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LDI strategies and LDI managers' performance measurement for (Dutch) pension funds

ERASMUS UNIVERSITEIT ROTTERDAM

Author:	A.F. Ouwehand
Student number:	449534
Thesis supervisor:	Prof. Dr. Onno Steenbeek
Second assessor:	Prof. Dr. Mary Pieterse-Bloem
Thesis Supervisors extern:	Niek van Breukelen (Cardano), Rik Klerkx (Cardano)
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Abstract

The goal of this paper is to define which liability driven investment (LDI) strategy maximizes the pension fund' interest rate hedging strategy, i.e. minimizes the tracking error vis-à-vis the pension liabilities. To this end, two stylized bond portfolios are constructed with the objective to be representative for a separated LDI strategy, whereby a swap overlay is added to a separate bond mandate and to represent an integrated LDI strategy, whereby these two building blocks are combined in one LDI mandate. In addition, a case study is performed on Cardano's LDI performance. The results indicate that an integrated LDI strategy maximizes the pension fund' interest rate hedging strategy in all swap spread scenarios analyzed. This outcome could be interesting for the management of Dutch pension funds when designing and implementing the LDI investment strategy. In addition, this research could serve as a guidance in the performance measurement of LDI managers. An enhanced LDI performance ultimately benefits the Dutch pension scheme members.

Keywords: *Liability driven investment (LDI) management, liability-driven performance benchmarks, integrated LDI strategy, separated LDI strategy, swap spread*

Contents

1. Introduction

This research is geared towards liability driven investment (LDI) management for Dutch pension funds. In particular, this research examines which LDI strategy maximizes the goals set by a pension funds' interest rate hedging strategy. In addition, it analyzes different performance benchmarks that are used to measure the performance of institutional investors and discuss the pros and cons of each performance benchmark with respect to the performance measurement of LDI managers.

The Dutch pension fund system is based on three pillars. The second pillar is based on the so called prefunded system. Hereby, employees or their employer pay into an investment pool that is used to pay future benefits. Subsequently, Dutch pension funds invest these assets to create a return on the cash inflows. Dutch pension funds generally have a defined benefit structure, hence the nominal cash outflows, i.e. the pension liabilities, are fixed. According to the regulatory framework called the new Financial Assessment Framework (abbreviated "nFTK" in Dutch), pension funds have to meet these cash outflows with a 97.5% certainty.[1] In addition, Dutch pension funds have the ambition to increase the pension benefits with the inflation rate. Although this is not a hard obligation, Dutch pension funds devote part of their balance sheet for indexation purposes. Hence, in essence Dutch pension funds have two objectives: the 'hard' objective of paying out nominal pension benefits and the 'soft' objective of indexation. Accordingly, pension funds structure their balance sheet towards these objectives by creating two portfolios with a different risk profile: *a 'matching'- or 'LDI portfolio'* that should match the nominal pension liabilities and a '*return portfolio'* that should create an excess return above the risk free rate for indexation purposes, and also serves as a buffer.

The pension fund's assets and liabilities are sensitive to market risks. One of the largest market risks pension funds face is the interest rate risk. A falling interest rate could severely increase the pension liabilities relative to the pension fund's assets, if not appropriately managed. LDI managers are responsible for managing and maintaining the LDI portfolio. Hence, their job involves amongst other things, to efficiently manage the interest rate risk of the pension fund as instructed by the board of the fund. In particular, in order to meet the objective of a nominal pension benefit that has to be realized at a high certainty

[1] Pension Act, Chapter 6, Financial Assessment Framework for Pension funds, Article 132:2

(97,5%), LDI managers have to create almost risk free cash flows involving interest rate and inflation rate risk, while eliminating other sources of risk.

At the moment, two main LDI strategies are used in practice; a *separated LDI strategy,* whereby a separate swap overlay is added to a bond mandate, and an *integrated LDI strategy,* whereby these two building blocks are combined in one mandate. The academic literature provides little guidance on how to measure the performance of a liability driven investment strategy. In practice, the LDI managers' performance is often evaluated based on a government bond benchmark or another market-based index with a short horizon focus (Chambers, 2005). Hence, while pension funds have a long-term objective, the performance is in most cases based on short-rate returns. Studies have shown that a good performance on short-term returns is not a guarantee for meeting the long term objective of robust pension benefits (Hinz et al, 2010). Consequently, liability based performance benchmarks have been introduced for liability driven institutions, whereby the liability cash flow profile effectively becomes the LDI manager's performance benchmark (Fabozzi, 2006). Different performance benchmarks induce different investment behavior (Blake, 2002). Hence, pension funds should think carefully about the preferred investment outcome when setting the LDI performance benchmark.

In this research, I will follow former research (Chambers, 2005) and use the liability cash flow profile as the ultimate performance benchmark to measure the LDI performance. Given this performance benchmark, I will give an answer to my main research question:

What type of LDI strategy maximizes the goals set by a pension fund's interest rate hedging strategy?

Hereby, the pension fund's interest rate hedging strategy involves a certain size of the LDI portfolio and a certain interest rate hedging percentage. To answer the main research question, I will look at two stylized LDI portfolios that have the objective to be representative for the separated LDI strategy and the integrated LDI strategy. To this end, I constructed a 10-year bond portfolio to represent the separated LDI strategy. Second, I constructed a 2-year bond portfolio to represent the integrated LDI strategy. I arbitrarily set the bond portfolio maturity at 2 years as the integrated LDI strategy leaves freedom to reduce the bonds' duration and also to show the impact of a short bond portfolio maturity relative to a longer bond portfolio maturity. Furthermore, I follow former research (Chambers, 2005) and use the tracking error to analyze the difference in LDI performance between the two types of LDI mandates. Additionally, I will present a case study of Cardano's LDI performance over a historical period from 2015 till 2017. Cardano performs both the integrated- and separated LDI strategy for its clients. Hence, the stylized LDI portfolios show a rather extreme LDI performance of a static 10-year bond portfolio and a static 2-year bond portfolio, whereas the case study brings some nuance by showing the real LDI performance of both the integrated- and separated LDI strategies combined, whereby the bond portfolio duration can vary over time.

This research shows that an integrated LDI strategy maximizes the goals set by a pension fund's interest rate hedging strategy, i.e. *the integrated LDI strategy minimizes the tracking error vis-à-vis the pension liabilities*. The difference in historical tracking errors for various LDI strategies has not been analyzed in former research. Hence, by quantifying and comparing the obtained tracking errors between different LDI strategies, this paper adds substantial knowledge to the academic field of LDI management. This research result has important implications for the way pension funds should implement their LDI strategies and the way the LDI manager's performance should be evaluated.

The outcome of this research could be interesting for pension funds when they reconsider their LDI strategy. In addition, it could be used as a guidance to assess the performance of internal- or external LDI managers. Ultimately, it could benefit the Dutch pension members when an enhanced LDI strategy, with improved performance measurement, leads to better solvability management of Dutch pension funds. Hereby, this research gives important academic insights in a practical issue affecting almost the entire Dutch population.

The remainder of this paper is structured as follows. Chapter 2 gives a short overview of the Dutch pension system. Chapter 3 elaborates on the different LDI strategies. Chapter 4 describes different valuation methods to discount the liability structure, which effectively becomes the LDI managers' performance benchmark. Subsequently, Chapter 5 discusses different performance benchmarks that are used in practice to measure the performance of institutional investors. Chapter 6 outlines the formed hypothesis. Chapter 7 describes the data used for this research followed by Chapter 8 which provides an outline of the applied methodology to answer the key research question. Chapter 9 presents the empirical results and the conducted analysis. Lastly, Chapter 10 provides concluding remarks as well as proposes recommendations for future research.

2. The Dutch pension fund system

2.1 General information about the Dutch pension scheme

The Dutch pension system is one of the best pension systems in the world according to the Mercer Global Pension Index, based on its robust retirement income system (Mercer, 2016). As described by Bovenberg and Nijman (2009) the Dutch pension system consists of three pillars (cappuccino model). The first pillar is a general old-age insurance and provides pension for all retirees. The first pillar is also called the “Algemene Ouderdomswet” or “AOW”. The AOW is a flat-rate pension benefit as a percentage of the net minimum wage. The AOW is dependent on the number of years lived in the Netherlands and independent of someone’s earned salary. After reaching the age of 67, the government will pay out this flat-rate pension benefit.[2] The AOW is pay-as-you-go financed, which means that the contributions paid by the active workforce participants are immediately passed on as benefits to the retirees.

The second pillar is a work-based or occupational pension, of which the pension level is dependent on the contributions of the participants and employer. Participation is compulsory for most employees. According to the CBS, only around 4% of the Dutch employees between 25 and 64 years did not have an occupational pension in 2013 (Kuiper, 2016). The second pillar can be divided into three categories: *industry-wide*, *company-linked* and *profession-linked* funds. The industry-wide pension funds are organized by sector, like the government or the construction industry. Companies can decide to join these industry-wide pension funds. The company-linked pension funds are organized by one single company. Lastly, the profession-linked funds are pension funds for professions, like dentists or general practitioners. The pension scheme, as part of the labour contract, is usually a result of negotiations between unions and employers in a collective labour agreement. The value of the assets gathered in the second pillar amounted to about €850bn in 2013, which was equal to 135% of the Dutch GDP (Goudswaard, 2013).

The occupational pension can have a defined benefit (DB), defined contribution (DC) or a hybrid structure, where the latter is a combination of a DB- and a DC pension scheme. The Netherlands has a long tradition of defined benefit (DB) pension schemes. Hereby, the

[2] The retirement age has started to increase by one month as of January 2013. In 2018, the retirement age would reach the age of 66 and 67 in 2021. Source: http://www.svb.nl/int/nl/aow/wat_is_de_aow/wanneer_aow/

benefits are - in its very essence - not dependent on financial developments, but are fixed. In particular, around 90% of the Dutch pension schemes were DB schemes in 2013 (Goudswaard, 2013). A specific Dutch DC pension scheme is the collective defined contribution scheme (CDC). In a CDC pension scheme the pension contributions are only fixed for a certain time, in most cases five years. CDC pension schemes have increased in popularity, but DB schemes are still the majority (Goudswaard, 2013).

Due to the recent financial- and economic circumstances, the DB pension schemes are under pressure. In particular, for Dutch pension funds it has become harder to manage various financial shocks, such as *investment risk*, *longevity risk* and *interest rate risk*. In addition, the support base for increased pension contributions relative to the level of pension benefits is decreasing. Also, companies are less willing to increase the pension benefits, due to international competitive pressure and changes in accountancy regulations (Goudswaard, 2013). This has led to an increase in defined contribution (DC) pension schemes, whereby the contributions rather than the pension benefits are fixed. This trend from DB to DC pension schemes shifts the risk of the level of the pension benefit from the pension fund to the pension scheme member.

However, also the level of pension benefit has become less secure in DB schemes. After the *dot.com crisis*, indexation has become conditional upon the pension fund's solvency ratio. In addition, the pension benefit has become a percentage of the median loan, rather than a percentage of the last received salary (Goudswaard, 2013). Moreover, due to the recent economic circumstances, the majority of the Dutch pension schemes have not increased pension benefits with indexation in the last couple of years. A decrease of the nominal pension benefits is an '*ultimum remedium'*, but has also been seriously considered or already passed on by various pension funds. So, actually the pension benefits are not so 'defined' in DB schemes and can be more considered as a hybrid arrangement (Goudswaard, 2013).

The third pension pillar is a funded private pension and is voluntary. In the third pillar, everyone can build up additional pension in order to complement the benefits received in the first and second pillar, up to the allowed fiscal ceiling as set by the government (Kuiper, 2016). The third pillar is also meant for self-employed individuals who do not build up pension rights in the occupational second pillar. Additional investments can be made for example by saving in a personal pension account or by purchasing other pension products.

Table 1 below shows the distribution of pension benefits across the three pension pillars for various countries.

Table 1: Distribution of pension benefits across the different pension pillars in various countries

	% Of total retirement benefits							
	The Netherlands	Germany	France	Italy	Spain	Switzerland	UK	US
PAYG public pensions	50	85	79	74	92	42	65	45
Occupational pensions	40	5	6	1	4	32	25	13
Personal pensions	10	10	15	25	4	26	10	42

Source: Bovenberg and Nijman (2009).

