Pension fund risk management: Multi-stakeholders, risk management and the embedded options approach

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Abstract Pension funds have gradually become institutions where various stakeholders — retirees, employers and employees — share the risks. These risk-sharing agreements imply that various complex options, with different characteristics, are 'traded' within the pension fund. Different stakeholders assume different kinds and levels of risk that need to be valued and managed. The approach put forward in this paper aims to make the valuation and risk characteristics of these embedded options transparent. This approach is gaining importance as the new form of risk management for pension funds. It has important applications in solvency management, merger and acquisition activities, pension fund redesign and hedging pension fund risks. The exact structure of the models and the corresponding assumptions are to a large extent omitted in the text. The underlying research in this paper and the quantitative results are based on the author's book, 'Curious Contracts. Pension Fund Redesign for the Future'. Anyone wishing to check the results or understand the quantitative modelling of embedded options can download the text, free of charge, from www.cardano.com.

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THE NEED FOR UNDERSTANDING EMBEDDED OPTIONS IN PENSION FUNDS

The balance sheet sizes of European defined benefit (DB) pension funds often equal or exceed the capitalisation of the sponsor. Employers have implicit or explicit covenants with their pension fund to support any funding deficit. This resembles a kind of put option on the funding ratio of the pension fund, written by the employer to the pension fund. At the same time, many pension funds are structured so that beneficiaries such as pensioners and active employees bear risks. For example, the scheme can be structured such that inflation-linked indexation may be forgone where the funding level falls below a certain threshold (called conditional indexation) or liabilities may be reduced where longevity numbers unexpectedly increase.[1] Expressed as embedded option values, the contingent claims that stakeholders have in pension funds can easily exceed 20–30 per cent of total liabilities in a pension fund. Considering that the estimated value of the liabilities of the UK and Dutch pension funds alone already exceeds €2,000bn, the value of the embedded options exceeds hundreds of billions. The value of these embedded options is even greater if other European countries with DB schemes are included (especially countries with sizeable schemes such as Switzerland, Sweden and Denmark).

In these 'pension deals', risks are shared among stakeholders; however, not every stakeholder assumes the same risks. This is understandable (some are better equipped to absorb risks than others), but what is striking is:

- When valuing risks, insufficient consideration is given to assigning an objective market value to the embedded options.
- There is even less understanding of the risk characteristics of these options. The hedging of pension fund risks cannot be conducted properly without a clear understanding of the characteristics of these options.
- Little is known about the conflicts of interest that exist between stakeholders because of their different positions in these embedded options. This insight would be useful in solving stakeholder conflicts.
- Risks are not properly compensated. The lack of any kind of explicit compensation agreements could create strong incentives for some groups to retreat as risk takers. This may eventually cause a serious threat to the sustainability of the collective risk sharing within the pension system. An understanding of these options is therefore a necessary condition for reshaping these pension contracts and for securing the DB pension system.

Following the recent market turmoil, funding ratios have come down, corporate ratings have often been downgraded due to highly leveraged balance sheets, and volatilities have gone up. The value of embedded options has therefore increased significantly, as will be shown, and their importance in risk management and pension fund design is growing. Due to low funding ratios, conflicts between employers and beneficiaries will be more likely, and insight into these options could support the process of finding solutions and easing the tensions in the pension fund system. The impact of risk hedges on the risk exposure the corporate sponsor has to the fund is another item that will most certainly gain attention in the aftermath of the credit crisis.

The main focus in this paper is to provide further detail on the valuation of embedded options and their risk profiles. Valuation of such options has many uses, such as helping corporate sponsors to assess the claim the pension fund has on its balance sheet. The information contained in the value of these options can also be used by beneficiaries to assess the impact on their pension value of changes in policies, such as higher volatility or different indexation policies. This can also prove equally valuable for many other purposes, such as in merger and acquisition negotiations or in value transfer mechanisms to define how (groups of) participants move from one pension fund to another.

This paper discusses the value of embedded options and the application of this to risk management, using case study examples. The studies themselves are not explored in any detail here, however, references to papers where more detail can be found have been included.

The paper aims to provide an insight into embedded options, their value as a function of various parameters and risk characteristics, and explains how this can be used for better risk management and pension redesign.

