ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Master Thesis

'Investments of Dutch Pension Funds in Domestic and International Real Estate'

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Abstract

This study examines the investments of Dutch pension funds in domestic and international real estate. It first introduces the unique features of real estate investments, the Dutch pension system and the investment policies of the funds. Historical total allocations to real estate are around 9 percent of total assets. Pension funds have several reasons to invest in real estate of which liability hedging is very important. Previous research suggests that real estate can hedge the specific liabilities of pension funds. Most literature sees allocations between 10 and 15 percent as reasonable, but might be higher for a liability driven investor. The data and methods of this study are designed to provide insight in optimal allocation to domestic and international real estate for a long-term, liability driven investor. Results show that an average allocation of 9 percent is equitable and that international real estate should be the most important sub-class of the asset.

Table of Contents

"Real estate cannot be lost or stolen, nor can it be carried away. Purchased with common sense, paid for in full, and managed with reasonable care, it is about the safest investment in the world."

Franklin D. Roosevelt

1. Introduction

1.1. Problem & Relevance

The Netherlands are home to of the largest pension sectors in the world, relative to the size of the economy. In total Dutch funds have over €1,200 billion of assets invested (Willis Towers Watson, 2016). The Dutch pension sector is not only very large, it is also praised for its sustainability and integrity. It is seen as one of the best functioning systems in the world (Mercer, 2014). Research from the economic centre of ING Bank (2016) shows that most people in the Netherlands are gloomy about the financial status of their pension. Even young people, aged between 18 and 34, are worried about their future pension. Those worries are, given the situation and developments of the funds and the financial markets, valid to a certain extent. Volatility of investment returns and historically low yields on corporate and sovereign bonds have had its effects on the financial position of the funds. The quality of the Dutch system could not prevent solvency ratios to drop dramatically, with negative effects for all participants (Willis Towers Watson, 2016).

Pension funds are under constant attention of the media globally and especially in the Netherlands. The worrying position of some pension funds are widely discussed in the newspapers and often they refer to the situation as a 'pension crisis'.[1] To a certain extent, there is a crisis in the Dutch pension sector, since the solvency ratios are so low that the cutting of benefits of retirees seem inevitable. The State Secretary for Social Affairs and Employment, Mrs Jetta Kleinsma, informed the parliament in May 2016[2] that it was likely that 27 funds will have to cut benefits of approximately 1.8 million retirees for the next year. Mrs Kleinsma and the supervisor for the pension sector, the Dutch central bank, acknowledge the large impact of a discount on benefits but state that this *ulitimum remedium* might be necessary to prevent even lower solvency ratios in the future.

While the pension sector might be in a crisis, not all parts of the Dutch economy are struggling. After a few difficult years, the real estate market and especially the residential sector are now flourishing. Over the second quarter of 2016 the Dutch Association for Real Estate Brokers reported a strong growth in prices especially in urbanized areas and the amount of transactions reached an all-time high (NVM, 2016). Prices however, are still 7 per cent below the pre-crisis level, but are up 14 per cent from the lowest point. Low interest rates and the low mortgage costs are ought to be the most important drivers of the growth. On the rental side of the housing market the financial crisis has had much less influence. Since 2008 the increase in rental prices has been highly correlated with inflation and Dutch residential properties are now around 14 per cent more expensive to rent than in 2008 (IVBN, 2016). This is remarkable given the low interest rates and declined costs of capital for real estate investors. As a result of this remarkable financial result, institutional investors are now very willing to invest in Dutch residential real estate and €5 to €6

[1] See i.a. M. Pröpper, 'Pensioencrisis is niet alleen schuld van ECB' *Volkskrant 22 March 2016*

[2] Kamerbrief: Kabinetsappreciatie rapport DNB over financiële positie pensioenfondsen, 20 May 2016

billion is waiting to be invested in that specific market segment (IVBN, 2016). This further increases the investment opportunities for institutional investors.

In the sight of recent national elections, various economists including DNB-president Klaas Knot (Knot, 2016) have pleaded for dismantling fiscal regulations that stimulate home ownership and debt. This could lead to a shift from owning a house to renting a house and increase the size of the rental market in The Netherlands.

Over the past decades, the Dutch pension system has evolved and the investment policy of the funds has changed as well. Equity investments for example increased from 10.8 percent of the total portfolio in 1995 to 31.8 percent in 2007 for various reasons (Bikker J. A., Broeders, Hollanders, & Ponds, 2012). Not only equity investment changed, real estate assets are now only around 9 per cent of all pension assets. With a $350 million investment of the Dutch pension funds for civil servants, APG, in a Chinese real estate developer, the investment policies regarding real estate seems to be in constant development (Preesman, 2015).

In the Dutch institutional setting, pension funds have a certain freedom in applying their own investment believes. Funds can decide on their own strategic asset allocation and investment strategy but their funds financial position is supervised by the Dutch central bank, DNB. The freedom of the funds has led to a diversity of investment strategies in real estate. The pension fund for construction workers, Bpf Bouw, for instance has 16% of its assets invested in real estate of which 64% is directly invested in properties in the Netherlands (Bpf Bouw, 2016). The rest of their real estate investments (36%, c. € 3bn) is invested in international real estate investments trusts, REITs. The long term strategic goal of the fund is to have 60% directly invested in The Netherlands and 40% in international real estate. Giving the relatively high allocation to domestic real estate there should be rational reasons for this investment strategy.

1.2. Research Objective

Goal of the research is to provide insights in the rationale of real estate investments for a Dutch pension fund and wants to conclude if the funds are investing correctly in real estate. With the application of portfolio theory, optimal allocation of real estate in the pension portfolio will be estimated. This will be done with a traditional mean-variance model and an asset-liability model, ALM. The results retrieved from these optimizations will be compared to the current and historical portion of real estate in the portfolio and leading literature. The analysis as briefly described here will try to answer the following research question:

> ***Are investments in domestic and international real estate adding value to a portfolio of a Dutch pension fund?***

Before the exact methodology to answer the research question is provided, this question is further elaborated and hypotheses are formulated.

1.3. Outline

The first step in answering the research question is to give an overview of the Dutch pension sector. The position and importance of the funds in the whole system are elaborated. An elaboration on the liabilities of the funds, in order to construct a portfolio optimization, is provided. The chapter also provides insights in the real estate investment landscape. It will describe the characteristics and historical development of institutional real estate investments.

The third chapter will provide an overview is the most relevant existing academic literature. First this chapter will take a closer look at diversification properties of real estate. Next, hedging capacities of the asset class will be discussed in relation to pension funds. After that the differences between public and private real estate found in academic literature are provided. Then investment properties of real estate for a long-term investment horizon are discussed. The chapter will conclude with hypotheses about the research question.

The fourth chapter will provide the methods used in the research. The basis of this is formed by the mean-variance model as first introduced by Markowitz (1952). This will be extended for a long-term investment horizon and a liability driven investor.

The next chapters include the data and the results of the analysis. This thesis will end with conclusions, the answer to the research question, discussion of the results and suggestions for further research.

2. Institutional Background

This chapter provides background information to real estate investments and the Dutch pension funds. First, the Dutch pension system including the financial regulatory framework is explained. Second, key features of real estate investing, characteristics of real estate and its historical performance and investments are provided.

2.1. Dutch Pension System

In the 19th century the industrial revolution led to a rapid growth of the working class in the Netherlands. With this transformation of society came the need for social security. After the introduction of the Industrial Injuries Act (Ongevallenwet) in 1901 the pension system begin to take its shape. Since then, and especially after the Second World War, the system has changed a lot (Sociale Verzekeringsbank, 2008). Now the Dutch pensions are seen as one of the best of the world. The system is praised for its sustainability and integrity, but it faces its own challenges.

After the introduction of the Industrial Injuries Act and comparable laws, the crisis of the 1930s accelerated the social insurance debate. This debate eventually led to the introduction of the AOW scheme (Algemene Ouderdomswet, National Old Age Pensions Act) in 1956. The AOW scheme is designed as an instrument between an insurance and a state pension. Funding of the AOW is based on 'inter-generational solidarity in a Pay-As-You-Go system', meaning that the working population, aged between 15 and 65[3], cover the costs of the pensions paid to the current pensioners (Sociale Verzekeringsbank, 2008). The government ensures all pensioners a lifelong basic and minimum pension income. The AOW scheme forms the first pillar of the Dutch system.

In addition to the first pillar, over 90 per cent of the workforce is member of a supplementary second pillar pension plan. The second pillar is a fully funded system based on an agreement between the employee and his employer. Together with the AOW, the second pillar should provide a pension that is sufficient to maintain the standard of living at retirement (Van Der Smitte, 2013). Participation in a second pillar scheme is mandatory for those who have a labour contract and is governed by the collective labour agreement. Employers are obliged to contribute to an industry wide fund or to a professional group fund. It is however possible for employers to opt-out of the industry wide fund and offer their employees a better corporate pension plan (Kemna, Ponds, & Steenbeek, 2011). Currently 16,2 million participants are part of 219 separate funds in the second pillar (DNB, 2016). Traditionally benefits of pensioners are fixed and the second pillar was qualified as a defined benefit plan. However, benefits are only fixed when the financial status of the fund is strong enough, according to the financial assessment framework. Therefore the system is often characterized as a hybrid plan in which both plan contributions and benefits are dependent of investment returns and themselves (Ponds & Van Riel, 2009).

[3] Gradually increasing to 67 in 2021

The third pillar consists of fully voluntary schemes and savings, and is smaller and of less importance than the second pillar. Subject of this research are the quasi-mandatory second pillar funds. The Dutch government is not directly responsible for the second pillar funds but has influence by setting the regulatory framework with is supervised by the Dutch central bank, DNB, and is discussed in the next sub-section.

2.1.1. Financial assessment framework

The second pillar of the Dutch system is for a large part regulated by the Pensioenwet (Pensions Act). The funds are, according to article 151, supervised for all behavioural matters by the Netherlands Authority for the Financial Markets, AFM, and for all financial and other matters by the Dutch central bank, DNB. Because the second pillar is a fully funded system, the financial position of the funds is of great importance for financial stability and is to a large extent governed by chapter 6 of the Pensions Act which includes the financial assessment framework (financieel toetsingskader or FTK).

The system in the Netherlands is described as a 'hybrid DC-DB system'. It works in a way that both plan contributions and benefits are dependent of investment returns and themselves (Ponds & Van Riel, 2009). The goal is to provide inflation indexation for pensioners, but this is only possible if the financial position is strong enough. When the fund is meeting all capital requirement, full indexation is possible, otherwise it is not.

The financial crisis that started in 2008 led to the introduction of a renewed FTK in January 2015. The new FTK tries to mitigate some of the problems of the old FTK and is less vulnerable to shocks in the financial markets, without ignoring changing market conditions. The goal of the new FTKs was to make the pension system more future-proof and improve asset and risk management (Tweede Kamer, 2014). The core of the FTK is that for all future payable benefits, the fund's liabilities, the fund needs to have a certain amount of assets. Contributions and benefits need to be at appropriate levels, so that the amount of assets is within the bandwidth of the FTK.

According to the FTK, funds are bound to two capital requirements. Indexation of benefits is only allowed when capital requirements are met. The first requirement is the capital requirement (vereist eigen vermogen or VEV). The VEV of a fund depends on the risk characteristics of the specific fund. The FTK[4] indicates 10 relevant risk factors. Especially relevant for real estate is 'equity and real estate risk', which is 30 per cent for shares and listed real estate and 15 per cent for non-listed real estate (adjusted for leverage).[5] Currency risk will be relevant when the real estate investment is outside the Eurozone. Insurance risk and active management risk could be relevant depending on the exact characteristics of the investments. The second is the minimal capital requirement (minimaal vereist eigen vermogen, MVEV).

[4] Article 12 Besluit Financieel Toetsingskader Pensioenfondsen
[5] Article 24 Regeling Pensioenwet en Wet verplichte beroepspensioenregeling

The MVEV is the lowest VEV that is allowed only for a short period. If a fund does not comply to the MVEV for five years, it has to take measure to comply with the MVEV within six months.[6]

According to the framework, both assets and liabilities need to be valued on a fair value basis. For assets this means they are valued at the market price. As we will see later, determining the market price for real estate is not always easy. The importance and valuation of liabilities is discussed in the next section.

