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Nick Draper, Casper van Ewijk, Marcel Lever and Roel Mehlkopf

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Nick Draper[1]
Casper van Ewijk[2]
Marcel Lever[3]
Roel Mehlkopf[4]

Abstract: This paper examines stochastic or 'value based' generational accounting as a method to assess the intergenerational redistributive impact of pension reform. The analysis is applied to three policy changes to the regulation of Dutch occupational pensions during the years 2012 and 2013 that mark the transition from defined benefit pensions to 'defined ambition' pension schemes.

Key words: pre-funded pension schemes, value-based generational accounting, market valuation, asset pricing, scenario analysis.

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[1]CPB Netherlands Bureau for Economic Policy Analysis
[2]University of Amsterdam, Netspar: Network for Studies on Pensions, Ageing and Retirement
[3]CPB Netherlands Bureau for Economic Policy Analysis
[4]Tilburg University, Ministry of Social Affairs and Employment

1. Introduction[5]

Generational accounts are widely used as a method of long-term fiscal analysis to assess the sustainability of government finances and to measure the fiscal burdens facing current and future generations (see Auerbach, Gokhale and Kotlikoff (1991) and Kotlikoff (1992)). Recently, generational accounts have been applied in a different context, namely in the context of occupational pension schemes. In fact, they have become an important tool in the official assessment of reforms in the occupational pensions in the Netherlands. To our knowledge, this is unique in the world. For this purpose the traditional generational accounts have been developed into a stochastic framework using standard asset pricing theory. This so-called 'value based' generational accounting offers an objective framework providing insight into the intergenerational effects of policy reforms, and thus helping to reassure that policy reforms do not lead to an unintentional redistribution between for example younger and older generations.

Dutch occupational pension schemes are mandatory, funded, and traditionally framed as defined benefit (DB) contracts. They are typically part of labor contracts, which are negotiated between unions and employers in collective labor agreements, and cover more than 90% of the labor force. Government regulation matters as it determines the accounting rules and funding requirements for pension funds. Following the credit crisis and the European debt crisis several regulatory reforms were proposed and introduced to improve solvency of pension funds and to make pensions more robust with regard to the whims of financial markets. In 2010 social partners in the Netherlands agreed on a 'pension deal' featuring a transition from a system of nominal guarantees to a 'defined ambition' framework where pensions are no longer fixed in nominal terms, and where pension funds can take risks on their balance sheet in order to realize their pension ambition in real terms. This alternative contract should also mitigate the sensitivity of pensions to the nominal interest rate (yield curve), which is used to value the nominal pension rights. This major revision of the pension system is still in debate. In the mean time, in 2012 the government introduced a new method for the valuation of pension rights using the ultimate forward rate (UFR) aiming to bring more stability in the discount rates for the longer terms. And recently, in 2013 the government took measures to reduce the yearly accrual rate of pensions thereby containing pension contribution rates.

For each of these policy reforms, the government has asked CPB Netherlands Bureau for Economic Policy Analysis (an independent government body) to analyse the redistributive effects between generations that result from the proposed policy changes in regulation. The reason for the government to ask for these studies was a general concern that changing the rules could lead to intergenerational conflicts in an already highly politicized pension debate.[6] To minimize political turmoil, the government desired to practice utmost transparency by asking CPB to assess the impact on the intergenerational distribution. In this paper we account for the main results, and provide an analytical background for these generational accounting studies that were conducted for the Dutch government.

Value-based generational accounting is applied to calculate the change in the market value of

[5] The authors acknowledge helpful assistence by Jan Bonenkamp, Mark Brussen, Pascal Janssen, and André Nibbelink.

[6] See e.g. Bovenberg, Mehlkopf en Nijman (2014).

pension rights of each generation. These calculations employ stochastic discounting of projected stochastic cash flows. The use of market value to assess the distribution between generations is known as value-based generational accounting (see Ponds (2003)).. The generation accounts register for each generation the net benefit of the pension scheme as the difference between the discounted value of all cash flows received and the value of all resources paid into the scheme. A pension fund is a zero-sum game in terms of ex-ante market value. A positive change in ex-ante market value for one generation thus necessarily leads to negative change in market value for one or more other generations.[7]

Value-based generational accounting applies asset pricing theory (see e.g. Cochrane (2001)) to determine the ex-ante market value of stochastic cash flows in pension contracts. Asset pricing theory is based on the replication principle. When all risk factors are traded in financial markets, then any stochastic cash flow can be replicated by a portfolio strategy based on assets that are traded in financial markets. The value of any stochastic cash flow is then given by the price of its replicating portfolio strategy. The law of one price implies that this price is unique in a financial market that satisfies the no-arbitrage condition.

Market value offers an attractive criterion to assess the intergenerational redistribution in pension schemes as it is based on observed prices in financial markets.[8] No subjective assumptions with regards to the preferences of individuals are required. Such subjective assumptions can be difficult to determine objectively, which can be particularly problematic in the situation where generations are involved in a divisive battle over the distribution of pension shocks. Market pricing also avoids subjective assumptions on the valuation of risks. Unfortunately, this has a price too as the analysis has to assume market completeness. Therefore it cannot deal with the price of non-traded risks, and risks traded on imperfect markets. To illustrate, it may be hard to determine the value of cash flows with very long maturities because trade in assets with maturities beyond 30 years is limited.[9] An example of a non-traded risk is provided by aggregate wages since some pension promises are linked to aggregate wages. Also, for aggregate longevity risk no market prices are available in the absence of longevity bonds.

In principle, the method of market valuation could be extended to untraded risks using alternative methods to obtain a 'market consistent valuation'. This would however inevitably require arbitrary choices on the method and the empirical estimates. The paradox is thus that pension schemes that complete markets by trading untraded risk factors are difficult to value objectively, and may thus for this precise reason give rise to intergenerational conflicts and political risks.[10]

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[7] This follows from the assumption of complete markets. This and other limitations will be discussed in the conclusion of this paper.

[8] We apply a *partial* equilibrium framework in this paper in which there is an exogenous price of risk that is not affected by the intergenerational contract. In a *general* equilibrium framework, in which current generations can trade with future generations, market prices would adjust. Such 'fictional' trading between non-overlapping generations would change the market prices of risk, thereby redistributing resources between agents, see Ball and Mankiw (2007).

[9] This gives rise to the discussions about the so-called ultimate forward interest rate.