SOME EMBEDDED OPTIONS FOR STAKEHOLDERS

Before embedded option values are analysed it is useful to provide a brief description of some of the relevant options. In DB pension funds, it is interesting to compare the options based on the risks the employer assumes with the options the beneficiaries (actives and retirees) write to the pension fund.

The main (series of) embedded option(s) that the employer writes to the pension fund is the so-called parent guarantee, which also can be referred to as the sponsor covenant. This is the guarantee to support the pension fund in case of funding shortfalls. This option depends on, among other factors, the exact trigger levels at which the parent will pay and the amount that will be paid, as well as the development of the default probability of the parent company over time. The value of this option has gained attention since accounting rules such as Financial Reporting Standard 17 and International Accounting Standard 19 forced corporates to run pension deficits via their balance sheet. This 'sponsor covenant' option in fact provides the market value for future deficits, a good indicator for the risks they face.

Important options that the beneficiaries write to the pension fund are the indexation option and the pension put. The indexation option is the right of the pension fund to waive indexation in case of an insufficient funding level.[2] This is sometimes implemented as a full-indexation-or-no-indexation construction, with only (full) indexation granted to beneficiaries above a certain threshold level of the funding ratio. The cases applied in this paper assume this kind of 'digital' construction. This could also be structured as a scale of indexation gradually increasing as a function of the funding ratio as agreed by the board members.

The 'pension put' is the option on a joint 'default' event (ie a deficit in the pension fund and at the same time a default of the employer). Such a joint event will imply write-offs of the pension entitlements, defined as the 'pay-out' of the embedded option. The value of the option depends on, among other things, the (assumptions made with respect to) default probability as a function of time, recovery rates and correlation between financial markets and the default probability. In the example in the text, the correlation between the equity market returns and default probability equals –0.7; research revealed that values closer to 0 did not change the results considerably.

Many pension funds receive contributions from the employer, often partly paid by the employees, which deviate from the actuarial ('cost') price of the annuities provided to the beneficiaries. In other words, contributions fluctuate annually as a function of the funding ratio. If no risk was taken in the pension fund, the required contribution would equal the actuarial cost price. Because of the risks being taken, contributions within the pension scheme can on average be set below this price, but in times of bad performance, it is often agreed that contributions can increase and exceed the actuarial cost price. If contributions are partly paid by the employer and partly by the employees, both employer and employees have written options to the pension fund (higher contributions than the actuarial cost price in case of a low funding ratio), but they also receive options from the pension fund (in the form of contribution cuts in cases of a high funding ratio).

Many other embedded options are implicitly present in pension funds, although the set described above covers the majority of options in DB funds in Northern Europe. As all the embedded options impact other options, the process of valuation, understanding the risks and hedging the risks becomes extremely complex yet extremely important.

VALUING RISKS AS EMBEDDED OPTIONS

Various embedded options in pension funds can be identified and most can be explicitly calculated using market consistent valuation. The values of the embedded options in this paper are measured using arbitrage-free option pricing techniques and assuming complete markets.

The assumption of complete markets is quite a strong one. For example, inflation-linked derivatives and other products are available but not yet extremely liquid in most currencies. By incorporating larger bid-offer spreads for these kinds of products, this incompleteness can be captured to a certain extent.[3] Also, longevity-linked products are not yet available in a well-traded market, but risks can be reinsured via life insurance companies.

Furthermore, an assumption is made that the pension fund stakeholders have arranged very explicit contracts (options) between themselves and the pension fund. (In many cases, the 'pension deal' is not very well specified. This may hinder valuation considerably, but will also create an incentive for gaming and may be another reason for participants to try to escape pension fund membership.)

The options are path-dependent — the value of the option not only depends on the current values of the market variables but also on realised values of the market variables (their 'path') in the past. The options are also quite complex, which makes Monte Carlo simulations of market consistent and arbitrage-free scenarios (and taking the expected value under this risk-neutral measure) the most appropriate measurement technique.[4]

To provide an idea of the values of these options, Table 1 presents some results (at an initial funding ratio of 100 per cent and a stylised asset allocation of 50 per cent equity, 50 per cent bonds) for three different credit ratings of the underwriting employer.[5] The example shows a pension fund with a fixed contribution rate to make three specific

Table 1: Option values (% liability value) as a function of employer's credit rating

	Equity % in total assets		
Type of option	30%	50%	70%
Pension put	2.5	3.1	3.8
Indexation option	12.3	11.3	10.4
Parent guarantee	15.2	17.8	22.7

options and their interaction very explicit: the indexation option, the pension put (both belonging to the beneficiaries) and the parent guarantee (related to the employer).