2.1.2. Liabilities

The hybrid DB-DC system is based on full coverage of all benefits in the future and thus, requires estimation of those benefits. In the FTK future outgoing cash flows are discounted and are accounted for on the balance sheet of the fund as a liability. The height of the fund's liabilities depends on the height of future benefits, the life expectancy of a pensioner and the discount rate.

The height of future benefits in determined by the wage of the plan member, and so is the height of his contributions. Traditionally, benefits were a percentage of the final pay of the plan member, but since 2001 most funds use the average wage of the plan member (Ponds & Van Riel, 2009). The next step is to determine the average length of payments of the benefits ie. the life expectancy after retirement. This is done based on prudent principles[7] but exact expectancy can differ based on fund characteristics. Combining life expectancy and benefits creates the expected pension payout per year. This is visualized for an exemplary fund in Figure 1.

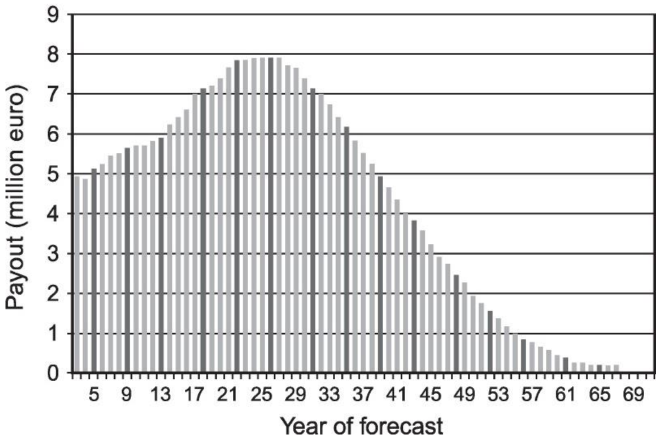

Figure 1: Pension pay-out over time

These expected cash outflows need to be discounted to represent its fair value in the fund's accounting. With the introduction of the original FTK in September 2012 the liabilities need to be discounted against the Ultimate Forward Rate, UFR. In 2013 the UFR Committee advised the Dutch government on renewal of the UFR. Their advice was adopted by the DNB.

The committee advised to apply an interest rate based on (1) a UFR based on realized 20 years forward rates over the past 10 years, (2) a starting point for the UFR after a *first smoothing point* of 20 years, and (3)

[6] Article 140 Pensioenwet
[7] Article 126 Pensioenwet

from the start the rate approaches the UFR but never equals it (Commissie Ultimate Forward Rate, 2013). Exact calculation of the UFR for different maturities is provided by DNB (2015) and leads to a value that is accounted for on the fund's balance sheet. In the funded system these discounted payouts are to be covered by the fund's assets.

2.1.3. Assets

Fund's outgoing cash flow, benefits, need to be covered by the fund's incoming cash flows, the contributions and the return on the assets, acquired with previous contributions. Funds are aiming to maximize investment returns on assets in order to keep benefits high and contributions as low as possible. On the other hand the fund aims to mitigate investment risk. Return and risk of pension investments are strongly influenced by economic trends (Valkenburg, Versloot, Wagenaar-Walch, & Dick, 1993).

Within the FTK, funds have freedom to choose their own investment policy and strategic asset allocation policies. Using asset and liability management, ALM, studies the fund decides on their strategic asset allocation which is typically set for a three to five year period. Bikker, Broeders & De Dreu (2007) measured strategic asset allocation and actual allocation over the 1999-2006 and statistics are provided in Table 1. Historically, stocks and bonds have been the most important asset classes, with an actual combined allocation of 86 percent.

Asset class	Average strategic asset allocation	Standard deviation	Average actual asset allocation	Standard deviation
Equities	42	15	41	15
Bonds	39	20	45	19
Real Estate	10	6	10	6
Cash	1	11	1	10
Other	8	11	3	11

Source: Bikker et al (2007) based on DNB
Table 1: Asset allocation 1999-2006 (in %)

The FTK has set boundaries for the maximum expectations returns of assets and minimum expectations of inflation and risk of investments. These parameters are used in any decision on the fund's recovery possibilities, indexation and contributions. In 2014 and advice committee to the Dutch government (Commissie Parameters, 2014) presented their advice for renewed parameters and this advice has been later adopted by the legislator. The renewed parameters are presented in Appendix A.1. The parameters are based on long-term historical data and provide an adequate expectation tool. It deserves attention that the risk and return on credits does not include credit risk and that non-listed real estate is adjusted for possible leverage in non-listed investment vehicles.

2.2. Real Estate Investments

In the current financial markets, there are many ways to invest in real estate. Currently the market consists of four 'quadrants' (Hoesli & Lekander, 2008). Real estate instruments can either be equity or debt and can be publicly traded on a stock exchange or not. First, the investment manager has to choose between an equity or debt instrument. Equity generates direct exposure to real estate, were mortgage instruments are fixed income products with only real estate exposure in case of a default. Debt investments are therefore part of the fixed income portfolio and not subject of this research.

	Equity	**Debt**
Private	Direct investments Private equity funds Fund-of-funds	Mortgage loans
Public	REITs	Mortgage backed securities

Figure 2: Four quadrant model

In the investment process of institutional investors, the first decision is whether to gain direct exposure to properties or indirectly via listed property companies (Andonov, Eichholtz, & Kok, 2013). The main indirect investment instrument are Real Estate Investment Trusts, REITs. These instruments are listed shares of companies holding a (often large) portfolio of properties and can contain leverage and include non-core activities such as real estate development. REITs seem especially suitable for smaller investors since the shares are liquid and small investments can be done relatively easy. Direct real estate is however the most common investment type for larger pension funds, according to Andonov, Eichholtz & Kok (2013). Investments in private, non-listed product can either be a direct property, an investment in a non-listed real estate fund, or a real estate fund-of-funds. In the next paragraphs, further elaboration of management and transaction costs and valuation problems of direct investments is provided.

2.2.1. Characteristics

Compared to other asset classes, real estate has its own special characteristics. Principal differences between real estate and public traded securities are (1) properties are unique and largely indivisible, (2) information is freely available and trading on insider information is legal, and (3) by the lack of a national exchange or auction market (a) transaction costs are large, (b) assets are illiquid, and (c) transaction prices do not necessarily represent fair values (Ennis & Burik, 1991).

Hudson-Wilson, Fabozzi & Gordon (2003) provide five primary reasons for an investor to invest in real estate. They state that real estate can (1) reduce overall risk by combining asset classes (diversification), (2) achieve absolute returns well above the risk-free rate, (3) provide a hedge against unexpected inflation of deflation, (4) constitute a market-neutral portfolio, and (5) deliver strong cash flow in the portfolio.

Typically real estate properties are categorized in five different groups; Residential, Office, Retail, Industrial and other.[8] Returns on different property types and locations are driven by different economic factors and provide possibilities for diversification. Correlation between property types is not perfect,

[8] Can include hotels, sports and leisure properties, amongst others.

between 0.8 and 0.9, and there are diversification benefits available to investors (Eichholtz, Hoesli, MacGregor, & Nanthakumaran, 1995).

The ability of real estate to provide a hedge against inflation can be especially important for pension funds, since their future payments to pensioners depend on inflation, as described in the previous chapter. Under a standard contract a landlord can increase the rent every year with a percentage linked to inflation. In the Dutch residential practice it is common to include a yearly rent increase that is equal to inflation as calculated by the CBS.[9] Rents are adjusted in July based on the inflation in the previous year. This should lead to a correlation between (residential) real estate returns and inflation. Academic literature referring to characteristics of real estate is extensively discussed in the next chapter.

Management and transaction costs

In their investment decision, funds will also look at possible agency problems and management and performance fees. In the Dutch market the standard fee is over 100 basis points and can consume a large part of the return. But if the portfolio is managed in-house these costs can be reduced to 30 basis points but are generally higher for smaller portfolios (Andonov, Kok, & Eichholtz, 2013). According to Andonov, Eichholtz & Kok (2015) pension funds should consider the whole spectrum of real estate instruments but avoid costly chains of financial intermediaries. Although fund-of-funds might look interesting from a diversification point-of-view, they generally underperform other real estate instruments. The FTK sets minimum management costs for pension funds.[10]

It is also important to notice the high transaction costs and illiquidity risks of real estate. Research has shown that illiquidity risks are priced in commercial real estate returns (Kawaguchi, Sa-Aadu, & Shilling, 2007). In residential real estate, illiquidity costs can be as much as 29.5 percent of the price of the property under certain market conditions. However, when the holding period of the investment is taken into account, costs are not very material (Hwang, Cho, & Shin, 2016). Transaction costs of public investments are a lot lower and in-line with those of regular stocks.

Valuation

In contrast to listed financial assets (including REITs), the value of a direct real estate investment cannot be derived from its current trading price. The value of an investment needs to be estimated using valuation techniques. According to international accounting standards, direct real estate investments should be valued using a fair value model under normal circumstances.[11] The fair value can be estimated using three valuation techniques: (1) the market approach, that looks at prices of comparable properties, (2) the cost approach, that looks at replacement costs of a property and (3) income approach, that discounts expected rental income minus operating expenses.[12] For real estate investments the second

[9] The Netherlands Bureau for Statistics
[10] See Table 2
[11] IAS 40.33
[12] IFRS 13.62

approach can be problematic and is seldom used, which leaves the first and third method as most used ones (Ernst & Young, 2013).

This appraisal-based valuation is also applied to indices that track unlisted real estate returns. It has been long recognized that appraisal based valuation adjustments are biased to zero. Value adjustments are often lagged or smoothed and appraisal-based returns are therefore often biased. However appraisal-based indices can be adjusted for these biases (Geltner, 1993). Transactions-based indices, TBIs, provide an alternative to the more traditional appraisal indices. TBIs originally face large selection bias problems but by applying econometrical methods these problems can be mitigated and TBIs can provide useful information to support appraisal based indices (Fisher, Geltner, & Pollakowski, 2007).

2.2.2. Historical performance and investments

While long-term performance of traditional assets is well-known for a long time, it lasted to the late 1990s till insight in long run performance of real estate was provided. Eichholtz (1997) constructed the *Herengracht* index, analysing the price developments of buildings on the Herengracht, one the canals in the old city centre of Amsterdam. Development of the Herengracht started in the 16th century and since the early 17th century the properties hardly changed. This enabled Eichholtz to compile a relevant price index starting in 1628 and ending in 1973. Over the complete sample nominal and real price increase was 1.8% and 0.5% biennial respectively. Most of this return is generated in post-World War II period with real biennial price return of 3.2%. Eichholtz notices that the latter period is the most used in any real estate research and that more long-term research is needed.

More long-term analysis of real estate price returns is provided by the Standard & Poor's/Case-Shiller Home Price Index. This index tracks inflation corrected prices of homes in the United States and is based on methodology introduced by Case and Shiller (1987). By combining various data sources the index traces back to 1890. Inflation corrected home price development has been visualized in Figure 3. The index shows little real return in the pre-World War II period, but relatively large returns since then. However, in the two mentioned indices the rental income is not incorporated and generated returns are higher than reported by these indices. Without taking rental income into account, real estate generated a modest historical return.

