Journal of Banking & Finance 34 (2010) 1201–1214

Contents lists available at ScienceDirect

Journal of Banking & Finance

journal homepage: www.elsevier.com/locate/jbf

Pension regulation and the market value of pension liabilities: A contingent claims analysis using Parisian options

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ARTICLE INFO

Article history:
Received 14 August 2008
Accepted 13 November 2009
Available online 24 November 2009

JEL classification:
G11
G23

Keywords:
Pension funds
DB and DC pension plans
Regulation
Parisian barrier options

ABSTRACT

We analyze the market-consistent valuation of pension liabilities in a contingent claim framework whereby a knock-out barrier feature is applied to capture early regulatory closure of a pension plan. We investigate two cases which we call "immediate closure procedure" and "delayed closure procedure". In an immediate closure procedure, when the assets value hits the regulatory boundary, the pension plan is terminated immediately. Whereas in a delayed closure procedure, a grace period is given to the pension fund for reorganization and recovery before premature closure is executed. The framework is then used to construct fair pension deals. Furthermore, we provide rules for deriving the optimal recovery period in pension regulation using utility analysis and interconnect the recovery period to the regulatory liquidation probability.

1. Introduction

Since Sharpe's (1976) seminal contribution, defined benefit (DB) pension plans are often viewed as a combination of option contracts. The beneficiaries of such a pension plan are entitled to a prespecified amount related to years of service and salary. In some cases the beneficiaries have a share in the pension fund's surplus as well. This surplus is to some extent also accruable to the sponsor (often via contribution holidays). Conversely, the sponsor might have the obligation to increase contributions to the pension fund in case the funding level is inadequate. All these claims can be considered as options on the pension fund's assets. Unlike most other financial contracts, pension plans have a peculiar legal status, i.e. they are in most cases not entirely legally enforceable. Contrary to a life insurance contract, a defined benefit pension promise is not completely irreversible. Most current pension contracts implicitly enable their sponsors to terminate the deal prematurely or to convert it along the way.[1] This implies that the sponsor can avoid the payment of recovery premiums by changing the nature of the pension liabilities from a DB to a defined contribution (DC) pension plan when the pension fund is unable to settle its original DB promises.[2] In reality, many sponsoring companies consider this as an ultimate escape route, via which they are able to discard DB pension obligations if the financial burden of maintaining them gets too high. For instance, in the early 2000s when funding ratios fell substantially after the stock market crash, some companies indeed changed the nature of their pension promise from DB to DC. Some closed the pension fund for new entrants and others transferred the liabilities to an insurance company. Furthermore, the extra burden related to improved longevity and lower interest rates makes DB plans expensive to maintain. Some other important drivers of this conversion are changes in pension regulation and accounting, exposing marked-to-market values of pension liabilities and asset-liability-mismatch risks. Aaronson and Coronado (2005) and Broadbent et al. (2006) provide a wider variety of reasons to convert, also with respect to the interests of employees.

The conversion trend is most manifest in the US. According to the US Flow of Funds Accounts, the division between assets held in private DB plans and private DC plans was 60% versus 40% in 1987, whereas in 2007 this ratio was exactly reversed; the turning point appears to be 1995. Recently large companies such as Ford, General Motors, IBM and Sears made a (partial) shift towards DC

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[1] More on the peculiar nature of pension contracts can be found in Treynor (1977), Bulow (1982) and Ippolito (1985).

[2] A detailed description on the differences between DB and DC plans can be found e.g. in Bodie et al. (1988).

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doi:10.1016/j.jbankfin.2009.11.019

plans. The changes in the UK reveal a similar development. In 1979, final salary DB plans constituted 92% of all pension funds. However, in 2005 the Government Actuary's Department observed that 41% of all active members accrue their DB rights in pension plans closed to new entrants. This closure has been accompanied by the emergence of DC plans and average pay DB schemes. Starting from a relatively wealthy position with a funding ratio around 200% at the turn of the millennium, the Netherlands have been able to avoid a bulky shift towards DC plans. However, the perfect storm (negative stock returns combined with decreasing market interest rates) generated a change from final pay DB schemes (66% in 1998) to conditionally indexed average pay DB schemes (85% in 2007), see Bikker and Vlaar (2007). Under such schemes, the benefit depends not on the final but on the career average salary. Furthermore, in a career average plan both during the accrual and the benefit stage the pension rights are indexed to price or wage inflation conditional upon a sufficient funding ratio of the pension fund. As such, inflation and investment risks are shifted in part to active fund members. The valuation of conditional indexation is recently discussed by Nijman and Koijen (2006) and by de Jong (2008). All these changes imply that DB pension plans do *not* provide their participants with a guaranteed amount and regular (unconditional) options introduced by Sharpe, but the premature closure and conversion features of the pension plans have made the various claims of the participants on the pension fund's assets more exotic. With this feature, the pension plan participants are in fact exposed to more risks. When the pension fund's assets value falls below the applicable regulatory boundary (roughly speaking in case of underfunding), the guaranteed payment may be fulfilled only partially. This affects the economic value of the beneficiaries' claim. The pension conversion feature has been pointed out by several empirical studies in the literature. For instance, Petersen (1992) examines three hypotheses concerning the motivation underlying pension plan reversion and finds that all the hypotheses are empirically supported by the US data. Niehaus and Yu (2005) analyze the conversion of DB plans to cash balance plans in the US in the nineties. From a regulatory point of view cash balance plans are treated as DB plans, however beneficiaries conceive it as DC plans.

