The role of pensions: Exploring the link between pension funds, monetary policy and economic performance

A case study of the Netherlands

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Abbreviations

AEX Amsterdam Exchange Index

APP Asset purchasing program

DB Defined-benefit (pension scheme)

DC Defined-contribution (pension scheme)

DNB De Nederlandsche Bank

ECB European central bank

EONIA Euro Over Night Index Average

ESA European System of Accounts

FEVD Forecast error variance decomposition

FRED FRED of the St. Louis Federal Reserve

IRF Impulse response function

MSCI Morgan Stanley Capital International

MP Monetary policy

PAYG Pay-as-you-go (pension scheme)

QE Quantitative easing

SVAR Structural Vector-Autoregression

UMP Unconventional monetary policy

ZLB Zero lower bound

The role of pensions: Exploring the link between pension funds, monetary policy and economic growth

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Abstract

Shocks to the European Central bank's unconventional monetary policy trigger Dutch pension funds to search for yield: A structural VAR analysis shows that the pension funds reallocate their asset holdings from bonds towards equity and alternatives. The latter suggests the existence of a portfolio rebalancing channel through institutional investors in the euro area. Moreover, we emphasize that the portfolio reallocation induced by monetary policy has increased the overall riskiness of the funds' investments, which has potentially systemic risk implications. As the Dutch pension sector has evolved into a key player in financial markets, we additionally investigate the domestic real effects of a further increase in its size. In this context a second SVAR approach shows that an expansive shock to total asset holdings boosts economic growth. Nevertheless this link also works in the reverse direction and hence points out the potential problematics of a sudden dissaving of pension funds. Our case study is restricted to the Netherlands, where the pension sector accounts for almost 200% of GDP, which is an exceptional case in the euro area. However, our results are of general interest for the aging societies in Europe as they improve the understanding of pension funds' potential importance for economic policy in a period of demographic change.

1 Introduction

The purpose of this paper is to decipher the overall relationship between a growing pension sector, monetary policy and the macroeconomy. It provides empirical estimates to answer, on the one hand, if the ECB's monetary policy affected Dutch pension fund's asset allocation and on the other hand, if the size of the pension system affects economic performance in the Netherlands.

Applying a Structural Vector-Autoregression (SVAR) approach using a short term Cholesky identification we find evidence that Dutch pension funds have engaged in a search for yield behavior in the period from 2008 to 2020. Concretely, we observe them shifting their investments from bonds to equity and alternatives in response to a persistent expansionary shock to unconventional monetary policy shock. Increasing the overall riskiness of their portfolios, this might have effects on local financial stability.

Interestingly, we cannot observe any effect of monetary policy on Dutch pension funds' portfolio composition between 1999 and 2007, the conventional monetary policy period of our sample. As this suggests that it is ultimately the depression of the long term interest rates via the ECB's asset purchasing programs (APP)s that impacts the Dutch pension funds' investment behaviour, our results provide evidence that the portfolio rebalancing channel of unconventional monetary policy is effective in the Netherlands. An additional SVAR analysis yields that the size of their pension system affects overall economic performance. As pension funds have become major actors in the Dutch economy, their behaviour seems to contribute to a deeper financial market and a more effective capital allocation, boosting economic growth.

Many nations see it as a responsibility to provide financial security for their retired citizens as solid funding of pension claims is crucial for social stability, economic prosperity and development. Over the last decades, substantial assets have been accumulated in retirement savings plans globally, gathering over USD 50 trillion of assets at the end of 2019[1]. The financial crisis and its aftermath only had a minor impact on this impressive growth: since 2009, the global pension sector has doubled its asset holdings. According to Levine (1997), these holdings contribute to deepen financial markets, they decrease firms' investment costs and allow for more efficient risk sharing. By efficiently allocating the savings of citizens they are therefore contributing to fostering investment, economic productivity and growth[2]. Pension funds are hence experiencing an evolution turning them into systemically important key players: due to their sheer size and their tendency towards herding behaviour, e.g. Koetsier and Bikker (2021), they have the possibility to move markets. While that might contribute to more efficient financial markets, it might also have the potential to

[1] OECD Global Pension Statistics, https://www.oecd.org/pensions/pensionmarketsinfocus.htm.

[2] Davis and Disney (1995).

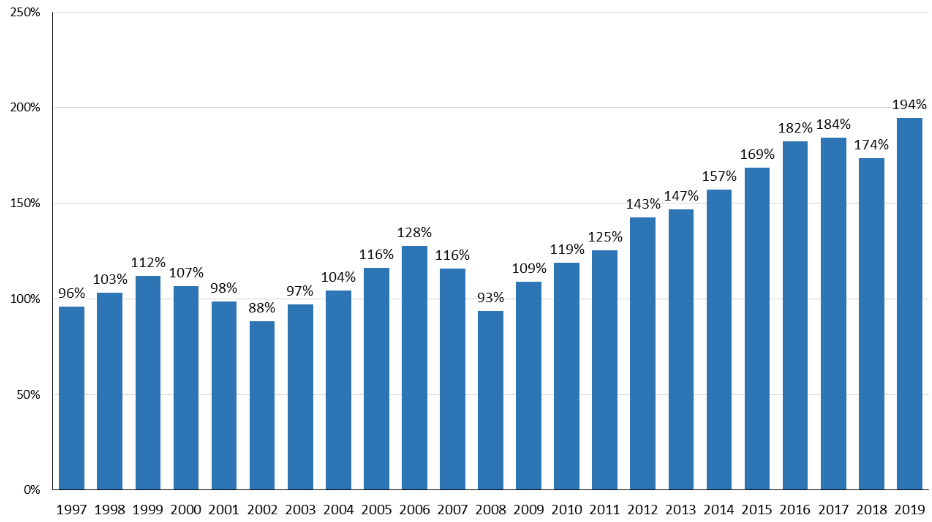

Figure 1: Assets in retirement savings plans in the Netherlands
Source: OECD Global Pension Statistics, 2020

affect financial stability.

The significant growth of the pension sector worldwide has been encouraged by policy makers fearing the effects of demographic change. A report of the World Bank (1994) advised governments to adopt "multipillar" pension systems in which the main part of retirement income should be provided by both mandatory and voluntary pension funds, the pay-as-you-go (PAYG) scheme remaining only as a basic re-distributive pillar[3]. The European Parliament adopted this directive in 2003[4], with the aim of using pension funds as an instrument to increase the integration of financial markets across Europe. Up to this day, many countries in the European Union still rely heavily on PAYG pension schemes. The Netherlands with a quasi-mandatory second pillar remain an exception. In the euro area, they are the only country with a ratio of pension fund assets over 100% of GDP. Figure 1 illustrates the evolution of the Dutch pension funds' total asset holdings in absolute value and as a ratio of GDP over the last two decades[5]. While the relative amount of pension asset holdings to GDP was fairly stable around 100% before the financial crisis, we observe a significant growth after 2008. To some extent, this pattern has been stimulated by demographic change. Mainly referred to as a challenge for PAYG systems, funded systems are also put under pressure by an aging population and ever-rising life expectancy, albeit rather indirectly[6]. The substantial growth trend in Dutch pension funds' asset holdings also coincides with the introduction of unconventional monetary policy. Lowering the short term rate for expansionary real effects became

[3]A PAYG system works as social insurance: the currently working provide for the retired. This resembles a contract between generations, Brunner (1996).

[4]The Directive 2003/41/EC of the European Parliament and of the Council on the activities and supervision of institutions for occupational retirement provision.

[5]See https://www.oecd.org/pensions/pensionmarketsinfocus.html.

[6]Aging societies constitute new economic conditions such as lower labor supply and demand, fewer investment and lower returns, different consumption patterns, i.e. Visco et al. (2005).

ineffective when the policy rate reached the Zero-Lower-Bound (ZLB) after the Financial Crisis. Central banks therefore started to adopt additional non-standard monetary policy measures, mostly summarized in quantitative easing (QE) policies. Conducting extensive Asset Purchases Programs (APP) changing the relative supply of assets on the markets, central banks are now affecting the entire yield curve and depressing the long-term interest rates. Pension funds in response see returns from their traditional long term and minor risk investments in debt diminishing. They are pressured to alter their strategies: the low interest rates threaten their funding status considerably by rising the present value of future liabilities. To meet their trustees' obligations, pension funds might therefore engage in a search for yield further than ever before, shifting their assets towards riskier categories offering a higher return. This search for yield in turn induces the portfolio rebalancing transmission of UMP: the funds' equity investments ease borrowing restrictions for agents not directly benefiting from the APPs, possibly contributing to stimulate the economy.

While the results presented are country-specific for the Netherlands, they are intended to encourage further research on the links between demographic change, pension schemes, and the macroeconomy. Understanding them is indispensable in the context of designing economic policies for the aging European society as their interactions are altering economic foundations.

The rest of the paper is structured as follows. Section 2 provides a review of the current literature and section 3 provides insight into the role of pension funds in general and their characteristics. Section 4 explains the main data used and section 5 explains the empirical research provided as well as the identification approach used. Section 6 reports the results and section 7 entails the discussion. Section 8 provides conclusions.