From Table 1, it is clear the embedded option values can be substantial relative to the size of the liabilities. This is particularly significant when one considers that many pension funds have liabilities that equal or even exceed the capitalisation of the parent company.

Clearly, for an employer with a low credit rating, the amount of risk beneficiaries are taking is higher in embedded option value terms than the risk assumed by the employer. This picture is completely reversed in the case of a supporting employer with a high credit rating.

Option values depend heavily on other parameters, such as the composition (and hence the volatility) of the asset mix. Table 2 provides some insight into the impact of asset allocation on the embedded option values. A very stylised asset mix of equity and bonds is applied for explanatory reasons and the asset allocation is represented by percentage equity versus percentage bonds. The credit rating of the sponsor in Table 2 is BB.

Although only a limited set of outcomes is presented, Table 2 reveals very interesting patterns. For example, increased levels of risk taking increase the value of the parent guarantee as well as the pension put, with the relative increases being of similar size.[6] However, the indexation option value is shrinking as a function of higher volatility. This latter — slightly counterintuitive — phenomenon can be explained by the fact that, where there is a low funding ratio, a higher level of volatility increases the likelihood of avoiding indexation cuts. In other words, in case the funding ratio is such that no indexation is granted, the only way to improve this no-indexation situation for the beneficiary is by getting to a higher funding ratio. This is more likely to be achieved with high volatility than with low volatility (without the possibility of any more losses in terms of more indexation cuts, as indexation is already reduced to its lowest level, zero).

Table 2: Option values (% of liability value) as a function of asset mix composition

	Employer's credit rating		
	CCC	BB	A
Pension put	10.0	3.1	0.3
Indexation option	12.1	11.3	11.0
Parent guarantee	8.7	17.8	21.3

EMBEDDED OPTION APPLICATIONS IN RISK MANAGEMENT

Knowing the value of the embedded options generates new applications in many different ways. For example, the sensitivity of these options to market variables such as real or nominal interest rates can be determined, which makes it a very useful tool in hedging pension funds' risk. The sensitivity to more implicit market-related variables such as the funding ratio is another important measure. Furthermore, these embedded options are sensitive to the volatility of the pension fund's assets. For some parties, it may be advantageous to increase the volatility of the pension fund, for others it may be more advantageous to reduce volatility. This implies that conflicting incentives can be revealed through better understanding of the nature and quantitative characteristics of the embedded options.

Another relevant application is in the area of pension redesign. Knowing the amount each stakeholder is writing to the pension fund reveals how much stakeholders implicitly inject into the pension fund. If these values differ too much between stakeholders, this may cause tensions if nothing is granted as compensation for taking these risks. In these cases, the pension system may very well be non-sustainable in the long run. Therefore, the embedded option information can be used to help reduce these tensions, by using knowledge of the values of the various options.

SENSITIVITY ANALYSIS

Embedded options can be treated similarly to 'normal' options, including the risk management of these options. In the case of conditional indexation, for example, a pension fund is exposed to both nominal and real interest rates. Given the nature of the indexation option, the risk associated with nominal or real rates very much depends on the 'health' of the pension fund (ie the funding ratio). In the case of a low funding ratio, little inflation-linked indexation is expected to be paid in the future and the pension fund is mainly sensitive to nominal interest rates. At very high funding levels, indexation is very likely to be granted many years ahead and the pension fund is mostly sensitive to real interest rates.