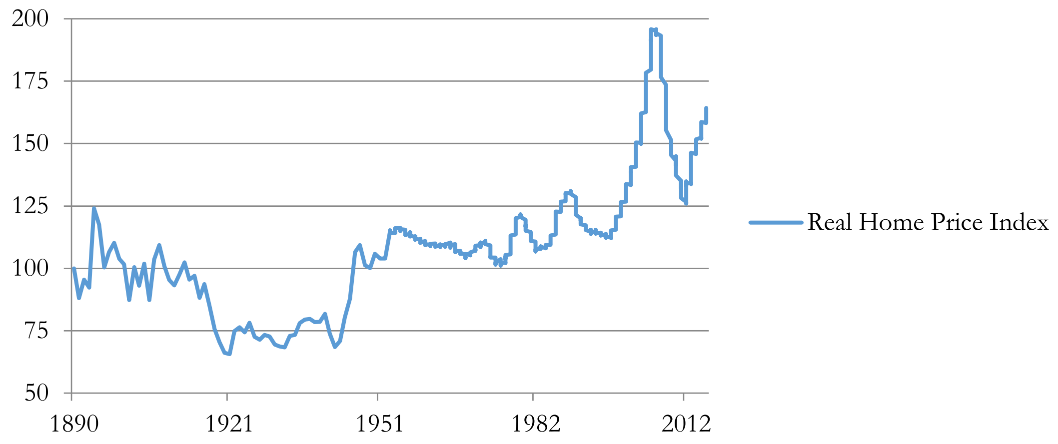

Figure 3: Standard & Poor's/Case-Shiller Index (1890-2016)
Source: S&P Dow Jones Indices

To benefit from the price increase and rental income many institutional investors acquired real estate assets. According to OECD (2015) bonds and equities are still the most important assets classes for pension funds globally. Real estate is however an important asset class for funds in various countries including Australia, Canada, Finland, Portugal and Switzerland. Allocation to real estate lies between 5% and 20% of total assets in those countries.

Andonov, Kok and Eichholtz (2013) examined 884 international pension funds, mainly from US and Canada, between 1990 and 2009. They found that 70-80% of all pension funds invests in some form of real estate. The average allocation of their complete sample to real estate was 5.1% in 2009. They also notice that small pension funds generally invest less in direct real estate, due to larger costs.

Earlier research from the Netherlands (De Wit, 1996) concludes that Dutch pension investors have invested quite a lot in real estate, and more than US funds. At the year-end 1989 total allocation of institutional investors, pension funds and insurance companies, was 10.8 percent in the Netherlands and just 3.9 percent in the United States. Over a longer time period, the mean pension fund allocation, of 27 pension funds, corrected for the disproportional size of the APB,[13] to real estate is 18.4 percent.

Research with a focus on the Netherlands is scarce, but data is provided by DNB. The database of the DNB provides an allocation of Dutch pension funds around 9 percent between 2012 and 2016. This includes both direct real estate and REITs, but excludes debt instruments. Dutch allocation has declined over the past years but is still relevant at an allocation of 8.7% in October 2016. Figure 4 provides historical asset allocation to real estate of the whole Dutch pension sector. Recent allocations are signifincantly lower than previously reported by De Wit (1996).

[13] Algemeen Burgerlijk Pensioenfonds, Dutch pension fund for civil servants

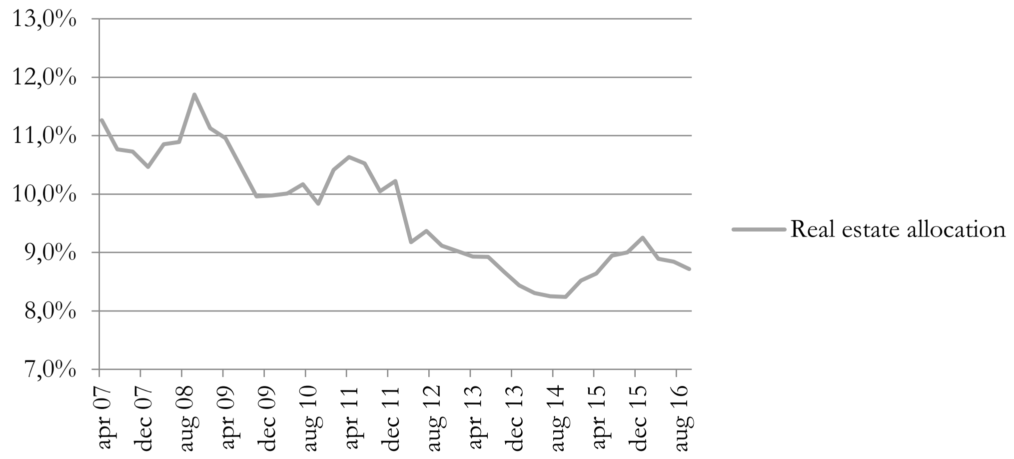

Figure 4: Historical real estate allocation of Dutch pensions funds
Source: De Nederlandse Bank

3. Academic Literature

This chapter will provide an overview of the most relevant existing literature about real estate investments especially in the light of pension funds. First, diversification benefits of the asset class and mean variance allocation are elaborated. Second, literature concluding on liability hedging capacities of real estate and allocations that incorporate these views are discussed. Third, the differences between public and private real estate instruments are given. Next, the effects of a long-term investment horizon on asset allocation is elaborated. This chapter will end with conclusions and with the formulations of hypotheses for the rest of this research.

3.1. Diversification and Mean Variance Allocation

The most widely used method for optimizing asset allocation is the modern portfolio theory, MPT, introduced by Nobel prize laureate Markowitz. In his paper (Markowitz, 1952) the view of looking at expected mean return is expanded and incorporates 'variance of returns'. Most traditional research using a mean-variance framework concludes that a pension fund should invest around 15 to 20 percent of their assets in real estate.[14] In an asset-only optimization for a non-specified investor, the authors found that real estate did not outperformed stocks and bonds between 1987 and 2002 in absolute terms (Hudson-Wilson et al., 2003). The authors analyzed a combination of real estate debt and equity and concluded that real estate is should be a large part of especially risk averse investment portfolios. They estimate an allocation of 23 percent in a portfolio with a standard deviation of 2% and an allocation of 10 percent for a standard deviation of just under 8%. The authors suggest that real estate could provide a good hedge against inflation. They suggest a higher allocation to private real estate equities if liabilities are dependent of inflation and advise further research.

Primarily, real estate can provide diversification benefits in a traditional portfolio consisting of stocks and bonds, as discussed in the previous chapter. The top-down approach of portfolio allocation also involves a decision of allocation within the asset class. In real estate, two dimensions are traditionally used for diversification within the asset class: property type and geographical location

Geurts and Jaffe (1996) acknowledge that international diversification for real estate is slightly more problematic than for traditional assets. This is caused by illiquid nature of the asset and possible political, economic, credit and financial risk. However, correlation between real estate returns across different countries is generally low, which enables diversification benefits (Anderson, Mueller, Xing, & Hurst, 2010). Stevenson (2000) however, concluded that a portfolio of a US investor does not improve significantly when international real estate is added to the asset mix. For an investor from a small economy such as The Netherland the benefits are more likely to be significant given the small contribution of domestic real estate in the investment universe.

[14] See ia. Fogler (1984), Firstenberg, Ross and Zisler (1988) and Ennis and Burik (1991)

Other research by Hoesli, Lekander & Witkiewicz (2004) analysed the return and variance of private real estate in various countries, including the Netherlands. They used annual data from 1987 to 2001 for every country. The authors found an optimal weight to real estate allocation in the 5-15% range when only domestic real estate is included. When (unhedged) international real estate is also added to the portfolio, the optimal total real estate allocation increases to c. 15% across all countries. The authors conclude that international and domestic real estate adds value to the portfolio but that the balance between international and domestic varies per country. This depends on the country specific correlations and currency risk. In the Netherlands the optimal ratio domestic/international real estate is approximately 1:3 for an expected return of 8.4%.

More recent research by Lekander (2015) applied the same methodology as Hoesli et al. (2004) to data from 1987 to 2011. Compared to the real estate segments used by Hoesli et al. (2004), the author adds globally dependent (offices) and locally dependent (retail, industrial and residential) real estate. Conclusions of this research are broadly in-line with previous research and observed allocations, in the range of 5-20%. The author concluded that investors can benefit from including both international and domestic real estate real estate in their portfolio. An optimal Dutch real estate portfolio has relative high allocations to international real estate, except for the MVP. In addition, he found that locally dependent real estate tends to be dominant over globally dependent real estate.

Although an internationally diversified portfolio might have benefits, many investors put too much wealth in domestic assets and thus engage in a sub-optimal degree of diversification. This is often referred to as home asset bias and has been discussed by various scholars[15]. In relation to Dutch pension funds, De Drue and Bikker (2009) concluded that especially smaller funds are likely to suffer from the home asset bias.

3.2. Hedging Capacities and ALM Allocation

The hedging capabilities of real estate investments have been extensively researched, but with varying results. Early research by Gyourko and Linneman (1988) investigates a wide range of real estate types and their relation with inflation. The research finds that REIT returns are negatively correlated with inflation and they behave more like traditional stocks. Prices of owner occupied homes are positively related to inflation, but the strongest positive correlation with inflation is found in non-residential property returns. Other early research (Liu, Hartzell, & Hoesli, 1997) further examined the inflation hedging capacities across different countries. They find that in some countries stocks are a better against future inflation than REITs, but in others REITs are stronger correlated.

In a study that examined the hedging capabilities of certain asset classes against a deterioration in consumption opportunities (Sa-Aadu, Shilling, & Ashish, 2010), it was concluded that real estate provides a good hedge and that pension funds are generally underinvesting in real estate. Their mean-variance

[15] See Geurts and Jaffe (1996) for an overview of early literature on home asset bias of real estate

analysis includes the returns of REITs in the United States between 1972 and 2008. In strong markets the tangency portfolio should consists of 15 percent real estate and in bad times the weight should be increased to approximately 19 percent. In the rest of this section more recent research, specified to pension fund liabilities is presented.

To incorporate hedging capabilities of an asset class, an asset liability management, ALM, approach is necessary. ALM is an integrated holistic approach that is trying to match the assets of an investor with their future expenditures (Boender, Van Hoogdalem, Vos, & Van Lieshout, 2009). In addition to mean-variance analysis the hedging possibilities of real estate could lead to different outcomes in an ALM framework. Chun, Ciochetti & Shilling (2000) constructed the first asset-liability model for a pension fund that includes (listed) real estate. They constructed portfolios that minimized the surplus return-variance over the fund's liabilities. The optimal allocation in their ALM analysis is significantly lower, between 6 percent and 13 percent, than in their mean-variance model. Robustness of the results of this study is questionably since the sample only includes annual assets returns between 1987 and 1997.

Craft (2001) conducted both an asset only and a ALM study over the years 1979 to 1998. The ALM study uses the same surplus approach as Chun et al. (2000). He concludes that in a portfolio with both listed and non-listed real estate the allocation should be 17 percent respectively 37 percent in a mean-variance model. Combined, this forms a real estate allocation of around 55 percent, which is fairly high compared to earlier research. In his asset-liability model he comes to an optimal allocation to private real estate between 12 and 16 percent and to 4 to 10 percent for public. The real estate allocation in ALM, 16 to 26 percent is significantly lower than in asset-only, but is still higher than in most other research.

Revised research by Chun, Sa-Aadu & Shilling (2004), using the same methodology, examines US data and includes both listed and direct real estate. The authors find that optimal asset-liability investment policy involves an average allocation to real estate of 6-12%. They notice that real estate is c. 4% of investable wealth and that most investors should probably hold an allocation close to that. An investor who is exposed to consumption risk might have to invest more in real estate and an allocation of 15 to 20 percent could be optimal for those investors.

The same methodology has been applied for the UK pension sector by Booth (2002). The asset mix has been expanded with index linked bonds and direct real estate. Booth concludes that optimal allocation to real estate in an ALM setting is at a typical level of 5-10%, which is lower compared to previous research.

Research using US data from 1983 to 2006 (Brounen, Prado, & Verbeek, 2010), including listed and direct real estate used that same framework as Chun et al. (2000). They see a decrease of listed real estate in the ALM portfolio, as compared to the asset-only portfolio. Allocation to direct real estate, however, increases. They see a considerable role for real estate in an ALM portfolio. Depending on various factors the optimal allocation is between 16 and 35 percent in their ALM analysis.

De Groot and Swinkels (2008) applied a framework inspired by Black and Litterman (1992) to mitigate extreme outcomes of a traditional optimization. The study examines data from the United Kingdom between 1994 and 2007 and includes 5 alternative asset classes; emerging markets, real estate, commodities, hedge funds and private equity. They concluded that pension fund allocation to alternative asset is roughly between 15 and 30 percent. Real estate shows to be the most important alternative asset with an allocation of c. 11 percent in a 2% surplus portfolio. Their Black-Litterman-inspired approach creates more robust outcomes.

