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Liability-Driven Investment Strategy

Sensitivity analysis of a UK Pension Scheme

Daniela da Costa Tavares

Dissertation presented as partial requirement for obtaining the Master’s degree in Statistics and Information Management

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LIABILITY-DRIVEN INVESTMENT STRATEGY:

SENSITIVITY ANALYSIS OF A UK PENSION SCHEME

by

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Dissertation presented as partial requirement for obtaining the Master's degree in Statistics and Information Management, with a specialization in Risk Analysis and Management

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ABSTRACT

Pension schemes and hedging strategies are constantly being subject to research throughout the years. However, to the best of our knowledge, there is no literature that studies how changing actuarial assumptions affects the hedging position of the schemes. Therefore, the objective of this study is to analyze the hedging sensitivity to demographic and economic assumptions used on the Actuarial Valuation and, consequently, contribute to an unexplored topic.

This research will be directly focused in a dummy UK pension scheme for the liabilities calculations while the asset portfolio was constructed using a duration and convexity matching strategy, where the scheme's asset allocation is built with the main goal being that its sensitivity to interest and inflation rates changes is matched with the corresponding scheme's liabilities sensitivity.

To calculate the liabilities sensitivity of a pension scheme, it is derived a Liability Benchmark Portfolio. However, not only interest and inflation rates shifts represent a risk for the pension scheme. All the assumptions used to derive the Liability Benchmark Portfolio will also be a risk that will not be hedged in the immunization strategy. The assumptions that were analyzed throughout this research are the following: mortality table, rate of improvement, spouse's age, discount basis, inflation rate and the wedge between CPI and RPI.

This dissertation therefore tests how changing assumptions impacts the hedging strategy of the scheme and the respective consequences in the final designed asset portfolio.

KEYWORDS

Liability-Driven Investment; Liability Benchmark Portfolio; United Kingdom pension schemes; Defined-benefit pension scheme.

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LIST OF ABBREVIATIONS AND ACRONYMS

LDI	Liability-Driven Investment
LBP	Liability Benchmark Portfolio
UK	United Kingdom
DB	Defined-Benefit
DC	Defined-Contribution
CPI	Consumer Price Index
RPI	Retail Price Index
LPI	Limited Price Indexation
JY	Jarrow Yildirim
NAE	National Average Earnings
GMP	Guarantee Minimum Pension

1. INTRODUCTION

Hedging strategies are used by the investors in order to reduce their exposure to various risks in their asset portfolios. These types of strategies will reduce the potential profit of the investors however will protect them from losses. By other words, the investors will protect themselves against a negative impact on their finances.

In this thesis we will talk through liability hedging in UK Pension Schemes, more specifically this study will be focus on Liability-Driven Investments (LDI).

On an ongoing basis, the market is constantly changing, and the interest rate and inflation uncertainty are the most considerable risks for pension schemes since these changes will have an impact on both asset and liabilities of the schemes. Given this, schemes may need to hedge against these unexpected changes in the market in order to have enough assets to cover short and long-term liabilities.

Therefore, liability hedging is the process used to reduce a pension scheme's net exposure to changes in interest rates and inflation given that these are the main risks that a pension scheme is exposed to.

Thus, interest rate and inflation risk are usually the main risks that defined-benefit pension schemes are exposed to given that their primary objective is to guarantee that members receive their pensions in the long-term. Given this, to control the impact of market conditions changes, pension schemes usually use liability hedging strategies that consist in investing in assets that would behave in the same way as the liabilities when inflation and interest rates changes. The most common liability hedging strategy used by UK pension schemes is the Liability-Driven Investments, in which the pension schemes invest in assets that will move in line with their liabilities once interest and inflation rates change. By using this strategy, the schemes are hedged against the uncertainty of a mismatch between assets and liabilities movements. Also, when using a LDI strategy, the people that are responsible for monitoring the schemes' investments avoid investing in more risky assets if not necessary and will potentially reduce the compensation paid by the company, making sure that all the members receive all the pensions.

Furthermore, when choosing an LDI strategy the pension scheme is reducing his net exposure to changes in interest rates and inflation given they are trying to offset the impact of movements in interest rates and inflation on the value of liabilities by holding assets that behave in the same way.

However, the main objective of this dissertation is to show that not only the interest rate and inflation are risks to be considered when designing a hedging strategy but that there are also other factors that can influence the liability movements.

In the following sections we tested how other variables also impact the liabilities and therefore the hedging of the scheme. We tested the impact of actuarial variables like mortality tables, rate of improvement and spouse's age and the consequences of following economic variables: the interest rate, the inflation rate used to derive the LBP and the wedge between CPI and RPI.

Our evidences suggest that by using assumptions that lead to an assumption of people living longer, the hedging of the scheme will deteriorate. In our research, this was reflected when we assumed a lighter mortality table and a lower rate of improvement.

When we increase the difference between the scheme's member age and the spouse's age and assume that males are always older than the females, in a scheme with higher proportion of males, we expect a decrease in the hedge ratios because it is assumed that a female spouse lives for a longer period.

In terms of the economic assumptions, as expected we have a proportional behaviour of the hedging when changing the discount rate. Which means that when we increase the discount rate, we will be decreasing the estimated present value of the liabilities, thus, we will be improving the hedging of the scheme.

Regarding the change on the inflation, when we decrease the inflation rate it is less likely for the LPI caps to be reached, hence, the LBP will have a higher proportion of benefits linked to inflation that would not been taken in account when designing the current asset profile. Therefore, the hedge ratio will decrease.

When analysing the wedge between CPI and RPI, if we increase this wedge, we will be assuming a lower CPI curve and will consequently see the same impact as on the inflation test mentioned above. However, in the inflation analysis we will just see the impact in the CPI-linked benefits.

This dissertation will be organized as follows: in section 2 we will introduce in general the UK pension schemes and the common hedging strategies used. Section 3 contains the methodology and the data used. The results of our research are presented on section 4. Finally, section 5 contains the main conclusions and proposals for future researches.

2. LITERATURE REVIEW

2.1. UK PENSION SCHEMES

A pension scheme is a type of savings plan with the objective of save money for later life. This plan could be set by the employee or by the employer given that in this last case represents a company benefit to its employees.

There are three types of pension schemes: defined-benefit, defined-contribution and hybrid schemes.

The defined-benefit (DB) pension schemes specify a level of income that depends on the pension schemes' rules and it is calculated using the employee's years of pensionable service and its final pensionable salary. For the other type of pension schemes – defined-contribution (DC) – as the name indicates, the money received in retirement it is defined with the value that is accrued over the years of service. Lastly, there are schemes that combine both defined-benefit and defined-contribution pension schemes – these are called hybrid schemes.

This thesis will focus on defined-benefit pension schemes that are guaranteed by the employers.

For this type of schemes there are several groups involved: Beneficiaries, Sponsor, Trustees and other third parties.

The Sponsor is the company for which the Beneficiaries have worked for. The Sponsor is responsible for ensuring that the employees receive their retirement income that they are entitled to from the scheme.

The Trustees are a group of people or a firm in case of a Corporate Trustee, independent of the employer, that are responsible for monitoring the schemes' investments to ensure that members' benefits are secured (The Pensions Regulator, 2007a). They are also responsible to be aware of the financial strength and health of the employer. The third parties are the ones responsible for all the valuation and investment procedures, for example, the Scheme Actuary, the Investment Adviser and the respective Investment Managers.

Given that on DB schemes it is the pension benefit that is defined, it is important for the Sponsor to make sure that they have the required money to cover their long-term liabilities.

In order to regularly monitor the scheme liabilities, the UK legislation requires that all pension schemes, at minimum once every three years, calculate the value of the benefit accrued to a specific date – this analysis is called Actuarial valuation.

The Actuarial Valuations have several objectives (Mercer, 2020a):

- Evaluate the pension scheme's liabilities
- Produce technical and actuarial reports
- Determine the annual contribution of the company

- Set the schemes funding level
- Develop amortization plans of liabilities

The liabilities of pension scheme are the value of benefits accrued until the valuation date. The valuations also mention this value as Past Service and use it to compare with scheme's assets. These liabilities will be calculated using a future salary increase assumption for active members.

The Future Service represent the value of the benefits earned over one year following the valuation date and it is used to calculate the contributions required to meet the cost of a benefit earned by the active members during that single year. These required contributions are named future service contribution rate.

It is important to understand some of the risks underlying these valuations. The Scheme Actuary is responsible to choose prudently the assumptions that will be assumed, both demographic and economic. Some examples of the demographic assumptions are the mortality table, the rate of improvement, loading and percentage married. While for the economic assumptions, the Actuary needs to choose the basis to discount the cashflows, Inflation Risk Premium and the wedge between CPI and RPI (Deloitte, 2017).

Following this, the funding position of a scheme is how the current market value of the assets compares with its liabilities and can be calculated using different funding approaches, where the only difference between those approaches are the assumptions used. We have set out below the main funding approaches (AON, 2018):

- Statutory Funding Objective: Commonly called Technical Provisions (TP) valuation. The objective is that the scheme has sufficient and appropriate assets in order to provide the promised benefits as they fall due;

- Pension Protection Fund (PPF) buy-out/Section 179 basis: The assumptions used for this approach are equal across all schemes. PPF establish a pay compensation to scheme's members when an employer becomes insolvent or when the scheme does not have sufficient assets to cover PPF levels of compensation. Section 179 of the Pensions Act 2004 requires schemes to estimate the funding needed to secure PPF compensation levels. The liabilities calculated in this basis are usually lower than the scheme's full benefit because this valuation relates to a compensation offer by the PPF;

- Self-Sufficiency: This approach requires a minimal level of reliance on the Sponsor given that is expected that the scheme is able to sustain itself by investing their assets on a low risk basis and pay members' benefits with their return without any support from the Sponsor. The strategy of investing in a low risk basis consists in minimizing the chances of having investment losses;

- Insurance buy-out: Buy-out is a strategy where the promised benefits to members are paid out and are responsibility of an insurance. Therefore, the buy-out valuation consists in calculating the amount of money needed by the scheme to buy all the accrued benefits from an insurance company;

- Accounting Valuation: Often referred as International Accounting Standard19 (IAS19) or Financial Reporting Standard 102 (FRS102) valuation. The measurement basis is in line with accounting standards and it is equal for all companies. The purpose of this method is to calculate the pension schemes liabilities to publish in their annual report and accounts and, thus, allowing accurate comparisons between different pension schemes.

Therefore, we can calculate different funding positions taking into account different approaches. We can analyze the funding position by calculate the ratio between scheme's assets and liabilities, i.e. funding level, or we can look at the difference between assets and liabilities, where we can conclude if the scheme is in surplus or deficit (The Pensions Regulator, 2018).

Given this, it is easy to understand that the importance of regularly monitor the pension scheme is due to the constant changes in market conditions, that will affect economic assumptions, but also due to the all the membership changes that will impact the demographic assumptions.

Using all the assumptions chosen by the Scheme Actuary, it is important to understand how the benefits of the Scheme are calculated.

In the UK, pension schemes are well known by their complex benefit structure that split the benefit indexation into different periods and tranches (Mercer, 2020b).

We can typically mention three periods with different inflation linkages:

- Time from valuation to decrement: Salary increases
- Time from decrement to start of payment: Deferred revaluation
- Time from start of payment to actual occurrence of the cashflow: Pension increase

Following these periods, we can divide the scheme's membership into the following groups: active, deferred and pensioner. Active members are the ones that are still on service and will have benefits receiving salary and pension increases. However, they can also have a part of the benefits assumed to increase in line with deferred revaluation in the case that Actuary assumes that a part of active members will leave the scheme prior retirement. Deferred is the name used to define a member that did not reached the retirement age yet, however, does not contribute to the scheme. These members will then have their benefits index to revaluation and pension increases. Finally, pensioners are the members that already retired and are currently receiving benefits so will only be impact by the pension increases (Marcaillou, 2016).

The three periods above are then linked to different inflations between them, however each period will also have different indexations – to these splits we call tranches.

The tranches are split by different revaluations and pension increases that benefits will receive and are defined accordingly to the scheme's rule. Note that pension schemes have statutory minimum increases to provide (Mercer, 2020a):

- Pension increases in deferment (Revaluations):

  - Guarantee Minimum Pension (GMP) accrued between 6th April 1978 and 5th April 1997: Three different revaluations that could be applied - Fixed rate (depends on the date of leaving of the member), Section 148 order (in line with NAE index) and Limited Revaluation (minimum between S148 and 5% p.a.)
  - Before 5th April 1997 in excess of GMP: if member leaves before 31 December 1985, no revaluation is applied to this benefits; if members leaves between 1 January 1986 and 31 December 1990, no revaluation is applied to pension accrued until 1 January 1985 and the remaining pension is revalued in line with Inflation Prices subject to a cap of 5% p.a.; if members leaves after 1 January 1991, all of this pensions revalue in line with Inflation Prices subject to a cap of 5% p.a.
  - Between 6th April 1997 and 5th April 2009: Inflation Prices subject to a cap of 5% p.a.
  - After 6th April 2009: Inflation Prices subject to a cap of 2.5% p.a.
- Pension increases in payment:
  - GMP before 5th April 1998: No increase is applied to this benefits
  - GMP between 6th April 1988 and 5th April 1997: Consumer Price Index subject to a cap of 3% p.a.
  - Before 5th April 1997 in excess of GMP: No increase is applied to this benefits
  - Between 6th April 1997 and 5th April 2005: Inflation Prices subject to a cap of 5% p.a.
  - After 6th April 2005: Inflation Prices subject to a cap of 2.5% p.a.

