader the of Longevity swaps market, has completed approximately \$ 90 billion in international Longevity reinsurance transactions.

The most popular Longevity derivatives are the **different types of survival bonds, forwards, swaps, options, and swaptions, collateralized insurance obligations**.

The new age of Longevity derivatives **is biological age derivatives**, Derivatives 2.0. **Biological age – physiological integrity of organism** at the moment of research evaluated and **based on measurement of biomarkers**. They reveal physiological processes that change with age, diseases linked to aging, and aging itself.

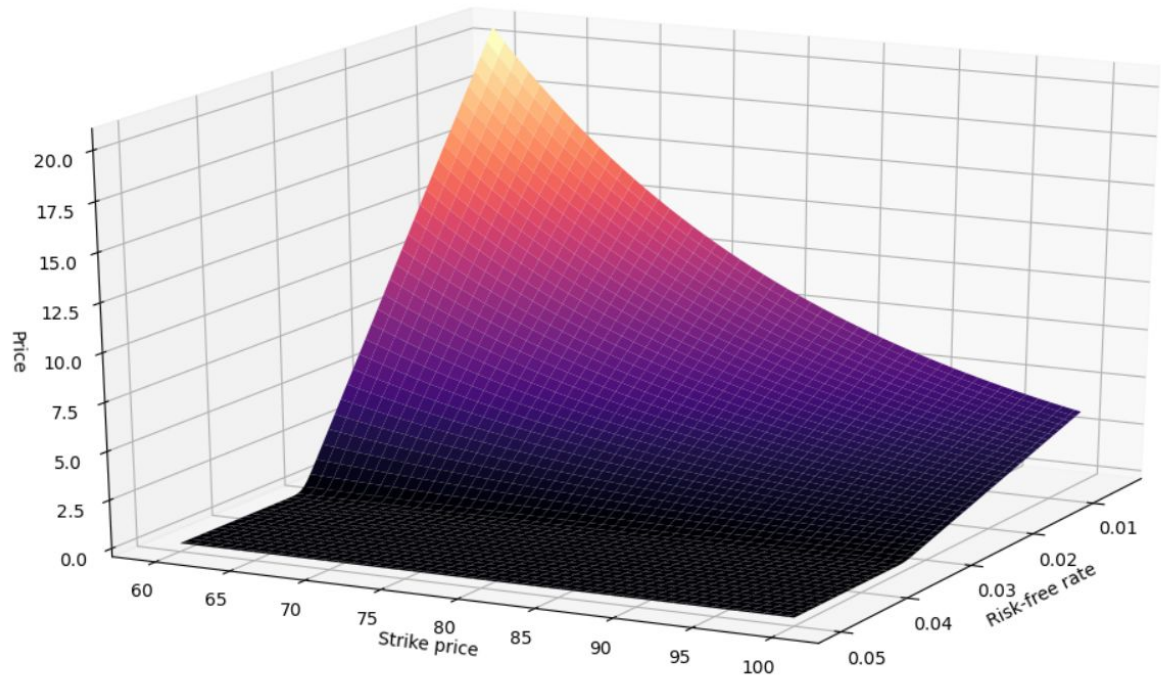
Since biological and chronological age derivatives variations are not equal in terms of predictability potential, we can imply that **biological age derivatives enable more efficient hedging** due to the fact that the correlation between the biological age and age-related diseases is higher in comparison to the chronological age.

Proprietary Version of the Report

This report consists of two versions: open and proprietary. The proprietary version provides advanced investment analytics made using sophisticated data management tools and algorithms. The report includes specific models and computational methods for Longevity-based financial instruments, statistical data and simulation results, option pricing approaches and other information.

Furthermore, it includes practical answers to certain questions in order to optimize the short and long-term strategies of corporations and other institutions related to the industry, with a newly updated edition being released each quarter, incrementally increasing the precision, practicality, and actionability of its technological and financial analysis.

Call Option Price Simulations



Longevity Finance Big Data Analytics Dashboard



Longevity Finance Big Data Analytics Dashboard

Market Intelligence

Longevity Finance
Market Intelligence

SWOT Analysis

Interactive Mindmaps

Market Intelligence

Interactive Mindmaps



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Dashboard Parameters

DATA POINTS

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PERSONALITIES

2000

CORPORATIONS

1000

ASSETS UNDER
MANAGEMENT

15

INDUSTRIES

6

SECTORS

50

SWOT Analysis



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Dynamic Network Diagrams

Competitor Search

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FinTech

WealthTech

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Interactive Network Diagrams

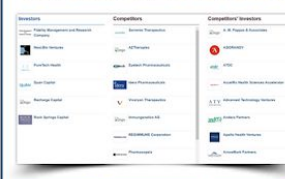


FinTech

WealthTech

InsurTech

Competitor & Investor Search



FinTech

WealthTech

InsurTech

Longevity Finance
Search Engine

Personalities

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Investors

www.aginganalytics.com/finance-dashboard

Longevity Investment Big Data Analytics Dashboard



www.platform.dkv.global/dashboards/longevity-investment

Longevity Governance Big Data Analytics Dashboard



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DATA POINTS

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PARAMETERS

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REGIONS

50

LAYERS OF FRAMEWORK

6

DYNAMIC CHARTS

100

SWOT ANALYSIS PROFILES

50

SWOT Analysis



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Longevity Progressiveness 3D Visualization