2 Literature Review

Despite the extensive literature on the effects of unconventional monetary policy on the real economy and the financial sector, only a few have touched on how monetary policy affects the portfolios of pensions funds directly. While it has been documented that low interest rates influence their funding status through a substantial increase in the present value of their liabilities, Antolin et al. (2011), it has hardly been investigated how exactly interest rates affect the portfolio composition of pension funds.

The search for yield is commonly analyzed as the risk-taking channel of monetary policy in the literature. It is defined by Yellen et al. (2011) as "a sustained period of very low and stable yields may incent a phenomenon commonly referred to as "reaching for yield", in which investors seek higher returns by purchasing assets with greater duration or increased credit risk". B. S. Bernanke

(2013) states similarly that investors and portfolio managers might "reach for yield" by taking on more credit risk, duration risk or leverage in order to yield higher returns[7].

The search for yield behavior of institutional investors and insurers is discussed more widely in the literature. This line of literature focuses on how pension funds have shifted from their traditional investments in bonds to holding riskier securities such as equities or alternative assets[8] in order to achieve higher returns, e.g. Rauh (2009). As low interest rates increase the liabilities of pension funds due to a smaller discount rate, De Nicolò et al. (2010) argue theoretically that due to their longer duration of liabilities compared to assets, a low interest rate motivates pension funds and insurers to search for yield in riskier asset classes. Chodorow-Reich (2014) provides empirical evidence of increased risk-taking for private US pension funds from 2009 to 2012. Focusing on the change in risk taking behavior induced to pension funds via the low interest rate environment, Boubaker et al. (2018) find that for US pension funds the share of equity investment has risen significantly and is accompanied by a decrease in the share of fixed income securities in the aftermath of the financial crisis. Using a vector-autoregression, this paper is, to our best knowledge, closest to our analysis.

With conventional monetary policy being limited at the ZLB, the ECB has adopted a variety of additional unconventional monetary policy measures to stimulate the economy via improving monetary conditions. A key tool of those policies has been the large-scale asset purchases which are commonly referred to as quantitative easing (QE)[9]. Portfolio rebalancing, policy signaling, and liquidity effects have been debated as channels through which QE affects the macro-economy. Among others, Bernanke (2010), Yellen et al. (2011) and Bean (2011) have emphasized the portfolio balance channel as a major transmission mechanism of monetary policy in the US and the UK correspondingly. The portfolio rebalancing channel goes back to the work of Tobin (1963), arguing that under imperfect substitutability between financial assets, changes in asset supplies result in financial asset price changes. The idea that central banks can influence economic activity and inflation via this channel was further developed by Friedman and Schwartz (1963): accordingly, a central bank purchasing assets from non-banks increases liquidity. If the sellers perceive money as an imperfect substitute, it is likely that they rebalance their portfolios with other, riskier assets, e.g. buying corporate bonds rather than low risk bonds, so-called gilts[10]. During the rebalancing process, asset prices rise until investors are indifferent between the overall money supply and financial assets. In short, the portfolio rebalancing channel works by APPs reducing the yields of

[7] See also B. S. Bernanke et al. (2012).

[8] Broadly speaking, alternatives are investments in assets other than stocks, bonds and cash, for example: private equity and hedge funds.

[9] APPs have since then become a standard tool to ease monetary conditions, e.g. a pandemic emergency purchase program worth 1,350 billion euro (September 2020) is intended to ease the economic effects of the Covid-19 pandemic.

[10] A gilt describes a low risk fixed income financial instrument which yields a correspondingly low rate of return.

long term securities, inducing a search for yield behaviour especially for institutional investors and insurers [11]. Unconventional monetary policy then indirectly eases borrowing constraints for riskier economic sectors by putting pressure on their credit supply.

Most empirical research on the portfolio rebalancing channel infers the latter's existence only indirectly from the behavior of government bond yields and other asset prices, e.g. Gagnon et al. (2010) and Joyce et al. (2011). While the literature on the direct impact of QE on the investment behavior of financial institutions has been limited, Joyce et al. (2014) find that in the UK, QE led to institutional investors shifting their portfolios away from government bonds toward corporate bonds. Note, however, that for example Bams et al. (2016) find that pension funds have decreased their exposure to equity and increased their fixed income holdings, which is counter-intuitive to the literature on strategic asset allocation. As low interest rates decrease bond yields, one would rather expect equities becoming relatively more desirable as an investment option.

Common to most theoretical macroeconomic models are assumptions of perfect substitution between assets. They impede that changes in the quantities of assets alter their prices and hence results in the private sector consolidating the public sectors balance sheet into its own. Eggertsson and Woodford (2003) therefore label the portfolio rebalancing channel as irrelevant. However Vayanos and Vila (2009) and Gagnon et al. (2011) show that less restrictive assumptions such as "preferred-habitat" theories [12] and different types of agents allow portfolio rebalancing effects.

The expansion and innovation of financial markets have been observed to be closely linked to the growth of pension funds, i.e. Bonizzi and Churchill (2017), Lysandrou (2011). Their demand-side pressure for assets generating significant returns while being manageable in risk continuously sparks the innovation of new instruments and growth in financial markets. The long-term investment behavior of institutional investors managing major parts of domestic savings fosters long-term capital market development, Opazo et al. (2015), Eichengreen (2009). They are therefore found to have the potential to affect economic growth rates as well: Bijlsma et al. (2014) provides empirical evidence that the size of funded pension systems has a positive effect on economic growth in 34 OECD countries. Growing pension savings are hence related to a deepening of capital markets and in particular beneficial for firms heavily relying on external finance. The European Commission (2013) sums up that pension funds long investment horizon enables them to behave in a patient, counter-cyclical manner and reduce the need for maturity transformation, contributing to more efficient financial markets that enhance economic growth.

[11] For the portfolio rebalancing channel to work, institutional investors are essential, as can be seen by the example of Japan, where most of the Japanese government bonds were hold by banks used to deleveraging without increasing the demand for other assets.

[12] See e.g. Modigliani and Sutch (1966).

3 Characteristics of the Dutch pension system

Commonly recognized to have one of the world's most comprehensive pension system at its disposal, the Netherlands offer a favorable environment to investigate the effects of economic policies to pension funds and their portfolio allocations. The Dutch pension system consists of three pillars, the first one being a pay-as-you-go scheme funded through social security contributions of the working population. It provides a minor flat, public pension, intended as a redistributive anti-poverty tier. The quasi mandatory second pillar is constituted of occupational and industry specific pension funds that manage employees' additional savings. Those are provided as joint contributions from employers and employees. Individually arranged private pension schemes define the complementary third pillar. As up to 2020, Dutch pension funds mainly operate as defined benefit schemes (DB)[13], our analysis focuses on this type of plan. The reader should however be informed that this is a backward looking analysis as in June 2019 a framework agreement for the reform of the Dutch pension system has been signed. It dictates that DB pension schemes will be terminated by 2027, starting in 2023, new pension accruals will only be provided via defined contribution (DC)[14] schemes based on the available premium starting in 2023. The goal of DB schemes is to generate the highest return possible that complies with the contemporaneous liabilities and liquidity needs of the pension plan at an acceptable level of risk, e.g. measured in terms of the probability of underfunding. The way in which pension funds' assets are invested impacts the level of required premiums or final benefits considerably.

Pension funds' portfolios are typically divided in two categories, a return-seeking portfolio to cover future long term liabilities as well as a liability-matching portfolio minimizing the resulting volatility. The structure and exposure of their liabilities drive their investment strategy, which is therefore often called a liability-driven investment strategy. Generally, there is no agreement in the literature on the optimal asset allocation of pension funds. As an advantage of a portfolio consisting mainly of equities is commonly listed that in the long run their extra return in form of the risk premia will outweigh the short term volatility risk. On the other hand, a portfolio based primarily on fixed income securities resembles closely the pension fund's liabilities from future payment obligations. Hence, a bond portfolio is specifically good at providing the certainty that the fund will be able to meet its obligations.

The investment strategy of pension funds is not only monitored periodically regarding its adequacy to the economic situation but it is also subject to regulation. Dutch pension funds face almost no

[13]In a DB scheme, the future payment to the policyholder is pre-determined, or has at least a guaranteed minimum amount.

[14]In a DC scheme, the regular contribution (or "premium") paid to the scheme is fixed and the value of the policyholder's pension wealth depends on the performance of the pension funds' investments.

legal restrictions regarding their investment decisions. Their regulation framework is based on the prudent person rule[15]. However, the Netherlands were the first country implementing risk-based capital requirements for pension funds. Since 2007 the Financial Assessment Framework dictates that besides a 105% funding ratio[16] pension funds have to set capital buffers corresponding to the requirement of being fully funded with a 97.5% of confidence. The specific capital buffer requirements depend on the given asset's impact on the riskiness of the portfolio. Boon et al. (2014) show that this regulation resulted in a decline of risky assets in portfolios of about 5% on average. This trend of de-risking could hence via demand-supply imbalances on financial markets lead to problems for financial stability and create incentives for pro-cyclical investments, Severinson and Yermo (2012).