Hoevenaars, Molenaar, Schotman & Steenkamp (2008) analyzed long-term alternative asset returns (including listed real estate) in an ALM framework. They used quarterly US data from 1952 for stocks and bonds, from 1970 for listed real estate and other years for other alternatives. All series ended on the fourth quarter of 2005. Liabilities are modeled for a 20 year zero coupon government bond. The authors find no significant allocation to real estate in both an asset-only MVP and a liability hedge portfolio. This does not materially change by increasing the investment horizon.[16]

3.3. Public vs. Private Real Estate

Public real estate securities indirectly represent a claim on a part of the lumpy properties of the fund. Securitization enables portfolio diversification for smaller amounts of capital and mitigates some of the transaction and illiquidity costs of real estate. It is important to know whether private and public real estate returns are different and if the legal structure of the investment matters. This could be of influence on portfolio allocations

Risk-return

Pagliari, Scherer & Monopoli (2005) questioned themselves if the investment 'platform' (ie. the legal structure of the investment vehicle) matters. They observed a 5% higher annual return and a 9% higher volatility for public real estate over the 21-year period ended in 2001. The return gap has narrowed over the years to approximately 60 bps in the last 8 years of the sample. The authors adjusted their annual data for differences in leverage, property-type mix and appraisal smoothing. With these adjustments they concluded that both return and volatility of REITs and direct real estate do not significantly differ and that the 'platform' does not matter.

Ang, Nabar & Wald (2013) analyzed the performance of REITs and direct real estate over the long run, usingthe same data adjustments as Pagliari et al. (2005). In this research both a transaction-based, an appraisal-based index and a REIT index are used. These are combined in a Common Real Estate Factor, that is used for estimating common real estate cycles. The authors find that REIT returns are correlated with stocks and bonds in the short-term. Direct real estate and REITs have a different idiosyncratic behavior in the short- and medium-term suggesting that diversification benefits could arise from combining private with public real estate. Over the full real estate cycle these diversification effects however largely disappear and over the long run investment vehicle specific effects fade out. Measured

[16] See Section 3.4 for more on long-term investment horizons

over the complete real estate cycle, private and public real have very similar risk and return characteristics. They also stipulate that public real estate returns often leads returns generated in the private market.

Lead-lag

Barkham and Geltner (1995) compared the public and private market in the United States and the United Kingdom. They used appraisal-based private indices, that have been de-smoothed following Geltner (1993). The public data was adjusted for leverage with the application of a simple weighted average cost of capital model. Even though they research is limited by short time series and the mentioned data problem the authors find evidence that price discovery appears in the securitized public markets first. It seems that this price discovery is not fully transmitted to the private market within one year.

Later research (MacKinnon & Al Zaman, 2009) concluded that this lag is smaller for transaction-based real estate indices. But TBIs still lag the public markets by approximately two quarters. The authors concluded that REITs have a role in optimized portfolios when direct property investments are not feasible given the lumpiness of the investment.

Hoesli and Oikarinen (2012) found that REITs and direct real estate are expected to offer similar diversification properties. They found that short-term co-movement (common movement of returns in one time period) between REITs and stocks is larger than between REITs and direct real estate. Measured on a typical long run investment horizon (3 to 4 years) REITs behave less like stocks and very similar to direct real estate. The authors used Johansen's trace test for co-integration which uses a vector error-correction model (Johansen, 1996). Data from the United States, United Kingdom and Australia is used, with slightly varying results. They conclude that their findings have important implications to long-term asset allocations.

Cotter and Roll (2015) compared US residential REITs with the S&P/Case-Shiller index for private real estate. They examined predictability of private real estate returns by applying a Vector Auto Regressive model. The authors concluded that both REITs and private real estate are self-predictable and that REITs generally leads private real estate. Predictability of private real estate returns based on REITs returns however, does not find support.

3.4. Investment Horizon

The typical mean-variance framework looks at short-term expected returns and risks. Campbell and Viceira (2005) extended mean-variance analysis to a multi-horizon setting by modelling risks and returns as a vector autoregressive (VAR) model. The authors only included stocks, T-bill and 5-year bonds in their analysis. They found that the variance and correlation structure of real returns changes dramatically by investment horizon. T-bills showed little variance in the short-term and thus a large allocation in the minimum variance portfolio. Over longer investment horizons, the allocation to T-bills decreased dramatically and allocation to stocks and bonds increased.

Hoevenaars et al. (2008) applied the same methodology, but widened their scope by adding alternative assets (commodities, hedge funds and real estate) and an asset-liability portfolio. They found that benefits of long-term investing are larger when liabilities are taken into account. The real estate index used is based on REIT returns and only a small part of the LHP, less than 2%, is allocated to real estate. Their findings support the view that REITs behave like stocks, also from a long-term investment point-of-view.

MacKinnon and Al Zaman (2009) included transaction-based direct real estate index as an asset class in their quarterly VAR model. The term structure of bonds and stocks is quite similar to Campbell and Viceira (2005). Given the high partial autocorrelation after 4 quarters of direct real estate, the fourth lag is used in the VAR estimation, instead of the first lag. The authors found that real estate becomes less risky over the long-term, just as stocks. The long-term risk effect is less strong for real estate than for stocks and for investment horizons of over 10 years stocks become less risky than real estate. This leads to higher real estate allocations for longer investment horizons. They conclude that optimal allocation to direct real estate should be in the 20-30% range, fairly higher than currently observed by pension funds. In addition, they conclude that REITs play little or no role in the optimal portfolios of large, long-horizon investors. For smaller, short-term investors REITs can play a role since direct investments are not feasible.

Other research using the Campbell-Viceira framework (Rehring, 2012) examined the effects of a long investment horizon on direct real estate allocation in an asset only setting in the United Kingdom. Rehring used annual data from 1965 to 2008, a de-smoothed appraisal-based real estate index and included transaction costs. The author found that real estate allocation strongly increases with the investment horizon. For a short investment horizon of 1 to 5 years, the real estate allocation is below 20% in both the minimum variance portfolio and a portfolio with a 5% expected return. With a long investment horizon the optimum real estate allocation increases to almost 60% for the MVP and over 80% for the 5% return portfolio.

A completely different approach analyzing longer periods within a sample has been recently introduced by Pagliari (2017). The author increases the investment horizon from one year to four years and infinity. In the used model a first order autoregressive function, AR(1), is assumed and long-term volatility and returns are follow from that. By increasing the investment horizon, it is no longer needed to adjust real estate volatility for smoothening effects, since these effects fade out over time. Pagliari (2017) concludes that in a mixed asset portfolio with an infinite horizon, allocation to real estate, private and public combined, should be at a maximum of 10 to 15 percent range for an investor with an average risk appetite. Liabilities are not incorporated in the analysis and could have a large influence on optimal allocation.

3.5. Conclusion and Hypotheses

This chapter provides an overview of the most relevant literature. The traditional mean-variance view concludes that allocation to real estate should be in the 10-20% range. When other relevant factors of the allocation problem are taken into consideration this allocation will change. Models incorporating liabilities generally suggest a higher allocation to bonds, lower allocation to stocks, and little change in real estate. International real estate can provide additional diversification benefits but domestic real estate are often dominant. For long-term investors, real estate can be a less risky investment than bonds and behaves more like shares. All these findings depend on the data used in terms of period, sample size and the real estate index used amongst others. Concluding, real estate is an important part of investment portfolios of long-term pension funds but the strategic asset allocation is not straight-forward.

The past two chapter provide guidance in answering the research question: "Are investments in domestic and international real estate adding value to a portfolio of a Dutch pension fund?" To come to a more robust answer, the coming chapters will conclude on the following hypotheses:

(1) Both domestic and international real estate are adding value to a traditional mean-variance optimized portfolio.
(2) Domestic real estate provides a (relative) strong hedge against pension fund liabilities.
(3) Pension funds should invest a significant part (around 15-20%) of its assets in domestic and international real estate from a long-term ALM point-of-view.
(4) A strategy to invest 60% of the real estate portfolio in domestic assets is a sub-optimal strategy for Dutch pension fund.

In the next chapter, the data used to answer the research question and to confirm or reject the four hypotheses is presented.

4. Methodology

The methodology to answer the research question and to confirm or reject the hypotheses from the previous chapter is explained in this chapter. First, the classic mean-variance approach will be briefly elaborated. Second, the hedging opportunities of the different asset classes will be estimated using the liability hedge credit, LHC, approach. Third, the mean-variance and LHC will be combined in a ALM framework. Next, a more advanced model based on the Black-Litterman model, that prevents extreme outcomes, is elaborated. After that, mean-variance spanning will be introduced to test if an asset class adds significant value to the portfolio. Last, methods to test the robustness and sensitivity of the outcomes are presented.

4.1. Mean-Variance Model

The mean-variance model, as used first by Markowitz (1952), enables us to create a relatively simple model to determine the optimum proportion of an asset in the portfolio. The framework looks at return on the one hand, and variance of return on the other hand. The portfolio consists of different assets, *i,* and the weight of all assets, w_i, together are 1. In this research, short selling (ie. negative weights of asset classes), is not allowed. The total return generated by the portfolio in a certain time period ($r_{t,p}$) is the sum of the individual returns ($r_{r,i}$) times the value of the asset at the beginning of the period ($w_{t-1,i}$).

The covariance of two assets (σ_{ij}) is the product of the standard deviation of both assets (σ_i) and their correlation (ρ_{ij}). The variance of the total portfolio (σ_p^2) is calculated by using individual asset's covariance and the weighted sum of the individual assets variance.

$$\sigma_p^2 = \sum_i w_i^2 \sigma_i^2 + \sum_i \sum_{j \neq i} w_i w_j \sigma_i \sigma_j \rho_{ij} \tag{1}$$

After describing the two aspects of the model it is possible to minimize the variance for a desired return using the Lagrange. The optimized portfolios together form the efficient frontier, presented as the dotted line in Figure 5. The dots in this figure represent the individual assets.

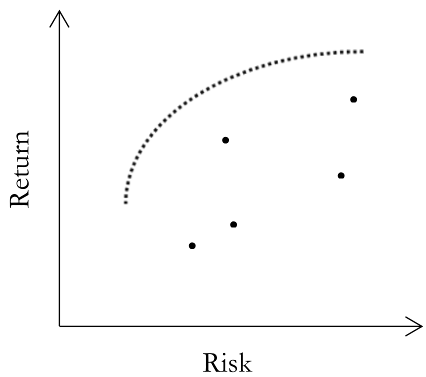

Figure 5: Efficient Frontier

4.2. Liability Hedge Credit

To create expectations and estimations of the hedging capacities of the different asset classes I use the liability hedge credit, LHC. Sharpe and Tint (1990) introduced the LHC and define it as: 'The degree to which a particular asset or asset class can provide utility for an investor with a particular set of liabilities.' Since pension investors have a very particular set of liabilities this is a very relevant measure. The LHC consists of the covariance between the return of an asset and the return of the liabilities at t+1. The covariance is then multiplied by three factors. The first is the inverse of the current funding ratio of the fund ($\frac{L_t}{A_t}$). The other are the risk appetite of the fund ($\frac{2}{\lambda}$) and the attached importance to coverage of the liabilities (*k*), where *k*=1 mean full coverage and *k*=0 is no coverage at all. The exact calculation of the LHC is provided in Equation 4.

$$LHC_i \ = \frac{2}{\lambda} k \frac{L_t}{A_t} COV_t(R_{i,t+1}, R_{L,t+1}) \tag{2}$$

A higher LHC indicates better liability hedging capabilities which will eventually lead to a higher allocation of high LHC assets in the Asset Liability Model. The ALM is discussed in the next section.

4.3. Asset Liability Model

The hedging capabilities as estimated by the LHC need to be incorporated in the optimization problem to create the ALM model. The same approach as Chun, Ciochetti and Shilling (2000), that has been repeated various times,[17] is used in this research. The approach is comparable to the mean-variance model, but now the variance of the surplus return is minimized given a certain level of surplus return. The surplus return is the return of an asset relative to the size of the portfolio, minus the return of the liabilities relative to the size of the portfolio. The surplus return can be calculated with Equation 5.

$$SR = \sum_i R_i w_i - R_L w_L \tag{3}$$

The variance of the surplus return can then be optimized with the Lagrange given a level of surplus return. Equation 6 describes the variance of the surplus return for the whole portfolio.

$$\sigma_p^2 = \sum_i w_i^2 \sigma_i^2 + w_L^2 \sigma_L^2 + \sum_i \sum_{j \neq i} w_i w_j COV_{ij} + \sum_i w_i w_L COV_{iL} \tag{4}$$

4.4. Long Investment Horizon

To give weight to the very long investment horizon of pension funds, additional methods can be applied. In this research the same approach as Pagliari (2017) is used to generate insights in the infinite investment horizon. Key in this analysis is a first order autoregressive, AR(1), model, as provided in Formula 5.