What can be observed from Table 1 is that the Netherlands has by far the highest occupational pension as a percentage of total pension benefits with 40%, compared to 5% in Germany and 13% in the US. Only Switzerland has also a high distribution of occupational pension with 32% of the total pension benefit. On the other hand, compared to most other countries shown in this Table, the Netherlands has quite a low distribution of pay-as-you-go (PAYG) financed public pension. For the Netherlands, this pay-as-you-go public pension is 50% of the total received pension benefit, compared to 85% in Germany and 92% in Spain. Since the occupational pension as a percentage of the total pension in the Netherlands is quite high, the pension benefits received by Dutch pension scheme members are relatively more exposed to interest rate risk, than the pension benefits received in Germany and Spain.

In 2008, the Dutch pension system was significantly hit by the global credit crisis due to its current design. In particular, amongst other things the protracting low interest rate environment and the low return on assets destabilized the Dutch pension schemes. Subsequently, several professionals in the industry such as Theo Kocken (Cardano), Lans Bovenberg (Netspar) and Dutch economist Sweder van Wijnbergen discussed the current Dutch pension system at the yearly pension summit in the beginning of 2009. They agreed the system had to renovate in order to survive the crisis.[3] Since then, many proposals have been made to improve the current pension system. Professionals of the industry argue that the new pension system should meet three main objectives: (1) it should keep the strong points of the current system; (2) it should be more flexible and transparent; (3) it should incorporate room for custom fit and freedom of choice. Hence, the new pension system should still share the

[3] Preesman, L., 2009. PensionSummit: Pensioenfondsen moeten vernieuwen. *PensioenPro*, 9 april.

investment risks and economic downturns between generations. Additionally, the new system should better anticipate on the increased job mobility. Moreover, the level of the pension benefit that has been built up so far should be more clear (SER, 2016). At the moment, the social partners seem to show the most interest in an individualized pension system.[4] However, although the SER has been working on this plan for more than three years, there is still no final consensus on the new Dutch pension system's design.

2.2 Goal of the Dutch Pension Fund

As stated by Goudswaard (2013), Dutch pension schemes can be viewed as a hybrid arrangement of guarantees and ambitions. The nominal pension liabilities are 'guaranteed', whereas the aim to increase the nominal liabilities with the level of inflation is an ambition. The degree to which pensions rise in line with prices and wages is dependent on the pension funds' investment performance (Bovenberg and Nijman, 2009). According to the nFTK, Dutch pension funds have to possess a buffer to ensure that the nominal pension liabilities can be guaranteed with a certainty of 97.5%.[5] This buffer should consist of around 20% additional to the nominal value of the pension liabilities, depending on the amount of risk the pension funds' balance sheet contains. Only if the pension fund's coverage ratio is above 120%, the buffer is considered to be sufficient to allow for indexation purposes. Furthermore, the pension fund has to undertake certain actions when the pension fund is not able to reach the required buffer (in Dutch: "vereist eigen vermogen"), or when there is a probability of 2.5% or more that the next year's funding ratio will be below 100%. Table 2 below summarizes the main rules regarding the required buffer and the indexation policy for Dutch pension funds.

Table 2: Main rules Financial Assessment Framework (FTK) regarding the required buffer and indexation policy

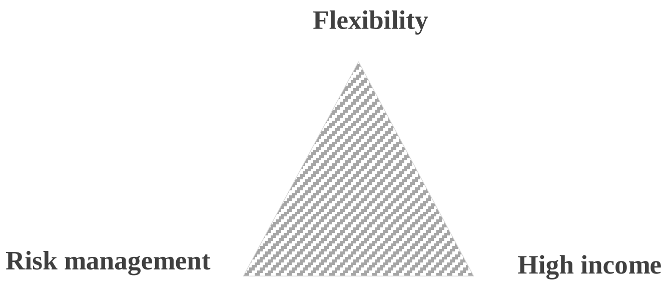
	Coverage ratio	Qualifier	Actions to be taken	Indexation
Nominal (%)	> 120	Sufficient buffer	None	Possible
	120-105	Back-up/buffer deficit	Long term recovery plan of 15 years	Limited
	< 105	Funding deficit	Short term recovery plan of 3 years	Not possible

Source: Pension Act (2006), Financial Assessment Framework for Pension funds.

[4] Preesman, L. 2017. Beoogde coalitie eens over individuele opbouw met collectieve risicodeling, *PensioenPro,* 24 maart 2017.
[5] Pension Act, Chapter 6, Financial Assessment Framework for Pension funds, Article 132:2

Since pension funds 'guarantee' a predefined pension level to their participants, they must employ investment strategies in order to meet this obligation. Simultaneously, they have to mitigate various risks such as: *investment risk, inflation risk, interest rate risk* and *longevity risk*. Hence, when pension funds set their investment strategy, they face a tradeoff between high return, risk and flexibility. This is visualized in Figure 1 below.

Figure 1: Triangle of needs and wants of a retiree investor



According to the Dutch Central Bank (DNB), Dutch pension funds are only allowed to take a certain amount of risk in their strategy depending on several factors amongst which their solvency ratio (Pension Act, 2006). In particular, the DNB poses constraints on the universe of investable assets for pension funds, which limits the possible strategies that Dutch pension funds can pursue. Hence, the goal of the pension fund is to meet their guarantees and ambitions between the boundaries of the allowed amount of risk.

2.3 How do pension funds achieve their goal?

In order to reach their goal of 'guaranteed' nominal pension benefits and their indexation ambition, pension funds have adopted different asset liability management (ALM) strategies over time depending on market conditions and market sentiment. In particular, ALM strategies have the objective to match the level of assets with the level of the liabilities, while mitigating risks such as the interest rate risk (Ryan, 2013).

In the late 1980's, pension funds followed a *surplus optimization strategy* (Ryan, 2013). Hereby, an ALM study was performed that would result in a certain *equity, bond* and *other* division. In the respective asset classes, assets would be chosen that were the outcome of a so-called risk-return optimization problem (Ryan, 2013). In addition, each division would receive its own performance benchmark. For example, the equity division would receive a published equity benchmark, whereas the bond division would receive a published bond benchmark. The ultimate goal of the asset manager was to beat the respective performance benchmark. The result of the surplus optimizations strategy is a '*standard balance sheet*' visualized in Figure 2 below.

Figure 2: Standard Balance Sheet

Assets	Liabilities
Fixed Income Equity Commodities Real Estate Derivatives Alternatives	Defined Benefits Surplus

Source: Bragt and Kort (2011).

What can be observed from Figure 2 is that the surplus optimization strategy combines the performance of all asset classes to make up for both the defined benefits and the surplus. The surplus optimization strategy was successfully applied until the 2000-2003 equity correction of the dot.com bubble. During the dot.com bubble, equity returns fell hard and some people claimed that equity had no place in a pension fund's asset allocation (Ryan, 2013).

Consequently, *liability driven investment* (LDI) became more popular among institutional investors, pension funds and insurance companies after the 2003 equity correction (Ryan, 2013). Liability driven investment (LDI) management has the objective to match the interest rate sensitivity of the assets, with the interest rate sensitivity of the pension liabilities. Hereby, liability driven investment management reduces the volatility of the pension funds' solvency ratio (Baldeaux and Platen, 2013 & Baars et al. 2012). In particular, LDI management assumes a separation of the balance sheet in two parts, a risky- and a low risk portfolio. The risky portfolio is also called the *performance-seeking portfolio*, whereas the low risk portfolio is also called the *matching portfolio* (Bragt and Kort, 2011). The matching portfolio is designed in such a way to meet the level of the nominal pension liabilities at a high certainty, as is required by the DNB. To this end, the matching portfolio only includes low risk financial instruments, such as high quality sovereign bonds. The performance-seeking portfolio includes more risky instruments such as equity and real estate, to allow for indexation of the pension benefits and to create a buffer. The LDI balance sheet is visualized in Figure 3 below.

Figure 3: LDI Balance Sheet

Matching Portfolio		**Performance Seeking Portfolio**	
Assets	**Liabilities**	**Assets**	**Liabilities**
Fixed Income Derivatives Fictive Cash	Defined Benefits	Equity Commodities Real Estate Derivatives Alternatives	Surplus Fictive Cash

Source: Bragt and Kort (2011).

Hence, what can be observed from Figure 2 and Figure 3 is that the main difference between LDI management and surplus optimization management is that LDI management assumes a separation of the balance sheet. Consequently, LDI management creates more certain cash flows to meet the pension fund's objective of guaranteed nominal pension benefits. Moreover, a formula can be used to assign a certain percentage of the assets to the matching portfolio and a certain percentage to the performance-seeking portfolio[6]:

$$\%\ Performance\ Seeking\ Portfolio = \frac{immunization\ target\ rate\ of\ return - minimum\ return}{immunization\ target\ rate\ of\ return - expected\ worse\ case\ return} \qquad (1)$$

[6] Fabozzi, 2013, Bond Markets, Analysis, and Strategies, Chapter 25.

3. Liability Driven Investment (LDI) Management

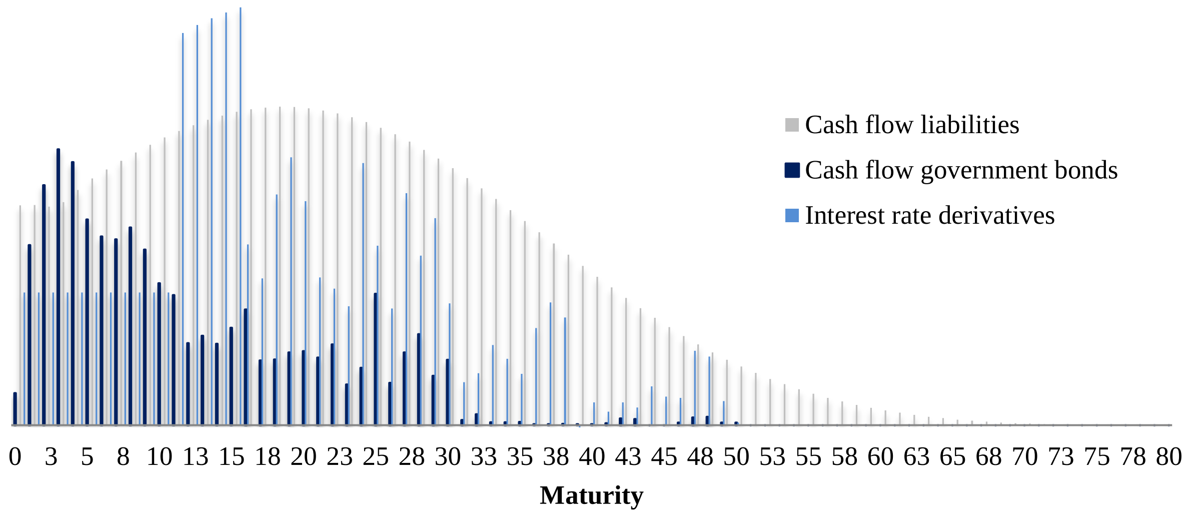
The academic literature discusses two main LDI strategies, the *immunization*- or *duration matching strategy* and the *cash flow matching strategy* (Fabozzi, 2006, p.9). Both the immunization strategy and the cash flow matching strategy are concerned with the matching portfolio. Hence, both LDI strategies have the objective to match the interest rate sensitivity of the pension's assets with the interest rate sensitivity of the pension liabilities. This section discusses both LDI strategies and specifically it discusses their subsequent cash flow profiles with respect to the pension liabilities.

3.1 Immunization strategy

The immunization strategy is one of the LDI strategies that is recently most used in practice (Cardano, internal documents 2017). The immunization strategy matches the *total weighted average duration* of the investment assets with the *total weighted average duration* of the pension liabilities. Hence, this strategy is also referred to as the *duration matching strategy*. Since the asset's duration is matched with the liabilities' duration, the (bond) portfolio is insensitive to *parallel shifts* in market yields, given that the portfolio is rebalanced at a regular basis. Hence, it can be stated that the (bond) portfolio is *immunized*. Due to the development of financial instruments and programming techniques in the 1990s, the immunized LDI strategy became more sophisticated (Zenios, 1995). In particular, a swap overlay could be added to the bond portfolio, which enhanced the interest rate sensitivity hedge. In particular, as government bonds are not highly available for the longer maturities, a swap overlay could hedge the interest rate sensitivity for the longer end of the yield curve.

In an immunized LDI portfolio, a LDI manager first invests in a bond portfolio. Hereby, the LDI manager tends to follow a published bond benchmark. The performance of the fund manager will be actively assessed against this bond benchmark (Chambers, 2005). Subsequently, another LDI manager matches the duration gap between the bond portfolio and the pension liabilities with an interest rate swap overlay. The performance of the overlay is not included in the fund manager's performance assessment (Chambers, 2005). In this paper, I call an immunization strategy, whereby a separate swap overlay is added to a bond portfolio, a *separated LDI strategy*. The cash flow profile of the separated LDI strategy is visualized in Figure 4 below.