[10] A number of studies have explored valuation techniques for non-traded risk factors in pension schemes. De Jong (2008) examines the valuation of wage-linked cash flows in an incomplete market setting in which the wage index cannot be hedged perfectly with financial market instruments. He discusses several methods to find a value in such incomplete markets and advocates utility-based valuation. Geanakoplos and Zeldes (2010) derive

The analysis in this paper builds on earlier applications of stochastic generational accounting to assess the distributional effects of Dutch occupational pension schemes. These contributions include Koijen and Nijman (2006), Kortleve and Ponds (2006), Bikker and Vlaar (2007), Hoevenaars and Ponds (2008) and Broeders (2010). Our paper discusses the application of this method in the official impact assessment of recent government proposals in the Netherlands.

The structure of this paper is as follows. Section 2 contains a brief description of Dutch occupational pensions. Section 3 introduces the modeling framework for economic scenarios, demography, and the pension contract. Section 4 explores three applications of generational accounting to reforms in the regulatory framework proposed by the government. Section 5 concludes.

2. Dutch occupational pensions

The Dutch pension system consists of three pillars.[11] The first is a pay-as-you-go public pension scheme. This Beveridge-type public system provides a uniform, flat pension to all residents at a level that is related to the minimum wage. For workers who earn middle and higher incomes this pension is only a smaller part of pension income. If these workers want to maintain their standard of living in retirement, they need additional pension provisions. This is the role of the second pillar of pension provision (*i.e.* occupational pensions). In contrast to the first pillar, the second pillar is earnings-related, and aims at maintaining the standard of living during retirement. The third pillar consists of voluntary personal pension provisions, which are tax-favored up to a ceiling. This pillar is relatively less developed in the Netherlands; it is especially important for self-employed individuals who lack occupational pension provisions.

This paper focuses on occupational pension schemes in the second pillar. These schemes are funded; the value of total assets currently amounts to about 1 trillion Euro (160% of GDP). Dutch pension funds are independent trusts with their own governance and administrative structures. The governing board of a pension fund traditionally consists of equal representatives of employers and unions, although more recently also retirees and independent specialists can become board members. These representatives act as fiduciary trustees.

The occupational plans aim at a specific lifetime income stream during retirement, thereby insuring idiosyncratic longevity risk. Indeed, property rights are defined in terms of a (deferred) nominal annuity. Years of service and a reference wage determine the benefit entitlement. The reference wage used to be the final wage, but in the last decade most funds have moved to career-average schemes. In these latter schemes, entitlements to deferred annuities accrue based on a percentage of the average wage level during the career. These schemes typically aim at an annuity level of about 75% of average pay (including the public pension) after 40 years of service. The benefit accrual rate (in terms of annuity level) is uniform across age groups. Hence, if the aim

the value of wage-linked cash flows on the basis of an assumed theoretical long-run relationship between wages and stocks.

[11] See Bovenberg, Mehlkopf and Nijman (2014) for a more elaborate description of the Dutch pension system and analysis of recent developments.

is to provide 75% of average pay after a working career of 40 years, the annual accrual rate is 75%/40=1.875% of the current wage. The uniform accrual rate implies that benefits are backloaded, because the time value of money implies that the value of the (deferred) annuity rises with age. Yet, pension funds charge the same contribution rate irrespective of age. Hence, firms with a younger workforce subsidize firms with an older workforce.
The goal of most pension funds is to index the deferred annuity to the development of contractual wages during the accumulation phase. Some funds aspire to link annuities to the development of contractual wages also during the pay-out phase; other funds aim to provide cost-of-living adjustments during the decumulation phase.

The aspired annuity levels are ambitions rather than guarantees. Pension funds aim to index the pension rights, but these bonus payments are conditional on the financial performance of the fund. In fact, not only indexation is conditional on fund performance: also the nominal pensions can be cut if the assets of a fund are insufiicient to cover the nominal liabilities (*i.e.* the value of the annuities excluding indexation). Dutch solvency regulation requires that a funding shortage is in expectation resolved within a three-year period. The length of the recovery period has temporarily been increased to five years in the aftermath of the recent financial crisis. In calculating the scope for recovery, funds can use expected returns on assets. Hence, risk premia on risky assets contribute to the potential for recovery. Funds, however, are not allowed to increase their risk profile if they are in a recovery program.

For the purpose of solvency regulations, Dutch pension funds must calculate nominal liabilities on the basis of the term structure of nominal interest rates (based on European swap rates) published by the Dutch Central Bank. This market-based valuation method thus assumes that nominal liabilities are to be considered as guarantees. Hence, valuation of pension rights is still based on a DB design, but in fact Dutch pension schemes provide variable annuities because plan sponsors no longer underwrite the risks of their pension funds, and pension funds continue to deliberately take mismatch risk at low funding rates. Indeed, supervisory authorities do not force pension funds to match their nominal liabilities if capital buffers become low.

In the aftermath of the banking crisis social partners agreed on a significant reform of the pension system in 2010. According to this 'pension deal' retirement age is to be raised to the age of 67 in 2025; from that year on retirement age will be linked to life-expectancy. With regard to supplementary pensions social partners agreed on the transition from a defined benefit system to a 'defined ambition' system. With defined ambition it is acknowledged that pensions can no longer be guaranteed in nominal terms but will be conditional on investment returns of pension funds. At best pension funds can state an ambition with regard to the average replacement rate. Furthermore, it was agreed that pension contribution rates should be stabilized, and will no longer be used to accommodate shocks in investment returns and longevity risks of pension funds. The rise in retirement age has been put into legislation by the Dutch government. The reform of the defined benefit system is still in debate. The government did, however, take a number of measures to mitigate the impact of the debt crisis; furthermore it was decided to limit the fiscal deductibility of pensions.

3. Model

The model employs stochastic discounting of projected cash flows to calculate the market value of pension rights of each generation. The cash flow projections are simulated on the basis of economic scenarios that are generated using an estimated capital market model for the Netherlands. The pension contract is modeled according to the typical contract for the major pension funds.