For non-extreme funding ratio situations, the indexation option is sensitive to both nominal and real interest rates. This sensitivity can only be determined by knowing the indexation option's value and its first-order derivative as a function of the two relevant types of interest rates. Figure 1 provides an example of how the interest rate sensitivities (both sensitivity to real yield changes as well as nominal yield changes) of the liabilities of a pension fund change as a function of the funding ratio. For a thorough explanation of the values in this example as well as the values in the examples below, see Chapters 3 and 4 of Kocken (2006).[5]

This approach is useful to determine the optimal hedge in case a pension fund wants to minimise interest rate risk or — as is often seen in practice — if there is a need for a liability benchmark

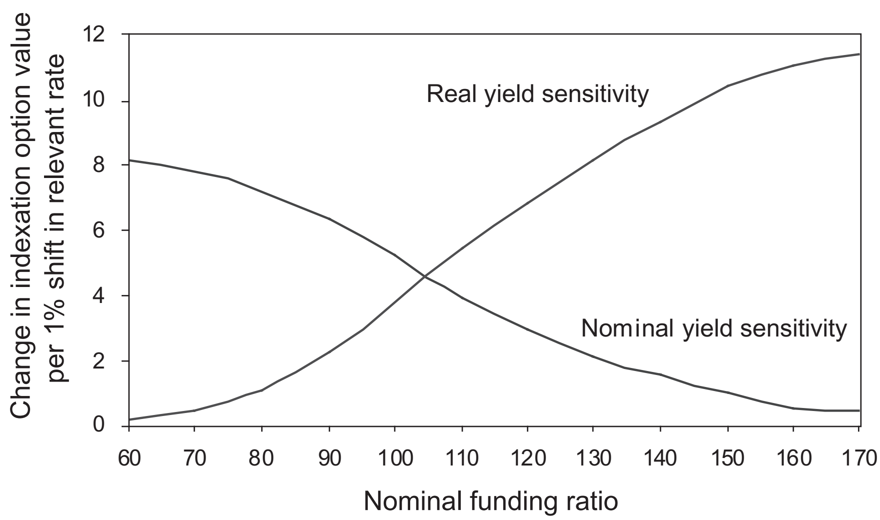


Figure 1: Nominal and real interest rate sensitivities of the conditionally indexed liabilities

against which risk and return will be measured.

In practice, interest rate risk is one of the dynamic market factors in which a pension fund may want to invest, in order to obtain a serious risk-return profile. Usually this profile is optimised in a going concern asset and liability management context. In this case, the sensitivity analysis is useful to understand the outcomes and compare against the risk minimising hedge position (liability benchmark).

The sensitivity of the option value to changes in the funding ratio can also be determined. This is akin to the concept of 'delta' in risk management, although the funding ratio itself is not a real market variable. This reveals the extent to which the stakeholders are exposed to changes in the funding ratio. An analysis of the second-order derivative of the value of various options to changes in the funding ratio, better known as gamma, therefore shows whether stakeholders are more exposed to downside risk (negative gamma for the stakeholder) or to upside opportunities (positive gamma for the stakeholder).

Figures 2a and 2b provide an indication of the delta and gamma values (sensitivities to changes in the funding ratio) for two relevant embedded options in DB schemes with conditional indexation: the indexation option and the parent guarantee. The delta values in this example are negative, but for clarity, the absolute (positive) values are presented.

The delta and gamma profile of the parent guarantee is quite different from the profile of the indexation option. The indexation option has very specific features because its value is limited at both the upside and the downside. This creates both positive and negative gamma values, which has serious implications for risk management. For those familiar with the theory of digital options, this will sound very familiar.

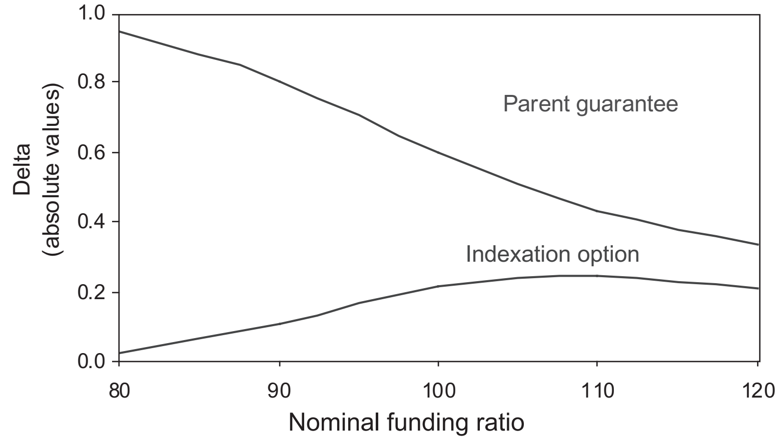
The indexation option in this example has a digital (binary) option structure. Other kinds of indexation agreements, with a more gradual increase of indexation with increasing funding ratio, are more similar to call-spread positions, although with the same kind of risk management characteristics.