Figure 4: Cash flow profile separated LDI strategy



Source: Aegon Asset Management (2016).

What can be observed from Figure 4 is that the separated LDI strategy over-hedges certain maturities, whereas for the longer maturities no financial instruments are hold. So, although the total weighted average duration is matched, *non-parallel interest rate movements* can lead to a difference in value of the pension liabilities and the investment assets in the matching portfolio. Hence, academic research has argued that the immunization strategy is often not a very good way to match the liability cash flow profile (Fabozzi, 2006).

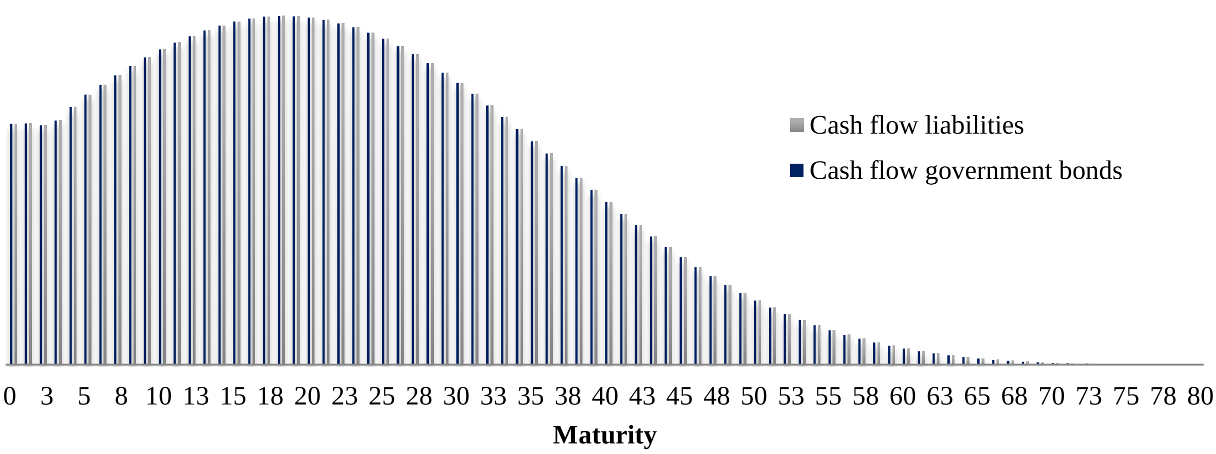
3.2 Cash flow matching strategy

Whereas the immunization strategy leads to a cash flow profile that is different from the liability cash flow profile, the cash flow matching strategy tackles exactly this issue and focuses on matching the investment cash flows with the liability cash flow profile. At first, the cash flow matching strategy was solely constructed with the use of (zero coupon) government bonds, since derivative instruments did not exist before the 1990s (Ryan, 2013).

In the cash flow matching strategy, the LDI manager first selects a bond with a maturity that matches the level and maturity of the last liability stream. For the next liability stream, the coupon of the first bond is deducted and another bond is selected for the remaining liability value. This process is continued until all the liability cash flows are covered by (interest) payments of bonds in the portfolio.

Although the cash flow matching strategy better protects again non parallel interest rate movements it is still sensitive to *credit risk*, since bonds include credit risk whereas the pension liabilities do not include credit risk. Credit risk encompasses the chance that the issuer is not able to fulfill its repayment (Haugh et al., 2009). When the credit risk increases, simultaneously a sovereign bond's yield increases, which decreases the value of the bond portfolio. Hence, the subsequent matching portfolio has to be rebalanced from time-to-time. In theory, if bonds of every maturity would exist and all the assets of the fund would be invested in bonds, a near perfect match could be obtained. Figure 5 below shows the cash flow profile of the cash flow matching strategy in such a frictionless market.

Figure 5: Cash flow profile cash flow matching strategy in a frictionless market

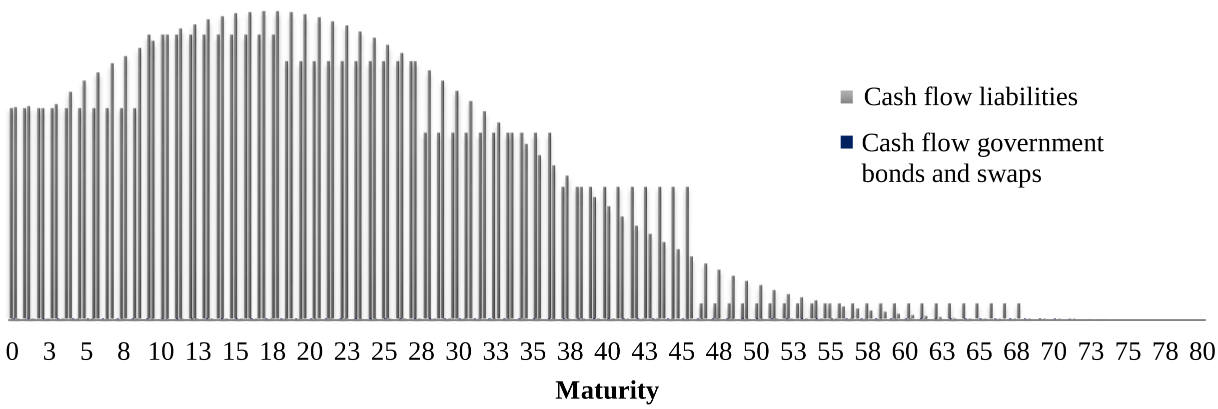


Source: Aegon Asset Management (2016).

What can be observed from Figure 5 is that the investment cash flows perfectly match the liability cash flow profile. However, in practice a perfect cash flow match is unlikely, since the required face value and coupon payments might not be available to construct the exact same cash flow profile. Also, excess funds might be available before the liability is due, which gives rise to *reinvestment risk* (Fabozzi, 2006). Furthermore, the cash flow matching strategy hedges liability cash flows that are highly uncertain, since the liability cash flow profile constantly changes, due to amongst other things decreases in *mortality rates* and increases in *longevity rates*.

In practice, since the introduction of the interest rate swap in the 1990s, next to government bonds also interest rate swaps are often used in the cash flow matching strategy. Furthermore, in practice the liability cash flow profile will not be perfectly matched, but the liability cash flow profile will be divided into different maturity buckets of for example 0-9 years, 11-20 years, 21-29 years etc. Subsequently, the duration of these maturity buckets will be matched with both bonds and interest rate swaps. The tradeoff between swaps and bonds is based amongst other things on the difference in return. In this paper, a cash flow matching strategy whereby both bonds and swaps can be used *interchangeably* to match the liability cash flow profile, is referred to as an *integrated LDI strategy*. Figure 6 below shows the cash flow profile of an integrated LDI strategy.

Figure 6: Cash flow profile integrated LDI strategy



Source: Aegon Asset Management (2016).

As the integrated LDI strategy increases the flexibility to switch between interest rate swaps and bonds to match the liability cash flow profile, the LDI manager can enhance the LDI performance. In particular, since the LDI manager does not have to stay close to a bond's benchmark duration in the choice of his bonds, he can benefit from higher returns and lower costs on swaps versus bonds, and vice versa. In addition, the LDI manager will be better able to reduce *swap spread risk* in the integrated LDI strategy. The swap spread is the difference between the bond yield and the swap rate for the same maturity. In particular, in case the credit risk increases, the bond yield increases. Subsequently, the swap spread increases if the swap rate does not increase in a similar fashion. Since the pension liabilities are discounted with the swap rate (up to a certain maturity), an increase in the swap spread has a negative effect on the LDI performance. In particular, when the swap spread increases the value of the bond portfolio will decrease more than the value of the pension liabilities, as the bond yield increases more relative to the swap rate. On the other hand, a decrease of the swap spread has a positive effect on the LDI performance, since the value of the bond portfolio will increase more than the value of the pension liabilities, as the bond yield decreases more relative to the swap rate. As the swap spread can have a significant impact on the LDI performance, the increased flexibility to switch between swaps and bonds in an integrated LDI strategy can enhance the LDI performance, relative to the separated LDI strategy according to Rik Klerkx, LDI manager at Cardano Risk management.

4. Applicable liability discount curve in a LDI mandate

In order for a LDI manager to match the liability cash flows, when he follows either the immunization strategy or the cash flow matching strategy, the LDI manager and the pension fund have to agree upon the way the liabilities should be discounted. Subsequently, the applicable liability discount curve in essence becomes the LDI manager's performance benchmark (Fabozzi, 2006). This section discusses two possible discount curves to value the pension liabilities: *the regulatory UFR curve* and *the economic swap curve*. Moreover, this section will address the pros and cons of the respective discount curves in a LDI mandate and explain why in practice only one of these two possible discount curves can be applied as a LDI performance benchmark.

4.1 Ultimate Forward Rate (UFR) curve

The Dutch law requires Dutch pension funds to discount their pension liabilities with the ultimate forward rate (UFR) curve when they calculate their solvency ratio (DNB, 2012). The UFR curve is an adjusted yield curve based on an alternative extrapolation method, whereby long-term interest rates converge to a stable long-term level – the ultimate forward rate (UFR). The UFR is an unconditional ultimate long-term forward rate for infinite maturities. The level of the ultimate forward rate is based on the long-term expected inflation and the long-term expected real short-term interest rate (DNB, 2012).

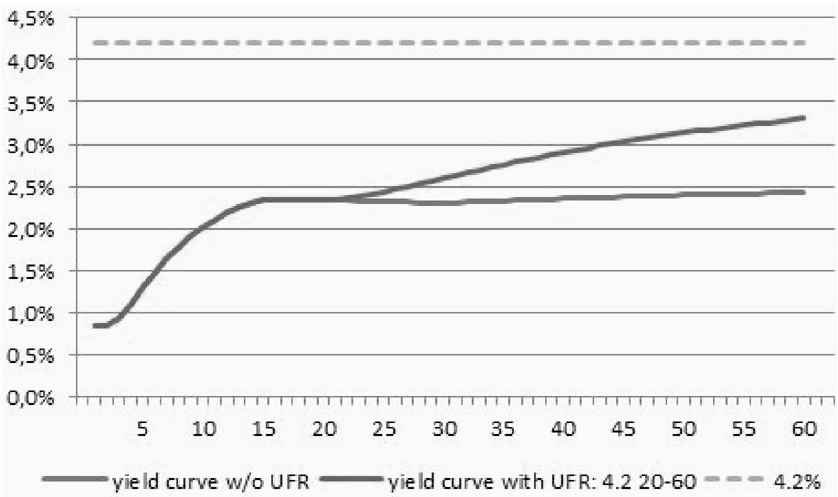
Before the introduction of the UFR curve, pension funds used a fixed discount rate of 4.0% to calculate the current value of their pension liabilities. Only the level of the pension assets varied with movements of the interest rates. In January 2007, the Act (2006) came into force, which introduced the Financial Assessment Framework (in Dutch "Ftk"). According to the FtK, *both* the pension assets and the pension liabilities had to be priced based on the market value, i.e. the nominal term structure of the interest rate. However, in 2008 the global financial crisis hit the financial markets and the term structure of interest rates became very volatile. Hence, the market information used to determine the rates at very long maturities became less reliable[7]. Consequently, the UFR curve was introduced in September 2012 by the Dutch Central Bank (in Dutch "DNB"), which led to a more stable yield curve and hence more stable funding ratios for pension funds. In particular, the UFR curve made pension

[7] DNB, 2012. UFR provides a beacon for pensions in turbulent markets, 3 October, 2012.

liabilities less sensitive to fluctuations and to possible disturbances in the financial markets (DNB, 2015), which was very important for the financial strategies pursued by pension funds (Langejan, 2013).

At the moment the UFR was introduced for Dutch pension funds, the UFR stood at 4.2%, of which 2.0% accounted for the expected long-term inflation rate, and 2.2% accounted for the expected real short-term interest rate[8]. Figure 7 visualizes the yield curve with and without the ultimate forward rate (UFR) of 4.2% as of 2012.

Figure 7: Yield curve as of 2012, with and without the UFR of 4.2%



Source: DNB (2012).