4 Data

We analyze quarterly data of economic and financial variables over the period from 1999:Q1 to 2020:Q4. We choose this starting point as it represents the available data for the Dutch pension system[17]. The period we analyze hence includes several periods of financial distress: the dot.com crisis at the beginning of the century, the financial crisis in 2008, a period where the short-term interest rate reached the ZLB, the credit crisis in 2015, and the most recent Covid pandemic in 2020.

The dataset used for the Dutch pension funds' asset holdings is provided by the De Nederlandsche Bank (DNB). It contains all pension funds operating under the second and third pillar of the Dutch pension system. It provides an extensive breakdown of asset holdings in categories based on accounting definitions of the European System of accounts (1995)(ESA): real estate, shares and other equity, securities other than shares, financial derivatives, loans, deposits and other liquid assets, re-insured technical provisions, other non-financial assets and other assets. For our analysis, we further categorise this extensive breakdown of funds' asset holdings into three main categories, namely "shares and other equity", "securities other than shares" and "other". This dataset is illustrated in Figure 2.

For our second approach the data used is derived from a DNB dataset on assets invested at pension funds' own risk. It represents the market value of investments from 2007:Q1 to 2020:Q4. Importantly, the assets are classified by a so called look-through principle, indicating that they are grouped according to their ultimate underlying investment category. This dataset accordingly

[15] Article 135 of the Dutch Pensions Act states that a pension funds' investment must be in the best interests of active and former members and pensioners.

[16] The funding ratio consists of assets as a share of liabilities.

[17] For the years up to and including 2005, the data of the pension funds were derived from a joint survey conducted by Statistics Netherlands and the DNB.

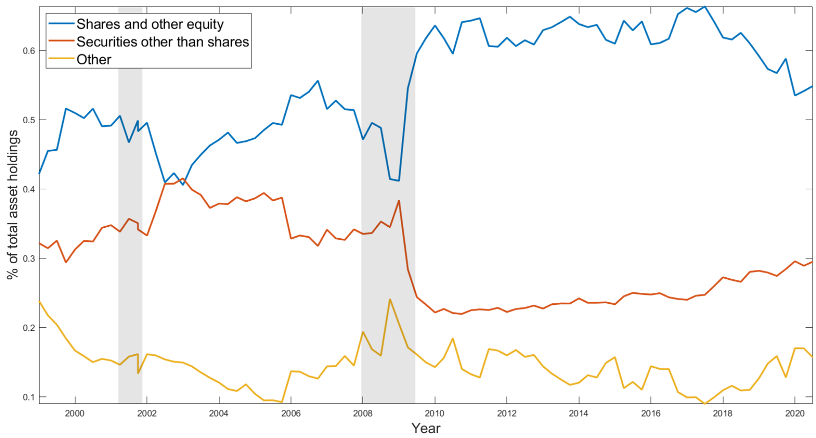

Figure 2: Asset Allocation of Dutch pension funds (accounting definitions) from 1999:Q1 - 2020Q4
Source: De Nederlandsche Bank (DNB)

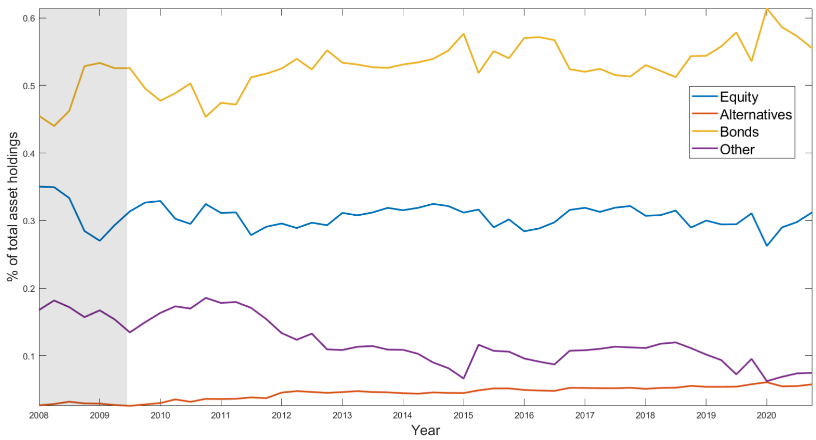

Figure 3: Asset Allocation of Dutch pension funds (look through approach) from 2008:Q1 - 2020Q4
Source: De Nederlandsche Bank (DNB)

breaks the pension funds' asset holdings down into seven categories: real estate investments, equities, alternative investments, fixed yield securities, hedge funds, commodities and other investments. We proceed by using the three main asset categories of interest for our analysis, namely "equities" plus "alternative investments"[18], "bonds" corresponding to fixed yield securities [19] and "other" consisting of the remaining asset categories. This dataset is illustrated in Figure 3. As a proxy for monetary policy in the Euro area we use the dataset of Wu and Xia's ECB shadow rate calculated according to Wu and Xia (2020) and Wu and Xia (2017), constructing the quarterly average. The shadow rate proposes a coherent summary of monetary policy as Figure 13 illustrates: it behaves similarly to the Euro Over Night Index Average EONIA rate when the ZLB is not binding and

[18] Alternative investments are mainly private equity, infrastructure and micro-financing where private equity is equity that is not traded publicly.
[19] Government bonds, mortgage loans, credits, short term claims on banks and investment bond funds.

turns negative otherwise, accounting for unconventional policy tools. In short, the Wu Xia rate is constructed via one-month forward rates. It is assumed to be a linear function of three latent variables called factors, which follow a VAR(1) process. The latent factors and the shadow rate are estimated with the extended Kalman filter [20].

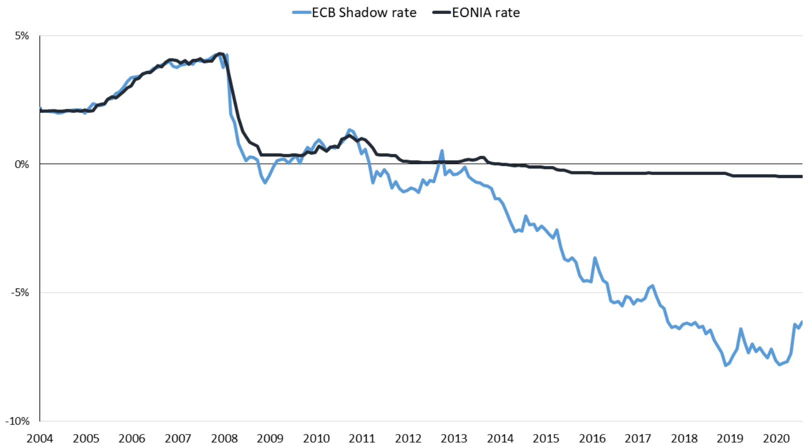

Figure 4: Monetary Policy: Euro OverNight Index Average and Wu-Xia's ECB shadow rate

It is hence able to capture the effects of the large scale asset purchase programs (APP) of the ECB. As it exhibits similar dynamic correlations with economic variables after the Great Recession as the short term interest rate did in the pre-crisis period it is commonly used to study the effects of unconventional monetary policy.

Observations for Dutch macroeconomic characteristics were obtained from several sources. GDP and unemployment were gathered from the FRED of the St. Louis Federal Reserve (FRED). To capture the effects on the Dutch yield curve, datasets for the two- and ten-year Dutch government bond yields were derived respectively from the Macrobond database and FRED. Finally, to account for domestic stock prices we use a dataset on the performance of the Amsterdam Exchange Index (AEX)[21]. To control for global stock prices we make use of observations of the MSCI world index performance, gathered via the Macrobond database.

5 Model

To evaluate if the monetary policy of the ECB affects Dutch pension funds' asset allocation we apply a standard SVAR approach. In a similar fashion, we investigate the behaviour of the Dutch real economy in response to a shock to the size of the pension sector as well as to a change in its portfolio composition. SVARs are one of the most popular tools to investigate the transmission mechanisms of shocks to the economy since the introduction of VARs by Sims (1980). Implementing

[20]See in detail at https://www.atlantafed.org/cqer/research/wu-xia-shadow-federal-funds-rate.aspx?panel=1.

[21]A stock market index composed of Dutch companies that trade on Euronext Amsterdam.

this strategy allows us to examine the joint impulse responses of economic and financial variables to an exogenous monetary policy shock, or a total asset shock. The different SVARs are described in the following paragraphs, starting with our various models showing the effects of monetary policy on Dutch pension funds' asset allocation.

5.1 Effects of a monetary policy shock on the portfolio composition

With our first, main model, we estimate the dynamic response of key macroeconomic variables to a monetary policy shock. Let Y_t denote the vector of variables included in the analysis. We partition Y_t as follows:

$$Y_t = \begin{bmatrix} Y_{1t} & SR_t & Y_{2t} \end{bmatrix}' \tag{1}$$

The vector Y_{1t} is composed of the pension funds' asset holdings based on ESA, in the following order; shares and other equity, securities other than shares and others. The shadow rate, denoted by SR_t is the fourth variable, followed by the vector Y_{2t} that consists of the time t values of fast moving financial variables supposed to react contemporaneously to the monetary policy shock. They embody endogenous control variables, namely, we use the spread between the ten-year and the two-year Dutch government bond, the AEX and the MSCI World Index, in said order.

