Netspar Network for Studies on Pensions, Aging and Retirement

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Discussion Paper 02/2009 - 009

February 12, 2009

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12 February 2009

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Abstract

New accounting rules and increased scarcity of risk capital have led to growing pressure on corporations to shift pension plan risk from employers to participants. This implies a shift from Defined Benefit (DB) plans to a variety of collective and individual Defined Contributions (DC) plans. Most of these shifts have been ad-hoc and not based on clear and objective criteria. This article shows how negotiations could be clarified by using modern option pricing and financing techniques. Both the value of the guarantees regarding accrued pension rights, as well as future rights to be accrued, can be objectively determined. For example, the authors show that a shift from a typical DB to a collective DC plan should cost the employer a lump sum payment of twelve percent of the accrued pension obligations and an increase in the contribution rate at four percent of pay.

Pension Risks as Contingent Claims

The advent of mark-to-market accounting and increased risk awareness are two of many reasons that corporations are closing their traditional DB plans and shifting pension-related risk to individuals. In the UK, this has usually meant switching to individual schemes for new entrants. In The Netherlands, a collective element has maintained through inter-generational risk pooling arrangements among plan participants, leading to the creation of collective DC plans. [1]

An important challenge with these shifts in risk is finding an objective way to determine the amount of compensation employers should pay when they withdraw as a risk bearer in the pension plan.[2] This article sets out methodology for doing this. This methodology makes use of valuation techniques used for options and other derivatives. These techniques are suitable, particularly for pension funds, because the values of key variables like the contribution rate and indexation policies relate to the plan's financial position. As these variables are largely conditional, these are comparable with the conditional nature of cash flows related to options and other derivatives. Embedded option valuation methods are already commonly applied to insurers and banks. The application to pension funds is still relatively new.[3]

The article is written from a Dutch perspective, as funding and reserving regimes, as well as the types of guarantees and conditional indexation, reflect current Dutch practices. The fact that plans may remain open in the future is different from the UK experience, where the corporate pension plans are to a large extent closed. The methodology used in this article can be applied to either open or closed cases. Any DB pension arrangement between an employer and its employees can be stated in terms of contingent claims and can be valued within a contingent claim analysis framework.

Embedded Options in Pension Contracts

Framing DB pension plans as aggregates of embedded options builds on the work of Sharpe (1976), Kocken (2006) and Hoevenaars and Ponds (2008), among others. There are three types of options in these plans: indexation, contribution and shortfall-related.

Each type is further described in the definitions that follow. The contribution rate in DB schemes should, in principle, be equal to the costs of the new accrual of pension rights, taking into account the expected return on investments. We will call this contribution rate the plan's 'uniform contribution' below[4]:

- The Indexation Option - indexation is either a hard guarantee or conditional on the plan's funded status. In the latter case, annual updates are determined by a graduated indexation scale. If the nominal funding ratio is equal to or lower than the lower limit of the graduated scale, no indexation is awarded. If the nominal funding ratio is equal to or higher than the upper limit of the graduated scale, full indexation is awarded, and possibly supplemented with previous unawarded indexations. With funding ratios between the lower and upper limit, indexation reductions are imposed proportionate to the funding ratio. The economic value of this conditional indexation method is called the indexation option.

- The Contribution Option - the basis of this is the 'uniform contribution rate', which can also be used as a risk management instrument. Although it is not fixed, it includes a variable component (positive or negative) that depends on the funded status of the fund. The resulting contribution option value is the net outcome of the economic values of contingent contribution increases and reductions.

- The Shortfall Option (employer guarantee) - employers usually have a hard or moral obligation to act as guarantor in situations involving a nominal funding shortfall. This guarantee has financial value. The employer has effectively written a series of complex put options, the exercise price being a nominal funding ratio of one hundred percent.[5] Valuing these options requires determining the annual probability of a nominal funding shortfall and the size of each shortfall that occurs over the entire settlement period of the existing rights. These future funding shortfall estimates can then be valued in present-value units of money.[6]

The employer may or may not have a right to withdraw excess surplus. Even without this right, restitution can still be obtained indirectly through contribution reductions (e.g., exercising the contribution reduction option).