[17] See ia. Craft (2001)

$$r_{i,t} = \alpha_x + \varphi_i r_{i,t-1} + \varepsilon_{i,t} \tag{5}$$
Where: $|\varphi_i| < 1$
$$\varepsilon_{i,t} \sim N\,(0, \sigma_i^2)$$

The AR(1) coefficient, φ_i, is then used to estimate long-term variances and correlations of the different asset classes. The infinite horizon (scaled) variance and correlations can be calculated by using formula 6 and 7 respectively.

$$\lim_{T\to\infty}\left(\frac{\sigma_T^2}{T}\right) = \sigma^2\left(\frac{1+\varphi}{1-\varphi}\right) \tag{6}$$

$$\lim_{T\to\infty}(\rho_{x,y|T}) = \rho_{x,y}\frac{1-\varphi_x\varphi_y}{\sqrt{1-\varphi_x^2}\sqrt{1-\varphi_y^2}} \tag{7}$$

The above presented methods mitigate the smoothening problems by adjusting long-term variance for high autocorrelation via coefficient φ.

4.5. Expected Returns

The classic mean-variance framework has been extensively used by academics but practitioners are reluctant in using them. In practice, mean-variance optimizers often act as *statistical error maximizers*. The inputs to mean-variance optimizers are estimated with error and mean-variance optimizers optimize these estimation errors. According to Michaud (1989), Best & Grauer (1991) and others this can lead to unrealistic high allocations to certain asset classes. This problem has been mitigated with the model introduced by Black and Litterman (1992). De Groot and Swinkels (2008) applied this approach to pension funds in an ALM setting. Historical risk patterns are used, but expected excess returns are estimated with application of Equation 8.

$$E(r) = \frac{\lambda}{2}\Sigma\omega \tag{8}$$

In Formula 7 Σ stands for the covariance matrix of realized excess returns and ω is a vector of weights of the different asset classes. These weights can be observed in the portfolio of the investor or in the market as a whole. In the equation λ represents the risk appetite of the investor or the market. This market price of risk is defined by Formula 9.

$$\lambda = \frac{E(r) - r_f}{\sigma^2} \tag{9}$$

In Formula 9, *E(r)* represents the expected return of the market, r_f, the risk free rate, and σ^2 the standard deviation of the market.

5. Data

In this chapter, the data used in the analysis in presented. In the first section elaboration of the asset classes and the used benchmarks is given. The second section provides a method to adjust real estate returns for underestimation of variance. The third section describes how the liability of pension funds are modelled. The last section provides descriptive statistics.

5.1. Asset classes

In the analyses four different asset classes are used: stocks, bonds, corporate bonds, REITs and international real estate and domestic real estate. All benchmarks are provided in Table 2. Descriptive statistics are provided in section 0. For all asset classes, annual returns are used. This mitigates the lead-lag problems of real estate.

Asset class	Benchmark
Stocks	MSCI World
Bonds	Bloomberg Barclays Global Aggregate
International real estate	MSCI World Real Estate
Domestic real estate	IPD Netherlands Property

Table 2: Asset Classes

Stocks

For stocks the used benchmark is the MSCI World Index. This market capitalization index covers approximately 1,600 large and mid-cap companies from 23 developed markets with a combined market capitalization of c. $33 trillion. The index is diversified amongst sectors and has a country weight of the United States of c. 60%.[18] The measure is based on total return, denominated in euro's.

Bonds

The used benchmark for bond returns is the Bloomberg Barclays Global Aggregate Index. This index consists of investment grade government, corporate and other bonds in various currencies and maturities. Government or government-related bonds form c. 68% of total market value.[19] The measure is based on total return and is denominated in euro's.

International real estate

For estimation of the return on international real estate the MSCI World Real Estate Index serves as a benchmark. This market capitalization index consists of large and mid-cap real estate equities listed in 23 developed countries.[20] With a country weight of c. 56% the United States are the largest contributors to the index, with Japan as the second largest contributor with c. 13%. The index is broadly diversified across all sub-industries. The index compromises of 105 constituents with a combined market capitalization of c.

[18] As of 30 November 2016, MSCI factsheet
[19] As of 1 August 2016, Barcap factsheet
[20] Investments of the constituents can be based in other countries

$1,044 billion.[21] As with Stocks and Bonds, this index uses total return in euro's. As mentioned in Section 3.3, a REIT index is not a pure real estate index and REITs include leverage and other activities, such as asset management.

Domestic real estate

For domestic real estate the IPD Netherlands Property Index is used as a benchmark. The index measures ungeared total returns to directly held standing property investments from one open market valuation to the next. The index tracks performance of 2,450 property investments, with a total capital value of €23.0 billion as of March 2016. The market coverage is estimated to be around 25% with results dating back to 2007. This index is available from 2008 and the annual index is available from 1995. As this is a Dutch index, it in denominated in euro's.

Cash

For the (risk-free) return on cash the Netherlands 1 year government bond is used. Using a 1 year bond eliminates reinvestment risk when an investment horizon of 1 year is used. The return on cash is subtracted from asset returns to generate excess returns. Even though data from 1995 is available for all series, returns of 1995 are not used since the first year is needed in de-smoothing of real estate returns as shown in the coming paragraph. All average returns shown in this research are geometric means, unless mentioned differently.

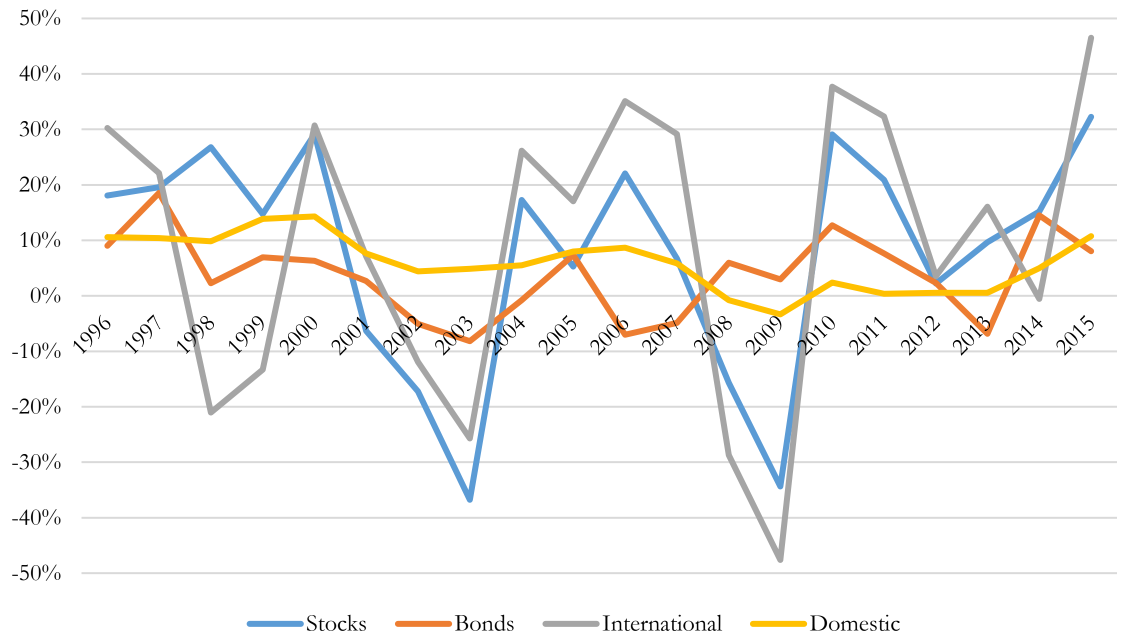

Figure 6: Asset classes, excess returns

[21] as of 30 November 2016, MSCI factsheet

5.2. De-smoothing

Real estate returns can be estimated by using an index of REITs or by using an appraisal based index of direct real estate. REITs returns have the problem to be behave more like a stock than the underling real estate. Appraisal based indexes can be distorted by smoothed valuations of the properties. Fund managers tend to adjust the value of the investments slowly and this makes the index underestimate volatility. To de-smooth an appraisal based index, Formula 1 can be used. This approach has been used by Geltner (1993) for the US, Barkham and Gelter (1994) for the UK, Clayton and Hamilton (1999) for Canada amongst others. In this approach the unsmoothed return (R_t^U) equals the unsmoothed return, minus the unsmoothed return in the previous period multiplied with 1 minus the appraisal factor (μ) divided with the appraisal factor.

$$R_t^U = \frac{R_t - (1-\mu)R_{t-1}}{\mu} \tag{10}$$

The model is designed for annual data and only removes autocorrelation with a one lag. Following Geltner (1993), an appraisal factor of 0.4 should be used based on the assumption that standard deviation of real estate is approximately half of that of stocks. Any factor that lies between 0.3 and 0.5 is seen as potentially realistic, depending on the index. The de-smoothing factor can also be set to a level that the standard deviation of the de-smoothed returns, is equal to the average of the national stock index and the bond index. This is demonstrated for different countries and the Netherlands All Property Index came to an appraisal factor of 0.4 and an autocorrelation of -0.02 (Lekander, 2015)

Given the high level of autocorrelation of the unsmoothed returns with an appraisal factor of 0.4, a lower factor of 0.3 is more suitable. De-smoothing then leads to excess returns with a geometric mean of 5.15% and a standard deviation of 11.46%. The de-smoothed return series with factor 0.3, will be referred with an asterisk,"*", in the rest of this research. Effectiveness of de-smoothening is questionable given the large amount of autocorrelation remaining. Results of de-smoothing are provided in Table 5.

1996-2015 (n=20)	**Excess return (%)**	**Standard deviation (%)**	**AR1**	**Jarque-Bera**
Smoothed	5.85	4.95	0.708	0.679
$\mu = 0.3$	5.15	11.46	0.353	0.924
$\mu = 0.4$	5.48	8.81	0.409	0.808
$\mu = 0.5$	5.63	7.33	0.470	0.677

Table 3: De-smoothening

5.3. Liability modeling

As explained in the first chapter the liabilities of a pension fund depend on the expected future payments that need to be discounted against the UFR. In the financial position of the fund is sufficient the fund will compensate for inflation. To estimate the liabilities of the 'average' Dutch pension fund, the same approach as others Hoevenaars et al. (2008) is used. This approach assumes that inflation and interest rate risk as the only relevant risk factors. They estimate the nominal log return on liabilities ($r_{b,t+1}$) with equation 3.

$$r_{b,t+1} = \frac{1}{4} Y_{t+1} - D_{n,t}(Y_{t+1} - Y_t) \tag{11}$$

In Equation 3 Y represents the log-yield of a 20-year bond and $D_{b,t}$ respresents the duration of the liabilities. Average duration of the liabilities is assumed to be 17 years (Brounen, Prado, & Verbeek, 2010). The real return on liabilities can be calculated by subtracting inflation from the nominal return.

In this research the Dutch CPI is used as a measure for inflation and the yield on the Netherlands 20 year zero yield government bond is used as the bond yield. The Dutch zero yield bond is only available from 2007, German rates go back to 1998. German rates have been used before 2007 by applying a simple regression (Appendix 2, table 1). For rates before 1998, the Dutch 10 year zero-coupon serves as a proxy. This has also been regressed against and results of this can be found in Appendix 2, table 2.

Core statistics about the liabilities is provided in Table 5. In the used sample, inflation is very low, well below the ECB target of 2%, and quite stable, standard deviation of 1.13%. The return on 20-year bond showed a large decline, reflected in a reasonably high return on liabilities.