All asset holding variables as well as the equity price indices are taken in log-levels and multiplied by 100 to express the impulse response functions in percentage rates of variation. Both the shadow rate and the spread are denoted in the corresponding difference between quarters. We use the shadow rate as our indicator of monetary policy actions of the ECB because as explained above in Section 4, it is able to account for the effects of unconventional monetary policy measures.

The identification concerns the short term dynamics and hence uses zero contemporaneous restrictions following B. Bernanke and Blinder (1992). It focuses on the monetary policy shock which is identified as the fourth Cholesky shock in the VAR and is embodied by the ordering of the variables in Y_t, as the key identifying assumption is that the variables in Y_{1t} do not respond contemporaneously to the monetary policy shock. Economic intuition for these identification assumption is provided below.

Our model is hence constructed by seven multivariate linear equations describing the mutually dependent dynamics of the variables given. The residuals of the autoregressive equations are combinations of the underlying structural shocks that are by assumption orthogonal to each other. This allows us to identify the reaction of the model variables to an explicit shock.

Both the application of the Aikaike information criterion and the Bayesian information criterion, Akaike (1979), yield an optimal lag length of one[22]. Our reduced form model specification therefore reads

$$Y_t = \mu + \phi \, Y_{t-1} + \epsilon_t \tag{2}$$

where μ denotes a constant[23]. How to move from the reduced form VAR(1) to the SVAR used for our estimation is shown in detail in Appendix A. We evaluate the resulting SVAR model for both the pre- and post-crisis period, from 1999:Q1 to 2007:Q4 and from 2008:Q1 to 2020:Q4. Note that for the pre-crisis period, the shadow rate is equal to the EONIA rate.

Following the same approach we construct a model based on the De Nederlandsche Bank (DNB) dataset of investments at pension funds own risk. This is the so called look-through approach further explained in section 4. Hence, compared to the above only the pension funds asset holding variables change and read, in that order, total bond holdings, the sum of total equity holdings and total alternative holdings, and other holdings. These variables are again taken in log-levels multiplied by 100 to express the impulse response functions in percentage rates of variation. We run this VAR for the period from 2008:Q1 to 2020:Q4.

The monetary policy shock is identified by the restriction that it has no contemporaneous effects on the pension funds asset allocation. This is a realistic assumption as pension funds as long term institutional investors generally follow long-term rebalancing horizons for the majority of their total assets under management. Those are defined as restrictions a fund imposes on itself and bundled in a funds' strategic asset allocation[24], see e.g. Campbell et al. (2002).

Rebalancing refers to the investment process applied to ensure that a fund's actual asset allocation continuously equals its strategic one. This implies selling asset holdings after relative high market returns and buying after relative low returns. Funds' long term horizon allows them to smooth and absorb short-term volatility in the margins of their long term strategic asset allocation, Schembri (2014). We are aware that short term deviations, e.g. in response to arbitrage opportunities, are often desirable providing short term profits. However, such moves fall under tactical asset allocation, which is not a subject for this paper and should be delegated to the day to day investment manager of the funds. Consistent deviations from the strategic asset allocation are only possible by adjusting the latter, which is time consuming: the strategic asset allocation is the result of carefully monitoring and evaluating long term trends of economic factors, see e.g. Campbell et al. (2002).

[22]This is in line with the literature as we use quarterly data and have only five to seven variables, as we all as only up to 50 observations.

[23]A constant is used to satisfy the critical regression assumption that the residual average equals zero.

[24]Each pension fund's investment policy includes the strategic asset allocation decision, which refers to choosing the investment percentages in each asset class.

As it has to be agreed on by the funds governing body and managers, the process of adjusting to a new economic environment takes time. In a survey of 57 UK-based DB schemes, 77% of respondents said it took a minimum of three months to take a new investment idea from discussion to implementation[25].

Therefore, during a quarter the pension funds re-balance to their ex-ante asset allocation to comply with the margins of the previously decided strategic target. Complementing the above, Bikker et al. (2007) find that the equity allocation of Dutch pension funds does not respond contemporaneously to shocks in the short term.

As already stated, following Gertler and Karadi (2015) we order the fast moving financial variables given by the spread and the equity indices last, as they react contemporaneously to changes in monetary policy[26]. Under this approach we prevent the problem of simultaneity: within a period, monetary policy does not only affect financial variables but might also be responding to them. Although the central bank might not respond to the financial indicators explicitly, there is a chance that the bank is taking into account variables that could be correlated with our model but are left out.

These restrictions then allow us to estimate the mutual relationships between the model variables and make it possible to express them as linear functions of current and past structural shocks. The resulting impulse response functions are obtained from the coefficients of the model equations.

5.2 Effects of shocks to the pension sector to the real economy

To evaluate real economic effects we construct again a VAR with a short term Cholesky identification scheme. We follow the same approach as above and build a SVAR based on eight multivariate linear equations with our Y_t partitioned as follows:

$$Y_t = \begin{bmatrix} Y_{1t} & RA_t & TA_t & SR_t & Y_{2t} \end{bmatrix}' \tag{3}$$

The vector Y_{1t} now contains, in that order, real GDP and unemployment. The consequent reallocation variable RA_t accounts for shifts in the portfolio composition from equity and alternatives towards bonds and vice versa. It is hence reads

$$RA_t = Equities_t + Alternatives_t - Bonds_t \tag{4}$$

[25] See https://www.funds-europe.com/pension-schemes-remain-slow-to-make-investment-decisions.

[26] There exists a direct relationship between conventional monetary policy and the short term interest rate: changes in the ECB policy rate influence the spread, i.e. the slope of the yield curve, contemporaneously through the short term interest rate. Due to sticky prices and the expectation hypothesis, long term interest rates also decline, but by a lesser amount than the decline in short term interest rates Nsafoah and Serletis (2019).

as we suspect a search for yield behaviour we are ultimately interested in leading to a shift of the asset classes in the direction of the assigned sign in equation 4. Hence, an increase in the reallocation variable originates either in investments in equities or alternatives rising or investments in bonds declining. The fourth variable TA_t denotes the total asset holdings of Dutch pension funds while SR_t again represents the ECB shadow rate. The vector Y_{2t} is equal to the one in our first model, containing again the fast moving financial variables that are contemporaneously affected by the shocks. As we only control for monetary policy in this second approach, the shadow rate behaves similarly contemporaneous with the shock.

We identify the total asset shock as the fourth Cholesky shock and impose with our restriction that the total asset shock has no contemporaneous effect neither on real GDP, unemployment or neither on the reallocation between asset classes. The economic intuition of the latter originates again in the strategic asset allocation being adjusted only with a lag in response to the economic environment. This way, our assumptions are consistent over different model specifications. Further, GDP and unemployment reacting slowly to a monetary impulse is standard in the literature, e.g. Gertler and Karadi (2015). We place GDP on top as it reacts to all the variables in our model.

We conduct several robustness checks. For instance, we place our shock variables all individually first in their corresponding VAR, making sure that they are not significantly driven by any other variable in the model but exogenous. Further, we use two different datasets for our first model, yielding comparable results. We provide detailed results of those checks in Appendix B.

It is important to address that our analysis seems to remain to some extent limited as we do not control for regulatory changes on the national or international level. However, the only major regulatory change the Dutch pension system underwent in the period of investigation is the introduction of the Financial Assessment Framework in 2007 as mentioned in section 3. The timing therefore coincides more or less with the split of our sample period, hence we expect it to not influence the results. All analyses for our defined UMP period starting in 2008 then naturally are subject to the same regulatory scheme.

6 Results

6.1 Effects of a monetary policy shock on the portfolio composition

The results of an expansionary monetary policy shock on pension funds' asset allocation are presented in Figure 5. A negative shock to monetary policy of around 40 basis points yields a shift from securities other than shares to shares and other equity. Concretely, it rises shares and other equity by about 2.5% after one quarter and finally results in a persistent total increase of around 3% after three quarters. Securities however only decrease persistently by about 2.5%, while other shows a

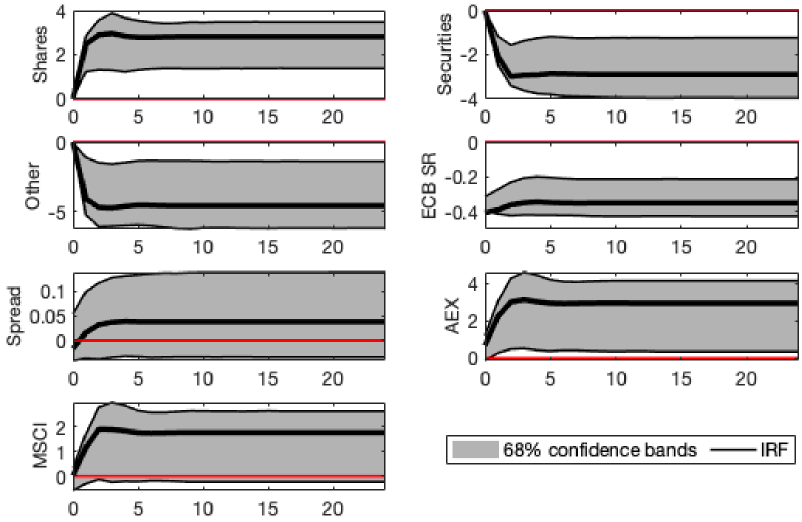

Figure 5: UMP effects on Dutch Pension funds' portfolios allocation (accounting definitions), 2008Q1-2020Q4

decrease in up to almost 5% in total after three quarters. Furthermore, from the Variance Decomposition (FEVD) we can observe that the change in shares and other equity is driven significantly by the change in the shadow rate over the sample period coinciding with unconventional monetary policy measures, see Figure 6. It is interesting to note that this shift can only be observed after