Risk Transfer Valuations in DB Plan Terminations

Following the pension crisis of 2001 to 2003, many Dutch pension funds switched from final earnings DB plans to career average plans with conditional indexation. Risk management is now conducted using graduated scales for determining the size of indexation (e.g., pension increases) and the contribution rate, based on the funding ratio of the pension balance sheet. When valuing risk transfers in these cases, a split must occur between accrued rights already paid for by the employer and employees and new rights to be accrued in future. The reason for this split is that the employer cancels its guarantee for the already accrued pension rights of existing participants and for the guarantee of pension rights to be accrued in future.

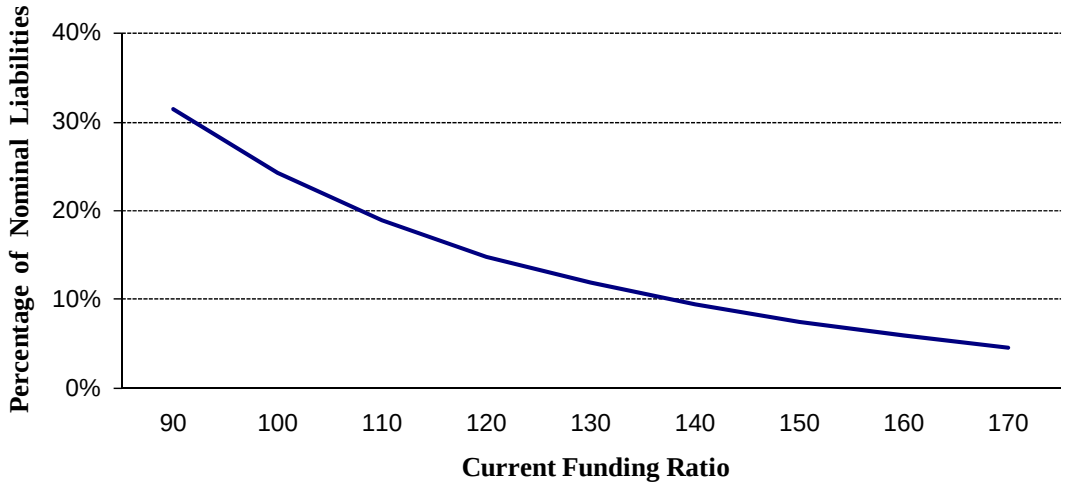
The valuation calculations that follow assume a typical pension fund with the following characteristics. The investment policy consists of fifty percent risk-bearing assets (e.g., equities, property and others) and fifty percent nominal government bonds. The lower limit of the graduated indexation scale is one hundred percent and the upper limit of the graduated indexation scale is one hundred thirty-five percent. The contribution rate is set at seventeen percent on the basis of a prudently-estimated real investment return.[7] At first, we fix the contribution rate to simplify analysis. Figure 1 gives the valuation of the employer guarantee for accrued pension rights for different values of the current funding ratio.

Remember that the employer guarantee is equal to the sum of the underlying put options with various terms, taking into account the entire settlement period of existing pension rights. In the case of a pension fund with a current nominal funding ratio of one hundred thirty percent, the employer guarantee is worth approximately twelve percent of nominal obligations. Figure 1 shows that the value of the employer guarantee is inversely related to the size of the current funding ratio and that the value rises faster if this funding ratio

falls. Many other factors also go into determining the value of the guarantee, like the selected asset mix and various policies (e.g., the indexation formula) agreed upon between stakeholders in the pension fund.[8]

In theory, if the employer contributes the calculated 'risk buy-off' amount into the fund, it can then use this amount to buy derivatives from another party so that the risks formerly carried by the employer are now transferred to other parties. In practice, risks will be transferred only in part to third parties through financial markets. This happens somewhat because the products are not easily obtainable in this exact form in the market and also because plan participants may be willing to bear part of the risk themselves. This applies mostly to funds with relatively young members and a reasonably high amount of – fixed or variable – contribution income.