Longevity Progressiveness Benchmarking Charts



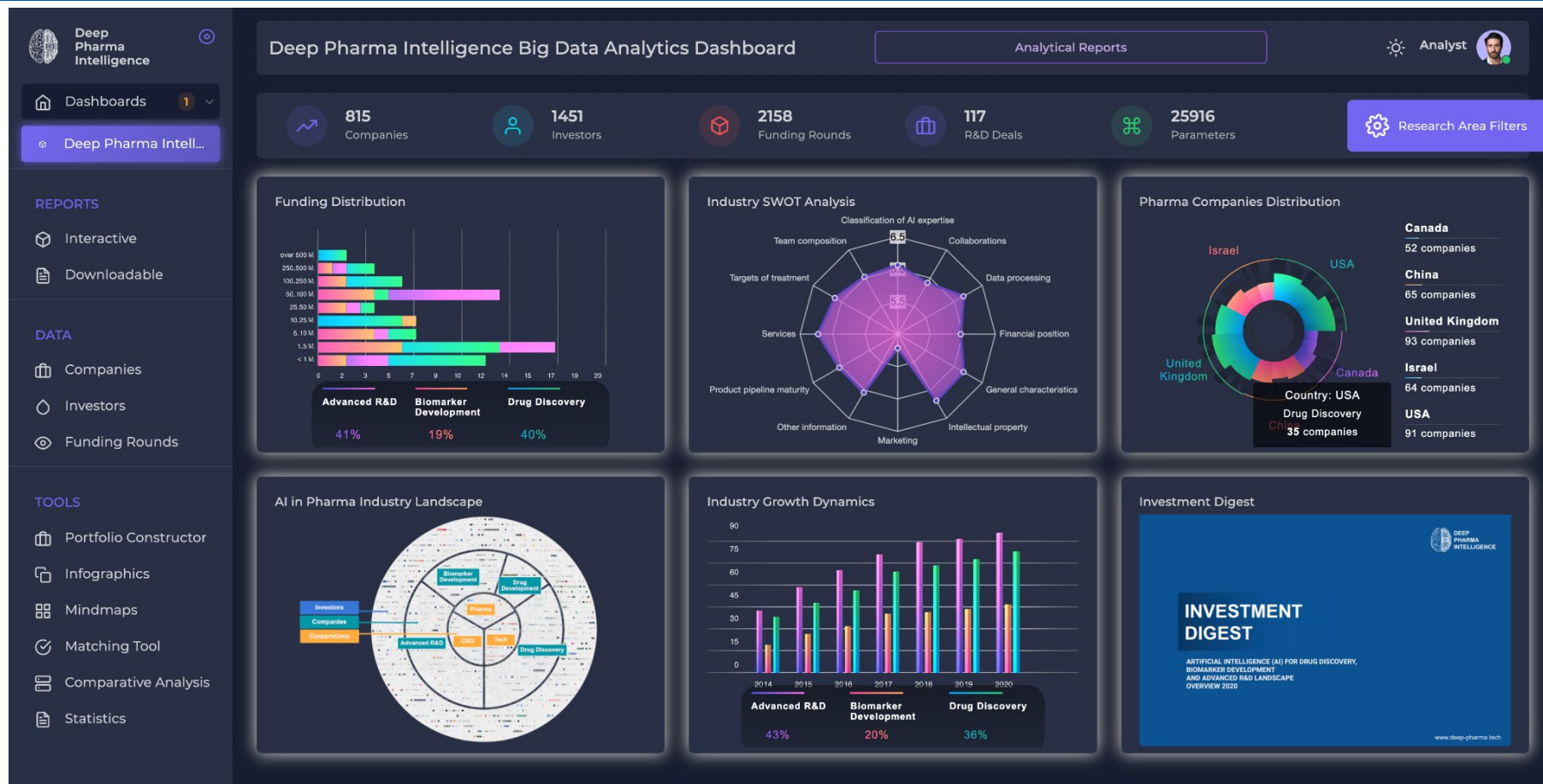
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Longevity Governance Search Engine

Health-Adjusted Life Expectancy (HALE) Gap and Life Expectancy

Health-Adjusted Life Expectancy (HALE) Benchmarking

Deep Pharma Intelligence Big Data Analytics Dashboard



AI in Pharma Industry Landscape

Investors

Companies

Corporations

Biomarker Development

Drug Development

Drug Discovery

Advanced R&D

Industry Growth Dynamics

Year	Advanced R&D	Biomarker Development	Drug Discovery
2014	30	15	15
2015	45	20	20
2016	50	25	25
2017	55	30	30
2018	60	35	35
2019	65	40	40
2020	70	45	45

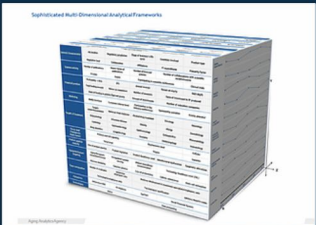
Investment Digest

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Multidimensional Analytics Frameworks



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Longevity Global Investment Digest

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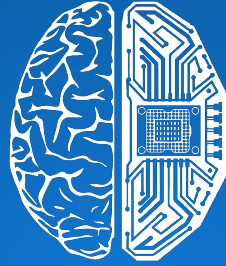
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