Besides the statutory minimums above, the scheme could have more tranches.

For future reference, when inflation prices are subject to a maximum and/or a minimum it is called Limited Price Index and they can be linked to CPI or RPI, depending on the scheme's rules.

The calculation of the pension schemes' liabilities is driven by innumerous factors that represent a risk for the scheme, from the market conditions to the actuarial assumptions.

2.2. Hedging strategies

For pension schemes the main risk linked to assets and liabilities is the possible losses that could occur on assets and increases in liabilities. Given this, the purpose of hedging is to offset the impact of movements in interest rates and inflation on the value of the liabilities by holding assets that respond in the same way (Vanguard, 2018).

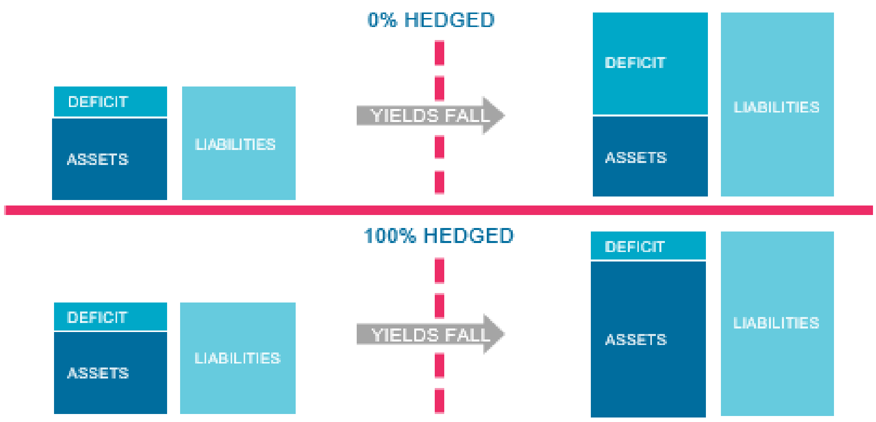
Immunization is an investment strategy used to mitigate risk for both assets and liabilities of a pension scheme, by minimizing the impact of changes in the term structure of interest rates (Bravo, 2002; Bravo and Silva, 2006; Simões et al., 2020). The immunization and consequent hedge of changes in interest rates can be achieved mainly by using a cash flow matching approach or a Liability-Driven Investment (LDI) strategy. Cashflow-Driven Investment (CDI) consists in a cashflows matching strategy. This strategy consists in looking at the estimated actual cashflows of a pension scheme instead of looking at the present value of the cashflows. This investment strategy focus on creating a portfolio of assets that generates predictable cashflows by investing in assets with returns less volatiles, to match the scheme's cash outflows requirements and its funding objectives (Insight Investment, 2020). This approach is suitable for mature schemes given that they are more focus on matching the cash outflows.

Moreover, an LDI strategy consists in investing in a way in which the main objective is to obtain enough assets to meet all the schemes' short and long-term liabilities. This hedging strategy seeks to align the sensitivity of a pension scheme's assets with the sensitivity of its liabilities. Consequently, the changes in the value of both the assets and liabilities are driven by the same fundamental markets factors, such as interest rates and inflation rates. Among others, the main metrics used when constructing an LDI strategy are the PV01, IE01 and duration. To obtain an exact behavior between assets and liabilities, investors try to match these metrics between both their assets and liabilities. The PV01 is a measure of sensitivity to a 0.01% change in interest rates, whereas the IE01 is a measure of sensitivity to a 0.01% change in the inflation rates. Finally, the duration is a term used to indicate how sensitive the present value of an asset or liability of a scheme is to changes in the term structure of interest rates (Mercer, 2020b). This metric is expressed in year and the higher the duration the greater the sensitivity to changes in interest rates.

Additionally, when analyzing a pension scheme's overall investment strategy, it is important to be aware of two main variables that will be used throughout this thesis, which are the scheme's interest rate hedge ratio and inflation hedge ratio. The interest rate hedge ratio is the ratio between the assets' PV01 and liabilities' PV01 while the inflation hedge ratio is based on the assets' IE01 and liabilities' IE01.

In Figure 1, we can see how the hedging of interest rates will impact the surplus/deficit of a pension scheme:

Figure 1 – Hedge Ratio impact on a scheme's funding position



Source: Mercer, 2017a

For the case that we have an interest rate hedge ratio of 0%, the assets will not move in line with liabilities changes. Therefore, if the yields fall, the scheme' liabilities will increase while the assets remain unchanged and this will make the scheme's deficit increase. However, if we have an asset portfolio that provides 100% hedging, the movements on the assets will be align with the liabilities' changes, which consequently will make the liabilities and assets increase in the same proportion, thus, the deficit will be unchanged.

3. METHODOLOGY

In order to study the sensibility of the LDI strategy to the different assumptions we will analyze a dummy client.

Following the pension schemes structure in UK, mentioned in a previous section, it is important to understand that we cannot directly use the projected payments of the scheme and use it to construct a portfolio of assets.

To have an asset profile matching exactly to an UK pension scheme's liability profile would be necessary to invest in assets like LPI swaps however this type of assets use annual caps and floors inflation and this are only relevant to hedge current pensions in payments given that revaluations in respect of the period before retirement typically have a cap and floor over the entire deferment period. Given this, to have assets with the same LPI characteristics of the liabilities would be very difficult and prohibitively expensive due to the absence of natural sellers of such caps and floors so the alternative is to hedge the benefits in an approximate way using a fixed and RPI-linked bonds, which is the Liability Benchmark Portfolio (LBP). The LBP will then be a series of fixed and RPI-linked cashflows that match the inflation and interest rate sensitivities of a pension scheme's liabilities at a given point in time (Mercer, 2020b).

As previous said, all the UK defined-benefit pension schemes are obligated to do an Actuarial Valuation at least every three years that will give to the company an estimated of the future liabilities that the Sponsor will have with the Beneficiaries of the scheme. Actuarial Valuations will then be used to obtain the payments projection of the Scheme year-by-year that will be used to produce the LBP. Payments are calculated based on benefits accrued up to valuation date and are projected using actuarial assumptions like mortality table, commutation, withdrawal, proportion married and age difference between member and spouse. The payments projection data will be split by indexation and, in order to use this information to obtain the LBP, a stochastic model will be used to derive consistent the prices for all capped and floored indexation within the scheme's benefit structure.

There are different methods that could be used to derive the LPI inflation assumption, however, the model that will be used to derive the LBP on this thesis is the Jarrow Yildirim model (JY). The JY model uses a Monte-Carlo simulation to project nominal and real gilts over a large number of scenarios, calibrated so that nominal and real yields projections match with the market data. Inflation and LPI simulations are then driven as the difference between nominal and real yields with appropriate adjustment for the caps and collars (Mercer, 2017b). Then, with the estimated LPI inflation assumption, it is possible to construct a portfolio of real and nominal zero-coupon bonds that closely matches liabilities' inflation sensitivity.

Note that the LBP changes accordingly to market conditions changes given that these changes will impact the inflation exposure of the LBP. The principal market conditions that will impact the final LBP are the expected future rate of inflation, future volatility of inflation and wedge between CPI and RPI. We can then understand why it is important to have a look on the economic changes impact on schemes' hedging. Inflation assumptions will be subject to the market conditions used to derive the LPI inflation assumption however demographic assumptions will be directly incorporated on the payments projection. In other words, the LBP will not hedge movements in liabilities arising from changing demographic assumptions, for example, future level of mortality rates, however it will be used to hedge against movements in the value of the scheme's liability arising from changes in market expectations for future levels of interest rates and inflation.

Therefore, the impact of changing economic assumptions will be reflected by changing the market conditions used on the stochastic results that is used to derive the LBP, while changes in demographic assumptions will have an impact directly on the payments projection obtained from the Actuarial Valuation.

Furthermore, the final LBP will then be an investible version of the complex pension scheme's liabilities and, therefore, it can be used to construct an asset portfolio that will match the scheme's liability characteristics and potential future movements.

To construct the asset portfolio and hedge the scheme against interest rate and inflation changes, several investments strategies can be used. Throughout this paper we will use a duration and convexity matching strategy. To define this strategy we will use the following terms (Shang & Hossen, 2019):

$\mathrm{AR}_t =$ continuous pension asset return for period *t*.

$B_t =$ pension benefit payment in period *t*. Benefit payments are assumed to be evenly distributed in the period and are modelled as one single payment at the midpoint of the period.

$C_t =$ pension contribution in period *t*. Pension distributions are assumed to be evenly distributed in the period and are modelled as one single contribution at the midpoint of the period.

$A_t = A_{t-1}e^{\mathrm{AR}_t} + (C_t - B_t)e^{\frac{\mathrm{AR}_t}{2}} =$ pension asset value at time *t*.

$\mathrm{DR}_{t,i} =$ continuous discount rate at time *t* for cash flow in period *t* + *i* for pension liability valuation.

$L_t = \sum_{i=1}^{\infty} e^{-\mathrm{DR}_{t,i} \cdot i} \cdot B_{t+i} =$ pension liability value at time *t*.

$H_t =$ target liability hedging at time *t*.

The main purpose of matching the duration of the liabilities with the assets is to protect the scheme against small parallel shifts of the curves:

$$\text{Asset duration} = \mathrm{AD}_t = \frac{A_t^- - A_t^+}{2A_t\Delta y}$$

$$\text{Liability duration} = \mathrm{LD}_t = \frac{L_t^- - L_t^+}{2L_t\Delta y}$$

where

$\frac{A_t^-}{L_t^-} =$ asset/liability value with a yield decrease;

$\frac{A_t^+}{L_t^+} =$ asset/liability value with a yield increase; and

$\Delta y =$ increase or decrease in the yield.

Following this, the target duration AD_t can be calculate as

$$\mathrm{AD}_t \cdot A_t \cdot \Delta y = \mathrm{LD}_t \cdot L_t \cdot H_t \cdot \Delta y \Rightarrow \mathrm{AD}_t = \frac{\mathrm{LD}_t \cdot L_t \cdot H_t}{A_t}$$

By matching the convexity, we will be adding the second-order impact of yield curve changes on asset and liability value:

$$\text{Asset convexity} = \text{AC}_t = \frac{A_t^- - A_t^+ - 2A_t}{2A_t(\Delta y)^2}$$

$$\text{Liability convexity} = \text{LC}_t = \frac{L_t^- - L_t^+ - 2L_t}{2L_t(\Delta y)^2}$$

$$\text{Asset value change} = \Delta A_t = -\text{AD}_t \cdot A_t \cdot \Delta y + \text{AC}_t \cdot A_t \cdot (\Delta y)^2$$

$$\text{Liability value change} = \Delta L_t = -\text{LD}_t \cdot L_t \cdot \Delta y + \text{LC}_t \cdot L_t \cdot (\Delta y)^2$$

In order to get the target asset convexity, taking into account the duration matching, the following calculation can be solved:

$$\text{AC}_t = \text{LC}_t \cdot H_t$$

Following the strategy quoted above, it is important to note that immunization can also be applied to mortality and longevity risk management (see, e.g., Lin and Tsai (2013), Bravo (2007), Bravo and El Mekkaoui de Freitas (2018) and Bravo and Nunes (2020)). For these cases, the objective of the scheme immunization is to protect schemes against different impacts on the assets and liabilities movements driven by unexpected changes in the scheme members' survival expectations.

Longevity increases and population ageing create challenges for the individual and all societal institutions, particularly those providing retirement income, health care, and long-term care services, whether public or private (Bravo, 2020; Bravo et al., 2020). Although advances in longevity are not homogenous across socioeconomic groups, securing an adequate, stable and predictable lifelong income stream and providing a cost effective and efficient risk pooling mechanism that addresses the (individual) uncertainty of death through the provision of a lifetime annuity are some of the main mechanisms pension schemes use to redistribute income in a welfare-enhancing manner (see, e.g., Ayuso et al. (2017a,b, 2020), Bravo and Herce (2020)). Pension schemes and annuity providers face long-run solvency challenges to provide guaranteed lifetime income due to uncertain financial returns and systematic (non-diversifiable) longevity risk.

For pension plans and annuity providers, traditional longevity risk management solutions include loss control techniques (e.g., via product re-design or risk-sharing arrangements between pensioners/policyholders and providers), natural hedging, liability selling via an insurance or reinsurance contract (through pension buy-outs, pension buy-ins or bulk annuity transfers) and Insurance-Based Longevity Swaps (Bravo, 2016, 2019; Blake et al. (2019); Bravo and Nunes, 2020). Capital-market-based solutions for mortality and longevity risk management have also been proposed and, some, successfully launched. They include insurance securitization, mortality- or longevity-linked securities such as CAT mortality bonds, survivor/longevity bonds, longevity-spread bonds and derivatives with both linear and nonlinear payoff structures (see, e.g., Blake and Burrows (2001), Hunt and Blake (2015), Coughlan et al. (2007), Cairns et al. (2008), Dawson et al. (2009), Chan, Li and Li (2014), Li et al. (2019), Dowd et al. (2006), Blake et al. (2019))Longevity is an underlying risk to pension schemes given that over time the life expectancy has been increasing at all ages. This constant improvement will affect the scheme's liabilities because the sponsor will have the responsibility of paying benefits for a longer period. Given the difficulty of predicting the life expectation improvement over the years, the longevity risk will strongly affect the funding level of the pension scheme.