Figure 1: Value of Employer Guarantee for Existing Pension Rights



Valuing Future Pension Rights

We will now discuss newly acquired rights that are financed with paid contributions. Suppose that the contribution is equal to the present value of the new rights discounted at the real default risk-free interest rate and that this contribution is subsequently invested in inflation-related, risk-free instruments. This contribution rate is the 'risk-free contribution rate' and will show the pension promise to be expensive. As a result, many pension funds invest in equities and other financial securities that carry risk but are expected to generate a higher return in the long-term. They then set the contribution at a lower level so that the sum of the paid contributions, plus *expected* investment returns, is equal over time to the payment obligations. We called this the 'uniform contribution rate' as previously described.

The difference between risk-free and uniform contribution is the economic value of the accepted risk (the 'contribution reduction'). On plan termination, the employer should also pay an annual compensation equal to the contribution reduction. In theory, the employer can do this by raising the gross wage by the risk-free contribution so that employees can pay the contribution themselves, or the employer can pay this amount directly to the pension fund. The reality of this scenario is more complex and interesting because the employer and its employees each implicitly pay part of the uniform contribution rate and take part of the contribution risk on themselves.

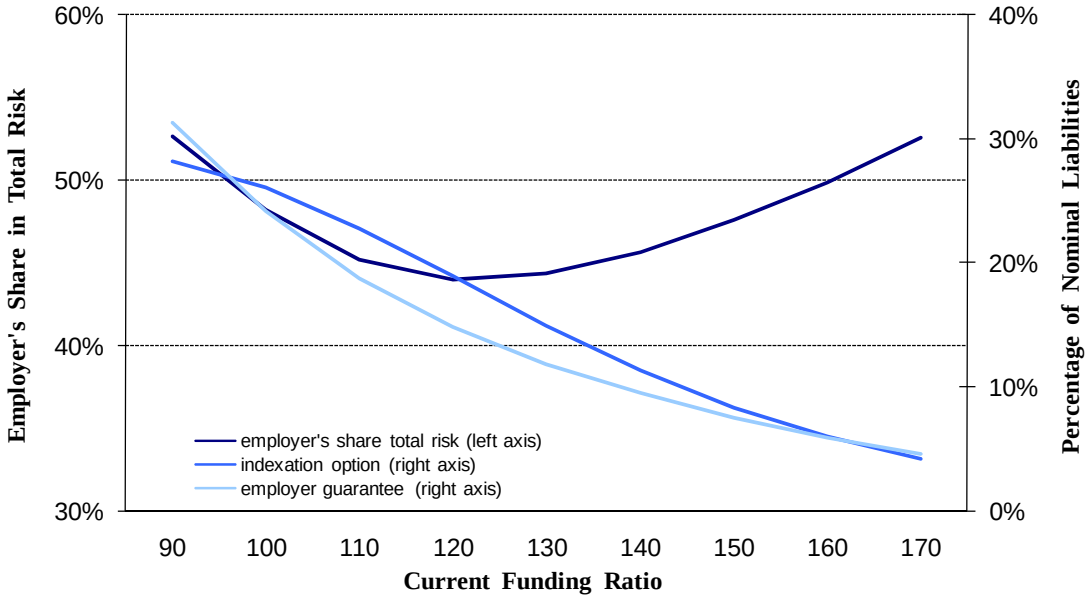
Calculating the Cost Split

The contribution risk ratio may be very different from the employer-employee ratio for paying the uniform contribution rate. The pension deal identifying what stakeholders are responsible for when, and to what extent, for absorbing shortfalls or surpluses is important. A value can be assigned to these arrangements using the option method previously discussed, leading to values of the employer's and of participants' options in the risk-bearing structure. These options are a composite of the previously described shortfall, contribution, and indexation options.

The employer's option is comprised of: the value of its commitment to make up a nominal shortfall, the net value of the right to receive a contribution reduction and the obligation to pay a contribution increase in line with the pension deal. The participants' option has indexation and contribution elements. The employer's risk share is then determined using the ratio of the employer's option, divided by the sum of the employer's and participants' options. This ratio permits the 'contribution reduction' to be divided between employer and participants in proportion with the risk incurred. In the calculations, the indexation and shortfall options of the existing rights were used to determine the share of risk.[9] Other valuation factors include the choice of investment mix, the size of the funding ratio at the time of employer withdrawal and actuarial factors such as the future development of participants.