Representative pension fund

The pension contract is in line with the features discussed in the precious section.[12] Under an average wage system the pension of a retired individual at age T can be written as

$$P_T = \sum_{t=0}^{T_R}[a_t w_t \prod_{i=t}^{T}(1+g_i)] \tag{1}$$

where t indexes age $t \in [0,T]$, T_R is retirement age ($\leq T$), a_t the benefit accrual rate, w_t the wage rate, and g_t the yearly revision in pension rights, the 'indexation'. We assume that the fund employs a linear rule for the indexation of pension rights dependent on the fund's solvency ratio (S); the solvency ratio measures the fund's assets as a ratio to its nominal liabilities. The indexation varies between 0 from lower boundary of the solvency rate (here 105%) to a maximum of 1 at the upper boundary (here 125%). Thus the upward revision in pension rights (g_t) - that is the uniform rate by which all pension rights are increased - can be written as the product of the indexation factor z and the change in the relevant price index π_t. The indexation factor depends on the solvency ratio S_t between the lower boundary $\underline{S}$ and the upper boundary $\overline{S}$, thus

$$g_t = z_t . \pi_t \text{ with } z_t = (S_t - \underline{S})/(\overline{S} - \underline{S}), \qquad z_t \in [0,1] \tag{2}$$

The relevant price index is taken to be the average of inflation and wage inflation, as part of pension entitlements in the Netherlands are indexed to prices and the rest to wages. For solvency ratios below the minimum $\overline{S}$ a special regime comes into force; pension funds have to hand in a recovery plan aimed at recovery of the solvency ratio to the minimum level within four years.

Regarding the fund's investments, we assume that the pension fund invests 50 per cent of its assets in stocks and the remaining 50 per cent in the risk free rate. The interest risk on the nominal liabilities of the pension fund is covered for 40 per cent, in line with data from the Dutch Central Bank, that supervises the pension funds in the Netherlands. The pension fund's participants feature a representative demography; life expectancy and composition of the participants are equal to the average of the Dutch population. We use the latest forecast from CBS Statistics Netherlands, published in December 2012. The duration of the liabilities is assumed to be equal to 16 years.

Capital market model

Since benefits and contributions are driven by the investment results of pension funds, the generation accounts can be written as derivatives of the fund's portfolio. The capital market dynamics are modeled following Koijen, Nijman and Werker (2010), now re-estimated on Dutch

[12] For a detailed description of the pension contract, see Lever et al. (2012).

data. Similar models have been developed earlier by Brennan and Xia (2002), Campbell and Viceira (2001) and Sangvinatsos and Wachter (2005). The investment portfolio consists of a stock index, long-term nominal and real bonds and a nominal money account. The appendix presents more details.[13]

The capital market model specifies the dynamics of three stochastic variables: inflation, the real interest rate, and the stock return. The dynamics in the real interest rate and the expected inflation are modeled using two state variables. The process in the state variables governs the autocorrelation in the interest rates and inflation. The state variables follow a mean-reverting process around zero, driven by a four-dimensional vector of independent Brownian motion representing uncertainty in financial markets. The model is completed with the specification of the nominal stochastic discount factor with the time-varying price of risk affine in the state variables. The stochastic discount factor is used to determine the value of all cash flows in all states of the world. For intuition, the stochastic discount factor may be interpreted as an indicator for the marginal utility. For instance, in a good state of the world (a positive shock) the value of a cash flow is lower than in a bad state of the world. A theoretical justification for this stochastic discounting can be found in Merton (1992) and Cochrane (2001). The price of risk is implied in market prices, and depends on the risk aversion of investors. We assume a zero risk premium for unexpected inflation. This restriction is imposed because the inflation risk premium cannot be identified in a reliable manner from market data.

The results for the Netherlands deviate in several respects from those for the US used in Koijen, Nijman and Werker (2010). For the unconditional expected inflation we find a lower estimate for the Netherlands (2.2%) than the figure used for US (4.2%). This also explains the 2% lower unconditional nominal interest rate for the Netherlands compared to the US. In general, shocks are more persistent in the Netherlands than in the US. The first-order autocorrelations on an annual frequency for the two state variables equal 0.7 and 0.9 for the Netherlands, and 0.5 and 0.9 for the US respectively. The equity risk premium is found to be lower for the Netherlands (3,5%) than for the US (5.4%) The risk premium for bonds with a maturity of 10 years is 65 basis points higher in the Netherlands than in the US. In general the estimates for the Netherlands are statistically less significant than for the US. A possible explanation may be that exchange rate fluctuations - not included as a separate risk factor - are more relevant for the Netherlands (and Northern Europe) than for the US.

The results of this model have been assessed on their robustness of the results using two alternative scenario sets: a scenario set provided by APG (a large pension service provider), and a scenario set of the consultancy firm ORTEC Finance. Each set includes 5,000 economic scenarios for interest rates, equity return, price inflation and wage inflation. The scenarios include both the actual returns of different assets and the corresponding risk-neutral values.[14]

4. Generational accounting of pension reforms

This value based generational accounting framework is applied to three recent reforms in the

[13] A thorough presentation can be found in Draper (2012).

[14] See Lever, Mehlkopf and Van Ewijk (2012) for the results for these alternative scenario sets.

regulatory framework for pensions in the Netherlands. First, we will explore the consequences of the transition from a defined benefit system to a 'defined ambition' system, as was recommended in the 'pension deal' of social partners in 2010. Second, we will discuss the generational consequences of the introduction of the ultimate forward rate (UFR) for the valuation of pension rights in 2012. And third, we will explore the impact of the change in the fiscal regime for pensions in 2013, aiming at a reduction in the tax deductibility of pension contributions.

In general, Dutch collective pensions are sensitive to changes in the regulatory framework, as they feature 'open accounts' at the individual level (Bovenberg & Van Ewijk (2012) and Kocken (2012)). That is, participants do not have individual property rights in terms of claims on traded assets, but share in the common investment pool. How this pool - and shocks therein - is distributed depends on the exact rules for pensions and contributions. Changes in these rules will generally lead to changes in the distribution over generations. Pension funds are essentially mutual funds; there is no sponsor holding the residual risks. As a result any change in favour of one group of participants, must lead to a loss for other participants. For example, if pension funds are forced to increase their buffers, this generally comes to the benefit of younger generations - who 'inherit' larger pension wealth - , and goes at the cost of older generations who will contribute to these buffers by temporarily lower indexation of their pensions. Similarly, more favorable rules for the valuation of pension liabilities tend to benefit the older generations, as a better solvency ratio leads to higher indexation of pensions in the short run (equation 2). Insight into these consequences is important to assess the generational impact of these measures; furthermore, it can help finding a proper combination of measures so as to avoid undesirable redistributional effects.

