VALUATION AND REGULATION OF HYBRID PENSION PLANS

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Abstract. Contemporary pension pension often are a mixture of defined benefit and defined contribution plans. The key characteristic of hybrid plans is that risks are shared between the pension plan members and its sponsor. Typically the pension benefit can be adjusted upward or downward with the performance of the pension funds assets or with changes in longevity expectations. We propose a general form of solvency regulation applicable to all .

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1. Introduction

The international structure of occupational pension plans has significantly changed over the last decades. Many Defined Benefit (DB) plans are converted into Defined Contribution (DC) plans, which nowadays represent approximately 44 percent of global pension assets. Recently, the pension universe is characterized by the evolution of hybrid pension plans that combine elements of traditional DB and DC plans. Hybrid pension plans were introduced as early as the 1980s in the United States, but their popularity soared over the last ten years as an innovative way of allocating funding risks and old age income between

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sponsor and employees evenly.

Although hybrid pension plans come in different forms, they all effectively involve a degree of risk sharing between employers and employees. The most common form of hybrid plans in the US so far are cash balance plans and pension equity plans. Both plans entail DC elements as benefits are defined as a lump sum figure which is allocated to individual account balances. On the other hand, both plans are legally classified as DB schemes as they accrue benefits to employees under a defined fixed formula. In a cash balance plan for instance, the member's account is periodically allocated with a percentage of pay (salary credits) and a guaranteed rate of return (interest credits). The latter is typically tied to the yield on long term government bonds. So contrary to a pure DC plan, the cash balance account grows at a rate that is not directly related to the plan's actual investment earnings, but is pre-determined and specified in the plan document. If the specified plan rate exceeds the return on the plan's assets, then a deficit will arise for which the sponsor is liable. Cash balance plans therefore generally operate like a traditional DB scheme from the perspective of the sponsor (Niehaus and Yu, 2005). Another prominent example of hybrid pension plans are career average defined benefit plans with contingent indexation in countries such as Canada and the Netherlands, in which the level of indexation is contingent on the pension fund's solvency status. These plans feature elements of DB as the yearly accrual of pension rights is specified in a similar manner as a traditional DB plan. However, these plans also contain DC characteristics as the indexation level is related to the fund's solvency status and therefore contingent on the actual investment returns (Ponds and Van Riel, 2007).

The adoption of hybrid plans is motivated by an attempt to mitigate the drawbacks inherent in pure DC and DB plans. The most common motivating factor from the sponsor's perspective is reducing the volatility of plan contributions. In a traditional DB scheme, the sponsor promises to the plan beneficiaries a final level of pension benefits which are

Risk factor	Defined benefit	Hybrid plan	Defined contribution
Investment risk	sponsor	both	members
Conversion risk	sponsor	members	members
Wage growth risk	sponsor	members	members
Sponsor risk	high	moderate	low
Regulatory feature			
Appropriate discount rate	risk free rate	members	not applicable
Solvency requirements	yes	yes	no
Freedom of choice	no	no	yes
Pension protection fund	possibly	possibly	no
other...	.	.	.

generally paid as a life annuity. As such, the plan sponsor is exposed to substantial investment and longevity risk which could lead to volatile and unplanned contribution expenses (Wesbroom and Reay, 2005). The liabilities of hybrid pension plans, however, are typically less sensitive to interest rate fluctuations than liabilities under a traditional DB scheme. An interest rate decline, for instance, increases the discounted plan liabilities for a cash balance plan, but also reduces the plan benefits through lower assumed interest credits. These opposite forces partially offset each other (Hill, Pang and Warshawsky, 2010). Hence, hybrid pension plans tend to reduce the volatility of the sponsor's contributions.

The changing workforce demographics are an additional motivation for the global transition towards hybrid pension plans, as these plans are better suited to aging populations which necessitate longer careers and a more flexible labor market. Employees in a hybrid pension plan generally accrue benefits more evenly over their years of service than in a traditional DB plan. This makes it easier for employees to switch jobs and not lose out on their pension. As such, hybrid pension plans stimulate a dynamic and mobile workforce. Furthermore, hybrid plans typically lack the early retirement incentives inherent in many DB plans and therefore do not penalize workers who remain with their employers after their retirement age (Johnson and Steuerle, 2004). This is supported by Friedberg and Webb (2003), who find that workers in DC plans that have similar retirement incentives as hybrid plans, on average, retire approximately two years later than similar workers in traditional DB plans. Hybrid pension plans also offer attractive features from the perspective of the employees. Cash balance plans are typically easier for employees to understand and appreciate than traditional DB plans. For example, employees can easily add the annual pay and interest credits to their lump sum account to understand how the value of their pension is expected to grow over time. By contrast, employees often do not know how to determine the value of a deferred annuity that traditional DB plans offer).