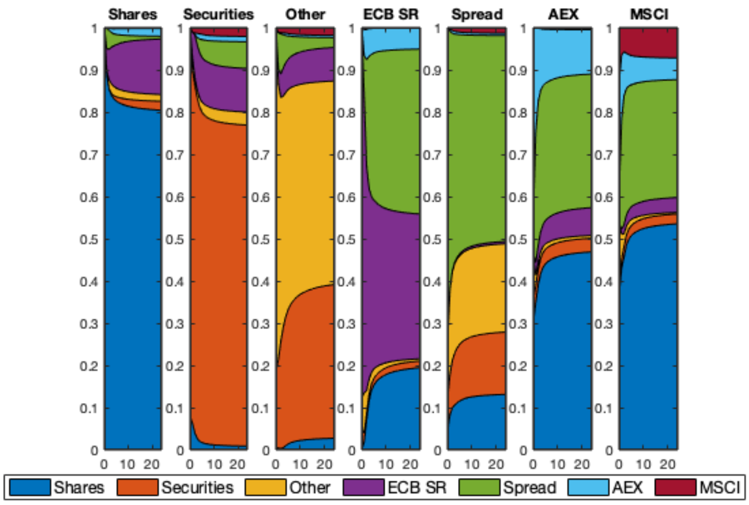

Figure 6: FEVD: Effects of UMP on Dutch Pension funds' asset allocation (accounting definitions), 2008:Q1 - 2020:Q4

the financial crisis, the impulse response functions presented account for the period from 2008:Q1 to 2020:Q4. In the pre-crisis period from 1999:Q1 to 2007:Q4 we cannot find significant evidence for an effect of monetary policy on asset allocation, see Figure 7.

In our sample period of conventional monetary policy (MP) in response to a monetary policy shock funds might rather move within instead of between classes, e.g. from short- to long-term bonds.

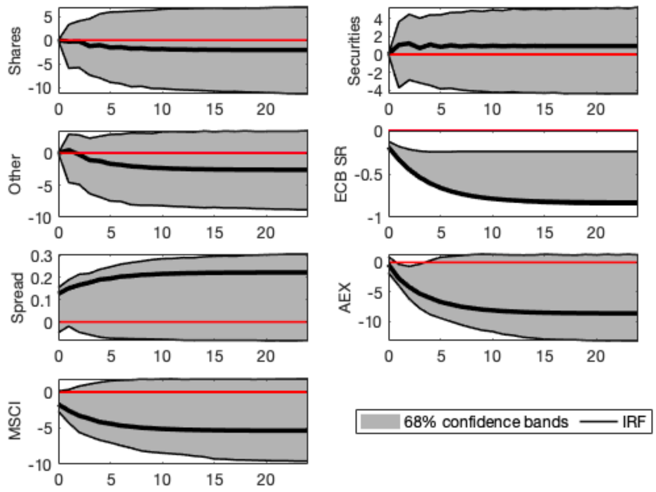

Figure 7: Effects of MP on Dutch Pension funds' asset allocation (accounting definitions), 1999:Q1 - 2007:Q4

This difference in the importance of monetary policy for the asset allocation might hence originate in the change from conventional to unconventional monetary policy conduction, which is included in the shadow rate used as our shock. The variance decomposition in Figure 8 further suggests

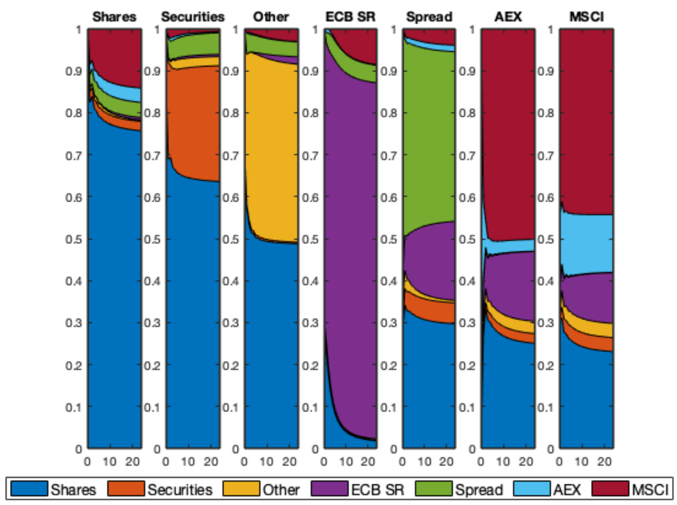

Figure 8: FEVD: Effects of MP on Dutch Pension funds' asset allocation (accounting definitions), 1999:Q1 - 2007:Q4

that the movement of the portfolio variables is only to a minor part influenced by the spread, the EONIA rate contributes almost nothing to their dynamics.

These results already indicate that there is movement in the portfolio composition of the Dutch pension funds in response to an unconventional expansionary monetary policy shock.

Notably, we observe a different pattern in the behaviour of the monetary policy shock depending on the time period analyzed. These dynamics are due to the fact that in conventional times we are looking at observable fluctuations of the EONIA rate in response to economic conditions. However, the unconventional monetary policy shock is immediately persistent in value as it also captures the QE measures forced onto the economy and are incorporated in the shadow rate.

It has to be pointed out that the quarterly dataset of the DNB based on the the ESA 1995 accounting definitions does not distinguish specifically between underlying asset classes such as equity, bonds and alternatives.

We can therefore not be sure whether the underlying instrument holdings in these categories are in bonds or in equity and alternatives. Shares and other equity might as well include bonds. In order to illustrate this problem, we provide the following example: Shares in other investment funds are a part of the former category. As there is no provision of a further breakdown of assets in which those funds invest in, we cannot know if the investment funds invests in bonds or other assets. Therefore, we can from this first result not argue with certainty that the monetary policy shock results in a movement from one asset class to another.

In line with the asset allocation literature we would however expect an expansionary monetary policy shock to result in a shift from bond holdings to equity and alternatives. Such behavior would have an effect on the funds individual risk exposure and likely even have implications for financial stability, given the sheer size of the funds. That is why for further analysis we follow a look through approach by using data on assets invested at pension funds' own risk which categorizes the underlying assets of pension funds' holdings, as discussed in Section 4. Figure 9 illustrates the effects of an expansionary monetary shock on the Dutch pension funds' total asset holdings in equity, bonds and alternatives. The shock is equal to the one above, scaled to a decrease of 40 basis points of the shadow rate on impact. These findings show a similar direction of behaviour as

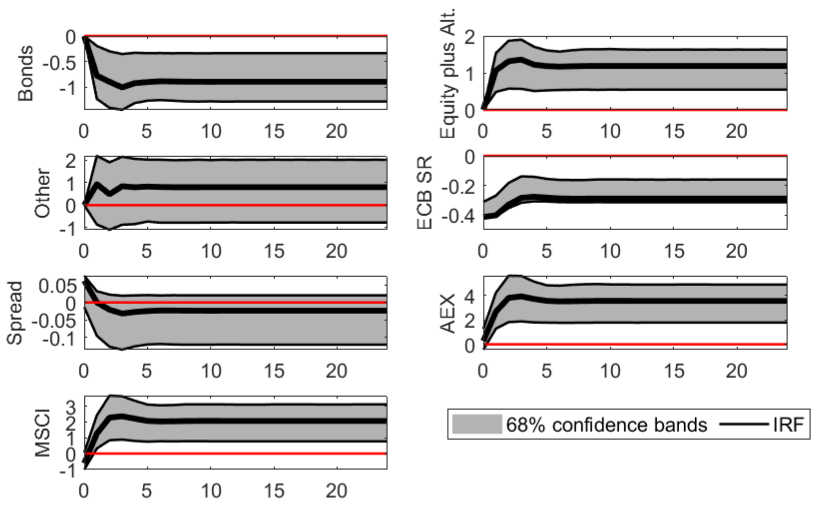

Figure 9: UMP effects on Dutch Pension funds' portfolios allocation (look through approach), 2008:Q1 - 2020:Q4

the one observed in Figure 5. The decrease in the policy rate leads to a total, persistent increase in equity and alternatives of about 1.2% after five quarters. The decline in bonds is persistently about 1% after three quarters. Moreover, confirming what the literature tells us, equity prices react to the new environment contemporaneously by increasing. It has to be mentioned that the decline in bonds is notably smaller than in our first approach, hence our thought that we would mislabel investment instruments was adequate.