From defined benefit to defined ambition

In the pension deal of 2010, the social partners proposed a transition in occupational pensions from a defined benefit (DB) contract towards a defined ambition (DA) contract. The move towards DA contracts provides flexibility to the pension funds in the face of the withdrawal of firms and younger generations as sponsors for the mismatch risk. In the DA contract pension rights are no longer considered as a fixed nominal annuity that should be guaranteed by the pension fund; instead, it is acknowledged that pensions are risky and adapt to unexpected changes in life expectancy and returns on financial markets. Unexpected biometric and financial shocks are to be absorbed in pension rights (i.e. annuity units), but smoothed over a period of 10 years. This could increase the flexibility of pension funds to deal with shocks in their balance sheets. Unlike the DB contract, there is no rigid nominal floor to the solvency of pension funds that might force pension funds to take harsh measures in the event of a bad shock. The government worked out this proposal for a DA system in 2012; at this moment it is still in debate. We consider this government's proposal in the analysis below.

If taken in its pure form the transition from DB to DA tends to benefit current pensioners at the cost of younger generations. This is due to the fact that the rigid floor to the solvency ratio is abolished in the DA contract. Figure 1 (step 1) presents the net gain for each generation - by year of birth - as a percentage of pension income during the remaining retirement period.[15] The precise result depends on the initial situation on financial markets, in particular the term structure of interest

[15] For details see Lever, Mehlkopf and Van Ewijk (2012).

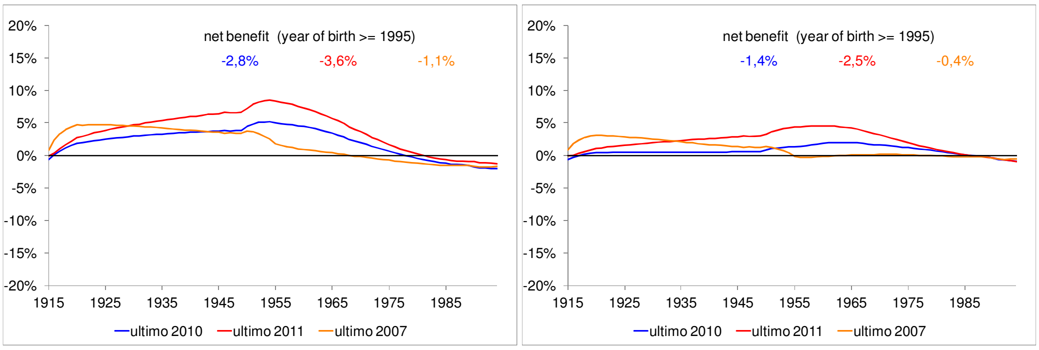
rates, here taken for the years 2007, 2010 and 2011. In all cases the generations born before 1980 tend to benefit, while younger generations and generations yet to be born - for whom an average effect is reported in the graph - bear the burden for this. Recall that in terms of market value the re-distribution is a zero sum game. The benefit can amount up to 5 per cent for the generations born around 1955, if 2010 is taken as initial situation.

The reason for this redistribution is that the DB contract is highly nonlinear around the minimum solvency ratio. As the actual starting condition of pension funds around 2010 happens to be approximately at this minimum, subsequent negative shocks lead to a sharp loss in pensions, whereas positive shocks are smoothed over a longer period. This follows from the short recovery period in case the fund is facing underfunding ($S < \underline{S}$), leading to a higher probability of pension cuts in the short term. This nonlinearity is absent in the DA contract as all shocks are smoothed over a ten years horizon irrespective the state of the pension fund (S). Therefore negative and positive shocks have symmetric effects on pensions, and pension cuts are on average less likely. This is clearly to the benefit of older generations.

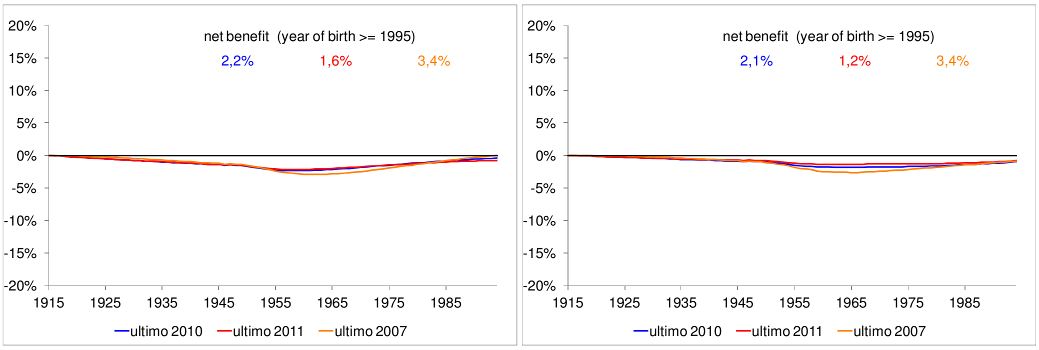
The impact of a transition to DA is less pronounced if the investment mix is more defensive, see the right hand panel in figure 1. With a defensive investment mix the chance of a severe financial setbacks is smaller, so that the nonlinearity around $\underline{S}$ becomes less decisive.

Figure 1: Effect of defined ambition on intergenerational distribution, expressed as a percentage of pension income during the (remaining) retirement period

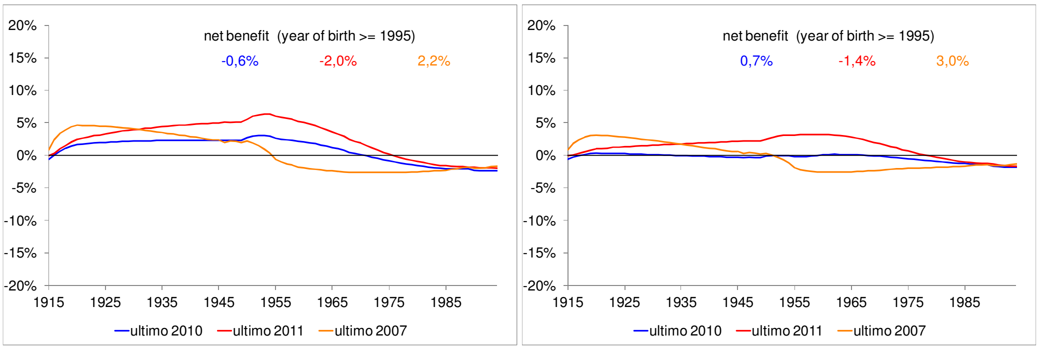
Step 1: Transition from defined benefits towards defined ambition



Step 2: Introduction buffer fund



Step 3: Combining both measures (step 1 + step 2)



Explanation: Net benefit from pensions during the remaining life span, by year of birth, for three different initial states of capital markets (ultimo 2010, ultimo 2011 and ultimo 2007), and for two investment mixes (50% fixed income, 50% equity (left) and 80% fixed income and 20% equity (right))

The generational impact of the new pension contract is mitigated by simultaneously proposing tighter solvency requirements. The introduction of a buffer fund is attractive to future generations, and disadvantageous for older generations. Generations born around 1955 now face a decrease in benefits from pensions by some 3 per cent of remaining life income, see step 2 in figure 1. Building up additional buffers requires pensions to be restrained for some time in the short term.