Consequently, linked to the inflation and longevity risks, the inflation-linked bond markets lack of capacity combined with a high concern on counterparty risk for derivatives-based hedging solutions, generate the called immunization problem.

It is difficult to measure the longevity impact on a pension scheme given that, most of the schemes use a standard mortality table that is not specifically created to the scheme's membership. However, this is one of the reasons why the scheme has the obligation of periodically updating their assumptions – financial and demographic - and calculate a more accurate liability figure. In this research, we will not be focusing on a longevity immunization strategy but instead we will study the impact of changes in the mortality assumptions in the overall hedging strategy of the dummy scheme.

Note that for all the analysis done on this thesis, we will use nominal and inflation gilt curves derived by Mercer based on the Debt Management Office. You can find all the curves used on the Appendix A.

3.1. DATA

In this thesis, we will perform a sensitivity analysis of the assumptions that impacts the final asset portfolio constructed based on the LBP.

To do such analyse, we will use a dummy client data that was built under a Technical Provision (TP) valuation and that it is defined by the following rules:

Table 1 – Scheme information

Scheme Information	
Open/Close to new entrants	Close
Open/Close to future accrual	Open
Earnings Definitions	
Pensionable Salary	Average weekly rate
Final Pensionable Salary	Greater of: • The highest of 3 years consecutive Pensionable Earnings in the 10 years immediately prior to retirement; • Average level of Pensionable Earnings over 12 months immediately prior to retirement.
Service Definition	
Pensionable Service	Continuous service as a member of the Fund

Rounding Rules	Complete Calendar months
Retirement Benefits	
Normal Retirement Age	65
Pension formula	1/60 x Final Pensionable earnings x Pensionable Service
Cash formula	Post A-day max
Spouse's pension	60% of pre-commuted member's pension
Deferred / Withdrawals	
Vesting conditions	2 years
Spouse benefit if death prior to retirement	60% of member's prospective pension with salary at date of death

The scheme's structure is defined by looking at the pension increases and the indexation of each tranche. The pensions in payment of the scheme are subject to increases as follow:

- The part of the pension which represents the Guaranteed Minimum Pension accrued before 5th April 1988 does not increase once in payment;
- The part of the pension which represents the Guaranteed Minimum Pension accrued since 6th April 1988 is increased in line with the increase in the CPI, subject to a maximum increase of 3% per annum;
- The part of the pension in excess of the Guaranteed Minimum Pension accrued before 5th April 1997 is increased annually in line with the increase in the Consumer Price Index, subject to a maximum of 5% per annum;
- The part of the pension accrued after 6th April 1997 and before 31st March 2015 is increased annually in line with the increase in the Consumer Price Index, subject to a maximum of 5% per annum;
- The part of the pension accrued after 1st April 2015 is increased annually in line with the increase in the Consumer Price Index, subject to a maximum of 2.5% per annum.

Deferred pensions are increased as follows in the period of deferment:

- The part of the deferred pension which represents the Guaranteed Minimum Pension is increased over the period of deferment receive revaluation at the applicable fixed rate;
- The deferred pension in excess of the Guaranteed Minimum Pension and accrued before 5th April 2009 is increased over the period of deferment at the rate of 5% per annum, or in line

with the increase in the Consumer Price Index if that is less over the whole period of deferment;

- The deferred pension accrued on or after 6th April 2009 is increased as above, but subject to a maximum of 2.5% p.a. compound over the period of deferment.

The assumption for the salary increases will be determined from the Consumer Price Index with an addition of 1% per annum. The Consumer Price Index assumption will be derived from the RPI inflation with an adjustment to recognise the difference between future CPI increases and future RPI increase. In this case, the adjustment will be a deduction of 0.70% per annum.

Regarding the membership data, we setup below a summarise table:

Table 2 – Scheme membership data

Active members	
Number	32
Total pensionable salaries (£000 p.a.)	902
Average age (weighted by salary)	54.9
Deferred members	
Number	53
Total deferred pensions revalued to valuation date (£000 p.a.)	192
Average age (weighted by deferred pension)	54.6
Pensioners members	
Number	312
Total pensions payable (£000 p.a.)	1,788
Average age (weighted by pension)	74.2

The table below summarises the demographic assumptions used in the calculations of the technical provisions used in the Actuarial Valuation.

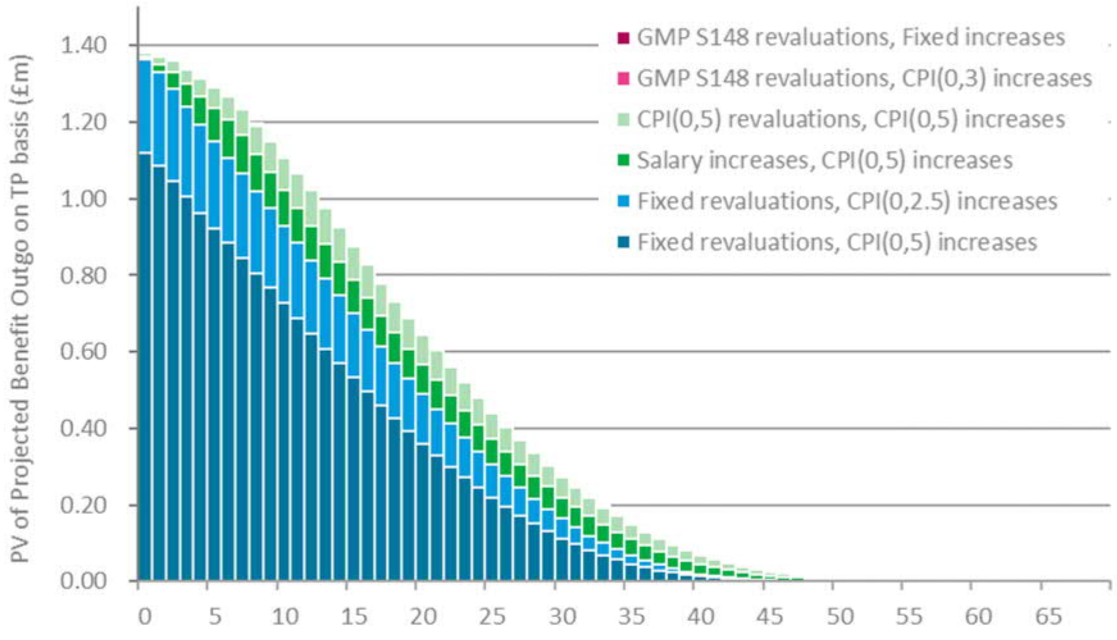
Table 3 – Demographic assumptions used on the Actuarial Valuation of the scheme

Mortality – base table	S3PA (year of birth) tables
Mortality improvements:	CMI 2018 model with a long-term rate of improvement of 2.0% for males and 1.5% for females
Commutation	No allowance
Proportion married	Assuming tables with the following sample rates: Age / Males / Females 60 / 95% / 93% 65 / 90% / 90% 70 / 80% / 76%
Spouse's age	Wives/partners are three years younger, on average, than their husband/partners.

Age	Males	Females
60	95%	93%
65	90%	90%
70	80%	76%

Using all the data and assumptions mentioned above, we obtained the following payments projection that will be used in the analysis done in the next section.

Figure 2 – Present Value on gilt+0.40% basis of Projected Benefits split by indexations



Source: Author

The Figure 2 shows the liability split between benefits with different inflation-linked and fixed increases. The profile reflects the complex benefit structure of the scheme, with different LPI components and show the cashflows split by revaluation in respect of the period before retirement and increases to pension in payment. Important to clarify that in the figure above and throughout this paper, when it is mentioned, for example, CPI(0,3), it means that the benefits are linked to CPI subject to a minimum of 0% p.a. and a maximum of 3% p.a..

Note that the chart shows the cashflows discounted on a gilt+0.40% basis using 31 December 2019 market conditions.

4. RESULTS AND DISCUSSION

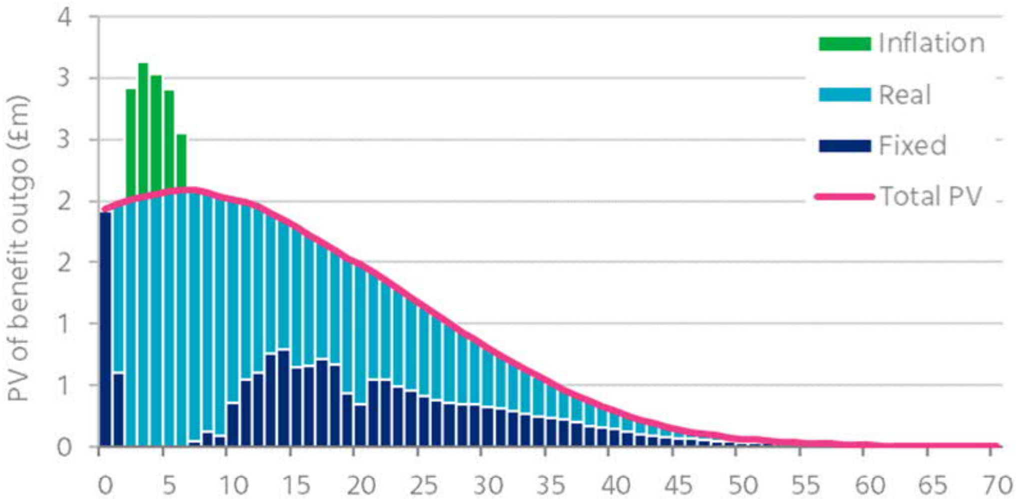
The objective of this thesis is to analyse the impact of changes in demographic and economic assumption on the hedging of a dummy pension scheme. The analysis will be done in two parts. Firstly, we will change some demographic assumptions chosen by the scheme's Actuary and will derive new payments projection and then, we will change the economic assumptions used to derive the Liability Benchmark Portfolio.

By using the original data, we constructed an LBP based on the 31 December 2019 market conditions and it was calculated on a gilt+0.40% basis.

With the scheme's structure and data mention in the previous section, we constructed an asset allocation to achieve an inflation and interest rate hedge ratios of c.100%. In order to construct the asset portfolio, we firstly needed to construct an investible liability profile to hedge against.

The LBP produced for the analysis is based on the 31 December 2019 market conditions and was discounted on a gilts+0.40% basis. The Figure 3 shows the profile of the LBP of the scheme and illustrates the proportion of the exposure cashflow that is sensitive to interest and inflation rates. The dark blue bars show the cashflow sensitivity to nominal interest rate and the light blue represent the inflation and interest rates sensitivity. The green bars above the pink total cashflow line show only the inflation exposure that happens because the inflation sensitivity is not evenly distributed. The main reasons are due to deferred liabilities being sensitive to inflation before the pension becomes in payment and the existence of LPI linked cashflows which are more inflation-linked in early tenors than later tenors, due to the relative confidence of caps and floors not being reached. By other words, this is largely due to the fact that increases in deferment are more highly inflation-linked than increases in payment, meaning (due to the method of constructing the LBP) that there is "too much" long fixed exposure in the short term.

Figure 3 – LBP profile of the original scheme



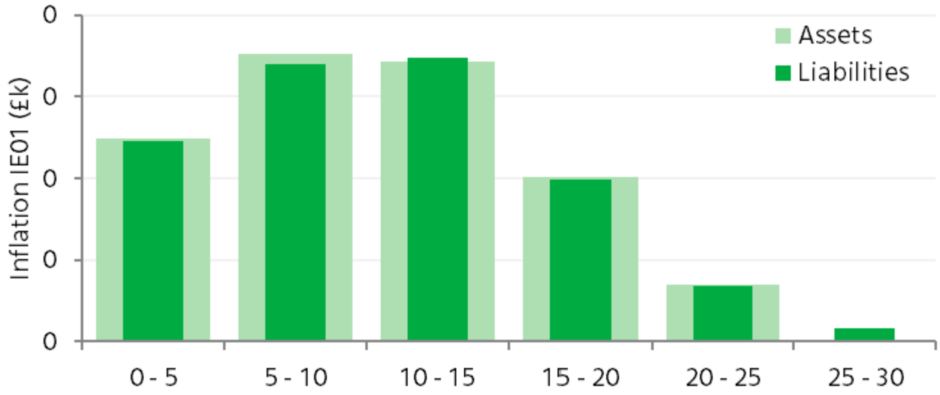
Source: Author

Table 4 – Summary of the key statistics of the original scheme

Present Value	£57.8m
Duration	16 years
PV01	£92.5k
IE01	£60.8k
Inflation Linkage (IE01 / PV01)	65.7%

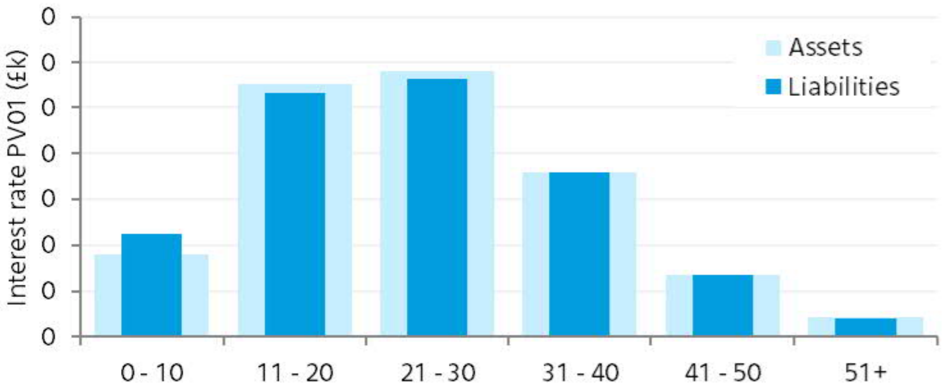
With the LBP profile, we were able to construct an asset portfolio that the sensitivity closely matches the liability sensitivity of the scheme. Overall, we get interest rate and inflation hedge ratios of c.100%.