The corresponding variance decomposition, see Figure 10, still stresses the importance of the shadow rate dynamics for the reallocation effect in unconventional times. It is also noteworthy that we can now also observe the changes in bond holdings affecting the dynamics of equity and alternatives significantly, pointing again to the fact that we are now classifying the financial instruments correctly. This latter approach allows us to state with confidence that unconventional monetary policy

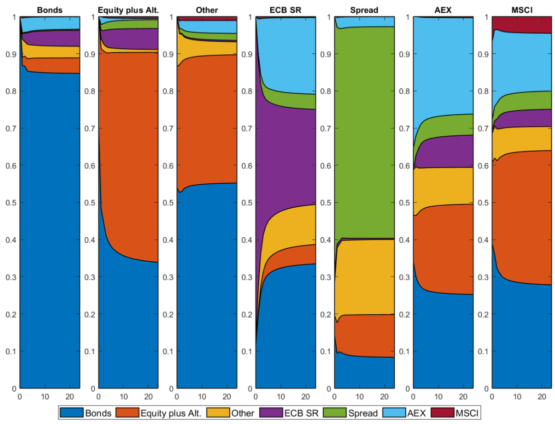

Figure 10: FEVD: UMP effects on Dutch Pension funds' portfolios allocation (look through approach), 2008:Q1 - 2020:Q4

measures shift the investments of Dutch pension funds' from bonds towards equity and alternatives. While the level of this transfer seems to be small at a first glance, when recalling the sheer size of the total pension funds' asset holdings it becomes obvious that even a one percent shift into equity can catalyze a significant response in stock markets. This holds especially for the domestic one, e.g. Galı and Gambetti (2015).

Unfortunately, due to data restrictions, we cannot perform a pre-crisis estimation similar to our look through approach above. However, it is likely that we would again yield insignificant results as our results from the look through approach also mirror the direction of our first findings.

6.2 Effects on the real economy

As the pension funds have become one of the largest investors in the financial markets we proceed to investigate whether their size is able to influence the real economy exogenously. Because of the

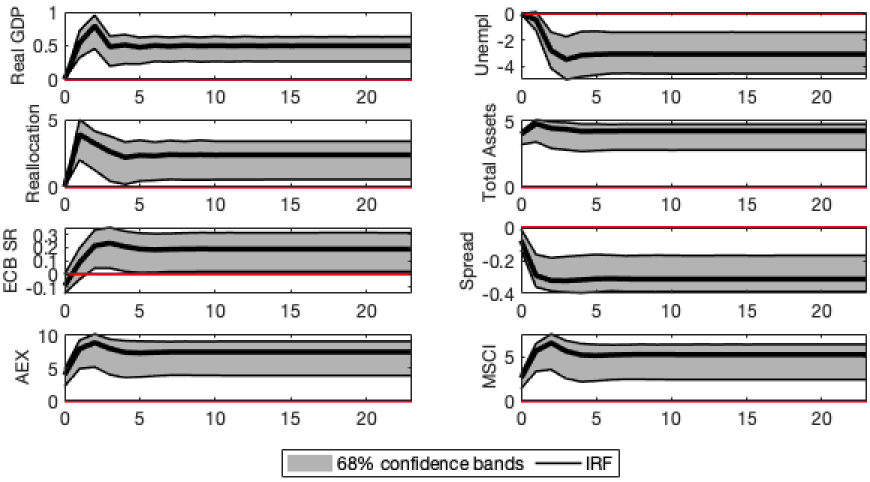

Figure 11: Effects of a total asset shock to the Dutch real economy, 2008:Q1 - 2020:Q4

sheer size of the pension fund sector, an increase in total assets by up to 5% describes a large amount of additional new holdings. Due to the limited supply of pension funds' preferred minor risk, stable return assets on the financial markets, we expect such a shock to ultimately effect the asset allocation of the pension funds. Therefore, we decide to control for this change in asset allocation via our reallocation variable. This way we make sure that the observed change in GDP is due purely to the shock in the size of the pension sector and not driven by a change in asset allocation.

The results presented in Figure 11 allow us to confidently state that a rise of around 5% in total assets of Dutch pension funds increases GDP, peaking at by 0.8% after two periods and settling down at a persistent change of 0.5% afterwards. This expansionary effect on the Dutch real economy is also visible in the persistent decrease of unemployment of about 3% after two periods.

Interestingly, the increase in total assets seems to be mainly invested in equities and alternatives in the first period after the shock, however this supports our argument that the short term supply of the funds' preferred instruments is limited, they need time to adjust to a new strategic asset allocation in response to the new economic situation.

The economic environment created by an increase in total assets leads contemporaneously to a significant contractionary monetary policy path after two quarters, a decrease in the spread between the ten-year and the two-year Dutch government bonds as well as an increase in the equity price indices, which is due to the exceptional increase in asset demand and its expansionary effect on the real economy, in line with our expectations. The variance decomposition, see Figure 12, confirms the importance of total assets for the expansionary real effects, the change in GDP is driven up to 20% by the shock to total assets. The same holds with a lag and to a smaller extent for unemployment.

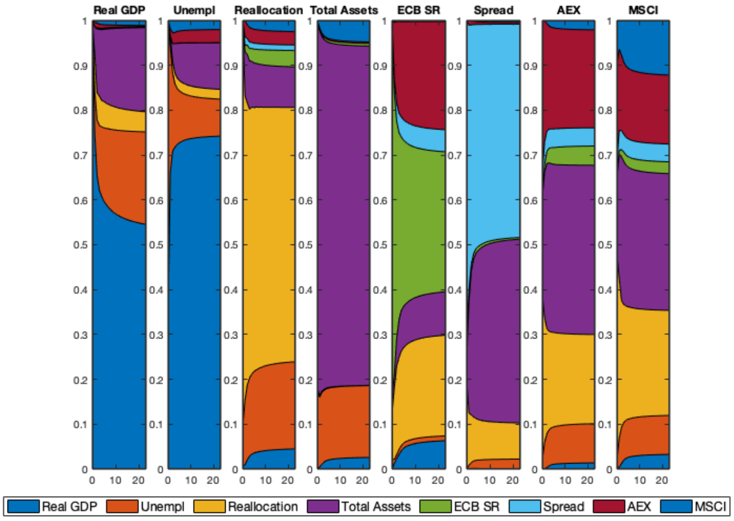

Figure 12: FEVD: Total asset shock effects on the Dutch real economy, 2008:Q1 - 2020:Q4

7 Discussion

Our SVAR approach provides evidence that unconventional monetary policy affects the asset allocation of the Dutch pension fund's sector portfolio. We observe a significant shift in asset holdings from bonds to equities and alternatives. This is in line with classical portfolio theory and the nature of pension fund's business model: to calculate liabilities, DB schemes, representing the major share of pension fund types in the Netherlands, discounting future cash flows using a rate that is linked to long-term interest rates. Hence, the lower the rate of interest, the higher the present value of liabilities. This weakens the long-term solvency of the funds and aggravates underfunding problems, especially since DB schemes committed a long term exact return promise to their trustees. Additionally, by increasing the present value of future increases in longevity, the low interest rate environment fuels the demographic challenge the funds are already facing, further worsening the solvency situation of the DB pension funds.

The behavior of pension funds following a decrease in the interest rate is therefore a reluctant but an essential response. A shock to the interest rate synonymously lowers bond yields. With bonds no longer delivering the returns needed to meet their guaranteed obligations, pension funds have not many other options than shifting to equities and alternatives offering a higher return.

It is common consensus that equity and alternatives on average offer a higher return while being riskier due to the fact that they do not promise a fixed return. The former is e.g. supported by calculations of 119 year global historical geometric averages of real returns[27]. Our results hence indicate that in the period from 2008 to 2020, Dutch pension funds were engaging in a „search for

[27] See Credit Suisse Global Investment Returns Yearbook 2019: https://www.credit-suisse.com/about-us-news/en/articles/news-and-expertise/global-investment-returns-yearbook-201902.html.

yield“. That is, they were explicitly seeking for higher expected returns through investing in assets with higher credit, interest rate or liquidity risk.

The funds' higher exposures in equity might be temporarily able to offset the drop in yield, however it has to be pointed out that this depends on an economy supporting equity gains, i.e. not slowing down.

Additionally, we have to address the reallocation towards alternative investments. While investing in long term projects such as infrastructure or private equity makes sense for institutional investors facing long term horizons, this poses several risks. Note that many of these alternative assets are not traded on markets, making it difficult to define their prices and expected returns. Moreover, they are to a large fraction highly illiquid. Having to set aside more liquid assets to cover the higher liquidity risks possibly implies that fewer funds are available to invest counter-cyclically. This goes in hand with pension funds having less flexibility to buy assets at distressed price levels. Hence, taking into account the above, the pension fund's search for yield combined with their size and tendency for herd-like behaviour might in the worst case be able to create asset price bubbles and to cause severe dislocations in financial markets. Similarly, the International Monetary Fund identifies in its 2019 financial stability report the increased holdings of riskier and more illiquid assets by institutional investors as a key vulnerability to the global financial system. However, this change in asset allocation could also constitute a chance for the role of institutional investors. By investing in infrastructure or equity, they might be important actors financing essential innovations, e.g. in the context of the transition to a carbon neutral economy.