Combining these two reforms gives a fairly balanced result with regard to the intergenerational distribution. The exact outcome is dependent on the state of the financial markets. For the world of 2007 with low volatility and low prices of risk, there is a gain for the eldest generations - who are by less in numbers - while for other generations a small effect is found. If the state of the world in 2011 is taken as starting point, then the effects are larger due to the turmoil in European financial markets. But even for this case the net effects on the intergenerational distribution are modest. This dependency on the state of financial markets illustrates that it is difficult to fine-tune the design of the reform to avoid any redistributive effects. Some uncertainty on the intergenerational effects is inevitable. But this holds for any change in government policy.

Introduction of Ultimate Forward Rate

Since 2007 pension rights are to be discounted using the term structure of interest rates. Before that year the valuation was based on a fixed discount rate of 4 per cent. Using market interest rates improved the consistency in valuation between assets and liabilities of pension funds. It could, however, increase interest rate risk for the pension fund if the risk exposure of liabilities is not sufficiently covered. During the European debt crisis it was felt that market rates were excessively volatile, in particular for the longer maturities where no liquid markets exist. In the third quarter of 2012 the Dutch government adopted the Ultimate Forward Rate (UFR) method for discounting liabilities with long maturities. The UFR is the interest rate to which (one year) forward rates are assumed to converge over a longer time horizon. The European Commission adopted a fixed UFR of 4.2 per cent in Solvency II, the regulatory framework for insurance companies.[16] The Netherlands Bank followed this Solvency proposal for Dutch pension funds, with the same UFR of 4.2 per cent, but with a slightly different way of adapting the yield curve to this rate.[17]

The introduction of the UFR led to an instantaneous increase of 3%-points in the solvency ratio of the average Dutch pension fund. This improvement in the financial position allows pension funds to provide more indexation, or reduce the size of required pension cuts (equation 2). The effectively higher discount rate benefited the older generations at the expense of younger generations. This again shows how adjustments in regulation may lead to redistribution of market value across stakeholders of pension funds. Because of these distributional concerns the Dutch government asked CPB to assess the consequences of the introduction of the UFR.[18]

Figure 2: Effect of UFR on the yield curve

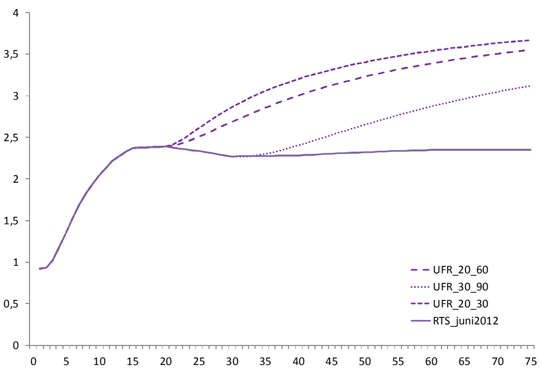


Figure 2 investigates three alternative versions of the UFR. The differences pertain to the intervals (from 30 to 90 year, from 20 to 60 year and from 20 to 30 year) in which the forward interest rates

[16] See https://eiopa.europa.eu/fileadmin/tx_dam/files/consultations/QIS/QIS5/ceiops-paper-extrapolation-risk-free-rates_en-20100802.pdf.

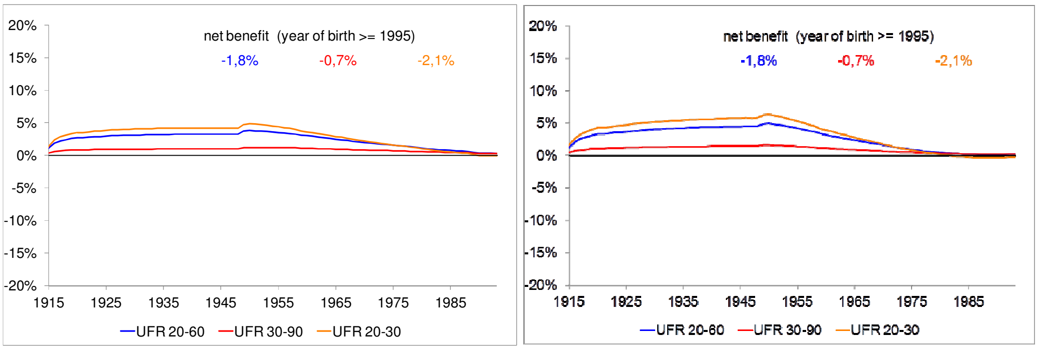
[17] See 'UFR method for calculating the term structure of interest rates', http://www.toezicht.dnb.nl/en/binaries/51-226788.pdf.

[18] For details, see Bonenkamp, Lever and Mehlkopf (2012).

converge to a stable level of 4.2%. The intervals start at the 'last liquid point' of the yield curve (20 or 30 years forward, respectively) and end at the point where the rates have converged to the UFR (30, 60 or 90 years forward). In all cases the UFR leads to an upward shift of the yield curve (figure 2), leading to a redistribution in favour of generations born before about 1990 (figure 3, left panel). This redistribution is less significant as the adjustment period to the UFR is longer, and starts later: the UFR with interval from 30 to 90 (UFR 30-90) benefits current older generations up to an amount of about 1 per cent of the pension entitlements for a participant with a modal income, which corresponds to about 2000 euro in net present value. The generations born around 1950-1960 have the largest benefit. With earlier starting points for the UFR and shorter intervals the yield curve becomes steeper, and leading to more substantial redistribution. The benefit for the current older generations amounts up to respectively 3 per cent of pensions (5000 euro) for UFR 20-60 and 4 of pensions (7000 euro) for UFR 20-30. Younger and future generations loose from the introduction of the UFR; an average this amounts to 0,7 per cent to 2,1 per cent of pension income for generations after 1995, as reported in the graph.