In July 2015, the DNB changed the calculation method of the UFR for Dutch pension funds to achieve a more realistic determination of the ultimate forward rate. In the new calculation method, the UFR had to be monthly calculated based on the rolling 10-year average of the 20-year forward rate[9]. Consequently, the UFR decreased from 4.2% to 3.3% when the new UFR calculation method was introduced in July 2015. Moreover, since interest rates were much higher a decade ago, the UFR continued to fall in recent years as lower rates were factored into the rolling 10-year average. As of July 2017, the UFR stood at 2.7%.

[8] DNB, 2012. UFR provides a beacon for pensions in turbulent markets, 3 October, 2012.

[9] DNB, 2015. Decision of DNB to adjust the UFR, 1 July 2015.

Moreover, since the UFR is calculated on a monthly basis, it is expected that the UFR will continue to decrease[10].

However, according to Rik Klerkx, LDI manager at Cardano Risk management, the UFR curve is not an applicable benchmark curve in a LDI mandate. First, since the UFR curve is politically determined, the UFR curve includes *regulatory risk*. In particular, if the LDI manager's performance is measured vis-à-vis the UFR discount curve, his performance is negatively affected in the case the ultimate forward rate is decreased. Since the interest rates have been on a decreasing trend and the UFR is calculated on a monthly basis, the UFR has decreased since its introduction for Dutch pension funds in 2012. Most LDI managers are simply not willing to let this regulatory risk affect their LDI performance. In addition, since no financial market instruments exist that perfectly match the regulatory UFR curve after the last liquid point of 20 years, the LDI manager has to take increased *investment risk* when his performance is assessed against the UFR benchmark curve (Budiono, 2012). An increase in investment risk would also negatively affect the LDI manager's performance, since this would result in a higher tracking error vis-à-vis the pension liabilities. Hence, due to the regulatory nature of the UFR discount curve, the UFR curve is not applied in practice as applicable benchmark curve in a LDI mandate.

4.2 Economic swap curve

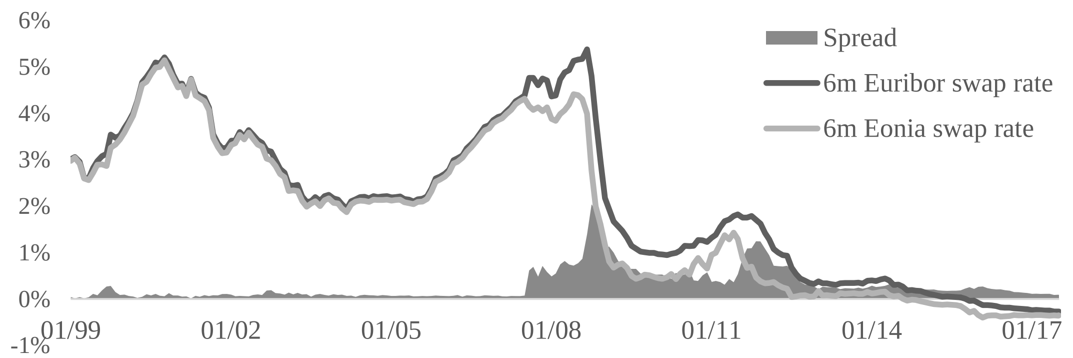
Whereas the UFR curve is politically determined, the economic swap curve is determined by market instruments. Hence, the economic swap curve is in essence an *investable benchmark*. Consequently, the LDI manager should be able to create a LDI portfolio that has the same payoff as the economic swap curve. Hence, the LDI manager can enhance his LDI performance, i.e. minimize the tracking error vis-à-vis the pension liabilities, when the economic swap curve is used, relative to when the UFR curve is used as the applicable benchmark curve. Moreover, the economic swap curve is also the curve on which the pension fund's interest rate hedge is measured in practice (Cardano, internal documents). In addition, the economic swap curve is the basis for the UFR curve and the two curves are intended to converge. Hence, according to Rik Klerkx, LDI manager at Cardano Risk

[10] KPMG, 2017. Ultimate Forward Rate voor Pensioenfondsen, 2 August, 2017.

management, opposed to the UFR curve, the economic swap curve could be used as an applicable benchmark curve in a LDI mandate.

However, even in the case the economic swap curve is used as the applicable discount curve, the LDI manager could still not be able to perfectly match the value of the pension liabilities due to the OIS-Libor mismatch. In particular, in the extreme case the LDI manager hedges the interest rate sensitivity fully with swaps, the performance of the investment assets could still not perfectly match with the pension liabilities' performance, due to the fact that the cash positions of the collateralized interest rate swaps return on the 6m Eonia curve[11], whereas the pension liabilities return on the 6m Euribor curve. Hence, the LDI manager will obtain a negative LDI performance in the case the 6m Euribor curve lies above the 6m Eonia curve. In particular, the respective OIS-Libor spread will result in a negative tracking error vis-à-vis the level of the pension liabilities. Figure 8 below shows the difference between the 6m Eonia curve and the 6m Euribor curve from 1999 till 2017.

Figure 8: Graph of the 6-month Eonia swap rate, and the 6-months Euribor swap rate with the respective spread between January 1999 and January 2017



Source: Bloomberg

What can be observed from Figure 8 is that the Eonia curve and the Euribor curve started to diverge around 2007. Over time, the spread between the 6m Eonia rate and the 6m Euribor rate ranged from 1 bps to around 200 bps, with its maximum at the end of October 2008. As of 3 August 2017, the spread between the Eonia rate and the Euribor rate was around 8 bps (Bloomberg). Hence, the spread has decreased again after 2007. Since the 6m

[11] Overnight interbank interest rate.

Euribor rate and the 6m Eonia rate still diverge, LDI managers should take this OIS-Libor spread into account when they set the LDI strategy, and when the economic swap curve is used as the applicable benchmark curve.

Moreover, if a pension fund decides to use the economic swap curve as the applicable benchmark curve in a LDI mandate, the pension fund will have to make up for the mismatch in return between the UFR curve and the economic swap curve in a different investment portfolio (for example in the equity portfolio). In particular, as pension funds are required to calculate their solvency ratio based on the UFR curve, they should realize a return on their pension liabilities that follows the UFR curve. However, in case the LDI manager matches the (currently) lower economic swap curve, the LDI manager does not realize the required (UFR) return. Hence, the pension fund should take this into account when they use the economic swap curve as the applicable performance benchmark in a LDI mandate. Furthermore, in theory the pension fund can decide to use a hybrid form of the UFR benchmark curve, whereby an *investable portfolio* is created based on the UFR curve. In this case, the investable portfolio and not the UFR curve becomes the LDI performance benchmark. This hybrid form whereby an investable portfolio is created has also been described by Fabozzi (2006). However, according to Rik Klerkx, LDI manager at Cardano Risk management, in practice it is (too) difficult to construct an investable portfolio based on the UFR curve. Hence, Cardano uses the economic swap curve as the applicable liability discount curve, and performance benchmark in a LDI mandate.

5. Liability discount curve versus more traditional performance benchmarks

This Chapter examines various performance benchmarks that are discussed in the empirical literature and that are used in practice to assess the performance of institutional investors. There is quite an extensive body of theoretical literature on the performance measurement of institutional investors. In particular, the optimal performance benchmark for the pension fund industry has been a hot debated topic in the recent literature. Performance benchmarks are important for three things: (1) they help to measure the performance of the institutional fund manager, (2) they provide a reference point to monitor that performance and (3) they can modify the behavior of fund managers. Moreover, performance benchmarks can seriously distort the manager's investment behavior as well as provide the right incentives (Blake, 2002). This Chapter will first discuss *the market-based performance benchmark,* followed by the *peer-group performance benchmark*. Lastly, the *liability-based performance benchmark* will be discussed that has been introduced recently and is more tailored towards the pension fund industry.

5.1 Market-based performance benchmarks

One of the first performance benchmarks that was used in the context of fixed-income and equity portfolios is *the market-based performance benchmark*. Market-based performance benchmarks typically include tradeable market instruments and are based on well-defined rules. The market-based performance benchmark mainly involves tailoring the weights of the external benchmarks to the specific fund requirements (Blake 2002). For asset managers the incentive is to outperform the market-based performance benchmark. Table 3 below shows several examples of market-based performance benchmarks for various asset classes.

Table 3: An example of a benchmark portfolio. It specifies the weighting and the indices used for different investment styles. The range specifies the boundaries within an active asset manager must control the allocation.

Assets	Weight (%)	Range (%)	Index
Fixed Income	*75*	*65-85*	
Governments	70	60-80	Citigroup gov bond index
Corporates	15	10-20	Citigroup non-EGBI EMU index
Private Loans	15	10-20	Customized private loan index
Equity	15	*5-25*	
Europe	40	30-50	MSCI Europe
USA	20	10-30	MSCI North America
Pacific	15	5-25	MCSI Pacific
EM global	25	15-35	MSCI EM global
Real Estate	*5*	*0-10*	
Residential	50	25-75	ROZ-IPD residential
Shops	50	25-75	ROZ-IPD Retail
Alternatives	*5*	*0-10*	
Commodities	50	0-100	DJ-AIG Commodity Index
Hedge fund	50	0-100	Euro 7-day Libid

Source: Huang (2012).

What can be observed from Table 3 is that a fixed income investor that is restricted to investments in government bonds can have the '*Citigroup government bond index*' as his performance benchmark. Hence, if the Citigroup government bond index has made a return of 3% in a certain period, the investor targets to make a return of at least 3%. Moreover, Table 3 shows a benchmark portfolio, whereby specific weights are attached to the various asset classes. Hence, when an active asset manager can invest 75% in fixed income, 15% in equity, 5% in real estate and 5% in alternatives (including commodities and hedge funds), the asset manager should try to outperform the benchmark portfolio by tailoring the respective weights to the benchmark indices. The active asset manager can somewhat change the range of the asset allocation for each asset class to outperform the benchmark, which is shown in the third column.

In addition, the CFA has composed six principles that constitute a ‘good performance benchmark’:

1. **Unambiguous:** instruments constituting the benchmark are clearly defined
2. **Investable:** it is possible to manage the benchmark actively as well as simply hold it
3. **Measurable**: the return on the benchmark is easily measured on a frequent basis
4. **Appropriate**: the benchmark reflects the manager’s preferences
5. **Reflective of current investment opinions**: the manager possesses current investment knowledge of instruments and risk factor exposures within the benchmark
6. **Specified in advance**: the benchmark is specified before the start of an evaluation
7. **Owned**: the benchmark should be an integral part of the investment process introduced by the investment manager

Based on the CFA principles, the market-based performance benchmark constitutes a ‘good performance benchmark’, since it typically includes tradeable market instruments and hence is an *investabl*e and *unambiguous* performance benchmark. Furthermore, the market-based performance benchmark can be *replicated* by the investment manager, although this can often be challenging in practice. Since the market-based performance benchmark is based on tradeable market instruments this makes the market-based performance benchmark a ‘neutral’ point of reference, that can be used in the performance evaluation of the investment manager (Peeters and Prins, 2011).

In a LDI portfolio also government bonds are used. Hence, LDI managers managing the bond portfolio often tend to receive a published bond benchmark to measure their performance (Chambers, 2005). The bond benchmark has received some critique, since it would not lead to the ultimate investment behavior for pension funds. In particular, if the LDI manager’s performance is assessed vis-à-vis a published bond benchmark, the LDI manager’s incentive would be to outperform the bond benchmark. In the case the bond benchmark has made a return of 3% and the LDI manager makes a return of 4% in the same period, the LDI manager has outperformed the bond benchmark. However, if simultaneously the pension liabilities increase with 5%, the LDI manager has underperformed vis-à-vis the pension liabilities. Hence, the market-based performance benchmark leads to short-term asset allocation to create short-term outperformance, which *conflicts with the long-term objective* of pension funds (Hinz et al., 2010). Moreover, it has been argued that funds with better short-term performance, do not necessarily perform well in the long run (Hinz et al., 2010). Based on these results, it can be argued that a market-based performance benchmark is not the optimal performance benchmark to measure the LDI manager's performance.

5.2 Peer-group performance benchmarks

Next to the market-based performance benchmark, *peer-group performance benchmarks* are used in practice to assess the performance of institutional investors. Compared to the market-based performance benchmark, peer-group indices can be a better measure to compare the performance of institutional investors in a certain sub-group. For example, a peer-group performance benchmark can distinguish between the performance of institutional investors of large (mature) pension funds and the performance of institutional investors of small (less mature) pension funds. Hereby, the peer-group benchmark can be a better representative than a market-based performance benchmark. However, most pension funds differ a lot from each other, which makes it hard to make a meaningful peer comparison.