Notably, we do not find evidence that conventional monetary policy before the financial crisis had any influence on the Dutch pension fund's portfolio allocation: an expansionary monetary shock to the EONIA rate[28] has no significant effect on pension funds investment behavior in the period from 1999 to 2007. Therefore, the investment behavior of Dutch pension funds reallocating their asset holdings between classes seems not to react significantly to changes in the short term interest rate. As pension funds are long-term investors, this is not surprising. Hence, we infer that the change in the portfolio composition following a shock of the same impact level to the shadow rate is driven by unconventional monetary policy succeeding in lowering the long term interest rates. With the shadow rate decreasing to significantly negative levels in response to the central bank's unconventional policy, Wu and Xia (2020), we are confident to interpret it as a proxy for the ECB's QE measures.

The rise in equity and alternatives can therefore be interpreted as evidence for the existence of a portfolio re-balancing transmission channel of QE in the euro area.

[28]The shadow rate variable before 2008 is equal to the EONIA rate.

As extensively described in Section 2, the portfolio re-balancing channel is suspected to be the main transmission channel of QE to the real economy. Our results confirm that institutional investors play a role in propagating the ease of credit restrictions to economic actors not able to profit from the extensive APP of the ECB directly. The process might be the following: In response to QE, we suspect the funds to sell their low-yielding government bond holdings to the ECB. When reinvesting the returns, they re-balance their portfolios which ultimately leads to a new strategic asset allocation. This induces the search for yield behavior extensively discussed above. Confirmed by our results, asset prices appreciate during this process.

The fact that bond holdings in our results only decline by a small amount might be due to the fact that from the data we can only infer the broad asset category, not each bonds specific type. In line with Joyce et al. (2014) we expect the pension funds to decrease government bond holdings, as their yields decrease significantly due to the QE measures. Pension funds are however still interested in decreasing the overall risk of their portfolio and might therefore shift toward corporate bonds, decreasing the level of the overall decline in bonds.

As pension funds have become increasingly important in financial markets an exogenous shift of Dutch pension funds towards equities and alternatives from bonds could stimulate domestic economic growth and decrease unemployment. This might be resulting from reduced credit constraints for Dutch firms, allowing for more investment.

Such an effect can be observed for an exogenous shock to the size of the pension sector. An increase in total assets boosts economic growth and labour productivity, decreasing unemployment. It is important to realize that this finding also implies a fall in GDP and a rise in unemployment in response to an exogenous decrease in pension funds' total assets. This might, in an extreme scenario, illustrate what could happen once several cohorts of the baby-boom generation start reaching retirement age claiming their benefits. Pension funds would then have to sell large amounts of assets, depressing their market prices.

Our results emphasize that pension funds have become major players in the economy. While they are subject to economic policy and regulation the pension funds are able to exogenously influence the economy, see Figure 11. This stresses the importance of policy makers starting to take them into account as active participants in economic policy processes.

These findings are of course country specific, however they are of broader interest for the general link between pension systems, aging and the macro-economy. Aging structurally affects the economic environment. Due to the baby-boomer generation's large savings, the capital to labour ratio has risen gradually. This development has been accompanied by a decline in the real interest rate balancing demand and supply on the capital market: demographic change in European countries has increased savings and with it the supply of capital for investments [29]. However, productivity growth has been declining gradually, reducing the return and demand for potential investments. Together with lower inflation expectations, these developments act as structural drivers for the decline in long term interest rates that began long before 2008. Interest rates are therefore likely to be lower for longer, regardless of a possible discontinuation of unconventional measures. This paper hence also intends to stress the importance of future research on demographic effects as e.g. the evolution of the size of funded pension systems on monetary policy conduction.

As presented above, pension funds are via the portfolio rebalancing channel able to act as monetary policy transmitters. For future research, investigating the effectiveness of this explicit channel on the real economy is a topic of interest. Our paper remains limited in a sense that we are not able to disentangle the exact effect of the APP from the shadow rate and can therefore not state to exactly what extent a change in the real variables would result from QE measures via the rebalancing channel or from direct unconventional monetary policy effects, e.g. from the credit channel. To grasp the effect of the reallocation channel on the real economy we propose to use data on the ECB's holdings from the various APPs directly.

Additionally, investigating the possibility of further monetary policy transmission channels operating via institutional investors seems promising. This is especially important considering that e.g. the change of the Dutch pension system towards a full DC system in 2027 will most likely alter the consumption and saving patterns of citizens. The importance of bank deposits could shrink, impeding the supply of bank loans to the corporate sector. Firms would then likely turn towards financial securities to finance their operations. This would imply an overall decline in the importance of the credit channel in the transmission of monetary policy regardless of "unconventional" times. Equally, this requires a deeper understanding of the influence of central bank policies on institutional investors and insurers.

Given the result that the level of collectively saved total pension assets is beneficial for economic growth in the Netherlands, we also encourage further empirical research especially regarding their systemic importance.

Despite the Netherlands currently being the only member of the euro area characterized by a significantly large pension fund sector, we are confident that our analysis contributes in shedding light on the possible role for pension funds in European financial markets and in transmitting monetary policy. This is especially important since the number of private, complementary DC schemes has been growing in many member states following the European Directive 2003/41/EC.

[29] With increasing life expectancy and equal age of retirement, individuals have to save more to keep their living standard over more retirement years.

8 Conclusion

Based on a structural VAR analysis, this paper provides evidence on the impact of the ECB's monetary policy on pension funds asset allocation. It also assesses the potential influence of the size of the Dutch pension system to the real economy.

This paper provides evidence of a significant impact of the ECB's unconventional monetary policy measures on Dutch pension funds' asset allocation. Concretely, we observe a search for yield behaviour in response to a monetary impulse in the period from 2008 to 2020. The resulting shift from bonds towards equity and alternatives moreover suggests the existence of a portfolio rebalancing transmission channel of monetary policy in the euro area.

These findings also imply that due to unconventional monetary policy the riskiness of Dutch pension funds' portfolios has been increasing gradually. Together with the Dutch pension sector holding assets in the value of 194% of GDP (2019) and the pension funds' tendency to herd-behaviour this might be affecting local financial stability and with it the safety of Dutch pensions.

Simultaneously combating the challenges of a low interest rate environment and demographic change, the Dutch pension sector has yet been growing significantly fast over the past decade. Our analysis has shown that changes to its total asset holdings can significantly impact economic growth and employment. While this sounds beneficial at first, it also raises concerns for the case of a negative shock to the amount of asset holdings: once the baby-boomer generation will start to claim their benefits, the funds will have to dissave significantly. The potential macroeconomic effects should be the topic of future investigation.

Although the Dutch pension sector is unique in the euro area, considering the fact that interest rates might also due to demographic change be lower for longer, our results still remain of interest for the broad public. Importantly it highlights the importance of institutional investors and insurers for economic policy conduction. As private DC schemes are on the rise in complementing PAYG systems around the euro area, their role might be of rising interest for policymakers and especially the ECB in the future.

Indicating the importance of including demographic factors to the analysis of the macroeconomic environment, this paper hence urges future research to contribute to a better understanding of the link between demographic change, growing pension systems and central bank policies.

Appendices

Appendix A Structural Vector-Autoregression

The structural form of a VAR(1) is given by

$$BY_t = B\mu + B\phi Y_{t-1} + B\epsilon_t \tag{A.1}$$

such that $B\epsilon_t \sim WN(0, I_N)$.

We have to recover this form from estimating our reduced form VAR given by Equation 2 and imposing appropriate restrictions. Those restrictions must ensure that the corresponding shocks are uncorrelated while making economic sense.To obtain the reduced form we pre-multiply equation 2 and estimate the resulting reduced form by OLS. To recover the structural shocks $B\epsilon_t = w_t$ we then fix B. B has to be chosen such that we achieve orthogonalization of the reduced form shocks, e.g.

$$\epsilon_t = B^{-1} w_t \tag{A.2}$$

The covariance matrix of the reduced form shocks $\text{Var}(\epsilon_t)$ is given by Ω. It then follows

$$\Omega = E[(B^{-1}w_t - E[B^{-1}w_t])(B^{-1}w_t - E[B^{-1}w_t])'] \tag{A.3}$$
$$\Omega = E[B^{-1}w_t w_t' B^{-1'}] \tag{A.4}$$
$$\Omega = B^{-1}B^{-1'} \tag{A.5}$$

From our estimated reduced form we obtain an estimate for the variance covariance matrix

$$\hat{\Omega} = \frac{\hat{\epsilon}\hat{\epsilon}'}{T - Np - 1} \tag{A.6}$$

where N refers to the number of variables in the model, p is the number of lags and T gives the number of observations. In the following we consider a trivariate model as illustrative example to further describe the dynamics, therefore $N = 3$.
The above serves as a consistent estimate for

$$\Omega = \begin{bmatrix} \text{Var}(\epsilon_1) & \text{Cov}(\epsilon_1,\epsilon_2) & \text{Cov}(\epsilon_1,\epsilon_3) \\ \text{Cov}(\epsilon_2,\epsilon_1) & \text{Var}(\epsilon_2) & \text{Cov}(\epsilon_2,\epsilon_3) \\ \text{Cov}(\epsilon_3,\epsilon_1) & \text{Cov}(\epsilon_3,\epsilon_2) & \text{Var}(\epsilon_3) \end{bmatrix}$$

There are $\frac{N(N+1)}{2} = 6$ unique elements. However,

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

As $N^2 = 9$, B has 9 unknown elements. Therefore, to identify the non-linear system $\Omega = B^{-1}B^{-1\prime}$ we need $\frac{N(N-1)}{2} = 3$ additional restrictions.