Figure 4 – Inflation Hedge Ratio of the scheme's liabilities with the original assumptions



Source: Author

Figure 5 – Interest Rate Hedge Ratio of the scheme's liabilities with the original assumptions



Source: Author

For the next sections, we will use this asset portfolio to analyze the impact on the hedging of the dummy pension scheme when changing the assumptions used.

4.1. Changes in Demographic Assumptions

The objective of changing the demographic assumptions is to show the impact that the Actuary choices will have on the investments done by the Scheme.

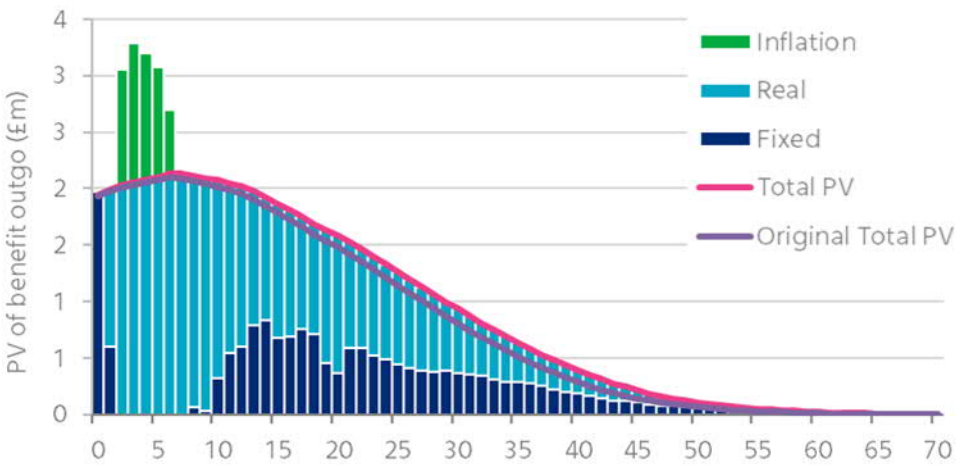
4.1.1. Mortality Table

Mortality tables set the proportion of people that are expected to die in the following year for each age, using a certain point in time and based on historical data of a particular group of people.

The tables used reflect the profile of the scheme's membership. The schemes in UK, commonly use the Continuous Mortality Investigation (CMI) tables to allow for the Actuarial Valuation's death probability given that this tables are based on mortality rates of members of defined-benefit Self-Administered Pension Schemes (SAPS).

In our analysis, as already mentioned, the original Actuarial Valuation used the CMI 2018 table to allow for the probability of death in the actuarial calculation. We will then estimate the impact of changing the mortality table to the CMI 2015 table could have on the hedging of the scheme.

Figure 6 – LBP profile of the scheme with the modified mortality table



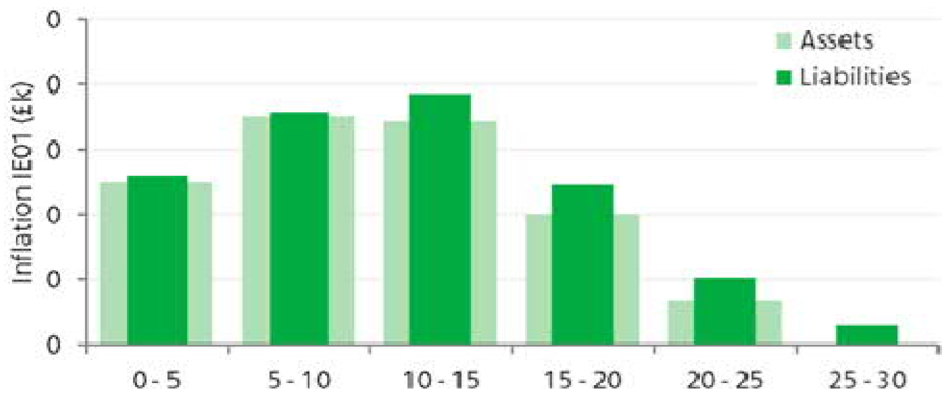
Source: Author

Table 5 – Summary of the key statistics with the modified mortality table

	Original	Modified
Present Value	£57.8m	£62.3m
Duration	16 years	17 years
PV01	£92.5k	£106.0k

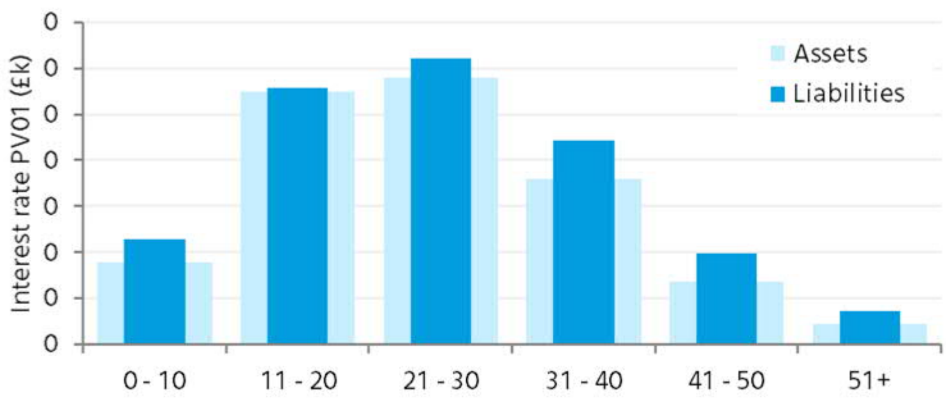
IE01	£60.8k	£69.1k
Inflation Linkage (IE01 / PV01)	65.7%	65.2%

Figure 7 – Inflation Hedge Ratio of the scheme with the modified mortality table



Source: Author

Figure 8 – Interest Rate Hedge Ratio of the scheme with the modified mortality table



Source: Author

Table 6 – Hedge Ratios of the scheme with the modified mortality table

	Original	Modified
Interest Rate Hedge Ratio	100.0%	87.2%
Inflation Hedge Ratio	100.0%	87.9%

By changing the mortality table from CMI 2018 to CMI 2015, we can see that the updated table will assume a materially lighter mortality. This means that the Actuarial Valuation will assume that members will live longer compared with what was assumed before. Consequently, the scheme will have to pay more years of benefits to the members and this is reflected by an increase in the liability and on the duration of the scheme (see Figure 6 and Table 5).

Given the explanation above, it is logical to decrease the hedge ratios (Figures 7 and 8 and Table 6) due to the fact that the scheme will now have to pay more benefits to the members but still has the same asset portfolio.

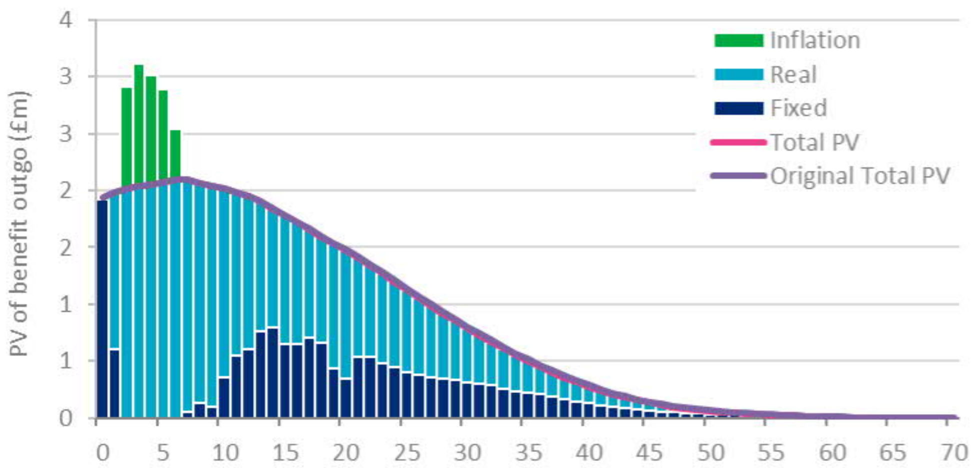
4.1.2. Rate of improvement

In order, to have a better reflection of the scheme's membership on the mortality table used, the Actuary can do some adjustments to the table used.

One of the adjustments that can be done is applying a rate of improvement to the mortality table. The rate of improvement measures the change from one year to the next of the proportion of people that are expected to die. A positive rate of improvement represents a fall in the proportion of people that are likely to die in the following year, whereas a negative rate represents a rise in this proportion.

Usually, UK pension schemes use a different rate of improvement for males and females. In our dummy client, we have used a rate of 2% for males and 1.5% for females and we have analyzed the impact of changing these figures to 1.75% for males and 1.25% for females.

Figure 9 – LBP profile of the scheme with the modified rate of improvement



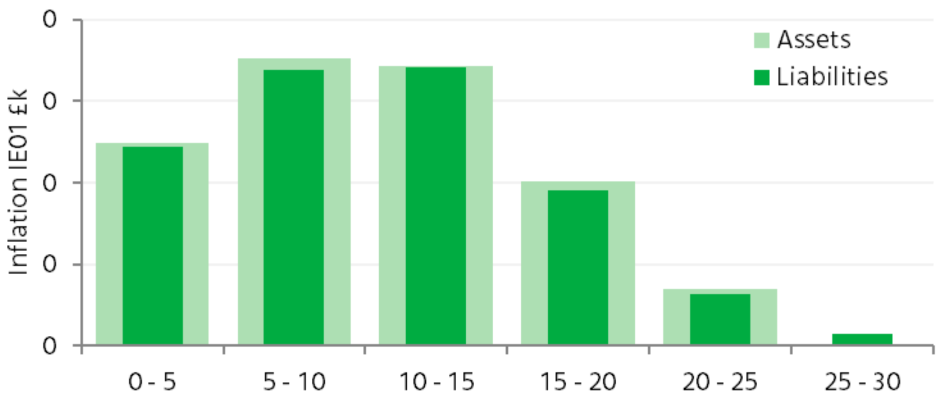
Source: Author

Table 7 – Summary of the key statistics with the modified rate of improvement

	Original	Modified
Present Value	£57.8m	£57.2m
Duration	16 years	16 years

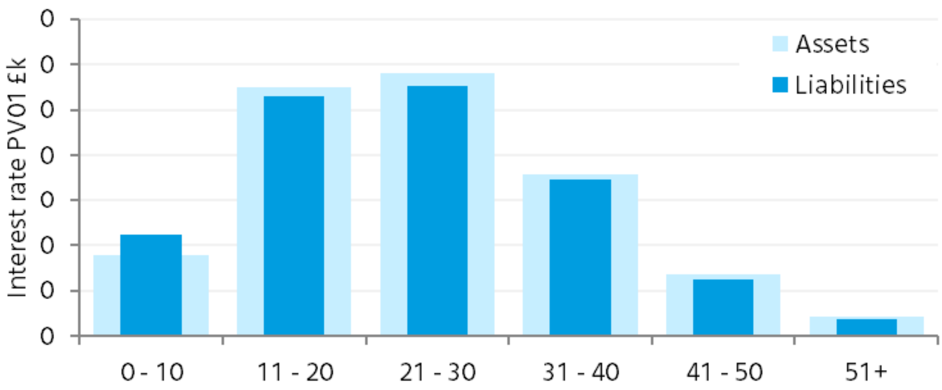
PV01	£92.5k	£90.8k
IE01	£60.8k	£59.7k
Inflation Linkage (IE01 / PV01)	65.7%	65.8%

Figure 10 – Inflation Hedge Ratio of the scheme with the modified rate of improvement



Source: Author

Figure 11 – Interest Rate Hedge Ratio of the scheme with the modified rate of improvement



Source: Author

Table 8 – Hedge Ratios of the scheme with the modified rate of improvement

	Original	Modified
Interest Rate Hedge Ratio	100.0%	101.8%
Inflation Hedge Ratio	100.0%	101.8%

By changing the rate of improvement to a lower figure, we are assuming a fall in the proportion of people that are likely to die, so we will assume that there is a higher probability of members to die sooner. Thus, the scheme will have to pay less benefits to its members. Therefore, as expected, the analysis show a decrease of the liabilities from £57.8m (Table 4) to £57.2m (Table 7). Important to note that we only changed the rate of improvement by a residual amount (a decrease of 0.25%), reason why we are seeing small changes in the statistics shown.