Furthermore, research has shown that the peer-group performance benchmark provides a strong incentive for herding behavior (Blake, 2002). This is very rational, since with a peer-group performance benchmark, the fund manager is evaluated based on his *relative performance* vis-à-vis another institutional investor, rather than on his *absolute performance* vis-à-vis a published bond benchmark. In particular, a strong distribution is found around the median fund manager, who generates a performance that is not very different from that of a passive index matcher (Blake, 2002). In a more recent research performed by the DNB, this herding behavior was also found concerning the Dutch pension fund market (Koetsier, 2017). Hence, while a pension fund should set its asset allocation that best enables it to meet its own liability cash flow profile at its projected rate of contribution, a peer-group benchmark tends to produce investment decisions based on what other pension funds are doing (Blake, 2002). So, based on these results it can be argued that also the peer-group performance benchmark is not the optimal performance benchmark to measure the LDI manager's performance.

5.3 Liability-based performance benchmarks

As market-based performance benchmarks and peer-group performance benchmarks fail to capture the long-term pension fund objective and fail to provide the right incentive, *liability-based performance benchmarks* have been introduced. According to Fabozzi (2006), a liability-based performance benchmark is "*a 'neutral' benchmark that gives the sponsor and manager a performance yardstick incorporating both the term structure constraints imposed by the liability schedule and the investment restrictions imposed by the sponsor's risk preferences".*

According to Fabozzi (2006) *a portfolio benchmark* is a possible liability-based performance benchmark and a good alternative for the market-based performance benchmark. In particular, a portfolio benchmark consists of investable market instruments and has the objective to match the liability cash flow profile while satisfying the sponsor's investment restrictions. Hence, a portfolio benchmark leads to an investment strategy, whereby the outcome is a cash flow profile with close resemblance to the liability cash flows. So, in comparison with the market-based performance benchmark and the peer-group benchmark, the liability-based performance benchmark seems to be the optimal benchmark that should be used to evaluate the LDI manager's performance. Moreover, it has been argued that index benchmarks will start to play a smaller part (Engaged Investor, 2010).

However, Cousin, Jiao, Robert & Zerbib (2016), argue in their paper that currently still no appropriate benchmark exists to evaluate the asset managers of liability driven institutions, such as pension funds and insurance companies. They emphasize that assessing the performance of an asset manager represents a major stake for the financial institution that delegates a mandate of asset management. The authors conclude that in the current financial environment that is characterized by high fixed income- and equities volatilities, the outcome of all admissible strategies is very different and that the choice of the benchmark has significant implications. Therefore, it is very important that appropriate LDI benchmark principles are constructed that can be applied market wide.

6. Hypothesis

The scope of this paper is to analyze different LDI strategies and to compare the resulting performance of the interest rate hedging strategy in different swap spread scenarios. Specifically, this paper analyzes both the *immunization strategy* and the *cash flow matching strategy* as described by Chambers (2005), which I define as the *separated LDI strategy* and the *integrated LDI strategy* respectively. In a separated LDI strategy, a swap overlay is added to a separate bond mandate, whereas in an integrated LDI strategy these two building blocks are combined. In line with the theory that the immunization strategy produces a cash flow profile that is significantly different from the liability cash flow profile (Fabozzi, 2006), I expect the following hypothesis:

Hypothesis 1: I expect to find that an integrated LDI approach maximizes the goals set by a pension fund's interest rate hedging strategy,. i.e. minimizes the tracking error vis-à-vis the pension liabilities.

7. Data and summary statistics

In this section I present an overview of the data and variables used with a particular focus on the portfolio construction of the two LDI strategies analyzed in this research paper. Furthermore, the data and variables are presented for the Cardano case study. Lastly, the yield movements and the swap spreads are visualized for the periods analyzed.

7.1 Summary statistics stylized LDI portfolios

This research paper analyzes both the immunization strategy and the cash flow matching strategy, which I define as the *separated LDI strategy* and the *integrated LDI strategy* respectively, in different swap spread scenarios. Both LDI strategies have been discussed by Chambers (2005) and are common practice in the pension fund's LDI management. As discussed before, in a separated LDI strategy first a bond portfolio is constructed and a swap portfolio is added later on. In the integrated LDI strategy, both swaps and bonds are combined in one mandate and can be used interchangeably to match the liability cash flow profile. Moreover, the separated LDI strategy tends to follow a bond benchmark (Chambers, 2005). Therefore, a rolling 10-year bond portfolio is constructed with the objective to represent the separated LDI strategy. This 10-year duration is comparable to the average Dutch pension funds' bond portfolio (Cardano, internal documents). The integrated LDI strategy focuses more on spread risk and therefore can have a shorter duration. Hence, a rolling 2-year bond portfolio was constructed to represent the integrated LDI strategy. Although, an integrated LDI strategy can also have an investment portfolio with a longer bond duration, a shorter duration is chosen specifically to show the potential performance difference between the two LDI strategies.

To construct the two stylized LDI portfolios, I used Bloomberg to select historical bonds and to extract data of their respective swap spreads. In addition, I used Bloomberg to extract the historical yields of the swap curve. Only bonds were included of which the data was available on Bloomberg during the sample period (from 29-6-2007 till 20-6-2017). Additionally, only rolling 10-year and 2-year bonds were selected, since otherwise a 10-year bond turns into a 1-year bond after nine years. Hence, I have used the *'on-the-run'* issued 10-year and 2-year government bonds, as defined by Bloomberg. Furthermore, since Dutch LDI managers face strict investment restrictions and can therefore often only invest in high investment grade European bonds, only bonds were picked from three European government issuers to construct the stylized LDI portfolios. In particular, only government bonds were included from Germany, the Netherlands and France. The objective is that these three issuers are representative for Dutch LDI portfolios. Table 4 below presents the descriptive statistics for both the stylized bond portfolios for the total sample period and during the periods of increasing- and decreasing swap spreads.

Table 4: Summary Statistics Stylized Bond Portfolios.

		10-year bond portfolio	2-year bond portfolio
Total sample period	Period:	6-7-07 till 20-6-17	6-7-07 till 20-6-17
	In weeks:	521 weeks	521 weeks
	Mean Bond Yield:	225 bps	86 bps
	Sum Δ Bond Yield:	-414 bps	-507 bps
	Sum Δ Swap rate	-410 bps	-490 bps
	Sum Δ Swap spread	-4 bps	-17 bps
Increasing swap spread	Period:	26-9-08 till 29-5-09	6-1-12 till 21-9-12
	In weeks:	36 weeks	38 weeks
	Mean Bond Yield:	366 bps	26 bps
	Sum Δ Bond Yield:	-54 bps	-22 bps
	Sum Δ Swap rate	-123 bps	-89 bps
	Sum Δ Swap spread	70 bps	67 bps
Decreasing swap spread	Period:	2-12-11 till 3-8-12	15-4-11 till 30-12-11
	In weeks:	36 weeks	38 weeks
	Mean Bond Yield:	220 bps	111bps
	Sum Δ Bond Yield:	-115 bps	-156 bps
	Sum Δ Swap rate:	-79 bps	-114 bps
	Sum Δ Swap spread:	-36 bps	-42 bps

What can be observed from Table 4 is that the total sample period covers 521 weeks, ranging from 6 July 2007 until 20 June 2017. In this period, the average bond yield was 225 bps for the rolling 10-year bond portfolio and 86 bps for the rolling 2-year bond portfolio. Both the bond yield and swap rate decreased for the 10-year and 2-year stylized bond portfolios during the 521 weeks. This resulted in a negative swap spread of -4 bps and -17 bps for the 10-year bond portfolio and the 2-year bond portfolio respectively.

Within this total sample period, two specific periods of increasing- and decreasing swap spreads are analyzed for both the 10-year and 2-year bond portfolio separately. In the case of the rolling 10-year bond portfolio, the period of increasing swap spreads ranges from 26 September 2008 till 29 May 2009, covering a period of 36 weeks. During this period, the swap spread increased with 70 bps. The period of decreasing swap spreads ranges from 2 December 2011 till 3 August 2012, also covering a period of 36 weeks. During this period, the swap spread decreased with -36 bps. In case of the rolling 2-year bond portfolio, the period of increasing swap spreads ranges from 6 January 2012 till 21 September 2012, covering a period of 38 weeks. During this period, the swap spread increased with 67 bps. The period of decreasing swap spreads ranges from 15 April 2011 till 30 December 2011, also covering a period of 38 weeks. During this period the swap spread decreased with -42 bps. Hence, during the analyzed periods of increasing- and decreasing swap spreads, the swap spreads changed with around 70 bps and -40 bps respectively, for both the separated- and integrated LDI portfolios.

7.2 Summary statistics Cardano Case Study

In addition to the performance analysis of the integrated- and the separated LDI strategy, a case study is performed to analyze Cardano's LDI performance and to compare it with the LDI performance of the two stylized LDI portfolios. Since Cardano implements both LDI strategies for their clients, the case study shows the combined LDI performance of the integrated- and separated LDI strategies. Furthermore, in the Cardano case study the duration of the bonds can vary over time, whereas the duration is static in both the stylized bond portfolios. Hence, the 10-year and 2-year stylized LDI portfolios show the rather extreme LDI performances, whereas the Cardano case study brings some nuance by showing the LDI performance of both the integrated- and separated LDI strategy combined.

In contrast with the stylized LDI portfolios, Cardano's LDI portfolio has a somewhat wider range of issuers that are included in the portfolio construction. In particular, Cardano's LDI portfolio includes next to government bonds from Germany, the Netherlands and France also government bonds from Finland, Belgium, and Austria as well as bonds from Supranational-, Sub-sovereign and agency issuers. Furthermore, the Cardano case study was performed over the total period for which LDI data was available on the constructed bond portfolios. Table 5 below presents the descriptive statistics for the Cardano case study.

Table 5: Summary Statistics Cardano's LDI portfolios

		Cardano LDI portfolio
Cardano dates	period:	18-7-14 till 24-3-17
	In weeks	141 weeks
	Mean Bond Yield	8 bps
	Min Duration	0.65
	Max Duration	18.44
	Duration LTM	7.50
	Median Duration	8.94

What can be observed from Table 5 is that the Cardano case study period ranges from 18 July 2014 till 24 March 2017, covering a period of 141 weeks. During this period the bond's duration ranged from 0.65 year to 18.44 years, with a median duration of 8.94 years. The Cardano LDI portfolios' duration of the last 12 months was 7.5 years. Hence, the portfolios' duration decreased over time. During the 141 weeks, the average bond yield was 8 bps. In addition, as new clients were added to the LDI portfolio over time, Cardano's bond portfolio constantly changed. Hence, I could not simply take the weekly swap spread, but I had to make some calculations to calculate Cardano's LDI performance. This will be explained in more detail in the methodology section.

To compare the LDI performance between Cardano and the stylized LDI portfolios, I also analyzed the LDI performance of the stylized LDI portfolios in the same period as the Cardano case study was performed. Table 6 below presents the descriptive statistics for the stylized bond portfolios for the Cardano sample period.