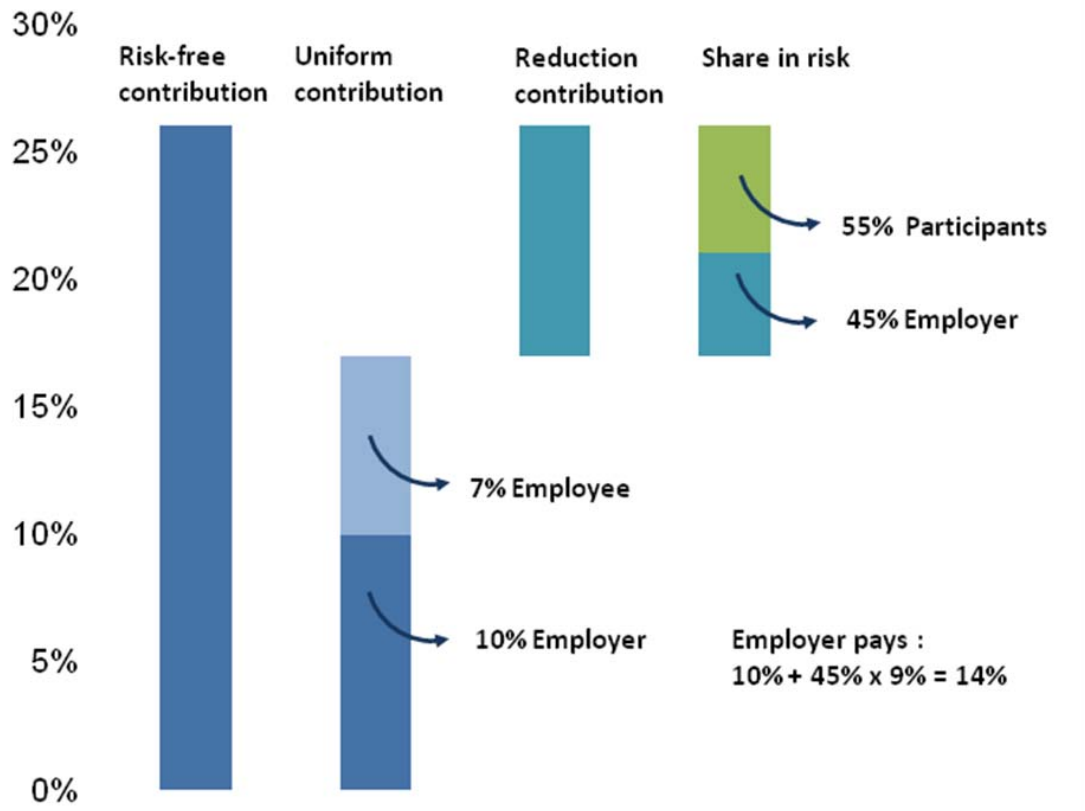
Let's look at a plan where the Board of Trustees has set the uniform contribution rate at seventeen percent, while the risk-free contribution rate is estimated at twenty-six percent. The 'contribution reduction' amounts to nine percent. So how much of this nine percent can be attributed to the employer and should be added to its contribution rate if it no longer wants to be a pension plan risk underwriter? Figure 2 provides the answer. The Y axis indicates the percentage of risk the employer assumed and represents the percentage difference between the risk-free and uniform contribution rates that the employer must pay through an annual contribution increase if it terminates its guarantee.

Figure 2: Employer's Share in Total Risk



In Figure 2, the additional employer contribution for the accrual of new rights depends on the funding ratio at the time of withdrawal. For example, with a nominal funding ratio of one hundred thirty percent the annual contribution increases by four percent on top of the uniform contribution rate. That is approximately forty-five percent of the nine percent rate reduction caused by the risk-taking aspect of the fund. Suppose that the employer paid ten percent of the wage sum as part of the uniform contribution rate and employees paid seven percent. After buying off its pension risk obligation, the new employer contribution rate is fourteen percent. We emphasize that these estimates are only illustrative and the ratios may differ significantly from one pension fund to the next. Figure 3 shows the described calculations on a step-by-step basis.