1996 –2015 (n=20)	**Return (%)**	**Standard deviation (%)**
Inflation	1.59	1.13
20-year Bond	4.38	1.44
Nominal Liabilities	6.68	11.93
Real Liabilities	3.91	11.33
	Excess return (%)	**Standard deviation (%)**
Nominal Liabilities	4.31	12.59
Real Liabilities	2.22	12.04

Table 4: Liabilties

5.4. Descriptive Statistics

The findings of the previous sections can be combined and descriptive statistics can be provided. In Table 4 the geometric average returns, standard deviation and Sharpe ratio are given.

1996-2015 (n=20)	**Excess return (%)**	**Standard deviation (%)**	**Sharpe ratio**
Stocks	5.80	20.34	0.285
Bonds	3.47	7.47	0.464
International Real Estate	5.75	26.32	0.219
Domestic Real Estate*	5.15	11.46	0.449
Nominal Liabilities	4.31	12.59	
Real Liabilities	2.22	12.04	

Table 5: Descriptive statistics

Descriptive statistics show that Stocks and International generate the highest geometric mean returns with 5.80% and 5.75% respectively. They also have the highest risk with standard deviations of 20.34% and 26.32% respectively. Bonds have shown to be the safest investment with a standard deviation of 7.47% and a geometric mean return of 3.47%. This gives bonds the highest Sharpe ratio, 0.74, and International the lowest, 0.219. Domestic Real Estate is somewhere between Stocks and Bonds in relation to risk but return is more in-line with Stocks. Domestic generates the highest Sharpe ratio. In these statistics management and transaction costs are not taken into account. Adjustments for management costs are made in the overview below. All costs are based on the findings of Commissie Parameters which is part of the regulatory framework.

1996-2015 (n=20)	**Excess return (%)**	**Management costs (%)**	**Net excess return (%)**	**Net Sharpe ratio**
Stocks	5.80	0.25	5.55	0.273
Bonds	3.47	0.15	3.32	0.444
International Real Estate	5.75	0.25	5.50	0.209
Domestic Real Estate*	5.15	0.80	4.35	0.380

Table 6: Returns adjusted for management costs

Of the asset returns the correlation matrix has also been computed and is provided below. It shows that Stocks are stronger correlated with Domestic and International Real Estate than with Bonds. International Real Estate is relatively strongly correlated with Bonds but not with Domestic. Domestic Real Estate is also weakly correlated with Bonds. All correlations are positive.

Looking at correlations with Liabilities we see that Bonds provide the weakest correlation with Real and Nominal Liabilities. Domestic Real Estate provides a quite strong correlation with Nominal and Real Liabilities, 0.329 and 0.368 respectively. Stocks and International Real Estate are again between Bonds and Domestic Real Estate. This confirms the general idea that real estate is an asset class that is fits between stocks and bonds. Positive correlation of International and Domestic with inflation, causes a higher correlation with nominal liabilities compared to real liabilities. The opposite is true for Stocks and Bonds. The coming chapter will combine this data with the methodology of the previous chapter.

1996-2015 (n=20)	**Stocks**	**Bonds**	**International**	**Domestic***
Stocks	1.000			
Bonds	0.431	1.000		
International Real Estate	0.765	0.195	1.000	
Domestic Real Estate*	0.739	0.352	0.562	1.000
Nominal Liabilities	0.212	0.175	0.244	0.357
Real Liabilities	0.214	0.188	0.234	0.361
Inflation	-0.350	-0.358	0.344	0.178

Table 7: Correlation matrix, excess returns

6. Results

In this chapter the results of application of the methodology on the data as described earlier are provided. First, the data is adjusted to an infinite investment horizon. Second, the classic mean-variance model is applied. Depending on the robustness of these results, implied returns will be calculated. Next, these implied returns will be used in a new mean variance optimization. After that the liability hedge credit of the different asset classes are provided to provide insight in the hedging capacities. The next step is to conduct an asset liability analysis. The last section of this chapter will consist of sensitivity analyses.

6.1. Infinite Horizon Risk Structure

To present long-term horizon data next to one year horizon methods of Section 4.4 are used. Fist, the results of the first order autoregressive models are displayed in Appendix A.3. Results show all asset classes show positive autocorrelation. Liabilities however have a negative autocorrelation coefficient. As expected from an appraisal-based index, Domestic shows a high autocorrelation coefficient, 0.743, which is also very significant. All other assets have non-significant coefficients (at reasonable confidence levels) that lie between 0.075 and 0.247. Liabilities show non-significant negative coefficients of -0.285, indicating a mean reverting movement.

The coefficients from the regression can be used in Formula 6 to estimate long-term volatilities and in Formula 7 for long-term correlations between the assets and the liabilities. Expected returns of the assets do not change by increasing the horizon but new standard deviations and Sharpe ratios are displayed in Table 8. New correlation matrix is provided in Appendix A.4. Infinite horizon standard deviations and Sharpe ratios are not directly comparable to 1 year horizons but are comparable within the horizon.[22] Results show that by increasing the horizon, the risk on Domestic exponentially increases, caused by high autocorrelation. This leads to an incline in standard deviation. Correlations between Domestic and other asset classes and liabilities decline materially, compared to the de-smoothed data. Correlations between the other assets show little change but correlation with liabilities slightly increase. Increasing the investment horizon changes the risk of Domestic materially, probably caused by the smoothening problem of the one year horizon.

		One year horizon		**Infinite horizon**	
1996-2015 (n=20)	**φ**	Std Dev	Sharpe[23]	Std Dev	Sharpe[27]
Stocks	0.247	20.34	0.273	26.19	0.212
Bonds	0.203	7.47	0.444	9.17	0.345
International	0.075	26.32	0.209	28.36	0.185
Domestic	0.743	4.95	0.880	12.89	0.392
Nominal Liabilities	-0.277	12.59		9.47	
Real Liabilities	-0.183	12.04		10.01	

Table 8: Asset standard deviation, different horizons

[22] See Pagliari (2017), note 40

[23] Net log returns, management costs are deducted

6.2. Mean-Variance

The short-term characteristics described in Chapter 5 and long-term characteristics of the previous section and the historical data can be optimized in the Markowitz framework. This has been done for de-smoothed 1 year horizon data, corrected for management costs in Table 9 and for the infinite horizon in Table 10. The outcomes give an indication for further analyses. Notice that returns and Sharpe ratios are presented on a non-logarithmic basis.

	MVP	**OSP**	**1**	**2**	**3**	**4**
Excess return (%)	3.41	3.57	4.00	4.50	5.00	5.50
Standard deviation (%)	7.11	7.28	8.97	11.84	15.31	19.85
Sharpe ratio	0.479	0.490	0.446	0.380	0.327	0.277
Portfolio Weights (%)						
Stocks	0.0	0.0	7.8	24.0	54.1	95.8
Bonds	79.8	65.9	37.6	11.8	0.0	0.0
International	0.0	0.0	0.0	0.0	0.0	0.0
Domestic*	20.2	34.1	54.6	64.2	45.9	4.1

Table 9: Mean variance allocation, 1 year horizon

For the 1 year horizon Bonds and Domestic make-up the complete portfolio for the low and medium risk portfolios. When a higher return is required, Stocks become part of the efficient portfolio. International is not part of the optimized portfolios. Large allocation to Domestic could be caused by de-smoothening. Therefore, optimization for the infinite horizon is constructed below.

For infinite horizon Bonds form the largest part of the low risk portfolios. Domestic forms the main part of the riskier portfolios and in the most risky portfolios, International is the largest asset class. Stocks are not part of any of the portfolios. This itself is questionable. Given the large allocations to a few asset classes, it appears that the period functions as a statistical error maximize. Therefore a Black-Litterman approach with implied expected returns could to add value and is discussed in the next section.

	MVP	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	3.32	5.05	3.50	4.00	4.50	5.00	5.50
Standard deviation (%)	8.16	8.84	8.24	8.44	8.63	8.83	9.96
Sharpe ratio	8.16	0.571	0.425	0.474	0.521	0.566	0.552
Portfolio Weights (%)							
Stocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bonds	100.0	0.0	89.4	60.6	31.8	3.0	0.0
International	0.0	0.0	0.0	0.0	0.0	0.0	99.0
Domestic*	0.0	100.0	10.6	39.4	68.2	97.0	1.0

Table 10: Mean variance allocation, infinite horizon

6.3. Implied Returns

To calculated implied returns expected by the market, all variables from Formula 7 and 8 are needed. Market weights are obtained from Doeswijk, Lam & Swinkels (2014) according to whom global (government and non-government) bonds make up 57.0% of the market, stocks 37.7% and real estate 5.3%. Real estate makes up a relatively small part of the market since most properties are owned by their occupier and not part of the financial market. Since the Dutch real estate is only a very minor part of the global financial market, the weight is set to zero. The used risk appetite of the market is calculated via Formula 8. The input of this formula is derived from the historical returns of the optimal Sharpe portfolio. These weights and risk appetite lead to expected returns as presented in Table 11. A separate calculation for the infinite horizon is conducted to mitigate de-smoothing issues. Standard deviations and therefor the risk appetite are not comparable between horizons and is different for both timeframes.

	Stocks	**Bonds**	**International**	**Domestic**
Observed weights (%)	37.7	57.0	5.3	0.0
1 year horizon, $\lambda = 6.97$				
Historical net excess return (%)	5.55	3.32	5.25	4.35[24]
Implied excess return (%)	7.49	2.04	7.42	3.17
Infinite horizon, $\lambda = 4.97$				
Historical net excess return (%)	5.55	3.32	5.25	5.05
Implied excess return (%)	7.82	2.02	6.50	2.59

Table 11: Implied excess returns

Implied returns for Stocks and International are remarkably higher than historical, while those of Bonds and Domestic are lower. The infinite horizon presents implied returns that show smaller differences than in the historical sample. Management costs are already incorporated in implied returns, so no adjustment is needed. Domestic has a fairly low implied return in a 1 year horizon, caused by low variance due to smoothening. The infinite horizon again mitigates the smoothening problem and comes to a higher implied return for Domestic. Mean-variance optimization based on these implied returns is presented in Table 12 for 1 year horizon and Table 13 for the infinite horizon.[25]

[24] De-smoothed

[25] Both optimizations are done with the implied returns depending on the horizon. According to Pagliari (2017) expected returns are independent of horizon. In this framework applying the same expected return would underestimate the impact of insufficient de-smoothening.

	MVP	OSP	1	2	3	4	5
Excess return (%)	2.27	4.38	3.00	4.00	5.00	6.00	7.00
Standard deviation (%)	7.11	11.21	8.08	10.26	12.87	15.76	18.80
Sharpe ratio	0.319	0.391	0.371	0.390	0.389	0.381	0.372
Portfolio Weights (%)							
Stocks	0.0	37.7	7.6	29.4	50.1	70.1	90.2
Bonds	79.8	57.0	68.2	60.1	45.7	27.4	9.1
International	0.0	5.3	6.4	5.6	4.2	2.5	0.8
Domestic*	20.2	0.0	17.9	4.9	0.0	0.0	0.0

Table 12: Mean variance allocation, 1 year horizon, implied returns

The first thing that is stipulated by Table 15 is the wider range of possible returns, caused by lower excess returns for Bonds and higher for International and Stocks. Next, it shows portfolio weights are more evenly distributed and that the results suffer less from 'statistical error optimization'. Stocks and Bonds form the largest part of the portfolio across the whole risk spectrum, with a strong focus on bonds in the low risk portfolio and vice-versa. Domestic is an important part of the low risk portfolios but loses its weight in more risky portfolios. International has a slightly more stable weight across the spectrum but is only a small part of high risk portfolios. In total, real estate is an important part of all portfolios especially those below the optimal Sharp ratio portfolio.

	MVP	OSP	1	2	3	4	5
Excess return (%)	2.18	4.44	3.00	4.00	5.00	6.00	7.00
Standard deviation (%)	8.36	14.06	9.90	12.69	15.89	19.38	23.07
Sharpe ratio	0.260	0.316	0.303	0.315	0.315	0.310	0.304
Portfolio Weights (%)							
Stocks	0.0	37.7	9.0	28.9	48.8	68.6	85.8
Bonds	72.2	57.0	64.5	59.3	47.9	31.4	14.2
International	0.0	5.3	7.9	6.1	3.3	0.0	0.0
Domestic	27.8	0.0	18.6	5.7	0.0	0.0	0.0

Table 13: Mean variance allocation, infinite horizon, implied returns

When the horizon is increased to infinity, Stocks and Bonds remain the most important asset classes. Domestic is of less importance than in the 1 year horizon, but international gains some weight in the lower risk portfolios. The differences in weights in the OSP are not very large but allocation to shares is slightly higher. Total real estate has notable allocation in low risk area, with an OSP allocation of 5.3%, all in International.