Table 6: Summary Statistics stylized LDI portfolios Cardano Case study

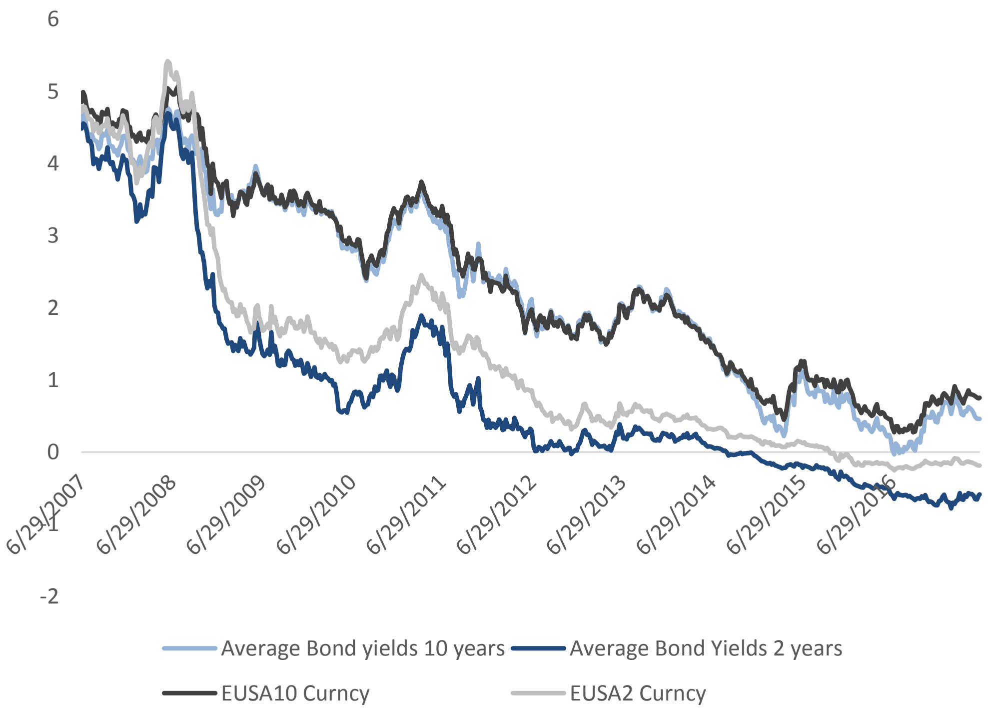
		10-year bond portfolio	2-year bond portfolio
Cardano dates	period:	18-7-14 till 24-3-17	18-7-14 till 24-3-17
	In weeks	141 weeks	141 weeks
	Mean Bond Yield	60 bps	-35 bps
	Sum Δ Bond Yield	-75 bps	-72 bps
	Sum Δ Swap rate	-58 bps	-41 bps
	Sum Δ Swap spread	-17 bps	-31 bps

What can be observed from Table 6 is that during the sample period ranging from 18 July 2014 till 24 March 2017, the mean bond yield was 60 bps for the 10-year bond portfolio and -35 bps for the 2-year bond portfolio. In addition, the swap spreads decreased with -17 bps for the 10-year stylized bond portfolio and -31 bps for the 2-year stylized bond portfolio.

7.3 Yield- and spread movements sample period

As discussed before, movements of the swap spread affect the effectiveness of the LDI portfolio. In particular, in periods of an increasing swap spread the performance of the LDI portfolio, relative to its goal of matching the pension liabilities, is likely negative. In periods of a decreasing swap spread it is the other way around. This is the case since the value of the bond portfolio moves with changes of the bond yields, whereas the level of the pension liabilities moves with the swap rate (up to a certain maturity). Figure 9 below visualizes the movement of the average bond yields[12] and the respective swap rates for the 2-year and 10-year durations from 2007 till 2017.

Figure 9: 10-year and 2-year bond yields and swap rates



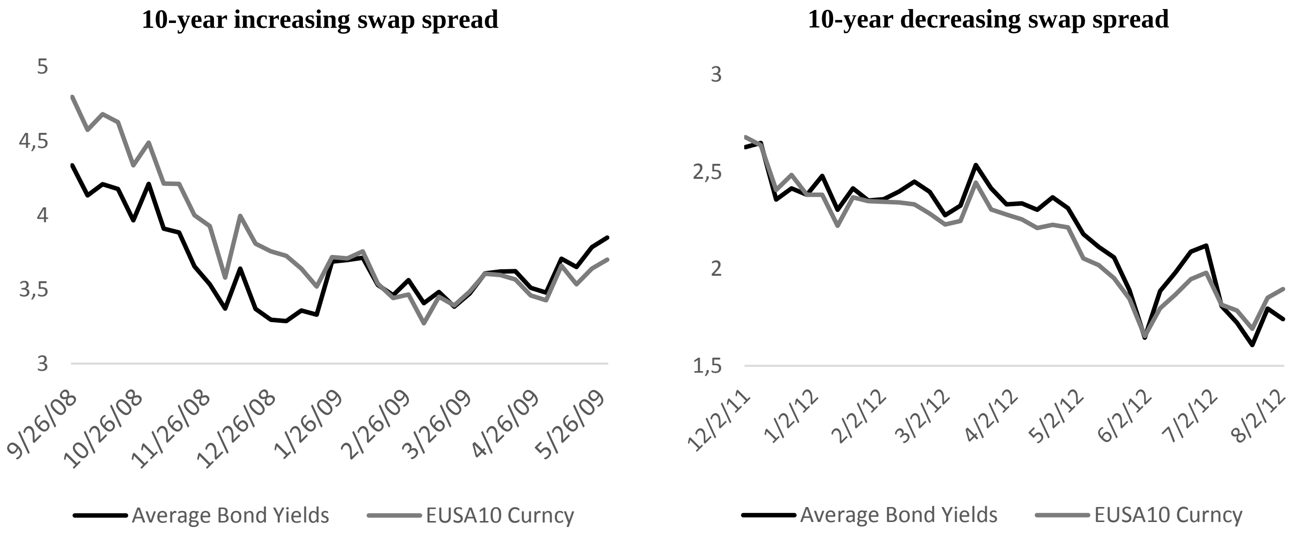
Source: Bloomberg.

[12] Consisting of a combination of German, French and Dutch bonds.

What can be observed from the figure is that although there was a spike around mid-2008, which is the likely consequence of the start of the 2008 global financial crisis, both the 2-year and the 10-year bond- and swap rates, experienced a significant decline over the sample period. Moreover, the 2-year bond- and swap rates even became negative at the end of 2014. This decline in the interest rate can be explained by several reasons according to Rik Klerkx, LDI manager at Cardano Risk management: (1) the expectation that the ECB would lower the interest rates to mitigate the impact of the financial crisis; (2) the flight of investors from risky products to government bonds; (3) the ECB’s quantitative easing program whereby an extensive amount of government bonds is bought each month. In addition, Figure 9 shows that especially the 2-year bond and swap rates experienced a significant decline at the end of September 2008, which caused a significant gap between the 10-year and 2-year, bond- and swap return. This significant decline for the 2-year bond yield can be explained by the fact that the ECB lowered the short interest rate with 3% in a reaction to the financial crisis and the collapse of Lehman Brothers specifically (ECB, 2011). This movement is directly visible in the short 2-year interest rate, whereas this effect is not one-to-one for the 10-year interest rate.

Furthermore, to analyze the impact of a change in the swap spread on the LDI performance of the two stylized LDI portfolios, I have taken two specific periods for both the integrated- and separated LDI strategy in which the swap spread either significantly increased or decreased. Figure 10 visualizes the increasing and decreasing swap spread periods for the 10-year bond portfolio.

Figure 10: Sample period of an increasing and decreasing swap spread for the 10-year bond portfolio

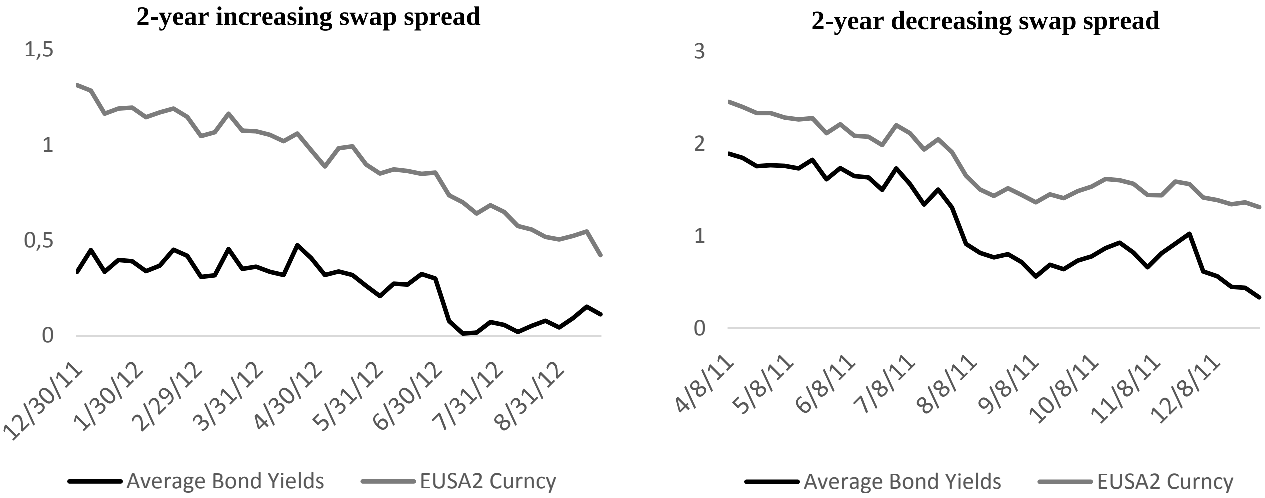


Source: Bloomberg.

What can be observed from Figure 10 is that for the rolling 10-year bond portfolio, the swap spread significantly increased with 70 bps from 26 September 2008 till 26 May 2009. Additionally, the swap spread significantly decreased with -36 bps from 2 December 2011 till 2 August 2012. In particular, in the period of an increasing swap spread, actually both the bond yield and swap rate decrease on average. However, in the beginning of the period, the 10-year bond yield lies below the 10-year swap rate, whereas at the end of the period the 10-year bond yield lies above the 10-year swap rate. Hence, although both the swap yield and the bond rate decrease during this period, since the 10-year bond yield decreases less than the 10-year swap rate, the swap spread *increases* in this specific period. In the period of a decreasing swap spread, both the bond yield and swap rate decrease. However, while on average the bond yield lies above the swap rate, at the end of the period the bond yield lies below the swap rate. Hence, compared to the swap rate, the bond yield has decreased *more* than the swap rate. As a result, the swap spread on average *decreased* and became even negative in the specific period.

Figure 11 below visualizes the increasing- and decreasing swap spread periods for the 2-year bond portfolio.

Figure 11: Sample period of an increasing and decreasing swap spread for the 2-year bond portfolio



Source: Bloomberg.

What can be observed from Figure 11 is that for the rolling 2-year bond portfolio, the swap spread significantly increased with 67 bps from 30 December 2011 till 31 August 2012. Additionally, the swap spread significantly decreased with -42 bps from 8 April 2011 till 8 December 2011. In particular, in the period of an increasing swap spread, the swap rate decreased more than the bond curve resulting in an increasing swap spread, i.e. *the swap spread becomes less negative*. In the period of a decreasing swap spread, both the bond yield and swap rate decrease. However, the bond yield decreases faster than the swap rate, resulting in a decrease of the swap spread. In particular, since over the whole period the bond yield lies below the swap rate, *the swap spread becomes more negative.*

8. Methodology

This section describes the methodology employed to define which LDI strategy maximizes the goals set by a pension fund's interest rate hedging strategy. To this end, I have analyzed both the integrated- and separated LDI strategy. This Chapter will first outline the assumptions that were made, followed by the calculations that were done to answer the key research question.

8.1 Assumptions

In order to measure the LDI performance of the integrated- and separated LDI strategy as well as Cardano's LDI performance, I follow former research and use the tracking error as the main performance measurement (Chambers, 2005). In addition, although Chambers (2005) suggests to also set a performance target, I suggest to initially set the performance target to zero. Consequently, *minimizing the tracking error vis-à-vis a performance benchmark* becomes the target of the LDI manager. Furthermore, I use the pension liabilities as the natural performance benchmark for the two stylized LDI portfolios. Hence, although the immunized bond portfolio is in practice assessed against an investable bond benchmark (Chambers, 2005), I will evaluate both the separated- and integrated LDI performance vis-à-vis the pension liabilities. In particular, since the ultimate objective of both LDI strategies is to hedge a certain percentage of the pension fund liability's interest rate sensitivity, I think it is best to evaluate the LDI performance against the pension liabilities and not against a published bond benchmark, which is in line with former research (see Chambers, 2005; Bragt and Kort, 2011).

As discussed in Chapter 3, different discount curves can be used to value the pension liabilities. In particular, Dutch pension funds are required by law to discount their pension liabilities with the UFR curve. However, in a LDI mandate the UFR curve will not be taken as the applicable performance benchmark for several reasons: (1), the UFR curve includes regulatory risk, which cannot be perfectly anticipated by the LDI manager since the UFR curve is politically determined. The LDI manager would simply not be willing to take this risk according to Rik Klerkx, LDI manager at Cardano Risk Management; (2) if the LDI manager's performance would be measured against the UFR curve, he has to take increased investment risk, since no financial instruments exist that perfectly match the UFR curve after the last liquid point of 20 years (Budiono, 2012). This increased investment risk might also negatively impact the LDI manager's performance, since it increases the tracking error vis-à-vis the pension liabilities. Hence, instead the economic swap curve could be used as the applicable performance benchmark to measure the LDI manager's performance for several reasons: (1) the economic swap curve is an investable benchmark; (2) the economic swap curve is the basis for the UFR curve and the two are intended to converge and; (3) the economic swap curve is also the curve on which the pension fund's interest rate hedge is measured in practice. Hence, for these reasons I have chosen the economic swap curve as the applicable performance benchmark to evaluate the LDI performance of the two stylized LDI portfolios and to evaluate the performance of the Cardano Case study.