These results include the impact of the UFR on pension contributions. The introduction of the UFR also lowers the price of deferred annuities, and thus reduces pension contributions. This is a disadvantage for the current old generations, and thus mitigates the net effect. If the UFR is not applied for the computation of pension contributions, the advantage (disadvantage) for the old (young) generations becomes larger, see figure 3 (right panel).

Figure 3: Impact of UFR on pension entitlements net of contributions (left) and on entitlements only (right), percentage of pension income during the (remaining) retirement period.

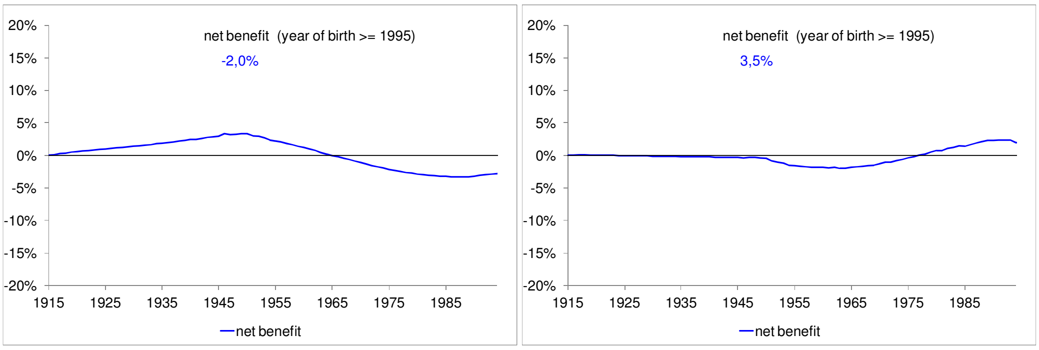


Reduction of benefit accrual rates

The fiscal deductibility of pension contributions in the Netherlands will be limited in 2015. The maximum accrual rate will be reduced from 2.15 per cent to 1.875 per cent. After the regulatory change a career of 40 years will accordingly result in a pension (public pension and occupational pension together) of 75 per cent of the average wage during the career. The impact on the intergenerational distribution of pension wealth is not clear a priori. If contribution rates are reduced together with the accrual rates, this measure could in principle be neutral from an intergenerational perspective. For this to happen, the change in contribution rates should be actuarially fair across generations. What does change, though, is the benefit of the tax regime, but this is not recorded by the generation accounts for pensions.[19]

Figures 4 reports the redistribution between generations due to the policy change for two scenarios, one in which contribution rates are constant, and one where they fall in proportion to the accrual rate.[20] Obviously, the first scenario leads to a redistribution in favour of older generations. Younger generations contribute to the funding of pension funds as they build up less pension rights with the same contribution rate. This benefits older generations because solvency ratios will increase, leading to higher indexation of pensions.

Figure 4 : Net benefit of lower accrual rate without adjustment of contribution rate (left) and with adjustment (right), expressed as a percentage of pension income during the (remaining) retirement period.



The redistribution between generations is limited if the contributions are adjusted simultaneously with the reduction of the accrual rate (figure 4, right panel). For current pensioners the impact is zero, old workers lose a bit and young workers and future generations win a bit. This minor redistribution within working and younger generations is caused by the system of uniform accrual rates and the uniform contribution rates. As a result of this uniform system contribution rates are not actuarially fair over the life cycle; because of the difference in time horizon contribution rates are 'too high' for the young, and 'too low' for the older workers. A reduction of accrual rates therefore hurts the older workers, as they benefit less from the implicit subsidy in pension contributions at higher ages.

5. Conclusions

Stochastic, value based generational accounting is an important tool in the assessment of redistributive effects of pension reforms, and more generally in any assessment of generational effects in a stochastic environment. In the Netherlands value based generation accounts have successfully been applied in the context of three different reforms in pension regulation between

[19] Participants are assumed to save any reductions in contributions and to consume them after retirement. This simplifying assumption allows us to limit the analysis to income (consumption) after retirement.
[20] For details, see Lever and Bonenkamp (2013).

2012 and 2014, all aiming to make pension funds more robust with regard to financial and demographic risks. Generation accounts provide an objective method for determining the impact in the intergenerational distribution, and thereby help to de-politicize the debate on the distribution of pension wealth over generations. Using generation accounts in the design of pension reforms makes it possible to find a balanced set of measures that allow for the necessary pension reform while avoiding major effects on the intergenerational distribution.

This is particularly relevant for the Netherlands where the large second pillar of occupational pensions is essentially still framed in terms of a defined benefit system, promising fixed nominal annuities upon retirement. At the same time pension funds take considerable risks on their balance sheet, in order to benefit from the equity premium, necessary to be able to index pensions to (wage) inflation. Since all participants share in the common investment pool of the pension fund, government regulation can have pervasive effects on the distribution of pension wealth over generations.

Generation accounts provide an objective record of the distribution over generations. Taking the market value of the fund's assets as starting point, any redistribution is a zero sum game; a gain for one generation always implies a loss for some other generation. This is a simple and clear cut starting point for the assessment of the distributional impact of some policy reform. It is a limited perspective, at the same time, as it neglects any welfare effects of such a reform. The zero sum principle follows from the complete markets assumption that is underlying this application of asset pricing. In the absence of complete markets, the real value of pensions for individuals may deviate from market prices. Actually, in a complete market setting with complete information and rational agents there happens to be no role at all for pension funds. The very function of pensions is to overcome failures existing in financial markets. One of the failures is the impossibility to trade with unborn generations. Pension funds contribute to intergenerational risk sharing by distributing shocks to future participants (Gollier, 2008). Another market failure concerns the absence of well-developed markets for certain types of risk, for example inflation risk, wage risk and longevity risk. In this respect the current analysis of generation account is limited, as it is restricted to the risks that are well priced in financial markets.

As mentioned in the introduction, the method of market valuation can be extended to take account of these untraded risks using alternative methods to obtain 'market consistent valuation'. This would however inevitably require arbitrary choices. This would touch upon the attractive feature of market valuation that it is based on observed prices in financial markets, and does not require subjective assumptions with regard to the preferences of individuals. This neutrality of the framework has been the great merit of generational accounting in the assessment of pension reforms in the Netherlands.