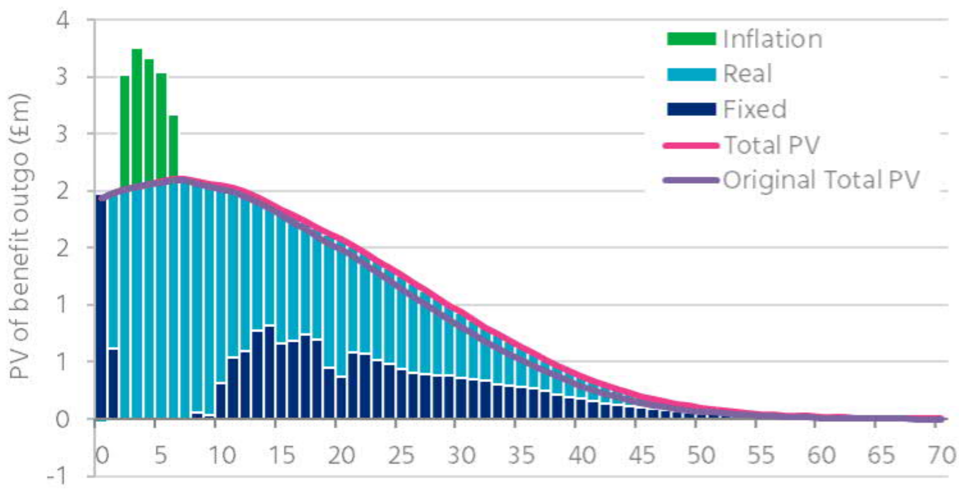
Regarding the hedge ratios, as we are assuming that members will stop receiving their benefits earlier, which means that the impact in the fixed and inflation-linked benefits will be similar as all the benefits will stop being received at the same period in time, thus, we conclude that there is an equal increase on both the interest rate and inflation rate hedge ratios (Table 8).

4.1.3. Spouse's age

The benefits provided to the scheme's members can also be a benefit to the member's spouse in case of his/her death. Given this, it is important to take into account the probability of death of the Beneficiaries. To consider this, the Actuary should establish an age difference between the scheme members and their spouses.

In the scheme that we are analyzing, the age difference was established to be 3 years, however, to test how this will impact the hedging of the scheme we change it to 7 years.

Figure 12 – LBP profile of the scheme with the modified spouse's age



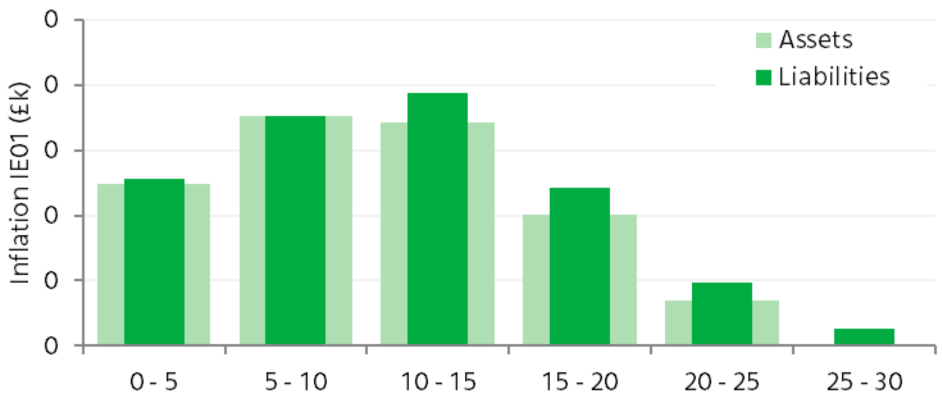
Source: Author

Table 9 – Summary of the key statistics with the modified spouse's age

	Original	Modified
Present Value	£57.8m	£61.5m
Duration	16 years	17 years

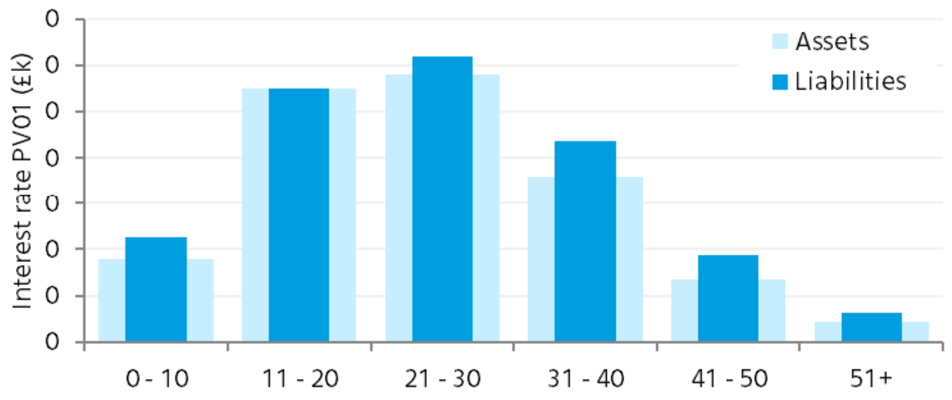
PV01	£92.5k	£104.0k
IE01	£60.8k	£68.0k
Inflation Linkage (IE01 / PV01)	65.7%	65.4%

Figure 13 – Inflation Hedge Ratio of the scheme with the modified spouse's age



Source: Author

Figure 14 – Interest Rate Hedge Ratio of the scheme with the modified spouse's age



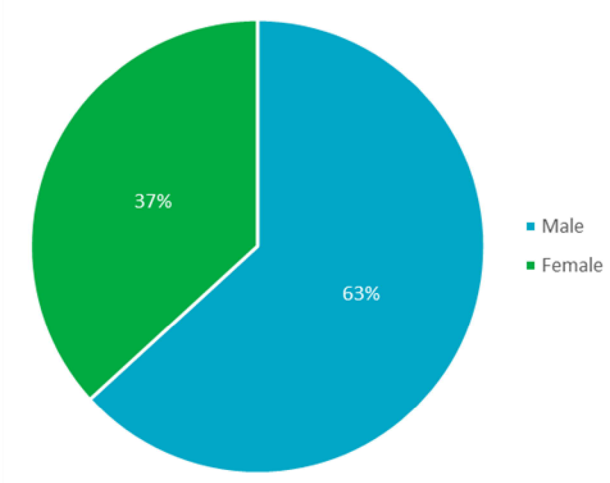
Source: Author

Table 10 – Hedge Ratios of the scheme with the modified spouse's age

	Original	Modified
Interest Rate Hedge Ratio	100.0%	88.9%
Inflation Hedge Ratio	100.0%	89.3%

The impact of the spouse's age will be related with the number of female members and male members given that the scheme assumes that male members are always older than their spouse. Therefore, by increasing the age difference between the members and the corresponding spouse, we are expecting a decrease in the liabilities if the scheme has more female members and a increase if it has more male members. This happens because in a scheme predominated by female members, their spouses are assumed to be male and older than before, so we are expecting that the spouse lives less since they have a lower probability of survival when the scheme's member dies. The opposite occurs when the scheme's member is a male.

Figure 15 – Percentage of scheme's membership split by male and female



Source: Author

In Figure 15, we show the percentage of males and female members in the dummy pension scheme used in this study. Given the higher percentage of male members, we expect an increase in liabilities in relation to the unchanged data since their spouses will be assumed to live longer. This is supported by our finding since the present value of the changed liabilities are £61.5m (Table 9) compared with the unchanged present value of £57.8m (Table 4).

4.2. Changes in Economic Assumptions

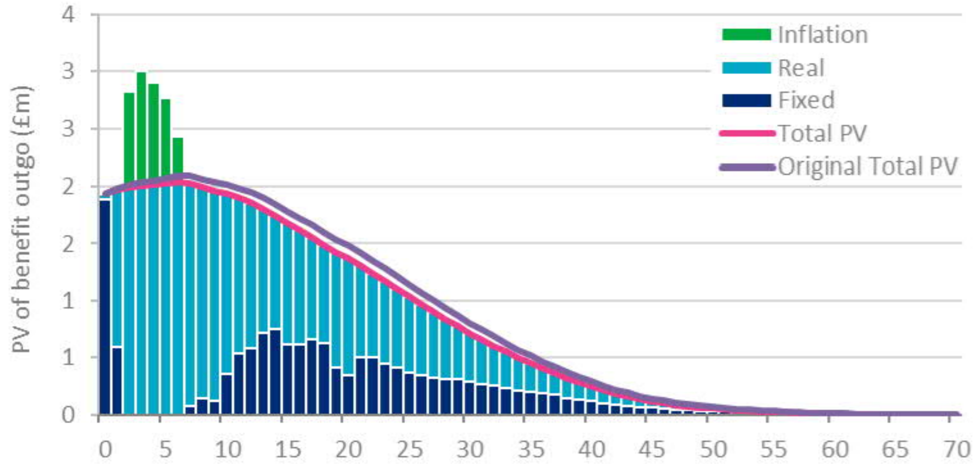
The economic assumptions will be used to derive the LBP used to construct the hedging strategy of the scheme.

4.2.1. Discount Basis

The scheme uses a gilt plus approach to establish the discount rate used to calculate the present value of the liabilities. This method is used to be align with the investment strategy given that the objective of the Trustees is to invest in gilts and this way they assure that by using gilts plus approach, the scheme's liabilities will move in line with the long-term strategy objectives. (AON, 2018)

The current Technical Provision basis of the scheme is based on gilts+0.40%. and to see the impact of changing this approach we move to gilts+0.80%. This change will not impact the valuation payments projection neither the LBP profile, however, will change the key statistics given that they are calculated based on the present value of the cashflows.

Figure 16 – LBP profile of the scheme discounted using gilts + 0.80% basis

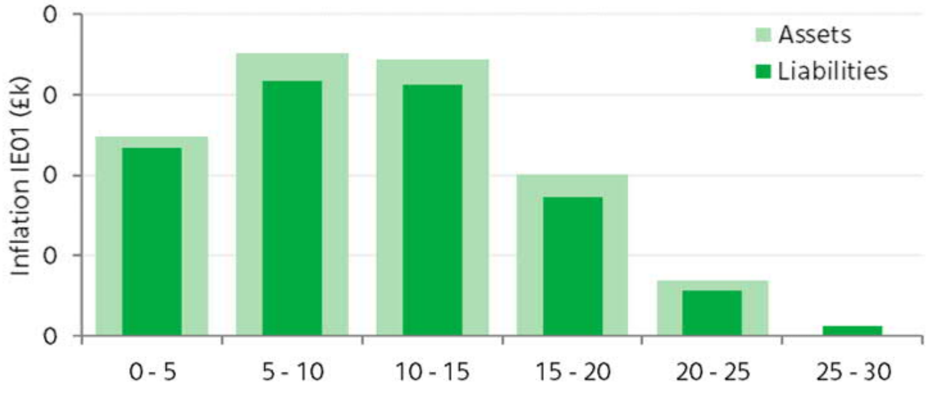


Source: Author

Table 11 – Summary of the key statistics with the modified discount basis

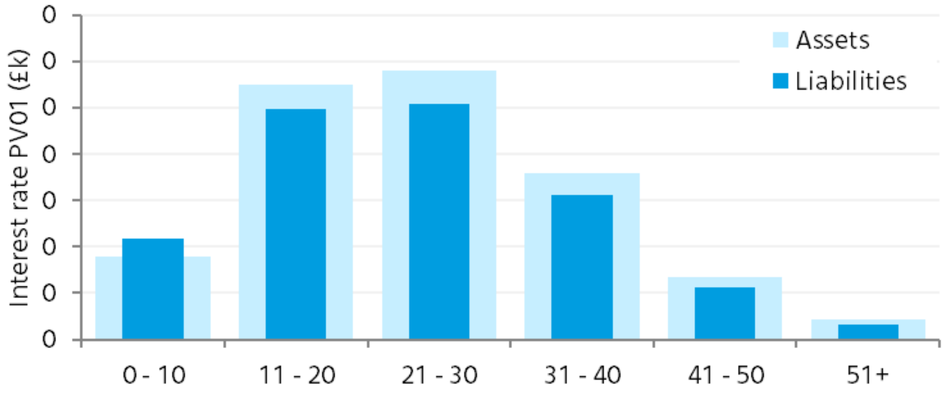
	Original	Modified
Present Value	£57.8m	£54.3m
Duration	16 years	16 years
PV01	£92.5k	£83.9k
IE01	£60.8k	£55.4k
Inflation Linkage (IE01 / PV01)	65.7%	66.0%

Figure 17 – Inflation Hedge Ratio of the scheme discounted using gilts+0.80% basis



Source: Author

Figure 18 – Interest Rate Hedge Ratio of the scheme discounted using gilts+0.80% basis



Source: Author

Table 12 – Hedge Ratios of the scheme discounted using gilts + 0.80% basis

	Original	Modified
Interest Rate Hedge Ratio	100.0%	110.2%
Inflation Hedge Ratio	100.0%	109.6%

The basis used to discount the cashflows will reflect a change on the calculated liabilities – the higher the discount rate used, the lower the present value of the liabilities will be. This way, it is important to be aware of the risks linked to the choice of the discount basis used for the calculation of the funding position.

As expected, an increase in the discount rate will lead to a considerable improvement in the funding position of the scheme given the decrease in the present value of the liabilities (£54.3m shown in Table 11 versus the base scenario of £57.8m shown in Table 4).