In addition, I will assume the same and perfect interest rate hedging strategy for the two stylized LDI portfolios, which involves the same interest rate hedging percentage and the same size of the LDI portfolio. For this research the actual interest rate hedging percentage does not influence the results. Furthermore, transaction costs are assumed to be similar for the two LDI portfolios. This is in line with the observed costs in the market for the integrated- and the separated LDI strategies (Cardano internal document, 2017).

8.2 Calculations stylized LDI portfolios

To calculate the LDI performance of the two stylized LDI portfolios, I can focus on the performance of the respective bond portfolios relative to the swap rates, as the rest of the interest rate sensitivity will be captured by interest rate swaps and hence would not contribute to the tracking error. In particular, since swaps have the same interest rate sensitivity as the liability cash flows, I can focus on the tracking error attributable to the swap spread of the 10-year bond portfolio and the 2-year bond portfolio. In addition, I can ignore the second-order effect of convexity, which is relatively minor for weekly observation periods.

As a result of this approach, the following calculations are performed to calculate the LDI performance of the two stylized LDI portfolios over a period of 'w' weeks:

(1) $$LDI\ performance = Annualized\ bond\ return - Annualized\ return\ pension\ liabilities$$

(2) $$Annualized\ bond\ return^{13} \approx \sum_w[-Duration_w * \Delta Bond\ yields_w] * (\frac{52}{total\ weeks})$$

(3) $$Annualized\ return\ liabilities^{14} \approx \sum_w[-Duration_w * \Delta Swap\ rate_w] * (\frac{52}{total\ weeks})$$

(4) $$\Delta\ Swap\ spread_w = \Delta Bond\ yield_w - \Delta\ Swap\ rate_w$$

Which can be rewritten as:

(5) $$\Delta Bond\ yield_w = \Delta\ Swap\ spread_w + \Delta\ Swap\ rate_w$$

So, since I ignore the change in the swap rate ($\Delta Swap\ rate_w$) as it is offset in the performance of the pension liabilities, I can calculate the LDI performance as:

(6) $$Annualized\ LDI\ Performance \approx \sum_w[-\ Duration_w * \Delta Swap\ spread_w] * (\frac{52}{total\ weeks})$$

Hence, I make the LDI performance a direct function of the change in the swap spread.

Lastly, I calculate the volatility of the LDI performance, also the tracking error (TE). Hereby, I take the standard deviation of the LDI performance and multiply it by the square root of 52 to get an annualized result of the volatility of the LDI performance.

(7) $$Annualized\ TE = STDEV\ (-Duration_w * \Delta Swap\ spread_w) * \sqrt{52}$$

8.3 Calculations Cardano Case Study

To calculate Cardano's LDI performance, I collected first all the bonds that were in the LDI portfolio between 4 July 2014 and 31 March 2017. In particular, I collected the *trade size*, the *bond's duration* and the *bond prices*. Secondly, I artificially gave the bond a duration between 5 and 30, depending on the actual duration. Hence, if the actual delta was between 0 and 3.5, I assigned the value 2, if the actual delta was between 3.5 and 7.5, I assigned the value 5 and so forth.

[13] For short periods of time this first order Taylor expansion holds.
[14] For short periods of time this first order Taylor expansion holds.

The delta stands for the percentage price change, when the swap rate changes with 1%. Hence, if the bond has a delta of 8, the price of the bond increases with 8% in the case the swap rate decreases with 1%. Table 7 below shows the artificially set bond delta's.

Table 7: Artificial bond delta's

Actual Bond delta	New Bond delta
0-3.5	2
3.5-7.5	5
7.5-12.5	10
12.5-17.5	15
17.5-25	20
25<	30

In addition, I collected the 2-, 5-, 10-, 15-, 20- and 30 year swap rates from Bloomberg. Subsequently, I calculated the percentage change in bond price caused by a change in the *swap rate* and the change in bond prices caused by a certain *error term*. This is shown in formula 8 below.

(1) $New\ Bond\ Price = Bond\ Price\ old - \ BPV * \Delta Swap\ rate_w + \varepsilon_w$

To this end, I first calculated the bond's basis point value (BPV), which is the price change of the bond if the swap rate changes with 1 basis point. As the delta is in percentages and the basis point value is the price change of a basis point, I first multiply the old bond price with the artificial bond delta, then I divide it by 10.000.

(2) $BPV = Bond\ price\ old * Delta\ /10.000$

Secondly, I calculated the expected new bond price based on the change in the swap rate multiplied by the bond's basis point value. If the swap rate decreases, the bond price increases. Therefore, I subtract the second part to get the expected bond price. This is shown in formula 10 below.

(3) $Expected\ Bond\ price = \ Bond\ Price\ old - \ BPV * \Delta Swap\ rate_w$

Thirdly, I subtracted the change in the bond price caused by a change in the swap rate from the actual observed bond price, to get the change in the bond price caused by something else, which is shown as the error term $'\varepsilon'$ in formula 11 below.

(4) $\varepsilon_w = New\ Bond\ Price - Expected\ Bond\ price$

Fourthly, I multiplied the outcome with the weekly bond positions to get the LDI performance based on changes in the swap rate and based on a certain error term. Since I am looking at weekly changes, I assume that the error term shows the change in the bond price as a result of a change in the swap spread. *Hence, I consider the sum of the weekly bond positions multiplied by the error terms, as Cardano's LDI performance.*

Since Cardano´s LDI portfolio constantly changes due to new clients that are added to the total assets under management, I calculated the annualized LDI performance as the sum of the weekly changes in the bond price caused by the error term (swap spread), as a percentage of total assets under management (AuM). I multiplied this result by 52 over 141 to get the annualized LDI performance. This is shown in formula 12 below.

(5) $Annualized\ Cardano\ LDI\ performanc \approx \sum_w [\frac{\varepsilon_w}{AuM}] * (\frac{52}{141})$

Lastly, I took the standard deviation of the weekly change in the bond price caused by a change in the swap spread as a percentage of the total assets, to calculate the volatility of Cardano´s LDI performance. I multiplied the result by the square root of 52 to annualize the result. This is shown in formula 13 below.

(6) $Annualized\ TE = STDEV\ (\frac{\varepsilon_w}{AuM}) * \sqrt{52}$

9. Empirical results and analysis

This Chapter elaborates on the findings of this study. This Chapter will first present the results of the regressions for the two stylized LDI portfolios. Thereafter, it will present the results for the Cardano case study and compare the results with the LDI performance of the two stylized LDI portfolios in the same sample period. Lastly, this Chapter will give a discussion on the results.

9.1 Results stylized LDI portfolios

Table 8: Annualized LDI performance stylized LDI portfolios

		Separated LDI Portfolio 10yrs + swaps	**Integrated LDI Portfolio 2yrs + swaps**
Inncreasing swap spread	Bond return	7.8%	0.6%
	Return Liabilities	17.8%	2.4%
	Tracking error	5.0%	0.7%
	LDI Performance	-10.0%	-1.8%
Decreasing swap spread	Bond return	16.6%	4.3%
	Return Liabilities	11.4%	3.1%
	Tracking error	4.9%	1.0%
	LDI Performance	5.1%	1.1%

Table 8 above presents the results of the regressions for the two stylized LDI portfolios, both in a period of an increasing- and a decreasing swap spread. All the results are annualized. The first column shows the results for the separated LDI strategy. Hereby, the 10-year pension liabilities are matched with a bond portfolio, whereas the rest of the pension liabilities' durations are matched with swaps. The second column shows the results for the integrated LDI portfolio. Hereby, the 2-year pension liabilities are matched with a bond portfolio, whereas the rest of the pension liabilities' duration is matched with swaps. Hence, the results are purely based on the performance of the 2-year bond portfolio versus the 10-year bond portfolio, since the rest of the LDI performance is in both cases based on swaps. In particular, since swaps have the same interest rate sensitivity as the pension liabilities as they are both discounted using the economic swap curve, they do not add to the result, i.e. they do not add to the tracking error vis-à-vis the pension liabilities.

What can be observed from Table 8 is that in the case of an increasing swap spread, the pension liabilities increased with 17.8%, whereas the bond portfolio increased with only 7.8% in the separated LDI portfolio. In the integrated LDI portfolio, the pension liabilities increased with 2.4%, whereas the bond portfolio increased with 0.6% in the period of an increasing swap spread. Furthermore, when comparing the tracking error of both the integrated- and separated LDI portfolios, it can be observed that the tracking error is significantly smaller for the integrated LDI strategy (0.7%) than for the separated LDI strategy (5.0%). Hence, the volatility of the LDI performance is much larger for the separated LDI strategy than for the integrated LDI strategy in the increasing swap spread scenario. Furthermore, when looking at the LDI performance, which is calculated as the return on the bond portfolio minus the return on the pension liabilities, the results show that the LDI performance is significantly more negative for the separated LDI strategy (-10%) versus the integrated LDI strategy (-1.8%) in the period of increasing swap spreads. These results are as expected, since the sensitivity towards interest rate changes and spread risk is higher for a 10-year bond portfolio, than for a 2-year bond portfolio. Hence, I expected that the results would be less negative for the integrated LDI portfolio in the case of an increasing swap spread, as is the case.

In addition, Table 8 shows that in the period of a decreasing swap spread, the pension liabilities increased with 11.4%, whereas the bond portfolio increased with 16.6% in the separated LDI portfolio. For the integrated LDI portfolio, the pension liabilities increased with 3.1%, whereas the bond portfolio increased with 4.3% in the period of a decreasing swap spread. In addition, it can be observed that the tracking error is again much smaller for the integrated LDI portfolio (1.0%), compared to the tracking error for the separated LDI portfolio (4.9%). When comparing the LDI performance of the integrated- and separated LDI strategies in the decreasing swap spread scenario, it can be observed that the LDI performance of the separated LDI strategy is much higher (5.1%), versus the LDI performance of the integrated LDI strategy (1.1%). Again, these results are as expected since the higher interest rate sensitivity of the separated LDI strategy would result in a more positive LDI performance in the case of a decreasing swap spread, which is what the results also show.

Hence, in both the increasing- and decreasing swap spread scenario, the tracking error of the separated LDI strategy is on average *six times larger* than the tracking error of the integrated LDI strategy. In addition, the LDI performance is more extreme for the separated

LDI strategy than for the integrated LDI strategy, both in an increasing- and decreasing swap spread scenario. In particular, the LDI performance is more negative in the case of an increasing swap spread and more positive in the case of a decreasing swap spread. Furthermore, it can be observed from Table 8 that the bond return is highest for the separated LDI strategy in both the swap spread scenarios. Hence, if maximizing the absolute bond returns would be the main performance measurement, *as is the case with the traditional bond benchmark*, the separated LDI strategy would outperform the integrated LDI strategy. However, since I made the tracking error vis-à-vis the pension liabilities the most important LDI performance measurement, I can conclude based on the results of the stylized LDI portfolios that the integrated LDI portfolio with a short bond portfolio duration, whereby the rest of the interest rate sensitivity is hedged with swaps, maximizes the pension funds' interest rate hedging strategy. This supports the formed hypothesis.

Furthermore, Table 9 below shows the investment portfolios degree of activity based on the observed tracking errors. Following this Table, the separated LDI strategy, which had a tracking error of around 5% in both the swap spread scenarios analyzed, can be described as a moderate risk strategy. The integrated LDI strategy, which had a tracking error of around 1% in both the swap spread scenarios analyzed, can be described as an enhanced indexing strategy. For Dutch pension funds, that are required to match the nominal liabilities with 97.5% certainty by law, it can be argued that an investment strategy that results in a tracking error of around 5%, in the case of an increasing- or decreasing swap spread, is too aggressive.

Table 9: Tracking Error (TE) for the degree of activity of an active Portfolio

TE	Strategy
0%	Passive Portfolio (Indexed)
1%-2%	"Index Plus" strategy (Enhanced indexing)
2%-4%	Moderate risk strategy
4%-7%	Fairly active strategy
Over 8%	Very aggressive strategy

Source: Fabozzi (2006), p. 18.