Also important from a risk management perspective is the change in the value of the embedded options to the various stakeholders resulting from changes in the volatility of the pension fund's assets (ie the 'vega' value). This reveals how stakeholders are affected by changes in, for example, the asset allocation (and thus the volatility) of the pension fund.

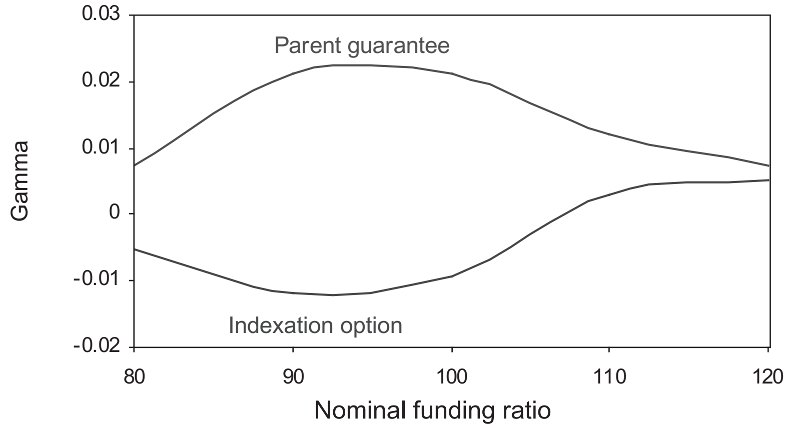
Figure 3 shows the vega value of the parent guarantee and indexation option.

Vega values are expressed in terms of the value of the pension fund and will be positive or negative depending on whether they are considered from the perspective of the parent or the pension fund. For example, the parent guarantee is positive for the pension fund (for all funding ratios) and is therefore negative for the parent. This implies that, in this example, the corporate sponsor will prefer a lower volatility to reduce the value of the parent guarantee. It should be noted that this example abstracts from other options available to the employer such as the contribution rate option that can have a positive vega value.

Interestingly, for a low funding ratio, the vega value of the indexation option is positive for the beneficiaries (and negative from the pension fund perspective). This



(a)



(b)

Figure 2: (a) Delta characteristics as a function of the funding ratio; (b) gamma characteristics as a function of the funding ratio

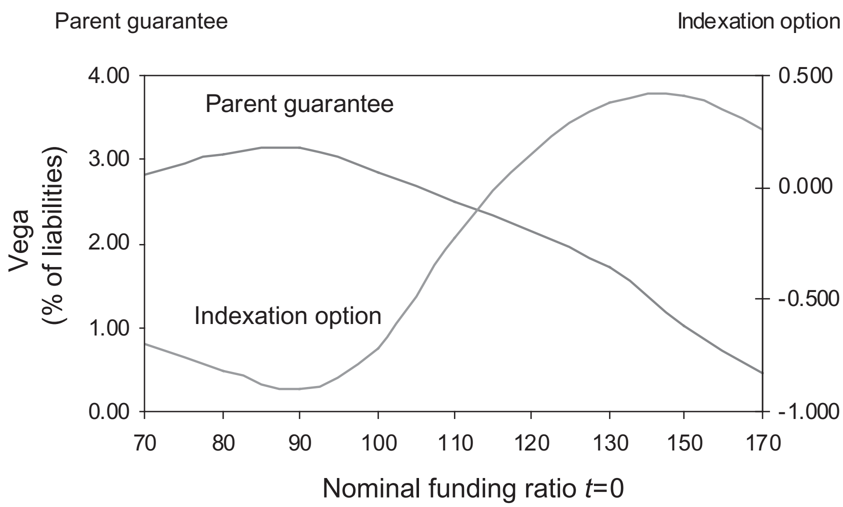


Figure 3: Vega characteristics as a function of the funding ratio

reveals a serious conflict of interest between the position of the employer (seeking a lower risk profile) and the beneficiaries (seeking a higher risk profile) in case of a low funding ratio.