Figure 3: Calculating the Employer's New Contribution Rate



The Funded Ratio and the Employer's Risk Share

An interesting phenomenon reveals itself in Figure 2. At first, the employer's share in the total risk undertaken in the pension fund decreases with an increasing funding ratio and then it increases. Why does this 'local minimum' happen? The explanation lies in the structure of options. The indexation option is a digital option because plan members receive either full indexation, partial indexation or no indexation. This implies there is a maximum on the option's value. This maximum is the difference between liabilities discounted at real rates minus liabilities discounted at nominal rates. When funding ratios are very high, the indexation option is worth little compared to the employer's guarantee. At lower funding ratios, the indexation option gains faster in value than the employer's guarantee, but at some point gets closer to its maximum value. That said, the employer's

guarantee continues to increase in value when funding ratios drop further, prompting the employer's share in total risk to increase again.

This naturally then begs the question: what funding ratio should be used to identify the employer's share percentage in Figure 2? It seems logical to take the ratio consistent with enabling a sustainable funding policy. This will differ from one pension plan to the next and depends partly on factors like the required funding ratio under the FTK (the Dutch Financial Assessment Framework), as well as where the upper limit of the graduated indexation scale is set. A value of approximately one hundred thirty may be considered a reasonable general guideline, as the employer's share percentage is relatively flat in that region.

Investment Policy and the Employer's Risk Share

Another interesting factor to consider is how results change according to the investment policy of the pension fund. Figure 4 shows the influence of asset allocation on the employer's share of total risk. Differing asset allocations change the contribution reduction as previously described, since the employer's stake in the total risk increases when return volatility also does. This happens because increasing volatility has more impact on the employer guarantee than on the indexation option. This is again due to the capping of the indexation option, since additional volatility does not have the same impact on this option as it does on the uncapped employer's guarantee.

So what is implied by the relationships in Figure 4 when change is negotiated to the terms of a corporate pension deal? The implication is that the contribution reduction of a pension fund used to taking considerable market risk has been high. At the same time, the employer has had a relatively high stake in total plan risk. So, underwriting pension risk in a high risk pension fund means the additional contribution the employer should pay on top of its previous (relatively low) payments will be significant.