9.2 Results Cardano case study

Table 10. LDI performance Cardano case study

		Separated LDI Portfolio **10yrs + swaps**	**Integrated LDI Portfolio** **2yrs + swaps**	**Cardano**
Historical (2015-present)	Bond return	2.8%	0.5%	4.0%
	Return Liabilities	2.1%	0.3%	3.4%
	Tracking error	2.0%	0.3%	1.4%
	LDI Performance	0.6%	0.2%	0.7%

Table 10 presents the annualized results of the Cardano case study. The Cardano case study compares the LDI performance between the two stylized LDI portfolios and the Cardano LDI portfolio in a sample period ranging from 18 July 2014 till 24 March 2017. The first column shows the results for the separated LDI strategy, the second column shows the results for the integrated LDI strategy and the third column shows the results for the Cardano LDI portfolio. What can be observed from Table 10, is that the liabilities in the separated LDI strategy increased with 2.1% in the sample period, whereas the bond portfolio increased with 2.8%. In the integrated LDI portfolio, the pension liabilities increased with 0.3%, whereas the bond portfolio increased with 0.5%. Lastly, the liabilities of all Cardano LDI portfolios combined increased with 3.4% during the sample period, whereas the bond portfolio as a whole increased with 4.0%. When comparing the tracking errors between the three LDI portfolios, the result shows that again the integrated LDI strategy has the lowest tracking error with 0.3%, followed by the Cardano LDI portfolio with a tracking error of 1.4%. The separated LDI strategy has the largest tracking error with 2.0%.

So, what can be observed from the Cardano case study is that the resulting tracking errors are more nuanced for the stylized separated- and integrated LDI portfolios over a historical period, than the observed tracking errors during the periods of an increasing- or decreasing swap spread. In particular, the separated LDI strategy had a tracking error of around 5% in both the increasing- and decreasing swap spread scenario, whereas over a longer historical period the tracking error is much smaller with around 2%. Additionally, when looking at the LDI performance, the result shows that the LDI performance is highest for the Cardano LDI portfolio with 0.7%, whereas the LDI performance is lowest for the integrated LDI strategy with 0.2%. The LDI performance of the separated LDI strategy lies in between with 0.6%. The strong LDI performance of the Cardano LDI portfolio can be explained by arguing that Cardano has decreased the bond portfolio duration in the case they expected an increase in the swap spread, and vice versa. By changing the interest rate sensitivity of the bond portfolio accordingly, Cardano has outperformed a static 10-year bond portfolio, while realizing a lower tracking error. Hence, when the portfolio duration is not static as a consequence of a published bond benchmark, having the pension liabilities as the ultimate performance benchmark can enhance the LDI performance since the LDI manager will focus more on spread risk. However, as I follow Chambers (2005) and use the tracking error as the main performance measurement of the pension fund's interest rate hedging strategy, the tracking error rather than the absolute LDI performance is the decisive factor in the LDI manager's performance measurement. Hence, based on the results of the Cardano case study I can conclude that, although the Cardano LDI portfolio has a higher LDI performance, the integrated LDI strategy again maximizes the pension fund's interest rate hedging strategy, since also in the case study it results in the lowest tracking error vis-à-vis the pension liabilities.

9.3 Discussion

Hence, the results for both the stylized LDI portfolios and the Cardano case study show that the integrated LDI strategy results in the lowest tracking error vis-à-vis the pension liabilities. This result supports the formed hypothesis. Also, this result is as expected, since an LDI portfolio with a bond duration of 2-years whereby the rest of the LDI portfolio is invested in swaps, has the lowest sensitivity towards changes in the interest rate and spread risk. Moreover, a LDI manager would minimize the tracking error by investing all assets in swap instruments and not to invest in bonds at all, since currently the liabilities are discounted with the Libor curve. However, as was already explained in Chapter 3, even when the LDI manager invests all investment assets in swaps, a zero tracking error is not feasible due to the OIS-Libor mismatch. In the case the LDI manager adds government bonds to the LDI portfolio, swap spread risk is included in the LDI portfolio, which also results in a certain tracking error. Hence, although this research has set the LDI performance target to minimize the tracking error, a zero tracking error is not possible as long as the pension liabilities are discounted with the Libor curve. This is something that should be taken into account when the LDI manager's performance is assessed vis-à-vis the economic swap curve.

In addition, the Cardano case study shows that the LDI performance can be enhanced when the LDI manager is flexible in choosing the bond portfolio duration. Hereby, the LDI manager can profit from a decreasing swap spread scenario by increasing the bond portfolio duration, while in the case of an increasing swap spread scenario he can minimize his losses by decreasing the bond portfolio duration. However, since I set the tracking error as the main performance measurement, this active portfolio management is not desired since it leads to an increase in the respective tracking error. Hence, in LDI management there is also a tradeoff between low risk, i.e. a low tracking error, and a high return. Therefore, pension funds have to think carefully about the preferred investment outcome, when they set the LDI performance target.

10. Conclusion

In this research, I analyzed the two main LDI strategies used in practice and researched which LDI strategy maximizes the goals set by a pension fund's interest rate hedging strategy. In particular, I compared the performance of a *separated LDI strategy*, which involves a bond mandate with a separate swap overlay, with an *integrated LDI strategy*, whereby bonds and swaps are combined in one mandate, in different swap spread scenarios. In addition, I analyzed the LDI performance of Cardano Risk Management, which serves both LDI strategies to their clients. I defined that the LDI managers' target is to minimize the tracking error vis-à-vis the pension liabilities. Hereby, I did not set an additional performance target of plus x%. The main results are presented in Table 10 below.

Table 10: Annualized performance stylized portfolios and Cardano case study

		Separated LDI Portfolio 10yrs + swaps	**Integrated LDI Portfolio 2yrs + swaps**	**Cardano Case Study**
Inncreasing swap spread	Tracking error	5.0%	0.7%	N/A
	LDI Performance	-10.0%	-1.8%	N/A
Decreasing swap spread	Tracking error	4.9%	1.0%	N/A
	LDI Performance	5.1%	1.1%	N/A
Historical (2015-present)	Tracking error	2.0%	0.3%	1.4%
	LDI Performance	0.6%	0.2%	0.7%

Based on the results of the two stylized LDI portfolios and the Cardano Case study, I can conclude that the integrated LDI strategy with a short bond portfolio duration, whereby the rest of the interest rate sensitivity is hedged with swaps, maximizes the pension funds' interest rate hedging strategy, i.e. minimizes the tracking error vis-à-vis the pension liabilities. In particular, I find that the tracking error of the integrated LDI strategy is on average *six times lower* than the tracking error of the separated LDI strategy, in all periods analyzed. Furthermore, the results show that the integrated LDI performance is on average *four times smaller*, relative to the performance of the separated LDI strategy. In particular, the integrated LDI performance is *less negative* in the case of an increasing swap spread, but also *less positive* in the case of a decreasing swap spread. However, since the goal of Dutch pension funds is to provide stable pension benefits with a limited amount of risk, I think it is important to measure the LDI manager's performance based on the volatility (tracking error) vis-à-vis the pension liabilities, *rather than to focus on the absolute LDI performance*. Moreover, when the LDI manager's performance is based on the tracking error vis-à-vis the pension liabilities, the LDI manager's incentive is more aligned with the pension fund's objective: i.e. to minimize the discrepancy between the pension fund's assets and the pension fund's liabilities. Hereby, it decreases the solvency risk in all swap spread scenarios.

In addition, the results of the Cardano case study show that, compared to the stylized LDI portfolios, Cardano realized a tracking error that was lower than the tracking error of the separated LDI strategy (1.4% versus 2.0%), while they realized a higher LDI performance (0.7% versus 0.6%). This shows that when the LDI manager has the flexibility to change the bond portfolio's duration in anticipation of certain expected swap spread scenarios, this can enhance the LDI performance. However, since I defined that the LDI portfolios' target is to minimize the tracking error vis-à-vis the pension liabilities, Cardano's LDI managers did not outperform the stylized integrated LDI strategy, while they did outperform the stylized separated LDI strategy. This is as expected as the case study shows the LDI performance of both the LDI strategies combined.

The way the performance target is formulated is crucial in the outcome of this analysis. However, this research does show the implications of different LDI strategies and in particular that spread risk can be an important risk determinant and if not managed properly, can seriously distort the LDI performance. Hence, when pension funds set the LDI performance target they have to think carefully about the preferred investment outcome. This might be dependent on the current solvency ratio and on the pension fund's risk appetite. I think that the optimal scenario would be to state a certain bandwidth of the tracking error in which the LDI manager is allowed to operate in, and in which the LDI manager should optimize the LDI performance. The bandwidth of the tracking error that should be used when setting the LDI performance target is something that could be incorporated in further research.

One of the limitations to this research is that the integrated LDI portfolio is restricted to a 2-year bond portfolio. In practice, an integrated LDI portfolio is flexible in choosing the average bond portfolio duration. Hence, the difference in LDI performance between an integrated- and separated LDI strategy could be different depending on the chosen bond durations. Also, the stylized bond portfolios only include bonds from three European government issuers: Germany, the Netherlands and France. Since in the Cardano LDI portfolio more government issuers are included, as well as Supranational-, Sub-sovereign and agency issuers this is also a limitation to the research results.

Also, I did not incorporate the market inefficiency of the Libor-OIS mismatch in the LDI performance target to minimize the tracking error vis-à-vis the pension liabilities. In particular, the Libor-OIS mismatch results in a decreasing LDI performance (negative tracking error) even in the case the Libor curve is perfectly matched (with only swap instruments). In the case bonds are added to the LDI portfolio, swap spread is included. Hence, a zero tracking error is unfeasible. This should be taken into account when pension funds set a LDI manager's performance target or when they evaluate their LDI manager. However, it would not have changed the outcome of my results.

In addition, I did not take into account the costs between different LDI managers. In particular, the Cardano LDI portfolio had a LDI performance of around 0.7% in the Cardano case study. However, if Cardano LDI managers are quite expensive because they claim to be the best in the market, the 'absolute' LDI performance could be different when the LDI performance is calculated *after the costs are subtracted*. For example, if the costs of Cardano LDI managers are 0.2% of the total LDI portfolio, the *'absolute'* LDI performance would be 0.5% instead of 0.7%. If another LDI manager does not actively invest based on a certain expectation of the direction of the future swap spread, but simply follows a 10-year bond benchmark, his costs might be less for example 0.1% of the total LDI portfolio. In this case, the performance of the separated LDI portfolio compared to the Cardano LDI would be both 0.5%. Hence, the LDI performance between different LDI managers should actually be compared *after* deduction of the costs. Since this information is not publicly available, this is a limitation to my research.

The contribution to the field regarding LDI management and LDI manager's performance measurement is first that this paper quantifies the difference in LDI performance between the separated- and integrated LDI strategy. Second, this research can serve as an example as to how the LDI manager's performance could be measured. In particular, whereas the current literature argues that at the moment no appropriate LDI benchmark exists, this research shows that the economic swap curve could be used as an applicable benchmark to measure the LDI manager's performance.

The outcome of this research could be interesting for pension funds when designing and implementing the LDI investment strategy. In particular, the result shows that an integrated LDI strategy decreases the volatility of a pension fund's solvency ratio. In addition, since the integrated LDI strategy provides more flexibility to switch between swaps and bonds, this could enhance the LDI performance through higher investment returns and lower costs, which could ultimately benefit the pension scheme member.

For further research, it would be interesting to analyze alternative discount curves to value the pension liabilities. In this paper, I used the economic discount curve as the appropriate discount curve. However, since the economic (swap) curve results in an OIS-Libor mismatch, the *OIS curve* or the *cash-repo curve* could be a good alternative. Moreover, as pension funds guarantee nominal pension benefits with 97.5% certainty, the discount curve should also contain a low amount of risk. To this end the cash-repo curve would actually be a better benchmark curve than the swap curve. On the other hand, a lower discount curve would also increase the value of the pension liabilities. Hence, it would be interesting to analyze the market consensus for a different discount curve in the pension sector and discuss the pros and cons respectively.

Furthermore, in this research I focused on the performance measurement of LDI managers. However, it would also be interesting to analyze the performance measurement of pension funds as a whole. At the moment, Dutch pension funds are required by the Dutch law to show their performance in the form of a *z-score*. The z-score is a risk-adjusted performance measure, focusing on absolute return relative to the anticipated amount of risk. However, like the government bond benchmark in the LDI manager's performance measurement, the z-score lags perfection since it focuses on absolute return rather than the relative return vis-à-vis the value of the pension liabilities. Hence, future research could focus on a better alternative for the z-score to evaluate the Dutch pension fund's performance.

Lastly, for quite an extensive period (more than three years) the Netherlands has been trying to reform its pension fund system. Currently, the Social Economic Council (SER) shows the most interest in a more individualized pension system. It would be interesting to investigate the implications of such a pension system for LDI management.

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