Also noteworthy is the magnitude of the vega value, which can be quite large. So, vega can exceed 3 per cent of the liability value. The reason for this is the fact that these options are somewhere between a single, very long-term option and a series of annual forward starting options. This implies that a corporate sponsor, with a large pension fund relative to its capital value, can easily increase the value of its equity by 20–30 per cent by reducing risk in its pension fund. This explains the drive towards risk reduction manifested by many employers.

This insight can be used to hedge against pension fund risks from a corporate perspective. However, as the hedge set up to improve the corporate perspective may be detrimental from the beneficiaries' perspective, adjustments in the pension agreement may be necessary. The embedded option technique is very useful in creating a situation where a combination of hedging and pension redesign is beneficial to all parties involved.

PENSION FUND REDESIGN

As discussed, embedded option theory can explain many of the risks borne by stakeholders in a pension fund, the risk-seeking or risk-avoiding incentives that can be created for the various stakeholders, and the possible clashes between stakeholders in the pension fund. Designing a pension fund so that it creates more stable relations between stakeholders is a logical extension of the embedded option applications.

The embedded option methodology can be used to improve the stability and long-term sustainability of DB pension funds. Assessing the embedded option values can help with the redesign of a fund to ensure risk taking is being appropriately rewarded. Embedded option theory can help determine the exact risks stakeholders take (in terms of the (net) value of the options written to the pension fund). If return potential is allocated according to these principles, for example by giving stakeholders entitlements to the surplus of a pension fund proportional to the (embedded option) value of the risks they assumed, the conflicts and instability associated with current DB pension systems could be avoided. The basic principles applied in this redesign are similar to those applied in corporate finance, with the fund's liability structure analogous to the corporate capital structure.

Although the more rigorous fundamentals of this approach can be found in Kocken (2008),[7] a brief example is provided showing how this principle works in practice. Take a career average DB pension fund with conditional indexation of the accumulated rights that applies to both retirees and actives. Actives below the age of 50 have also agreed to allow for the possibility of negative indexation (say a partial write-down of their accumulated wealth) where there is a shortfall in the nominal funding ratio, up to a maximum write-down of 35 per cent of their accumulated wealth. All remaining shortfall risk is absorbed by the employer.

Based on these agreements, the embedded options in this pension fund are priced. It is decided that, given the value of the risks assumed, stakeholders will get proportional access to any possible surplus in the pension fund. This leads to the agreement that retirees and older employees are entitled to 20 per cent of the surplus (which — in case of a surplus — is granted to them in the form of an upgrade of their entitlements), the younger employees to 30 per cent (again granted via an upgrade of accumulated entitlements) and the employer to 50 per cent (which can be granted via a restitution to the sponsor or lower future contributions in case a surplus exists).

By structuring the pension contract in this way, it also becomes easier to set Solvency II requirements for pension funds. These requirements only apply to senior debt, as is the case for solvency requirements at banks and insurance companies. In this case, senior debt is limited to 100 per cent of the nominal accumulated wealth of the retirees and older actives plus 65 per cent of the nominal accumulated wealth of the younger actives. The indexation rights and 35 per cent of the nominal rights of the younger actives are all conditional and therefore closer to subordinated debt. These kinds of close-to-equity entitlements do not require protection by means of solvency buffers. By clearly defining the nature of entitlements, the threat of Solvency II rules destroying the DB pension system can be evaded.

Although the example above is simple, it is in line with economic theory, in contrast with the current DB pension scheme design. It also solves many problems currently present in the DB pension model. The embedded option framework plays a dominant role in this redesign process.

CONCLUSION

The embedded option technique, although rather new in the area of pension fund risk management, is of paramount importance in an ageing society where pension funds become a real burden to the various stakeholders. From this perspective, embedded option applications can practically add value by:

- valuing the embedded options per stakeholder in order to determine both the financial situation of the pension fund as well as deciding how the risks in the pension fund are shared;
- hedging the typical risks in a pension fund that exist as a result of the structure of the embedded options — this hedging can be viewed from different stakeholder perspectives (eg the corporate perspective — how hedging within the pension fund affects the embedded option value that is implicitly on the balance sheet of the corporate sponsor);
- redesigning pension funds in order to remove the many conflicts between shareholders that are present within the current system and are potentially leading to the demise of the DB system.