6.4. Liability Hedge Credit

The next step in the analysis is to obtain an indication of the liability hedging characteristics of the different assets. The LHC, as elaborated in the precious chapter, requires the input of three factors. The first, is the risk appetite of the fund (λ). The same risk appetite as used in the previous section is used. For comparison, the same appetite is used for the infinite as the 1 year horizon. The inverse of the funding ratio (L/A) is assumed to be 1. This represents a fund with a coverage ratio of 100%. The attached importance to liability coverage (k) is set at 1.

λ=6.97, k=1, L/A=1	**Stocks**	**Bonds**	**International**	**Domestic**
1 year horizon				
Nominal liabilities (%)	1.89	0.57	2.82	1.79
Real liabilities (%)	1.83	0.59	2.58	1.74
Infinite horizon				
Nominal liabilities (%)	2.11	0.59	2.44	1.10
Real liabilities (%)	2.15	0.65	2.39	0.78

Table 14: Liabilities hedging credits

Table 14 shows that International provides the best liability hedge, both for real and nominal liabilities across both horizons. Domestic and Stocks also provide a good hedge for nominal and real liabilities but to a smaller extent. Bonds have a much smaller, but still positive, LHC and is likely to have a smaller allocation in the ALM setting. Extending the investment horizon to infinity changes the hedging capabilities especially of International and Domestic. LHC of Domestic increases while International decreases. This can be caused by de-smoothening but also by changing covariances in the long-term. Changing the other parameters of the LHC has an effect on the LHC but the main findings remain the same.

6.5. Asset-Liability

For a liability driven investor the asset-liability optimization is most important and is conducted in this section. The same implied returns as before are used. Results of the 1 year horizon are presented in Table 15 and of the infinite horizon in Table 16.

First, analysis of nominal liabilities in the 1 year horizon is conducted. Total allocation to real estate lies around 20% for all risk-return levels. Domestic is the leading real estate asset class in low risk-return portfolios and International at medium and higher levels. A typical portfolio for a pension fund would have an expected nominal excess return of c.1 to 2%. In such a portfolio allocation to Domestic would be not material and allocation to international would be just above 20%. Compared to the mean-variance optimization (Table 12) it is remarkable that allocation to Domestic in the lower risk portfolios disappears. International however becomes more important across a wide range of portfolios. Bonds remain an important part of the lower risk portfolios unless the weak liability hedging capacities.

When an investor aims at covering real liabilities, optimal allocations slightly change, due to different correlations with inflation. Allocation dynamics however, do not change. It is important to notice that real returns are lower due to inflation and the efficient frontier shifts but allocation do not materially change.

Nominal Liabilities	MVP	OSP	1	2	3	4	
Excess return (%)	-2.04	3.17	0.0	1.0	2.0	3.0	
Standard deviation (%)	15.90	29.54	19.42	22.2	25.43	28.93	
Sharpe ratio	n.a.	0.107	0.000	0.045	0.079	0.104	
Portfolio Weights (%)							
Stocks	0.0	77.6	23.1	39.9	55.6	71.3	
Bonds	81.7	0.0	51.0	39.6	21.4	3.0	
International	0.0	22.4	16.9	20.3	23.0	25.6	
Domestic*	18.3	0.0	9.0	0.3	0.0	0.0	
Real Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	0.03	5.26	1.00	2.00	3.00	4.00	5.00
Standard deviation (%)	15.48	29.54	16.61	18.80	21.60	24.81	28.31
Sharpe ratio	0.002	0.180	0.06	0.106	0.139	0.161	0.177
Portfolio Weights (%)							
Stocks	0.0	74.4	4.0	20.8	37.6	53.5	69.2
Bonds	81.1	0.0	63.1	51.6	40.2	23.0	4.7
International	0.0	25.6	13.8	17.3	20.7	23.5	26.2
Domestic*	18.9	0.0	19.1	10.3	1.5	0.0	0.0

Table 15: Asset liability allocation, 1 year horizon

The second ALM optimization examines the infinite horizon. In the LHC analysis it was shown that Domestic has worse hedging capacities than International and Stocks, possibly leading to a smaller allocation. Results for nominal liabilities show that Stocks and Bonds are the most important asset classes. International is important in a zero-excess return portfolio, but quickly loses its allocation in higher risk portfolios. Domestic is not a material part of any optimal portfolios. For real liabilities, the same dynamics are observed. Domestic however is part of low risk optimal portfolios, but those portfolios generate an expected return that will probably not cover inflation.

Nominal Liabilities	MVP	OSP	1	2	3	4	
Excess return (%)	-2.16	3.51	0.0	1.0	2.0	3.0	
Standard deviation (%)	9.52	17.32	14.88	18.14	21.68	25.38	
Sharpe ratio	n.a.	0.129	0.000	0.055	0.092	0.118	
Portfolio Weights (%)							
Stocks	0.0	100.0	37.3	56.7	73.9	91.2	
Bonds	76.1	0.0	59.8	43.3	26.1	8.8	
International	0.0	0.0	2.9	0.0	0.0	0.0	
Domestic	23.9	0.0	0.0	0.0	0.0	0.0	
Real Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	-0.05	5.60	1.00	2.00	3.00	4.00	5.00
Standard deviation (%)	13.77	29.11	15.43	17.73	20.48	23.60	26.99
Sharpe ratio	n.a.	0.192	0.065	0.113	0.146	0.169	0.185
Portfolio Weights (%)							
Stocks	0.0	100.0	15.3	35.2	55.2	72.4	89.6
Bonds	73.2	0.0	63.1	57.9	44.8	27.6	10.4
International	0.0	0.0	4.9	3.1	0.0	0.0	0.0
Domestic	26.8	0.0	16.7	3.9	0.0	0.0	0.0

Table 16: Asset liability allocation, infinite horizon

Looking at both investment horizons and both type of liabilities it can be concluded that Domestic should not be a relevant part of the ALM portfolios. International is only likely to be part of low risk portfolios. Given the allocation in the asset only framework and positive LHC's this is somewhat surprising. However, Stocks also have a large positive LHC and make-up a large part of the riskier ALM portfolios. The next section will conduct sensitivity analyses on the previous results.

6.6. Sensitivity analyses

The robustness of the results presented in the previous sections is tested by conducting two sensitivity analyses. The first involves the application of other appraisal factors for de-smoothing of the domestic real estate returns in the 1 year horizon framework. The second analysis involves a higher expected return on domestic real estate. A higher return than expected by the market as a whole might be expected, given the characteristics of Dutch pension funds.

Choosing an appraisal factor is a difficult-to-ascertain process. In the previous an appraisal factor of 0.3 is used, which is lower than the commonly used factor, 0.4. Assumed volatility would be lower by applying the common factor. Since implied returns are used in most analysis in this research, a higher volatility caused a higher expected return. The effect of the use of different appraisal factors is given in Appendix A.5

These renewed implied returns have been used to calculate new mean-variance portfolios and liability hedged credits (Appendix A.5). In the mean-variance framework a higher appraisal factor leads to a higher allocation to Domestic in lower risk-return portfolios. Across higher risk-return portfolios, the allocations do not differ. Volatility of the efficient portfolios slightly reduces by increasing the factor. Liability hedge credits reduce when a larger appraisal factor is used.

By using implied returns, this research assumes that a pension fund generates the same expected returns than the market. However, it is arguable the in the inefficient private real estate market a pension fund can invest better and less costly than the average investor. By investing in large blocks funds can keep their management costs low and the typical low investment horizon will reduce the effect of transaction costs. Investment in the domestic market can be more easily managed, which contributes to lower costs. In Appendix A.6 the effect of a higher expected return on domestic real estate of 0.5% on efficient ALM portfolio are displayed. 0.5% additional return seems reasonable, as it is the difference between the management costs set by the FTK and the minimum costs as estimated by Andonov et al. (2015).

As you would expect, the allocation to domestic increases when expected return increases. The increase in the 1 year horizon is approximately 25 percentage points across reasonable risk-return levels. Optimal allocation to domestic real estate then reaches the 25-30% range. In an infinite horizon the increase is much lower with 7.5 to 15 percentage points, but still very significant.

7. Conclusion and Discussion

In this last chapter conclusions based on the previous results are drawn. In these conclusions, the hypotheses of Chapter 3 are the confirmed or rejected and the research question answered. After the conclusions, these will be more extensively discussed. Next, implications of the findings for Dutch pension funds will be analysed. Also, the limitations of this research as discussed. This research will end with some suggestions for further research.

7.1. Conclusion

The central question is this research is: 'Are investments in domestic and international real estate adding value to a portfolio of a Dutch pension fund?' In order to answer this question, four hypotheses have been formulated. Each hypothesis is discussed below.

(1) Both domestic and international real estate are adding value to a traditional mean-variance optimized portfolio.

According to the optimizations with implied returns, real estate is a part of most efficient portfolios. Total allocation to real estate is around 5% in optimal Sharpe ratio portfolios, equal to the market weight. In low risk/return portfolios, domestic real estate is an important asset class International real estate is more important in medium risk-return portfolios, but also in low risk portfolios. Increasing the investment horizon to infinity, slightly changes efficient allocations, but dynamics remain the same. The hypothesis can be confirmed for international and domestic real estate across a range of lower risk-return portfolios, but when higher returns are required, real estate is not an important asset class.

(2) Domestic real estate provides a (relative) strong hedge against pension fund liabilities.

In Section 6.4 the liability hedge credits of all asset classes have been presented. They show that domestic real estate provides a positive hedge against pension liabilities. Other asset classes however provide a stronger hedge and only bonds provide a weaker hedge. On a one year horizon, LHC is stocks and international real estate are a better hedge and in an infinite horizon international is stronger and stocks are more or less equal to domestic real estate. Compared to bonds, domestic real estate is a strong hedge. This is against findings in other research, but is in-line with the general finding that private real estate fits between stocks and bonds.

(3) Pension funds should invest a significant part (around 15-20%) of its assets in domestic and international real estate from a long-term ALM point-of-view.

The LHC as discussed in the previous hypothesis gives insight in possible ALM allocations. With better hedging capabilities than bonds, real estate could become more important for a liability driven investor. This could especially be relevant for international real estate. ALM optimizations do not suggest a large allocation to domestic real estate. International real estate is an important part especially in the 1 year horizon. In the infinite horizon real estate is of less importance and is only part of low risk portfolios. It is surprising, and not corresponding with most research, that allocation in the infinite is not significant in the most acknowledged risk/return levels. This hypothesis can be rejected for the infinite horizon, but for 1 year horizon international real estate should be c. 15-10% of the portfolio.

(4) A strategy to invest 60% of the real estate portfolio in domestic assets is a sub-optimal strategy for Dutch pension fund.

In a basic portfolio optimization, a 1 year horizon mean-variance, domestic real estate is the most important part of the real estate portfolio. In the 4% excess return optimized portfolio, allocation to domestic real estate is 10.6%, and to international real estate 5.9%. In such a real estate portfolio, domestic assets should indeed be c. 60%. Such a portfolio is probably not desirable for a pension fund. Pension fund generally have a very long investment horizon and are liability driven investors. When those characteristics are considered the optimum allocation to domestic real estate vanishes. Also, given the de-smoothening problems the one year horizon mean-variance optimization cannot be seen as a sole indication. Therefore, it is very likely that a strategy to invest 60% of real estate assets in the home market is not optimal.

Not all hypotheses are confirmed by the findings of this research. Some of the results are a bit surprising, given the results of earlier research. Domestic real estate shows to be a quite weak hedge against liabilities and this leads to little allocation to the asset class in an ALM framework. This research does not find any evidence for large allocations to domestic real estate for Dutch investors. Reflecting on the research question, it can be stated that real estate is adding value to investment portfolios. It is a relatively low risk investment and is part of most efficient portfolios. International real estate is more important than domestic and adds value to most portfolios. Allocation with an infinite investment horizon generates materially different results than a common 1 year horizon with de-smoothed returns, reflecting problems with de-smoothing of appraisal based data.