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Appendix: The capital market model

This appendix contains a summary of the capital market model. The model builds on Koijen, Nijman and Werker (2010) and is re-estimated on data for the Netherlands. The appendix subsequently describes the model, the data, the estimation procedure and the estimation results.

Model specification

The model distinguishes four assets: a stock index, long-term nominal and real bonds and a nominal money account. The real interest rate and the instantaneous expected inflation are modeled using two state variables, which are collected in vector X. More precisely, the instantaneous real interest rate, r, follows

$$r_t = \delta_{0r} + \delta_{1r}' X_t$$

and the instantaneous expected inflation, π

$$\pi_t = \delta_{0\pi} + \delta_{1\pi}' X_t$$

The dynamics in the state variables govern the autocorrelation in the interest rates and inflation. The state variables follow a mean-reverting process around zero[21]

$$dX_t = \mu dt - KX_t dt + \Sigma_X' dZ_t$$

$$K \text{ is } 2 \times 2 \text{ and } \Sigma_X' = [I_{2\times 2} 0_{2\times 2}]$$

where Z denotes a four dimensional vector of independent Brownian motions. Four sources of uncertainty can be identified: uncertainty about the real interest rate, uncertainty about the instantaneous expected inflation, uncertainty about unexpected inflation and uncertainty about the stock return. Correlation between the real interest rate and inflation is modeled using δ_{1r}' and $\delta_{1\pi}'$. The actual inflation , Π is equal to expected inflation, π, except for unexpected shocks:

$$\frac{d\Pi_t}{\Pi_t} = \pi_t dt + \sigma_\Pi' dZ_t \quad \sigma_\Pi \in R^4 \text{ and } \Pi_0 = 1$$

The stock index S develops according to

$$\frac{dS_t}{S_t} = (R_t + \eta_S)dt + \sigma_S' dZ_t \quad \sigma_S \in R^4 \text{ and } S_0 = 1$$

where R is the nominal instantaneous interest rate, which is determined by the real interest rate and the inflation process, and η_S the equity risk premium. The model is completed with the specification of the nominal stochastic discount factor φ_t^N

$$\frac{d\phi_t^N}{\phi_t^N} = -R_t dt - \Lambda_t' dZ_t$$

with the time-varying price of risk Λ affine in the state variables X

$$\Lambda_t = \Lambda_0 + \Lambda_1 X_t \quad \text{and } \Lambda_t, \Lambda_0 \in R^4 \quad \text{and } \Lambda_1 \ 4 \times 2$$

[21] A thorough book about continuous time modeling in Finance is Shreve (2004). Hull (2003) is more convenient to get intuition for the subject.

A theoretical justification of this stochastic discount factor can be found in Merton (1992) and Cochrane (2001). The price of risk depends on the risk aversion of investors. Assume no risk premium for unexpected inflation, that is the third row Λ_1 contains zeros only. This restriction is imposed because unexpected inflation risk cannot be identified on the basis of market data (see Koijen, Nijman and Werker (2010))

$$\Lambda_1 = \begin{bmatrix} \Lambda_{1\,(1,1)} & \Lambda_{1\,(1,2)} \\ \Lambda_{1\,(2,1)} & \Lambda_{1\,(2,2)} \\ 0 & 0 \\ \Lambda_{1\,(4,1)} & \Lambda_{1\,(4,2)} \end{bmatrix}$$

Parameter restrictions

The stochastic discount factor is used to determine the value of cash flows in a complete market setting. For instance, the fundamental valuation equation (Cochrane (2001)) of the equity index

$$Ed\phi^N S = 0$$

implies that the expected value of the discounted stock price does not change over time. This equation implies a restriction. Using the Itô Doeblin theorem gives

$$\frac{d\phi^N S}{\phi^N S} = \frac{d\phi^N}{\phi^N} + \frac{dS}{S} + \frac{d\phi^N}{\phi^N}.\frac{dS}{S} =$$
$$= \left(\eta_S - \Lambda_t' \sigma_S'\right)dt - \left(\Lambda_t' - \sigma_S'\right)dZ_t$$

because in the limit dt tends to 0 , the dt^2 and $dtdZ$ terms disappear and the dZ^2 term tends to dt . Taking expectations gives the restriction

$$\eta_S = \Lambda_t' \sigma_S$$

which implies $\sigma_S' \Lambda_0 = \eta_S$ and $\sigma_S' \Lambda_1 = 0$. This restriction is imposed on the model.

Nominal and inflation linked bonds

The fundamental pricing equation for a nominal zero coupon bond is

$$Ed\phi^N P^N = 0$$

i.e. the expected discounted value of the price of a nominal bond does not change over time. The condition implies for inflation linked bonds

$$Ed\phi^N P^R \Pi = 0$$

i.e. the discounted value of the inflation corrected price of real bonds doesn't change over time. Define the real stochastic discount factor as $\phi^R \equiv \phi^N \Pi$. Using the Itô Doeblin theorem we derive for the real stochastic discount factor

$$\frac{d\phi^R}{\phi^R} \equiv \frac{d\phi^N}{\phi^N} + \frac{d\Pi}{\Pi} + \frac{d\phi^N}{\phi^N} \cdot \frac{d\Pi}{\Pi}$$

$$= -\left(R_t - \pi_t + \sigma_\Pi^{'}\Lambda_t\right)dt - \left(\Lambda_t^{'} - \sigma_\Pi^{'}\right)dZ_t$$

$$= -r_t dt - \left(\Lambda_t^{'} - \sigma_\Pi^{'}\right)dZ_t$$

because in the limit dt tends to 0, the dt^2 and $dtdZ$ terms disappear and the dZ^2 term tends to dt. The nominal rate can thus be written as

$$R_t = r_t + \pi_t - \sigma_\Pi^{'}\Lambda_t$$

$$= \left(\delta_{0r} + \delta_{0\pi} - \sigma_\Pi^{'}\Lambda_0\right) + (\delta_{1r}^{'} + \delta_{1\pi}^{'} - \sigma_\Pi^{'}\Lambda_1)X_t$$

$$\equiv R_0 + R_1^{'}X_t$$

Data

The data for the Netherlands are taken from Goorbergh, Molenaar, Steenbeek and Vlaar (2011).