4.2.2. Inflation

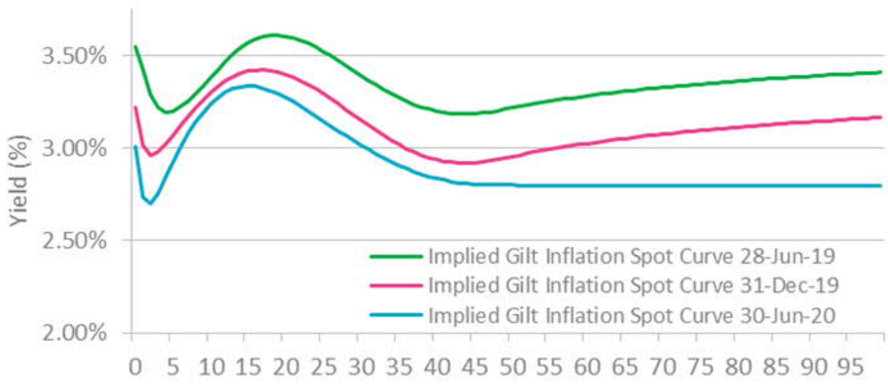
Inflation is one of the key assumptions that affect the LBP profile. As already mentioned, the LBP is derived based on the LPI curves determined at a certain moment in time.

To examine the impact of the inflation on the liabilities split between fixed and inflation-linked, we decided to run the LBP by using the LPI curves in two additional different dates: 30 June 2019 and 30 June 2020. By testing the LBP in these two dates, we were able to see the impact of only 6 months of changes in market conditions could have on the scheme's LBP.

Additionally, by analyzing these two dates, we can see how a big market event could change the profile of the LBP. In this case, we can analyze the impact of the novel coronavirus in the inflation rate.

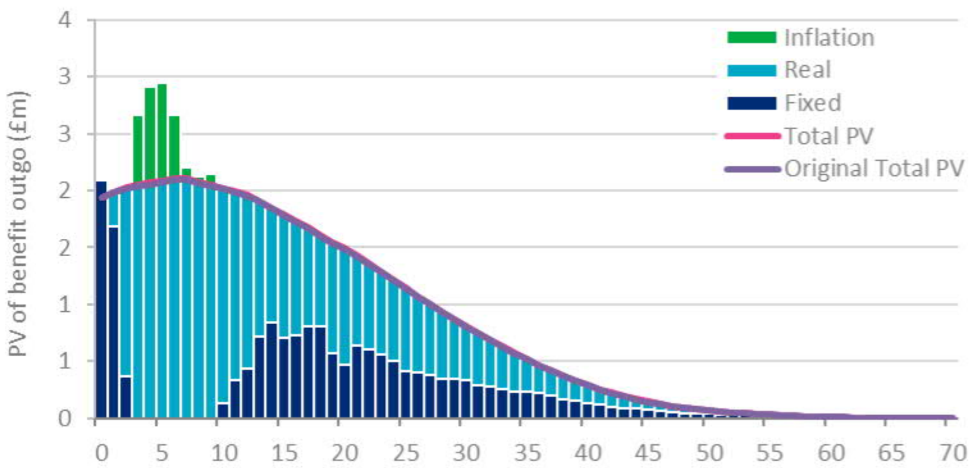
In Figure 19 we show how the inflation curves used to derive the LPI curves of the scheme's benefits changes among the different dates.

Figure 19 – Implied inflation curves



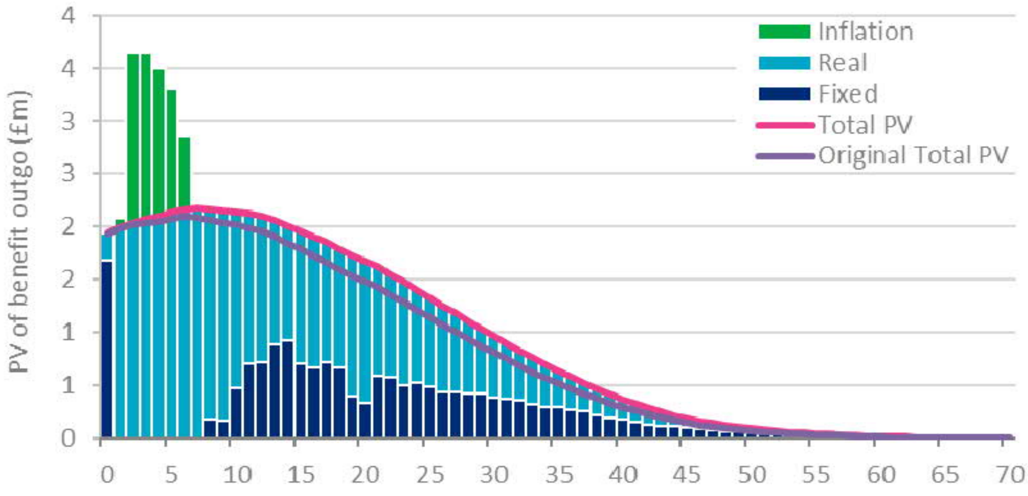
Source: Author

Figure 20 – LBP profile of the scheme derived using 28 June 2019 inflation curve



Source: Author

Figure 21 – LBP profile of the scheme derived using 30 June 2020 inflation curve



Source: Author

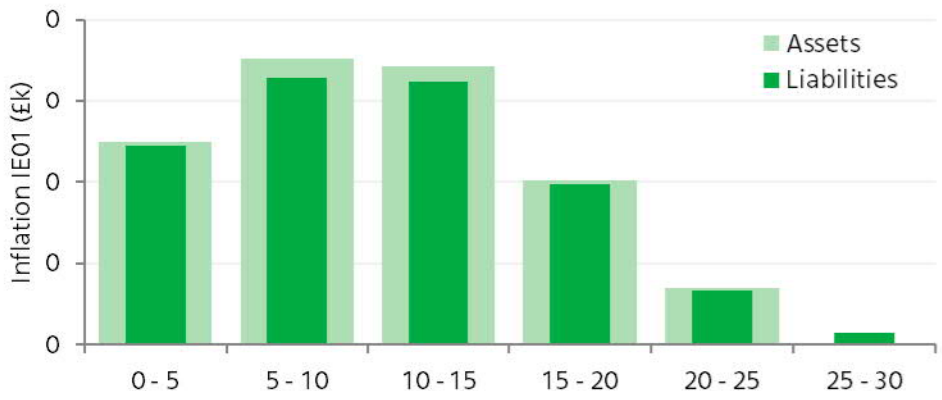
Table 13 – Summary of the key statistics with the LBP profile of the scheme derived using 28 June 2019 inflation curve

	Original	Modified
Present Value	£57.8m	£57.8m
Duration	16 years	16 years
PV01	£92.5k	£92.8k
IE01	£60.8k	£58.7k
Inflation Linkage (IE01 / PV01)	65.7%	63.3%

Table 14 – Summary of the key statistics with the LBP profile of the scheme derived using 30 June 2020 inflation curve

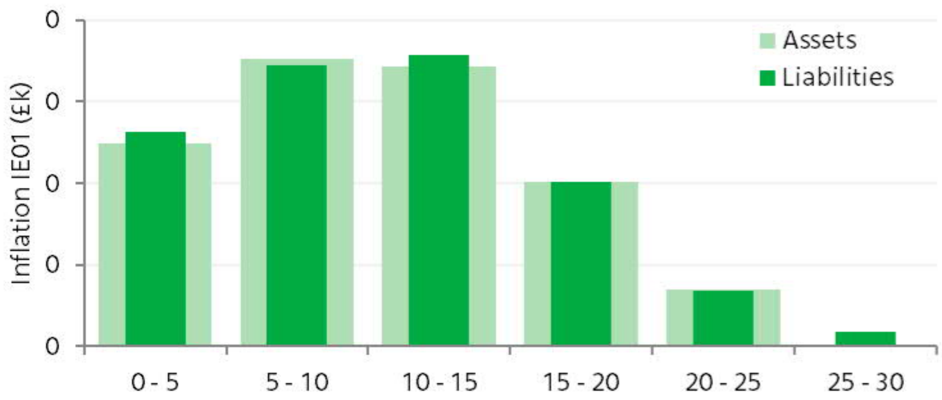
	Original	Modified
Present Value	£57.8m	£57.8m
Duration	16 years	16 years
PV01	£92.5k	£92.4k
IE01	£60.8k	£62.5k
Inflation Linkage (IE01 / PV01)	65.7%	67.7%

Figure 22 – Inflation Hedge Ratio of the scheme with the LBP profile of the scheme derived using 28 June 2019 inflation curve



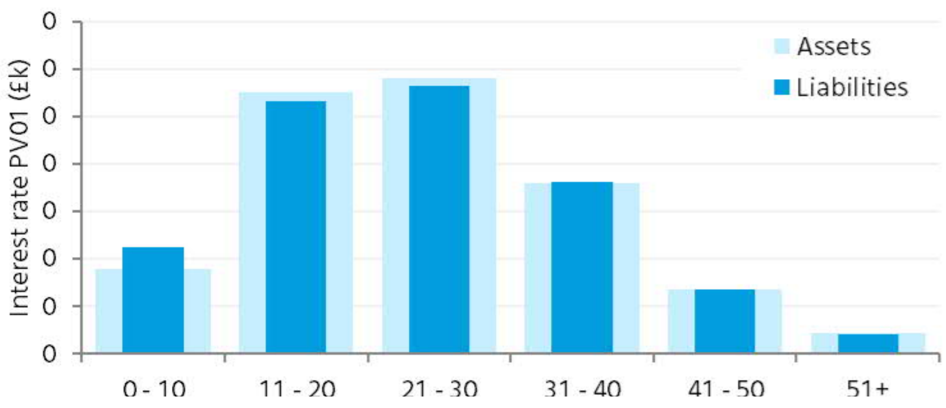
Source: Author

Figure 23 – Inflation Hedge Ratio the Scheme with the LBP profile of the scheme derived using 30 June 2020 inflation curve



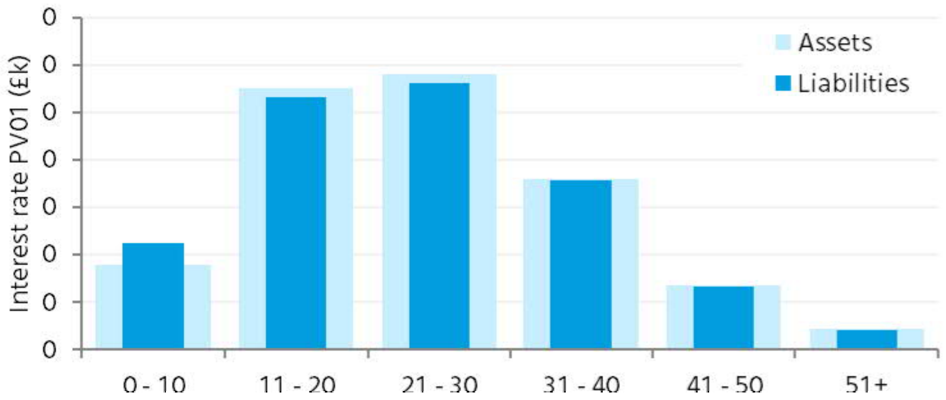
Source: Author

Figure 24 – Interest Rate Hedge Ratio of the scheme with the LBP profile of the scheme derived using 28 June 2019 inflation curve



Source: Author

Figure 25 – Interest Rate Hedge Ratio of the scheme with the LBP profile of the scheme derived using 30 June 2020 inflation curve



Source: Author

Table 15 – Hedge Ratios of the scheme with the LBP profile of the scheme derived using 28 June 2019 inflation curve

	Original	Modified
Interest Rate Hedge Ratio	100.0%	99.5%
Inflation Hedge Ratio	100.0%	103.4%

Table 16 – Hedge Ratios of the scheme with the LBP profile of the scheme derived using 30 June 2020 inflation curve

	Original	Modified
Interest Rate Hedge Ratio	100.0%	100.1%
Inflation Hedge Ratio	100.0%	97.1%

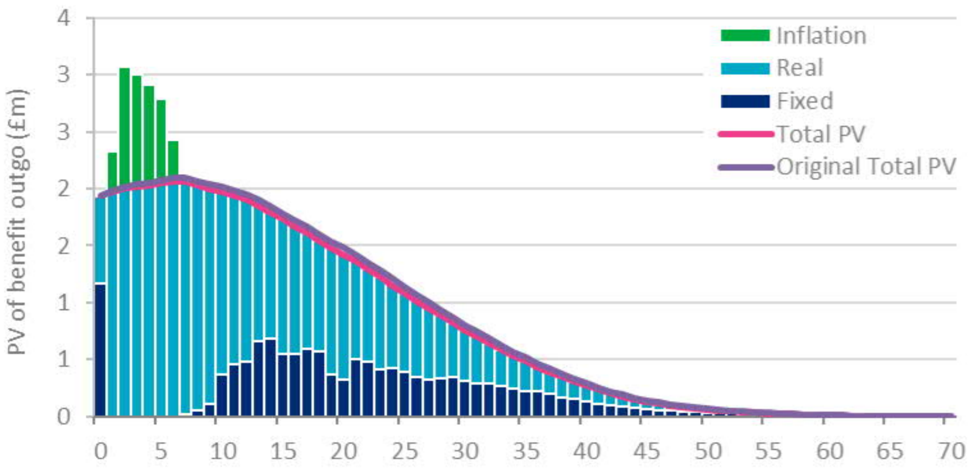
Given the high proportion of LPI-linked benefits, a decrease in the inflation means that there is a lower probability of reaching the caps, so we expect to see an increase on the scheme's inflation linkage. Therefore, the difference on the market conditions will be reflected on the LBP ran as at 28 June 2019 by presenting an inflation linkage of 63.3% (Table 13), while the LBP ran at 30 June 2020 shows a linkage of 67.7% (Table 14). In comparison with the unchanged scheme data, the 28 June 2019 LBP will now be less expose to the inflation, and this way will not need the same value of assets exposure to inflation – this is the reason why we are observing an improvement of the inflation hedge ratio (from 100% to 103.4%, as shown in Table 15). Whereas, in the 30 June 2020 analysis the inflation rate decreases (Table 16) so we conclude that the scheme needs more assets to hedge the changed liabilities.