Figure 4: Employer's Share in Total Risk for Various Asset Allocations

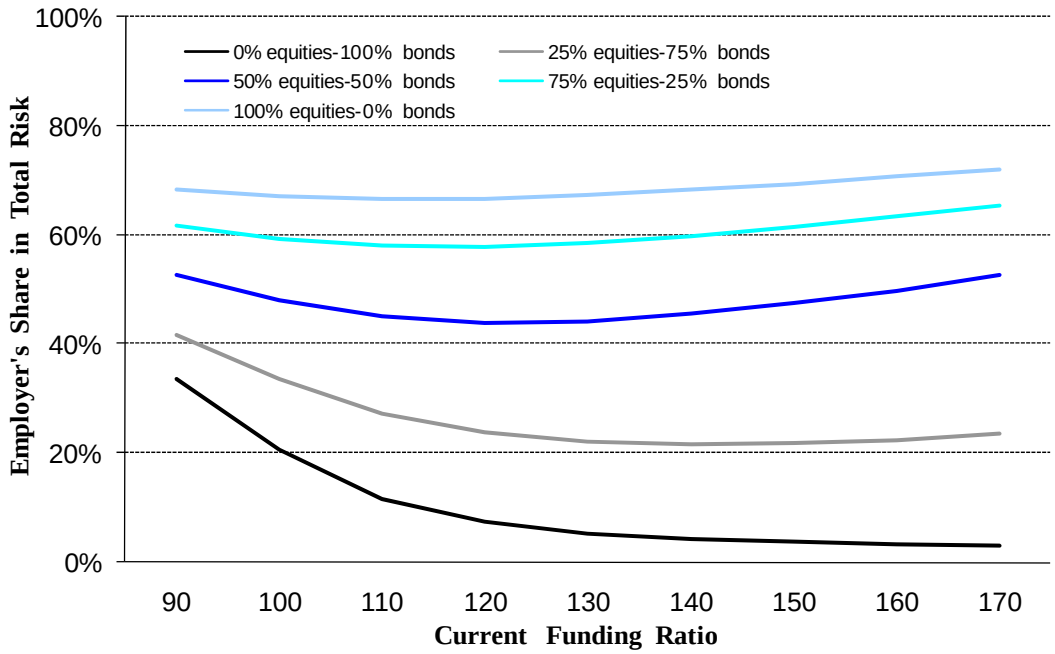


Table 1 pulls these different relationships together. Assuming a 'sustainable funded ratio' of one hundred thirty, it shows the impact of different asset allocations on the employer's risk share, the contribution reduction and the additional employer contribution the moment it stops being a risk underwriter. A riskier asset mix leads to a lower contribution rate due to the expected higher return. The rise of the employer's guarantee relative to the indexation option increases the additional contribution if the employer retreats as a risk taker. The last column also includes the fixed portion the employer pays in the uniform contribution (e.g., $10/17^{th}$ of the uniform contribution). With increasing investment risk, the uniform contribution reduces and as a result, the total contribution a risk-retreating employer pays increases only slightly as a function of risk levels in the pension fund.

Table 1: Employer's Contribution After Retreating as a Risk Taker

Asset Allocation	Employer's Share in Total Risk	Contribution Reduction Due to Risk	Total Additional Contribution in Case Employer Retreats as Risk Taker	Fixed Part Employer in Uniform Contribution	Total Contribution in Case Employer Retreats as Risk Taker
75% Bonds 25% Equity	22%	5%	1%	12.6%	13.6%
50% Bonds 50% Equity	45%	9%	4%	10%	14%
25% Bonds 75% Equity	58%	14%	8%	7.4%	15.4%

Further Considerations

After the employer has bought off the existing rights, the pension plan's financial policy parameters may need to be revised. This could involve a change in investment policy. The graduated indexation scales may also be revised, as might the uniform contribution rate. If plan members are prepared to run more risk, they could set a lower uniform contribution rate. On the other hand, if they want lower investment risk exposure, they must pay a higher contribution rate. That said, the employer has bought off its risks and changes in the pension fund no longer have any impact on this contribution.

The case examined above sketches out a situation where the employer switches over entirely to a fixed contribution rate for the future. All future risk contingencies have been laid off including changes in interest rates and longevity. Reality may be less clear-cut. Small contribution adjustments may still be necessary for significantly changing circumstances. The key point contained in the example is that the employer no longer provided any guarantees that can influence its balance sheet. This is particularly vital for employers who are willing to pay for good pensions, but simply cannot afford the risk of large fluctuations in their capital. Given the current credit crisis and the increasingly scarcity of available risk capital, this risk-averse attitude is likely to become even more prevalent among employers.

In Conclusion

Employers in The Netherlands are prepared to pay for good pension provisions. Despite this, the aging population, stricter accounting rules and the increasing scarcity of risk capital for companies is creating additional pressure to shift more risk from the employer to participants. This has resulted in the shift to the collective DC formula described in this article. That said these shifts are often negotiated without clear, objective criteria.

These negotiation processes can be greatly strengthened by using modern option pricing and financing techniques. This article has demonstrated that the value of guarantees regarding accrued rights, as well as future rights can be objectively determined. How plan participants distribute the risks can also be answered with the aid of the previously described techniques. Finally, the same techniques can also assist in negotiating DB plan conversions outside The Netherlands.

End Notes

[1] See Steenbeek and Van der Lecq (2007), Ambachtsheer (2007), Ponds and van Riel (2009), and Boeri et al. (2006) for more on the Dutch pension system.

[2] The models only address investment risks and wage inflation risk. Longevity risk is not incorporated. The longevity guarantee implicitly present in defined benefits is valuable but difficult to model. It is assumed that the survival table reflects the most recent 'best estimate' of longevity risk but unexpected changes are excluded from the model. Unexpected changes in the future may be partially compensated by changes in the age of retirement and therefore not impact the employer's guarantee too much.

[3] For a further explanation of the applied techniques and similar applications, see Kortleve et al. (2006), Kocken (2006), and Hoevenaars (2008).

[4] The options methodology employed in this article is described in greater detail in Appendix A. Pension-related options are valued with help of Value-Based Asset Liability Management (ALM) technology, described further in Appendix B. See below for more information on the Appendixes.