- Inflation: From 1999 on, the Harmonized Index of Consumer Prices for the euro area from the European Central Bank data website (http://sdw.ecb.europa.eu) is used. Before then, German (Western German until 1990) consumer price index figures published by the International Financial Statistics of the International Monetary Fund are included; note that the exchange rate of the Dutch guilders was pegged to the Deutschmark since 1983.
- Yields: Six yields are used in estimation: three-month, one-year, two-year, three-year, five-year, and ten-year maturities, respectively. Three-month money market rates are taken from the Bundesbank (www.bundesbank.de). For the period 1973:I to 1990:II, end-of-quarter money market rates reported by Frankfurt banks are taken, whereas thereafter three-month Frankfurt Interbank Offered Rates are included. Long nominal yields: From 1987:IV on, zero-coupon rates are constructed from swap rates published by De Nederlandsche Bank (www.dnb.nl). For the period 1973:I to 1987:III, zero-coupon yields with maturities of one to 15 years (from the Bundesbank website) based on government bonds were used as well (15-year rates start in June 1986). No adjustments were made to correct for possible differences in the credit risk of swaps, on the one hand, and German bonds, on the other. The biggest difference in yield between the two term structures (for the two-year yield) in 1987:IV was only 12 basis points.
- Stock returns: MSCI index from Fact Set. Returns are in euros (Deutschmark before 1999) and hedged for US dollar exposure.

Estimation procedure

The model implies relations for the yield curve linear in the state variables. Assume, two yields are observed without measurement error. For those yields it holds

$$y_t^\tau = (-A(\tau) - B(\tau)' X_t)/\tau$$

These observations can be used to determine the state vector X, given a set parameters which determine A and B. The other four yields are observed with a measurement error by assumption.

$$y_t^\tau = (-A(\tau) - B(\tau)' X_t)/\tau + \varepsilon_t^\tau \text{ and } \varepsilon_t^\tau \sim N(0, \sigma^\tau)$$

Assume no correlation between the measurement errors. This system of measurement equations is extended with the equations for the state, inflation and equity, which can be written as a vector autoregressive system

$$Y_{t+h} = \mu^{(h)} + \Gamma^{(h)} Y_t + \varepsilon_{t+h} \text{ and } \varepsilon_{t+h} \sim N(0, \Sigma^{(h)})$$

The likelihood is maximized with respect to the parameters using the method of simulated annealing of Goffe, Ferrier and Rogers (1994) to find the global optimum.

Estimation results

The estimation results for the Netherlands are presented in Table 1. For reference, the table also includes the estimates using the same model for the US (using the data in Koijen, Nijman and Werker). The significance of the estimates for the Netherlands is lower in general. The unconditional expected inflation is in the US (4.2%) larger than in the Netherlands (2.2%). This explains the 2% larger unconditional nominal interest rate in the US. The instantaneous short rate and expected inflation are increasing in both $X1$ and $X2$. $X2$ is more persistent than $X1$. Moreover, the persistence is larger in the Netherlands than in the US for both variables, which explains partly the less significant parameter estimates. The first-order autocorrelation on an annual frequency equals 0.503 and 0.861 for the US and 0.725 and 0.906 for the Netherlands, respectively. The equity risk premium (η_S) is 5.4% for the US and 3.5% for the Netherlands.. Table 2 reports the risk premium on nominal bonds along with their volatilities. The risk premium for bonds with a maturity of 10 years is 65 basis points higher in the Netherlands than in the US. Together these estimates determine the parameters of the model underlying the simulations of the pension cash flows and their valuation in the analysis of policy reforms in this paper.

Table 1: Estimation results for the US and the Netherlands

	US		Netherlands	
Parameter	Estimate	(Standard error)	Estimate	(Standard error)
Expected inflation $\pi_t = \delta_{0\pi} + \delta_{1\pi}' X_t$				
$\delta_{0\pi}$	4.20%	(1.03%)	2.24%	(1.45%)
$\delta_{1\pi(1)}$	1.69%	(0.19%)	0.49%	(0.27%)
$\delta_{1\pi(2)}$	0.50%	(0.24%)	0.49%	(0.24%)
Nominal interest rate $R_t = R_0 + R_1' X_t$				
R_0	5.89%	(1.66%)	3.70%	(2.77%)
$R_{1(1)}$	1.92%	(0.14%)	1.40%	(0.43%)
$R_{1(2)}$	1.03%	(0.26%)	0.82%	(0.68%)
Process real interest rate and expected inflation $dX_t = \mu dt - KX_t dt + \Sigma_X' dZ_t$				
κ_{11}	0.687	(0.177)	0.32	(0.23)
κ_{22}	0.172	(0.035)	0.13	(0.13)
κ_{21}	-0.350	(0.119)	-0.23	(0.16)
Realized inflation process $\frac{d\Pi_t}{\Pi_t} = \pi_t dt + \sigma_\Pi' dZ_t$				
$\sigma_{\Pi(1)}$	0.02%	(0.05%)	-0.01%	(0.07%)
$\sigma_{\Pi(2)}$	0.11%	(0.04%)	-0.01%	(0.06%)
$\sigma_{\Pi(3)}$	0.98%	(0.03%)	0.60%	(0.04%)
Stock return process $\frac{dS_t}{S_t} = (r_t + \eta_S)dt + \sigma_S' dZ_t$				
η_S	5.38%	(2.48%)	3.52%	(3.88%)
$\sigma_{S(1)}$	-1.98%	(0.57%)	-0.16%	(1.71%)
$\sigma_{S(2)}$	-1.79%	(0.70%)	1.01%	(1.61%)
$\sigma_{S(3)}$	-1.74%	(0.68%)	-2.65%	(1.56%)
$\sigma_{S(4)}$	14.82%	(0.32%)	16.71%	(0.98%)
Prices of risk $\Lambda_t = \Lambda_0 + \Lambda_1 X_t$				
$\Lambda_{0(1)}$	-0.293	(0.127)	-0.271	(0.266)
$\Lambda_{0(2)}$	-0.158	(0.071)	-0.279	0.238)
$\Lambda_{1(1,1)}$	-0.103	(0.182)	0.167	(0.252)
$\Lambda_{1(1,2)}$	-0.101	(0.038)	-0.114	(0.239)
$\Lambda_{1(2,1)}$	0.503	(0.078)	0.395	(0.246)
$\Lambda_{1(2,2)}$	-0.168	(0.132)	-0.126	(0.140)

Table 2: Risk premia and volatilities

	US		Netherlands	
Maturities	risk premium	volatility	risk premium	volatility
One-year	0.58%	1.77%	0.53%	1.37%
Five-year	1.44%	6.36%	1.80%	5.1%
Ten-year	2.06%	11.75%	2.71%	9.36%