However, to our knowledge, the premature closing or converting feature of pension plans has never been investigated analytically and theoretically. This paper aims to fill the gap. Our objective is to incorporate the closing feature in the valuation of DB pension liabilities, i.e. the contract payoff of the DB plan depends on the entire evolution of the pension fund's assets. When the funding ratio deteriorates, the DB plan might be closed or converted to a DC plan.[3] In this paper, the emphasis is not placed on how to model the DC plan, but on how the premature closing feature affects the market value of the DB plans. Therefore, we assume that the DB contract is terminated upon conversion. We set ourselves in a contingent claim framework and use knock-out barrier options to describe the closing feature. We distinguish between two procedures: "immediate closure procedure" and "delayed closure procedure". In an immediate closure procedure, when the assets value hits the regulatory boundary, the pension plan is terminated immediately. This immediate closure procedure does not reflect reality in all cases because pension funds are usually given time to reorganize and recover. The recovery period varies across jurisdictions, as will be shown in the next section. Therefore, in addition to the immediate closure procedure, the delayed closure procedure is analyzed to capture all possible regulatory situations. The main feature of this procedure is that the closure does not come into force immediately when default (or underfunding) occurs; instead, a grace period is given to enable recovery. Mathematically the immediate and delayed closure procedures can be realized by applying standard and Parisian down-and-out barrier options, respectively.

Barrier options belong to the family of exotic options and are first mentioned in Snyder (1969). The payoff of these products is not based on the final value of the underlying asset only, but linked to the additional conditions of the asset value evolution. Let us assume that we are interested in the modeling of a down-and-out barrier option. The option contract is knocked out if the underlying asset hits the barrier (from above) during the option life. The topic of barrier options has been studied very widely in the literature, e.g. Rubinstein and Reiner (1991) and Rich (1994), to mention just a few. Recently, Grosen and Jørgensen (2002) incorporate a regulatory mechanism into the market valuation of equity and liabilities at life insurance companies by using a down-and-out barrier feature to describe the regulatory intervention rule. Episcopos (2008) studies the role of barrier options in banking regulation.

Compared to standard barrier options, Parisian options do not have a long history in the literature on exotic options. They are introduced by Chesney et al. (1997) and subsequently developed by Moraux (2002), Anderluh and van der Weide (2004) and Bernard et al. (2005). In a standard Parisian down-and-out option, the contract is knocked out if the underlying asset value remains consecutively below the barrier for longer than some predetermined time κ before the maturity date. In the context of with-profit life insurance contracts, Chen and Suchanecki (2007) apply the Parisian barrier option framework to incorporate more realistic bankruptcy procedures (Chapter 11 bankruptcy procedure) in the market valuation of life insurance liabilities. de Giuli et al. (2009) apply Parisian style options to describe regulatory barriers in a mutual deposit guarantee scheme. The current paper is the first to incorporate Parisian barrier options in a pension fund setting. The contingent claim framework is used to construct fair pension deals. Furthermore, we provide rules for the optimal recovery period in pension regulation based on utility analysis and align the recovery period to the regulatory liquidation probability.

The remainder of this paper is organized as follows. Section 2 reviews funding requirements in different countries and Section 3 describes the basic payoff structure of pension plans and the underlying contingent claim model setup. Additionally, we introduce the theoretical background of barrier and Parisian barrier options. The next section focuses on the valuation of the DB pension plans. Section 5 contains a variety of numerical analyses aiming to derive fair pension deals, while Section 6 discusses the role of recovery periods in pension regulation. Section 7 concludes the paper with a summary of the results.

2. Overview of funding requirements

One of the key parameters in our framework is the regulatory boundary which represents the minimum funding requirement and will be captured by the parameter λ. It represents the minimum funding requirement. Following Grosen and Jørgensen (2002), $\lambda \geqslant 1$ describes a situation in which the regulator requires the financial institution to always maintain a *buffer* so that in an unforeseen event of default the beneficiaries do not experience a loss with respect to the marked-to-market value of their claims. Conversely, if $\lambda < 1$ the regulator allows temporary deficits which might lead to a marked-to-market loss in case of default. However, since we allow for extended recovery periods, the expected loss is not equal to $1 - \lambda$ but to the difference between assets and liabilities at the end of the recovery period (conditional on no recovery having occurred and the pension fund being liquidated). The importance of an adequate funding level is underlined by the OECD

[3] In an event of premature closure, the assets in the DB plan can also be used to buy deferred annuities from a life insurer.