References

1 Conditional indexation was first introduced in the Netherlands but is gradually being adopted in other European countries with DB systems. For an example of contingent indexation, see Nijman, T. E. and Koijen, R. (2006) ‘Valuation and risk management of inflation-sensitive pension rights’, in Kortleve, N., Nijman, T. E. and Ponds, E. (eds) ‘Fair Value and Pension Fund Management’, Elsevier, Oxford, pp. 85–117. Longevity-linked pension contracts are discussed in BAE Systems (2006) ‘Annual Report 2005’, available at: http://www.investis.com/investors/downloads/annualreport2006.pdf (accessed November 2008).

2 Different kinds of embedded options exist

related to indexation that are conditional or capped. In the Netherlands, for example, cuts in indexation are linked to the funding ratio (as is the case in the example in the text), so-called conditional indexation. In the UK, indexation cuts are linked to the inflation level itself (indexation is capped at a certain level, eg 2.5 per cent or 5 per cent), although introducing conditional indexation is on the UK political pension agenda as well. See, for example, Farr, I. (2007) 'A new breed of shared risk schemes to re-energise the provision of employer sponsored occupational pension schemes in the UK', ACA policy statement, available at: http://www.aca.org.uk/files/ACA_publishes_background_paper_on_shared_risk_schemes_26_March_2007-20070331123108.pdf (accessed November 2008).

3 Other techniques also exist, most importantly the pricing kernels approach (also called the 'deflators' approach). In a similar context of embedded options for pension funds, see, for example, Nijman and Koijen (ref. 1 above) and De Jong, F. (2005) 'Pension fund investments and the valuation of liabilities under conditional indexation', working paper, Universiteit van Amsterdam. These techniques rely less on complete market assumptions, although in these cases they have to make other assumptions on, for example, structure of utility functions.

4 In pension fund economics, the models for generating economic scenarios use real and nominal interest rate yield curves, relevant for measuring the (conditionally) indexed liabilities as well as the bonds in the asset mix. The yield curve models used are arbitrage-free with respect to their own measure, but an adjustment must be applied to make them arbitrage-free to the same numeraire. This adjustment is based on the change of numeraire principle. For the specific model used in 'Curious Contracts', see Den Iseger, P., Potters, J. and van der Werf, K. (2006) 'Asset & liability modelling under two measures', working paper, Cardano, Rotterdam. For an application in the nominal and real bond markets, see Jarrow, R. A. and Yildirim, Y. (2003) 'Pricing treasury inflation protected securities and related derivatives using an HJM model', *Journal of Financial and Quantitative Analysis*, Vol. 38, No. 2, pp. 337–358.

5 Although elaboration of the model is outside the scope of this paper, some parameter values are of specific interest to give a feeling about the underlying pension fund. The duration of the liabilities equals 13.1 and the ratio between the value of the liabilities belonging to the retirees (and 'sleepers') and the value of the liabilities belonging to the actives is close to 3, implying a mature pension fund (although observed quite frequently in practice). The indexation is fully granted above a (nominal) funding ratio of 100 per cent. Below this level, no indexation is granted. For full details, see Kocken, T. (2006) 'Curious Contracts. Pension Fund Redesign for the Future', Tutein Nolthenius, Den Bosch.

6 In some cases, pension protection institutes such as the Pension Benefit Guarantee Corporation (PBGC) in the USA and the Pension Protection Fund in the UK are writing the pension put. The retirees and the employees are writing an even more complex option on the joint event of default of the parent company, default of the protection fund and a deficit in the pension fund (which is unfortunately not an unlikely event as the PBGC case has proven). Both credit rating and asset composition have a huge impact on the risk values these protection funds assume. This methodology makes these values explicit.

7 Kocken, T. (2008) 'Ownership creates involvement', *Investments & Pensions Europe*, April, p. 24.