We rely on a recursive identification scheme consisting in setting

$$B = S^{-1}$$

where S is subject to

$$\Omega = SS'$$

and hence the Cholesky factor of Ω. With $N = 3$ this matrix will be:

$$S^{-1} = \begin{bmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{bmatrix}^{-1}$$

Therefore the 3 additional restrictions needed are that the upper right triangle entries in the matrix are all zero. This then achieves orthogonalization

$$\text{Var}[B\epsilon_t] = \text{Var}[S^{-1}\epsilon_t] = E[S^{-1}\epsilon_t\epsilon_t' S^{-1'}] = S^{-1}\Omega S^{-1'} = S^{-1}SS'S^{-1'} = I$$

To understand the reasoning behind this strategy, recall that the reduced form Wold representation reads

$$\phi(L)Y_t = \mu + \epsilon_t \tag{A.7}$$

As we have established above, the mapping between the reduced form shocks ϵ_t and the structural shocks w_t is via the matrix B in the following way

$$\begin{aligned} B\epsilon_t &= w_t \\ \epsilon_t &= B^{-1}w_t \\ \epsilon &= (S^{-1})^{-1}w_t \\ \epsilon &= Sw_t \\ \phi(L)y_t &= \mu + Sw_t \\ Y_t &= \phi(L)^{-1}\mu + \phi(L)^{-1}Sw_t \\ Y_t &= \phi(L)^{-1}\mu + C(L)Sw_t \end{aligned}$$

where $C(L)$ are the matrices of impulse responses of the variables in Y_t to the Wold shocks in ϵ_t[30].

For our VAR(1) being stable it must hold that all its roots lie outside the unit circle. As all the eigenvalues of our estimated companion form matrix are smaller than one in absolute value, the VAR is stable and stationary. We disregard the deterministic term as it tells us nothing about the IRFs or the FEVDs.

As it follows from the Wold representation,

$$C(L) = (I_N + C_1L + C_2L^2 + ...)$$

the IRFs on impact are then given by

$$\frac{\text{d}Y_t}{w_t'} = I_NS = S$$

[30]We can think of those impulse response as the change in Y_t for a change in ϵ_t at different horizons. However, the shocks in ϵ_t are not orthogonal but potentially correlated.

Recalling that the inverse of a lower triangular matrix is also lower triangular, S is given by

$$S = \begin{bmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{bmatrix}$$

Shocks to the variable ordered last in our Y_t have no contemporaneous effect on the ones located before. The same pattern applies to shocks to the second variable in Y_t: they have no effect on the first variable but can affect all the variables ordered after itself contemporaneously. Hence, the ordering of the variables in Y_t is crucial in a short term recursive Cholesky identification scheme. We recap the SVAR approach above with the example of a trivariate model as with a smaller size of the matrices involved the concept behind is easier to grasp.

Appendix B Robustness checks

To asses the robustness of our results we conduct several robustness checks. First, we place our shock variables all individually first in their corresponding VAR, making sure that they are not significantly driven by any other variable in the model on impact but their own shock.

In our second model we moreover also relax our assumption that the total asset shock has no contemporaneous impact on the reallocation variable. This yields the same results as our main conclusion, both the impulse response analysis and the variance decomposition are essentially unchanged, see Figure 13 and Figure 14 .

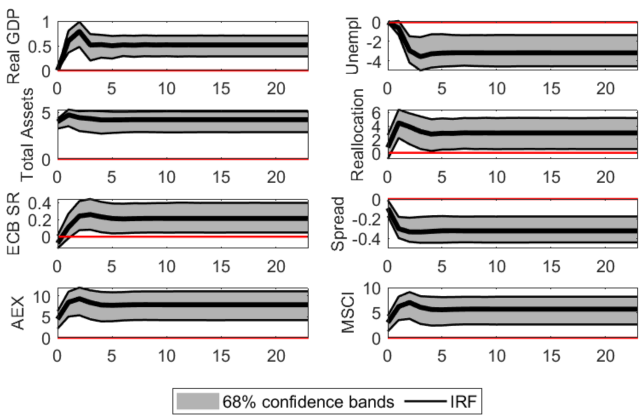

Figure 13: Effects of a total asset shock to the Dutch real economy (relaxed assumption), 2008:Q1 - 2020:Q4

For a third robustness check we use two lags instead of only one as it was suggested by the AIC and BIC criterion. Our results are comparable to the ones our original model specification yields. Additionally, we also change the proxy variable accounting for our monetary policy shock. Instead of using the shadow rate we use the change in the Eonia rate, i_t, plus a change in the 10 year government bond yield denoted by b_t

$$Q_t = \mathrm{d}i_t + \mathrm{d}b_t \tag{B.8}$$

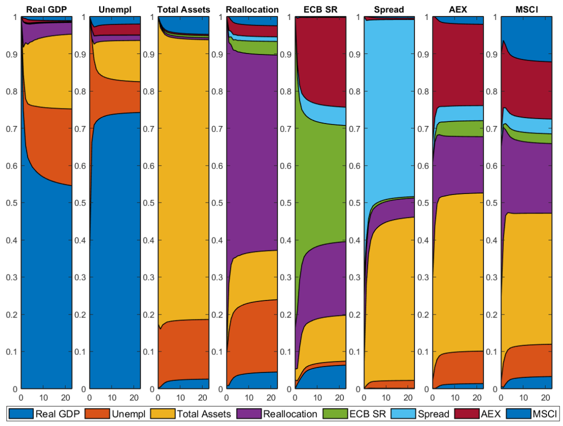

Figure 14: FEVD: Effects of a total asset shock to the Dutch real economy (relaxed assumption), 2008:Q1 - 2020:Q4

following the shock identification approach of Boubaker et al. (2018). Furthermore, instead of accounting for the ten to two year government bond spread we account for the short term interest rate with a proxy constructed of only the two year government bond yield. This approach provides similar results to the baseline specification as pension funds react significantly to an unconventional monetary policy shock in essentially the same way, see e.g. Figure 15 and Figure 16 of the accounting definitions. After two quarters the responses become insignificant, however this still shows evidence for unconventional monetary policy affecting pension funds' asset allocation.

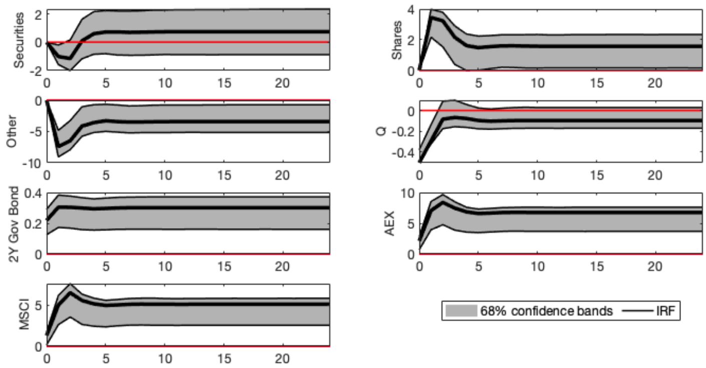

Figure 15: UMP effects on Dutch Pension funds' portfolios allocation via accounting definitions (different shock), 2008:Q1 - 2020:Q4

Further, for our fifth robustness check, as we show in our main conclusions, we estimate our first model using two different datasets for our first model, asset allocation via accounting definitions and the look through approach, yielding comparable results as the estimated responses are very similar.

All in all the results appear to be robust to changes in several features of our model specifications.

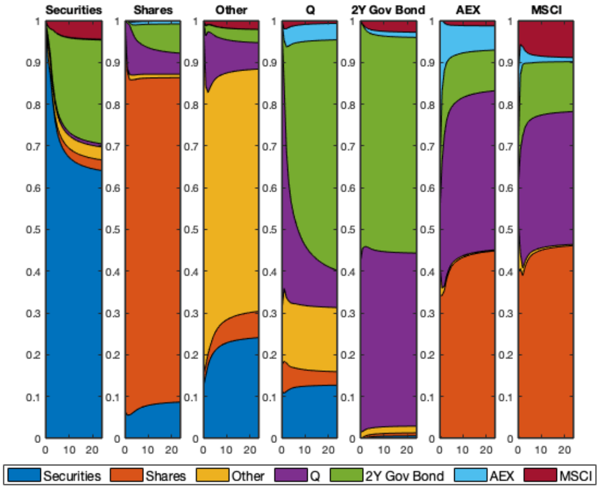

Figure 16: FEVD: UMP effects on Dutch Pension funds' portfolios allocation via acoounting definitions (different shock), 2008:Q1 - 2020:Q4

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