4.2.3. CPI/RPI Wedge

Until now, the UK Debt Management Office only issues RPI-linked gilts so the only yield curves estimated are based in these gilts. Therefore, the only implied inflation yield is based on RPI so when looking at the benefits linked to CPI, the CPI curve is derived from the UK implied inflation yield. The wedge between CPI and RPI is then other actuarial assumption defined.

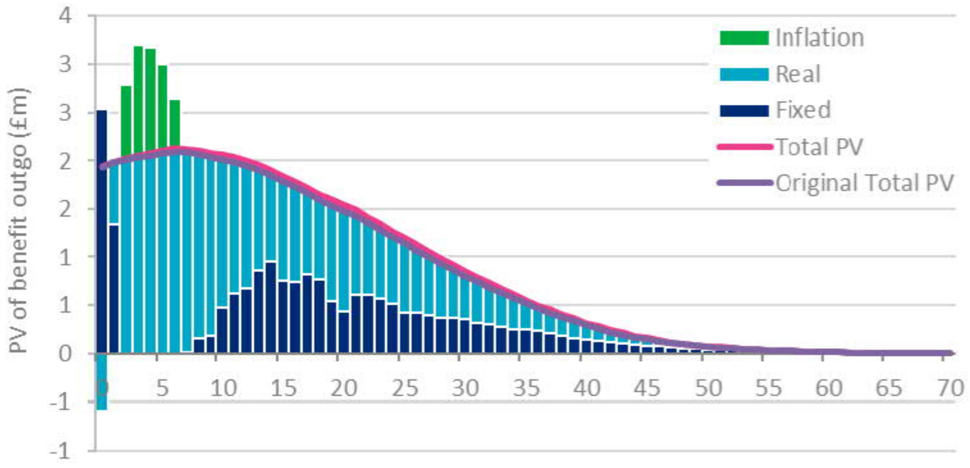
In this case, the original wedge of the client was 0.7% and to test the impact of changing it we have setup the LPI curves to derive from the inflation curve with a deduction of 1% and the other with a deduction of 0.4%.

Figure 26 – LBP profile of the scheme derived assuming wedge of 1%



Source: Author

Figure 27 – LBP profile of the scheme derived assuming wedge of 0.4%



Source: Author

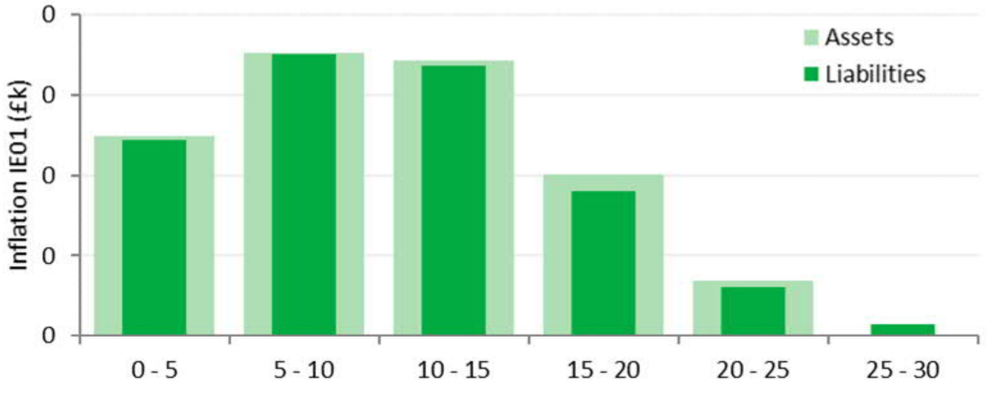
Table 17 – Summary of the key statistics with the LBP profile of the scheme derived assuming wedge of 1%

	Original	Modified
Present Value	£57.8m	£55.9m
Duration	16 years	16 years
PV01	£92.5k	£88.3k
IE01	£60.8k	£59.3k
Inflation Linkage (IE01 / PV01)	65.7%	67.2%

Table 18 – Summary of the key statistics with the LBP profile of the scheme derived assuming wedge of 0.4%

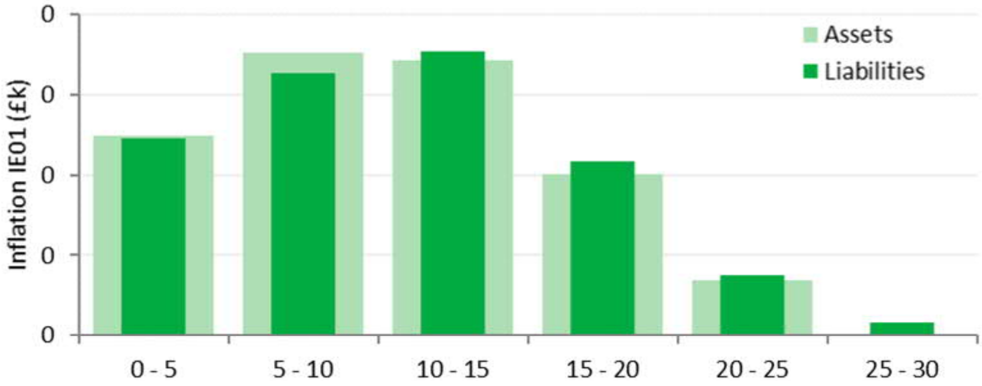
	Original	Modified
Present Value	£57.8m	£59.7m
Duration	16 years	17 years
PV01	£92.5k	£97.0k
IE01	£60.8k	£61.7k
Inflation Linkage (IE01 / PV01)	65.7%	63.6%

Figure 28 – Inflation Hedge Ratio the Scheme with the LBP profile of the scheme derived assuming wedge of 1%



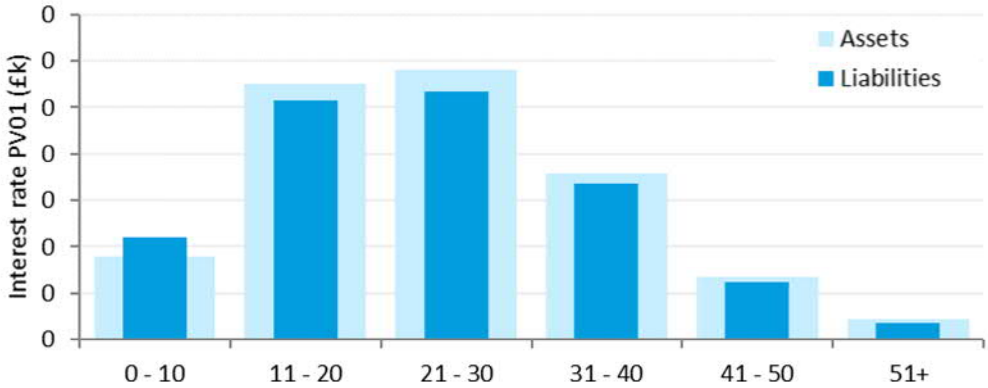
Source: Author

Figure 29 – Inflation Hedge Ratio the Scheme with the LBP profile of the scheme derived assuming wedge of 0.4%



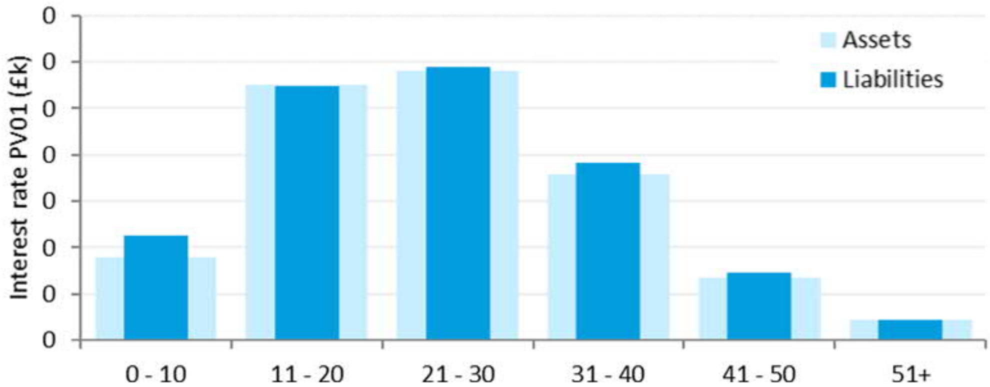
Source: Author

Figure 30 – Interest Rate Hedge Ratio the Scheme with the LBP profile of the scheme derived assuming wedge of 1%



Source: Author

Figure 31 – Interest Rate Hedge Ratio the Scheme with the LBP profile of the scheme derived assuming wedge of 0.4%



Source: Author

Table 19 – Hedge Ratios of the scheme with the LBP profile of the scheme derived assuming wedge of 1%

	Original	Modified
Interest Rate Hedge Ratio	100.0%	104.7%
Inflation Hedge Ratio	100.0%	102.4%

Table 20 – Hedge Ratios of the scheme with the LBP profile of the scheme derived assuming wedge of 0.4%

	Original	Modified
Interest Rate Hedge Ratio	100.0%	95.3%
Inflation Hedge Ratio	100.0%	98.5%

Given that all the inflation-linked benefits are linked to CPI, all of them with be impacted by the change of the wedge between CPI and RPI. Thus, this test will be in line with the test of the inflation change, given that in this case we are not changing the RPI curve instead we are changing the CPI curve that affects all the LPI benefits. By increasing the wedge between CPI and RPI, we will be allowing for a fall in the inflation curve used to derive the LPI curves.

Similar to the previous section, the inflation hedge ratio is higher where the CPI curve is lower, i.e., where the wedge between CPI and RPI is higher. The reverse occurs when the wedge is lower.

Given the proportion of change in the CPI curve, the interest rate hedge ratios will also be affected. When the wedge is higher, we will have less probability of reaching the cap of the LPI increases and, therefore, we will have less benefits assumed to be impacted by fixed increases and which means that we will need less assets with interest rate exposure. Therefore, we expect an increase in the interest rate hedge ratio. This is supported by our results as the interest rate hedge ratio is 104.7% (Table 19) compared with the base scenario of c.100%.

The opposite occurs when we observe a lower wedge between CPI and RPI. There is a decrease in the interest rate hedge ratio from c.100% to 95.3% (Table 20).

5. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORKS

The purpose of our research is to analyze the factors that could impact the hedging of a defined-benefit UK pension scheme. We used a dummy pension scheme composed by 397 members where a higher proportion of the member's benefits are linked to CPI.

In this dissertation, we aim to understand how Actuarial Valuation assumptions and economic assumptions could change the hedging of a pension scheme. For the Actuarial Valuation assumptions, we study the impact of the mortality table, rate of improvement and spouse's age while for the economic assumptions we looked to the impact of the discount basis, the inflation rate assumed and the wedge between CPI and RPI.

In order to study these impacts, we performed new Actuarial Valuations used to construct LBPs that are consequently used to compare against the asset portfolio and, therefore, look at the hedge ratios of the scheme.

Evidences confirm that the mortality assumed has a negative effect on the hedging of the scheme due to the change on the profile of the scheme's liabilities. The decrease of the hedging is related to the fact that when the scheme assumes a lower mortality, the scheme will have to pay benefits until a longer date in the future because members are assumed to live longer. Consequently, to have a better hedging on this scenario the scheme should invest in assets with higher maturities. These evidences are directly related with the mortality table and the rate of improvement used and confirm that using the adequate assumptions to the scheme is an important factor to decrease the market conditions risks that the scheme is exposed to.

The difference on the age between scheme's members and their spouses is also an important assumption to be aware of. In the analysis run on this dissertation, we conclude that for a scheme with a higher proportion of male members and that assumes the males are always older than the females, we expect a deterioration on the hedging of the scheme when the difference increases.

Regarding the economic assumptions, they were tested by changing the market conditions used to produce the LBP.

The basis used to discount the cashflows it is an important factor to take into consideration when structuring an investment portfolio. By using a higher discount rate, we will estimate a lower present value of the liabilities and this would be reflected as an improve in the hedging of the scheme. However, this assumption will differ in relation to the funding approach chosen for the Actuarial Valuation used to build the investment strategy.

In terms of the LBP, the inflation assumed will change the split between inflation-linked cashflows and fixed cashflows. To test how this split could change the hedging of the scheme, we ran the analysis at two different dates with a year of difference and with COVID-19 pandemic effects within both dates. The test shows that while the inflation curve falls, the inflation hedge ratio of the scheme decreases.

Regarding the wedge between CPI and RPI should be noted that the impact of this variable will depend on the scheme's structure. In this case, all the inflation-linked benefits were linked to CPI, so the impact will be higher in comparison with schemes with RPI and CPI linked benefits. The impact of the variable will also be in line with the inflation rate changes, given that we are testing a change in the CPI curve assumed.

Thus, this work contributes for the UK pension scheme's community to have an idea of how the actuary assumptions and market conditions impact the hedging strategy of a pension scheme.