7.2. Implications

This research concludes on optimal real estate allocation and for a liability driven long-term investor, such as a pension fund. In a long-term ALM setting, optimal allocation is generally low. In a one year (de-smoothed) horizon, real estate allocation should be higher and is in the 10-15% range, depending on risk levels. Data from DNB supervising the Dutch pension sector indicates an average real estate allocation of c. 9%. Empirical allocations seem to match with findings in this research and it is likely that Dutch pension funds on average invest a reasonable portion of their assets in real estate. Individual funds deviate materially from this mean and it has been shown that the investment strategy of Bpf Bouw is likely to be irrational and thus inefficient for their plan members. Dutch pension plans have a certain freedom in their investment strategy but their plan members would benefit from an investment strategy that is less focused on domestic real estate. Given the size of the pension sector in the economy, minor improvements can have major effects.

7.3. Limitations

The conclusions of this research are based on methods and data that have certain limitations. The main elements that limit the conclusions are the data set itself and the applied methods and adjustments. Using implied returns, infinite horizons and de-smoothing affects the results of this research.

As seen in Section 6.2, historical returns of the 20-year period are not a solid base for portfolio optimization. Using implied returns mitigates this problem but comes with its own assumptions and drawbacks. First, the implied return on stocks and international real estate is relatively high and above the limits of the financial regulatory framework. Normally, expected returns are the same for investment horizons. In this research that is not the case. This is driven by the smoothening of the domestic real estate data. The implied returns also don't reflect a difference between short-term and long-term investors and only looks at the market as a whole.

De-smoothening is needed on a 1 year horizon since data is suffering from appraisal bias. The data is strongly auto-correlated and this seems stronger than usually observed in private data. Even after application of the strongest sensible de-smoothening factor, the returns remain auto-correlated. This is mitigated by extending the horizon and requires other expected returns. This however also assumes that the complete market has an infinite investment horizon and reduces possible benefits for pension funds.

To conclude on the influence of de-smoothing and implied returns sensitivity analyses have been conducted. These analyses show that when pension funds can generate a higher return in their home market than the average investor, allocations to domestic real estate materially increase. An additional return of 0.5%, results in large allocations in the 1 year horizon (c.30% across a wide range of portfolios), and material allocations in the infinite horizon (with an upper bound of 20% across common risk levels). Low management costs can also be a reason to invest in large projects, such as the Chinese project mentioned in the introduction. Sensitivity analyses also shows that de-smoothing influences domestic real estate allocations across low risk portfolios. But due to the use of implied returns this effect is not large in medium and high risk portfolios.

7.4. Suggestions for further research

The conclusions of this research are somewhat limited by the design and assumptions of this research and these conclusions are not definite. Future research could focus on other elements to improve the results and conclusions. Improvements can be made in data and used methodology.

The used domestic real estate returns are appraisal-based. The return series seems to be suffering more from appraisal biases than usually observed. Future research could use a transaction-based real estate index to mitigate appraisal problems. This data can also be aimed at residential properties exclusively.

Residential rents directly influence the CPI inflation and liability hedging capacities of residential could be materially better.

Data used in this research is based on 20 years of historical returns. These 20 years have shown a relatively low and stable inflation and declining interest rates. This could have its influences on used covariances and eventually on efficient allocations. Looking at very long term price returns in the S&P Case-Shiller Index, the past 20 years might not be relevant at all. Representivity of the used covariances for the coming years is something that can be further examined. Especially in the light of increasing interest rates and unexpected inflation shocks. Further insight in expected long-term returns of pension funds would add value.

Conclusions of this paper are based on historical financial data only and do not involve expectations of pension funds. A more extensive study examining the expectations and rationale of funds could add value to existing literature. This study could also include specific fund characteristics, such as average plan member age, funding ratio and specific management costs of the different asset classes. Using value-at-risk measures could further explain investment behaviour.

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9. Appendix

A.1 Parameters

Asset class	Geometric mean	Costs	Std deviation
Price inflation	2.0%		
Wage increase	3.5%		
AAA government bonds	c. 2.5%	15bp	8%
Credits	c. 3.0%	c. 15bp	c. 8%
Stocks	7.0%	25bp	20%
Non-listed real estate	6.0%	80bp	15%
Commodities	5.0%	40bp	20%
Others[26]	7.5%	25bp	25%

A.2 20-year bond

Table 1: regression results of 20 year Netherlands zero-coupon vs 20 year Germany zero-coupon

Regression Statistics			
R Squared	0.982		
Adjusted R Squared	0.979		
Observations	9		
*NL = C + x *Germanys*	Coefficient	Standard error	T statistic
Constant	0.094	0.185	0.509
X	1.020	0.052	19.440*

*: significant at 5% level

Table 2: regression results of 20 year Netherlands/Germany vs 10 year Netherlands zero-coupon

Regression Statistics			
R Squared	0.892		
Adjusted R Squared	0.885		
Observations	18		
*Combi = C + x *NL10y*	Coefficient	Standard error	T statistic
Constant	0.939	0.316	2.974*
X	0.957	0.083	11.483*

*: significant at 5% level

A.3 Auto regressive model

$Y_t = \alpha + \varphi Y_{t-1}$

Asset	α	P-value	φ	P-value	R^2
Stocks	0.058	0.268	0.247	0.324	0.057
Bonds	0.027	0.175	0.203	0.402	0.042
International	0.076	0.260	0.075	0.771	0.005
Domestic	0.015	0.242	0.743	0.000	0.551
Nominal Liabilities	0.057	0.087	-0.277	0.359	0.050
Real Liabilities	0.020	0.487	-0.183	0.536	0.023

[26] Including private equity, hedge funds and infrastructure, amongst others

A.4 Infinite horizon correlations

Correlations infinite horizon Change compared to 1 year horizon (de-smoothed) are in parenthesis				
1996-2015 (n=20)	**Stocks**	**Bonds**	**International**	**Domestic**
Stocks	1.000			
Bonds	0.432 (0.000)	1.000		
International	0.777 (0.012)	0.197 (0.002)	1.000	
Domestic	0.679 (-0.060)	0.277 (-0.075)	0.526 (-0.035)	1.000
Nominal Liabilities	0.243 (0.031)	0.196 (0.021)	0.260 (0.016)	0.259 (-0.098)
Real Liabilities	0.235 (0.021)	0.203 (0.015)	0.242 (0.008)	0.173 (-0.188)

A.5 De-smoothing sensitivity

Table 1: implied return effects

1 year horizon, $\lambda = 6.97$	**Domestic**
Historical net excess return (%)	4.35[27]
Implied excess return (%)	
Factor = 0.3	3.17
Factor = 0.4	2.38
Factor = 0.5	1.91

[27] De-smoothed

Table 2: Mean variance allocation effects

Original factor 0.3	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	2.27	4.38	3.00	4.00	5.00	6.00	7.00
Standard deviation (%)	7.11	11.21	8.08	10.26	12.87	15.76	18.80
Sharpe ratio	0.319	0.391	0.371	0.390	0.389	0.381	0.372
Portfolio Weights (%)							
Stocks	0.0	37.7	7.6	29.4	50.1	70.1	90.2
Bonds	79.8	57.0	68.2	60.1	45.7	27.4	9.1
International	0.0	5.3	6.4	5.6	4.2	2.5	0.8
Domestic*	20.2	0.0	17.9	4.9	0.0	0.0	0.0
Factor 0.4	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	2.17	4.38	3.00	4.00	5.00	6.00	7.00
Standard deviation (%)	6.57	11.21	7.96	10.25	12.87	15.76	18.80
Sharpe ratio	0.330	0.391	0.377	0.390	0.389	0.381	0.372
Portfolio Weights (%)							
Stocks	0.0	37.7	10.4	30.2	50.1	70.1	90.2
Bonds	62.3	57.0	59.1	57.6	45.7	27.4	9.0
International	0.0	5.3	5.7	5.4	4.2	2.5	0.8
Domestic*	37.7	0.0	24.8	6.8	0.0	0.0	0.0
Factor 0.5	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	1.97	4.38	3.00	4.00	5.00	6.00	7.00
Standard deviation (%)	6.01	11.21	7.88	10.25	12.87	15.76	18.80
Sharpe ratio	0.328	0.391	0.381	0.390	0.389	0.381	0.372
Portfolio Weights (%)							
Stocks	0.0	37.7	13.0	30.9	50.1	70.1	90.2
Bonds	48.7	57.0	54.0	56.2	45.7	27.4	9.0
International	0.0	5.3	5.4	5.3	4.2	2.5	0.8
Domestic*	51.3	0.0	27.6	7.6	0.0	0.0	0.0

Table 3: Liability Hedge Credit effects

λ=6.97, k=1, L/A=1	**Domestic**
Nominal liabilities (%)	
Factor = 0.3	1.79
Factor = 0.4	1.26
Factor = 0.5	0.94
Real liabilities (%)	
Factor = 0.3	1.74
Factor = 0.4	1.19
Factor = 0.5	0.86

A.6 Domestic real estate return sensitivity

Table 1: One year horizon

Nominal Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	
Excess return (%)	-1.97	3.17	0.0	1.0	2.0	3.0	
Standard deviation (%)	15.9	29.54	19.18	22.02	25.27	28.89	
Sharpe ratio	n.a.	0.107	0.000	0.045	0.079	0.104	
Portfolio Weights (%)							
Stocks	0.0	77.6	18.4	34.5	50.5	74.4	
Bonds	81.7	0.0	38.0	21.0	3.9	0.0	
International	0.0	22.4	14.8	17.7	20.5	25.6	
Domestic*	18.3	0.0	28.7	26.9	25.0	0.0	
⊿ Original	-	-	*+19.7*	*+26.6*	*+25.0*	-	
Real Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	0.13	5.26	1.00	2.00	3.00	4.00	5.00
Standard deviation (%)	15.90	29.24	16.38	18.77	21.38	24.64	28.25
Sharpe ratio	0.008	0.180	0.061	0.107	0.140	0.162	0.177
Portfolio Weights (%)							
Stocks	0.0	74.4	0.0	0.0	32.2	48.3	67.9
Bonds	81.1	0.0	56.2	33.5	22.2	5.2	0.0
International	0.0	25.6	12.4	29.1	18.1	21.0	25.4
Domestic*	18.9	0.0	31.3	37.4	27.4	25.5	6.7
⊿ Original	-	-	*+12.2*	*+27.1*	*+25.9*	*+25.5*	*+6.7*

Table 2: Infinite horizon

Nominal Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	
Excess return (%)	-2.16	3.51	0.0	1.0	2.0	3.0	
Standard deviation (%)	9.52	17.32	14.76	18.12	21.68	25.38	
Sharpe ratio	n.a.	0.129	0.000	0.055	0.092	0.118	
Portfolio Weights (%)							
Stocks	0.0	100.0	35.8	55.3	73.9	91.2	
Bonds	76.1	0.0	47.0	37.2	26.1	8.8	
International	0.0	0.0	0.9	0.0	0.0	0.0	
Domestic	23.9	0.0	16.3	7.5	0.0	0.0	
⊿ Original	-	-	*+16.3*	*+7.5*	-	-	
Real Liabilities	**MVP**	**OSP**	**1**	**2**	**3**	**4**	**5**
Excess return (%)	0.08	5.60	1.00	2.00	3.00	4.00	5.00
Standard deviation (%)	13.77	29.11	15.20	17.57	20.43	23.60	26.99
Sharpe ratio	n.a.	0.192	0.066	0.114	0.147	0.169	0.185
Portfolio Weights (%)							
Stocks	0.0	100.0	12.5	33.3	52.9	71.8	89.6
Bonds	73.2	0.0	54.7	44.8	34.9	25.1	10.4
International	0.0	0.0	3.6	1.0	0.0	0.0	0.0
Domestic	26.8	0.0	29.2	20.9	12.2	3.1	0.0
⊿ Original	-	-	*+12.5*	*+17.0*	*+12.2*	*+3.1*	-