[5] The shortfall option is the value of the guarantee extended by the employer to supplement the assets up to the value of the nominal obligations if a nominal shortfall occurs. In the present study this is done for a horizon of N years (where year N is equal to the year with the last payment of existing accrued rights) by supplementing ⅓ of the shortfall in the first years 1 to N-1, in line with the wish of the Dutch regulator to make up shortfalls within a maximum of three years. In year N, however, everything is supplemented in order to close the analysis period without a shortfall.

[6] Obviously, there is counterparty risk to the beneficiaries: Situations where the employer cannot make payments to the fund for the full amount of the deficit. The model applied in this paper does not address credit risk. We assume the counterparty risk of the employer is small and does not have a material impact on the option price. We refer to Kocken (2006) for an elaborate treatment of the valuation of embedded options incorporating counterparty risk (corporate pension fund case), as well as an analysis of the impact under variations in the credit rating of the corporate sponsor.

[7] The ALM framework is based on a simulation study which projects the development of the pension fund in many future scenarios. As this paper focuses on the valuation of the employer guarantee, we have suppressed the investment universe of the ALM framework. The investment universe consists only of a MSCI world stock index and nominal bonds with a constant maturity of ten years. Furthermore we assume that wage inflation equals price inflation, so that real wage growth is zero. We describe the return dynamics by a first-order vector autoregressive (VAR) model. The relevant economic factors z_t in the model include the short three-month interest rate, the ten-year zero coupon rate, price inflation, stock returns in excess of the three-month interest rate, and the corresponding dividend yield. Returns on a rolling ten-year constant maturity bond portfolio are constructed from the nominal term structure. Formally, the VAR is written as:

$$z_{t+1} = c + Bz_t + \Sigma\zeta_{t+1}$$

where $\zeta_{t+1} \sim N(0, I)$. To derive an affine term structure of interest rates, we use the no-arbitrage assumptions, and we specify the pricing kernel as

$$-\log M_{t+1} = \delta_0 + \delta_1 z_t + 1/2\,\lambda_t^{'}\lambda_t + \lambda_t\zeta_{t+1}$$

Where λ_t are time-varying prices of risk which are affine in the state variables. Monthly European data (1973:01-2006:12) are used to estimate the parameters. MSCI world stock returns (in Euros and dollar hedged) and dividend yield are from Factset. German interest rates are from the Deutsche Bundesbank, and the price inflation (non-seasonally adjusted) is from Datastream. Stochastic scenarios are constructed by forward iterating the VAR. The estimation results are not reported here. For further technical details and a summary of the data and estimation results, we refer to Hoevenaars (2008).

[8] See Kocken (2006) for an analysis of changes in the value of such options due to changes in various policy and external variables in and around the pension fund.

[9] In this example the contribution has been set at a fixed percentage of the wage sum, and has thus been abstracted from the contribution option.

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Appendix A: Balance of Pension Fund Rewritten as an Aggregate Of Embedded Options

The balance sheet of a pension fund at any point in time can be rewritten as a system of embedded options. Let's assume that a one-off premium is paid in period 0, so that in the following period 1, a one-off pension benefit L_1 can be paid out. The premium paid in t=0, A_0, may be equivalent to the present value of the pension benefit in t=0 as shown in the balance sheet below whereby R_0 represents the pension fund residue at t=0. The term $PV[L_1]$ represents the present value of L_1, with the risk-free actual interest r as discount rate: $PV[L_1] = L_1/(1+r)$.[9]

A_0	|	$PV[L_1]$
	|	R_0

The premium A_0 can be equated to $PV[L_1]$. If this premium is paid into risk-free government bonds, then the capital in the following period, A_1, will be exactly the same as the pension to be paid out L_1: $A_0 (1+r) = L_1$, where r is the actual rate of interest, $R_0=0$. The disadvantage of this approach is the high contribution rate.