For future researches, we suggest analyzing other schemes with different rules and membership. In particular, study these impacts on younger schemes that present a higher percentage of active members. We invite future research to also include schemes with a higher percentage of RPI-linked benefits or with higher percentage of fixed benefits given that this will affect the outcome in changing the test variables. It would be interesting to analyze this further and compare the results between different schemes structures.

6. REFERENCES

AON (2018). Choosing the right actuarial valuation approach. Retrieved from: https://www.aon.com/getmedia/950c7669-0f23-4aa5-8f06-66384bf4dfda/Valuation-Approach-White-Paper-October2018.aspx

Ayuso, M., Bravo, J. M. & Holzmann, R. (2017a). Addressing Longevity Heterogeneity in Pension Scheme Design. Journal of Finance and Economics 6 (1): 1-21.

Ayuso, M., Bravo, J. M. & Holzmann, R. (2017b). On the Heterogeneity in Longevity among Socioeconomic Groups: Scope, Trends, and Implications for Earnings-Related Pension Schemes. Global Journal of Human Social Sciences - Economics, Volume 17 Issue 1 Version 1.0, 31-57.

Ayuso, M., Bravo, J. M. & Holzmann, R. (2020). Getting Life Expectancy Estimates Right for Pension Policy: Period versus Cohort Approach. Journal of Pension Economics and Finance, 1-20. https://doi.org/10.1017/S1474747220000050;

Barnett Waddingham (2019). Revaluation for Early Leavers. Retrieved from: https://www.barnett-waddingham.co.uk/comment-insight/blog/revaluation-for-early-leavers/

Blake, D. and Burrows, W. (2001). Survivor bonds: helping to hedge mortality risk. Journal of Risk and Insurance, 68, 339--348.

Blake, D., Cairns, A. J. G., Dowd, K. and Kessler, A.R. (2019). Still living with mortality: The longevity risk transfer market after one decade. British Actuarial Journal, 24(1), 1-80.

BMO Global Asset Management (2017). Liability Driven Investment Explained. Retrieved from: https://www.bmogam.com/wp-content/uploads/2018/06/ldi-explained-2017-final.pdf

Bravo, J. M. & Pereira da Silva, C. M. (2006). Immunization Using a Stochastic Process Independent Multifactor Model: The Portuguese Experience. Journal of Banking and Finance, 30 (1), 133-156.

Bravo, J. M. (2002). Modelos de Risco de Taxa de Juro: Estratégias de Cobertura e Imunização. Dissertação de Mestrado em Economia Monetária e Financeira, Instituto Superior de Economia e Gestão – Universidade Técnica de Lisboa (ISEG-UTL), Outubro. doi: 10.13140/RG.2.1.3383.0163

Bravo, J. M. (2007). Tábuas de Mortalidade Contemporâneas e Prospectivas: Modelos Estocásticos, Aplicações Actuariais e Cobertura do Risco de Longevidade. Dissertação de Doutoramento em Economia pela Universidade de Évora, Maio. doi: 10.13140/RG.2.1.3907.3041

Bravo, J. M. (2016). Taxation of Pensions in Portugal: A Semi-Dual Income Tax System. CESifo DICE Report - Journal for Institutional Comparisons. 14 (1), 14-23.

Bravo, J. M. (2019). Funding for Longer Lives: Retirement Wallet and Risk-Sharing Annuities. Ekonomiaz 96(2): 268–291.

Bravo, J. M. (2019). Pricing Participating Longevity-Linked Life Annuities: A Bayesian Model Ensemble approach. European Actuarial Journal. (Revised and resubmitted)

Bravo, J. M. (2020). Longevity-Linked Life Annuities: A Bayesian Model Ensemble Pricing Approach. Atas da Conferencia da Associacao Portuguesa de Sistemas de Informacao 2020 [CAPSI 2020 - 20th Conference of the Portuguese Association for Information Systems].

Bravo, J. M., & El Mekkaoui de Freitas, N. (2018). Valuation of longevity-linked life annuities. Insurance: Mathematics and Economics, 78, 212–229.

Bravo, J. M., & Herce, J. A. (2020). Career Breaks, Broken Pensions? Long-run Effects of Early and Late-career Unemployment Spells on Pension Entitlements. Journal of Pension Economics and Finance 1–27. https://doi.org/10.1017/S1474747220000189.

Bravo, J. M., & Nunes, J. P. (2020). Pricing Longevity Derivatives via Fourier Transforms. Insurance: Mathematics and Economics (Revised and resubmitted)

Bravo, J. M., Ayuso, M., Holzmann, R. & Palmer, E. (2020). Addressing the Life Expectancy Gap in Pension Policy. Preprint submitted to Insurance: Mathematics and Economics. (Revised and resubmitted)

Bravo, J. M., Oliveira, S. and Simões, C. (2020). Immunization Strategies for Multiple Inflation-Linked Liabilities

Cairns, A. J. G, Blake, D. and Dowd, K. (2008). Modelling and Management of Mortality Risk: A Review. Scandinavian Actuarial Journal, 79-113.

Chamboko, R., & Bravo, J. M. (2016). On the modelling of prognosis from delinquency to normal performance on retail consumer loans. Risk Management, 18(4), 264–287.

Chan, W.S., Li, J.S.-H. and Li, J. (2014). The CBD mortality indexes: modeling and applications. North American Actuarial Journal, 18, 38-58.

Coughlan, G.D., Epstein, D., Sinha, A. and Honig, P. (2007). q-Forwards: Derivatives for Transferring Longevity and Mortality Risks. J. P. Morgan Pension Advisory Group, London (July).

Dawson, P., Dowd, K., Blake, D. and Cairns, A. J. G. (2009). Options on Normal Underlyings with An Application to the Pricing of Survivor Swaptions. Journal of Futures Markets, 29, 757-774.

Deloitte (2017). Pension scheme Valuation Corporate guide – 2nd Edition. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/consultancy/deloitte-uk-pension-scheme-valuations-corp-guide.pdf

Dowd, K., Blake, D., Cairns, A. J. G. and Dawson, P. (2006). Survivor Swaps. Journal of Risk and Insurance, 73, 1-17.

Dowd, K., Blake, D., Cairns, A. J. G. and Dawson, P. (2006). Survivor Swaps. Journal of Risk and Insurance, 73, 1-17.

Hunt, A., and Blake, D. (2015). Modelling Longevity Bonds: Analysing the Swiss Re Kortis Bond. Insurance: Mathematics and Economics, 63, 12-29.

Insight Investment (2020). Cashflow Driven Investment (CDI). Retrieved from: https://www.insightinvestment.com/uk/institutional-investors/investment-range/cdi/

Li, J. S., Li, J. Balasooriya, U. and Zhou, K. (2019). Constructing Out-of-the-Money Longevity Hedges Using Parametric Mortality Indexes. North American Actuarial Journal, 1-32.

Lin, T., and Tsai, C. (2013). On the mortality/longevity risk hedging with mortality immunization. Insurance: Mathematics and Economics, 53(3), 580-596.

Marcaillou, P. (2016). Defined Benefit Pension Schemes in the UK - Asset and Liability Management, OUP Oxford

Mercer (2017a). Mastering LDI – Internal document

Mercer (2017b). Estimating the value of capped and collared inflation – Internal document

Mercer (2020a). UK Training - Internal document

Mercer (2020b). Liability Benchmark Portfolio – Internal document

Shang, K., & Hossen, K. (2019). Liability-Driven Investment. Benchmark Model. Retrieved from: https://www.soa.org/globalassets/assets/files/resources/research-report/2019/liability-driven-investment.pdf

Simões, C., Oliveira, L. & Bravo, J. M. (2019). Immunization Strategies for Funding Multiple Inflation-Linked Liabilities. Preprint submitted for publication

The Pensions Regulator (2007). Trustee guidance. Retrieved from: https://www.thepensionsregulator.gov.uk/en/document-library/regulatory-guidance/trustee-guidance#pagetop

The Pensions Regulator (2018). Understanding DB pension scheme funding. Retrieved from: https://www.thepensionsregulator.gov.uk/-/media/thepensionsregulator/files/import/pdf/understanding-db-_scheme-funding.ashx

Vanguard (2018). Liability-hedging strategies for pension plans: Close may be best. Retrieved from: https://www.vanguardinvestments.de/documents/institutional/liability-hedging-strategies.pdf

APPENDIX A – MARKET CURVES

We have set out below the curves used throughout this thesis that were derived by Mercer.

Nominal Gilt Spot Curve	Implied Gilt Inflation Spot Curve		
31 December 2019	31 December 2019	28 June 2019	30 June 2020
0.00%	0.00%	0.00%	0.00%
0.57%	3.22%	3.55%	3.01%
0.54%	3.02%	3.42%	2.74%
0.54%	2.96%	3.29%	2.70%
0.56%	2.98%	3.22%	2.76%
0.58%	3.02%	3.19%	2.84%
0.61%	3.07%	3.20%	2.93%
0.65%	3.12%	3.22%	3.01%
0.70%	3.17%	3.26%	3.08%
0.76%	3.22%	3.29%	3.14%
0.83%	3.26%	3.34%	3.20%
0.89%	3.30%	3.38%	3.24%
0.96%	3.33%	3.43%	3.28%
1.03%	3.36%	3.47%	3.30%
1.09%	3.38%	3.50%	3.32%
1.15%	3.40%	3.54%	3.33%
1.20%	3.41%	3.56%	3.34%
1.25%	3.42%	3.59%	3.33%
1.29%	3.42%	3.60%	3.32%
1.32%	3.42%	3.61%	3.31%
1.35%	3.41%	3.61%	3.29%
1.37%	3.40%	3.60%	3.27%
1.39%	3.38%	3.60%	3.25%
1.40%	3.37%	3.58%	3.23%
1.41%	3.34%	3.56%	3.20%
1.41%	3.32%	3.54%	3.17%
1.40%	3.29%	3.52%	3.15%
1.40%	3.27%	3.50%	3.12%
1.39%	3.24%	3.47%	3.09%
1.37%	3.21%	3.44%	3.07%
1.36%	3.18%	3.42%	3.04%
1.34%	3.15%	3.39%	3.02%
1.33%	3.12%	3.36%	2.99%
1.31%	3.09%	3.34%	2.97%
1.29%	3.07%	3.31%	2.95%
1.28%	3.04%	3.29%	2.93%
1.26%	3.02%	3.27%	2.91%
1.25%	3.00%	3.25%	2.89%
1.24%	2.98%	3.24%	2.87%

1.23%	2.96%	3.22%	2.86%
1.22%	2.95%	3.21%	2.85%
1.21%	2.94%	3.20%	2.84%
1.20%	2.93%	3.19%	2.83%
1.20%	2.92%	3.19%	2.82%
1.19%	2.92%	3.19%	2.81%
1.19%	2.92%	3.18%	2.81%
1.19%	2.92%	3.19%	2.80%
1.19%	2.92%	3.19%	2.80%
1.19%	2.93%	3.19%	2.80%
1.19%	2.94%	3.20%	2.80%
1.19%	2.95%	3.21%	2.80%
1.19%	2.95%	3.22%	2.80%
1.19%	2.96%	3.22%	2.80%
1.19%	2.97%	3.23%	2.80%
1.19%	2.98%	3.24%	2.80%
1.19%	2.99%	3.25%	2.80%
1.19%	2.99%	3.25%	2.80%
1.19%	3.00%	3.26%	2.80%
1.19%	3.01%	3.26%	2.80%
1.19%	3.01%	3.27%	2.80%
1.19%	3.02%	3.28%	2.80%
1.19%	3.02%	3.28%	2.80%
1.19%	3.03%	3.29%	2.80%
1.19%	3.04%	3.29%	2.80%
1.19%	3.04%	3.30%	2.80%
1.19%	3.05%	3.30%	2.80%
1.19%	3.05%	3.31%	2.80%
1.19%	3.06%	3.31%	2.80%
1.19%	3.06%	3.31%	2.80%
1.19%	3.07%	3.32%	2.80%
1.19%	3.07%	3.32%	2.80%
1.19%	3.07%	3.33%	2.80%
1.19%	3.08%	3.33%	2.80%
1.19%	3.08%	3.33%	2.80%
1.19%	3.09%	3.34%	2.80%
1.19%	3.09%	3.34%	2.79%
1.19%	3.09%	3.35%	2.79%
1.19%	3.10%	3.35%	2.79%
1.19%	3.10%	3.35%	2.79%
1.19%	3.11%	3.36%	2.79%
1.19%	3.11%	3.36%	2.79%
1.19%	3.11%	3.36%	2.79%
1.19%	3.12%	3.36%	2.79%
1.19%	3.12%	3.37%	2.79%
1.19%	3.12%	3.37%	2.79%

1.19%	3.13%	3.37%	2.79%
1.19%	3.13%	3.38%	2.79%
1.19%	3.13%	3.38%	2.79%
1.19%	3.13%	3.38%	2.79%
1.19%	3.14%	3.38%	2.79%
1.19%	3.14%	3.39%	2.79%
1.19%	3.14%	3.39%	2.79%
1.19%	3.14%	3.39%	2.79%
1.19%	3.15%	3.39%	2.79%
1.19%	3.15%	3.40%	2.79%
1.19%	3.15%	3.40%	2.79%
1.19%	3.15%	3.40%	2.79%
1.19%	3.16%	3.40%	2.79%
1.19%	3.16%	3.40%	2.79%
1.19%	3.16%	3.41%	2.79%
1.19%	3.16%	3.41%	2.79%