A lower contribution rate is possible when investment risk is accepted. The expected return on the risky portfolio E[R] (with $E[R] > r$) can be used to calculate the premium: $L_1/(1+E[R])$. The premium will then be smaller than the present value of L_1 in t=0: $A_0 < PV[L_1]$. The expectation here is that the amount of the premium, plus investment yield, will be equal to the pension payment. An investment return higher than the expected return will provide a surplus, where a return lower than the expected return will produce a shortfall. A surplus situation can be seen as the payment of a call option with L_1 as the strike price and with $A_1 - L_1$ or 0, whichever is greater as the pay-out. A situation producing a shortfall can be seen as an obligation to pay off a written put option with L_1 as the strike price and with $A_1 - L_1$ or 0, whichever is less as the pay-out. This can also be

expressed in terms of the familiar put-call parity. This parity states that the payoff of a high risk asset can be replicated by an investment portfolio consisting of a risk-free investment (e.g., a government bond, but in this case, a pension benefit), plus the payoff of a call option, minus the payoff of a written put option:

$A_1 = L_1$ + payoff call – payoff put.

Expressed in market value terms we arrive at:

$A_0 = PV[L_1] + PV[call] – PV[put]$.

The expression above can be alternatively rewritten to a balance sheet position:

A_0	|	$PV[L_1]$
	|	$R_0 = PV[call] – PV[put]$

At a single point in time 0, due to a deliberate choice to enter into a risk and a premium contribution A_0 (uniform contribution) that is less than the value of the liabilities, we find $A_0 < PV[L_1]$, or $PV[call] < PV[put]$ and so $R_0<0$. If things go as expected and the 'risk premium materializes', the call increases in value and the put value decreases. For every existing pension fund with a pension contract that specifically states what party will bear what part of the risk going either up or down, this contract can be translated in concrete, embedded options.

In setting the paper, the put-call parity contains the terms below (where assets no longer include just the premium payments but a complex mix of premium payments, investment yields and pension payments):

$A_0 =$ $PV[L_1]$ + Surplus Option – Indexation Discount Option – Nominal Shortfall Option + Premium Discount Option – Premium Loading Option

The key question is: how are the various options allocated amongst stakeholders? The content of the pension contract is very important to this question since it sets out consequences of any change in the financial position of the fund for fixing premiums, indexation policy, and so on. A pension contract is not always conclusive and all options are not always neatly allocated between employer and employee. The surplus option in particular – the biggest part of the upside (the call) – usually receives little attention in terms of ownership rights.

As a result, the analysis in the article will not include the surplus option as 'undefined ownership' and the analysis shall focus on the risk element assumed by employers and employees.

Appendix B: Value-Based Asset Liability Management as a Supplement to Classic Asset Liability Management

The basic technique used in this study to value the various embedded options is Value-based Asset Liability Matching (ALM). This method makes it possible to determine the value of a complex long-term commitment as if it were a negotiable financial contract. This information is used, for instance, to determine the compensation level for a major policy change such as the transition to Collective DC.

How does Value-Based ALM relate to Classic ALM as prescribed by financial theory and practice? Classic ALM analysis focuses on showing probability distributions of key pension fund variables. This occurs using econometric techniques for statistically-responsible projection of economic scenarios regarding the development of equity markets, interest rates and inflation in the future. This results in a series of probability distributions for the most important variables of a pension fund such as the funding ratio and the extent to which indexation is awarded. The information from the probability distributions are used to weigh up risks on one hand (e.g., probability of a funding

shortfall), versus the expected return (e.g., the expected percentage of indexation awarded to the participants and the expected average paid contribution) on the other.

By adjusting control variables such as the allocation to investment classes, derivatives overlay and pension contribution, it is possible to look for the most acceptable solution. Given that a pension plan has different stakeholders – employers, employees, retirees and future participants – and represents different and sometimes conflicting interests, there is no uniform set of objectives leading to an optimal result. Instead, this situation calls for a highly complex analysis of multiple criteria where diverse interests need to be reconciled.

With Value-Based ALM, the policy is not only evaluated on the basis of probability distributions but also in terms of economic value. By determining all contributions, payments and investment returns in each of the future scenarios and calculating their present value with the stochastic discount rate belonging to each of these scenarios, it is possible to determine the present economic value of these cash flows. Economic value can then be understood to mean the present financial value of uncertain future cash flows. For example, this relates to the value of future indexation flows and contributions. By changing policy now and looking at how the value of these factors changes, we obtain an idea of the absolute and relative changes in the value contributed by stakeholders. This, in turn, can be used to make policy changes value-neutral for each stakeholder.

In short, Classic ALM optimises the policy, while Value-Based ALM can be used to ensure that this takes place on fair economic terms between stakeholders.