Hybrid pension plans also provide certain advantages over pure DC plans. Employers in a pure defined contribution scheme are only obliged to make fixed contributions. The employees thus bear the brunt of risk and typically face uncertain replacement rates caused by fluctuations in the capital markets (Bodie and Merton, 1992). Hybrid pension plans, however, reduce the variability in the range of potential outcomes as they may include a DB element such as guaranteed benefits or returns. Another feature of a pure DC plan is that plan members have extensive control over their account's investment strategy, which enables them to shape their portfolio to their individual risk and return preferences. In practice, however, many plan members are not willing or able to determine a suitable investment strategy and are thus prone to make suboptimal decisions. Hybrid pension plans are managed by dedicated trustees and professionals and therefore protect employees against these pitfalls. Finally, hybrid pension plans also appear to have a tax advantage over pure DC plans. Niehaus and Yu (2005), for instance, find empirical evidence in support of the excise tax avoidance hypothesis in the United States. According to the hypothesis, several firms have transformed their DB plan into a cash balance plan because conversion allows the firm to avoid excise taxes on its excess pension assets. If instead the firm converted to a pure DC plan, the firm would have lost a substantial part of the excess assets to excise taxes. However, the avoidance of taxes is not costless as cash balance plans typically incur greater administrative costs than a pure DC plans (Niehaus and Yu, 2005).

Despite the advantages of hybrid plans, the growing numbers of firms converting their DB plans to hybrid plans has also generated some controversy. Some view hybrid plans as attempts by employers to reduce pension costs and that conversions discriminated against older workers. [DRAWBACKS NEED TO EXPLAINED FURTHER]

Regulation is of hybrid pension plans is the key subject in this paper. Traditionally, pension plans could either be classified as defined contribution or as defined benefit. Regulation of these types of pension plans is rather straight forward. This paper is, to the best of our knowledge, the first to rigorously analyze regulation of hybrid pension plans. We develop a model which allows for a continuum of pension plans range from pure DB to pure DC. etc...

This paper is organized as follows...

2. Pension fund regulation

Either DB, DC or hybrid pension plans typically operate under regulation. Pension fund regulation aims to offer a high degree of safety to current and future retirees through the imposition of supervisory standards. Before turning to our solvency model we first discuss some key concepts that play an important role in creating incentive compatible regulation. Financial regulation is typically aimed at: (i) defining, (ii) overseeing, and (iii) enforcing minimum requirements as to the funding, solvency and disclosure of the supervised institutions. We therefore first discuss the three building blocks of modern risk based regulation: valuation, risk assessment and disclosure.

2.1. **Valuation.** Valuation of assets is typically based in observed market prices, observed market prices of comparable instruments or, in case market prices are obsolete, models based on the no-arbitrage principle. Marked-to-market valuation of liabilities is also possible on the basis of the replication principle. Thus, in a world without arbitrage opportunities, the market consistent value of a pension liability equals the market price of that investment portfolio that generates exactly the required cash flows under all future states of the world. The expected payments in this calculation are based on actuarial sound underwriting principles (mortality rates, longevity risks, surrender rates, frequency of transfers of value, etc.) that are deemed to be realistic. A pension fund must take into account expected demographic, legal, medical, technological, social or economic developments. This means for example, that the foreseeable trend in improvement in life expectancy must be reflected in the expected value, given the fact that, on average, people tend to live longer as time goes on.

2.2. **Risk assessment.** The financial crisis has shown that pension funds are exposed to sizeable risks. This exposure entails market risk, interest rate risk and liquidity and operational risk, besides more traditional insurance risks like mortality risk and longevity risk. It has become evident that identifying, quantifying and managing those risks is a key responsibility of pension funds. There are three ways of managing risks. First, *insurance* is accomplished by paying an insurance premium to a third partying for a risk transfer. A pension fund, may, for instance, transfer its longevity exposure to a reinsurance company by paying a market-based premium. Second, *hedging* is achieved by taking an opposite economic position. A pension fund holding short-term bonds may convert them into long-term fixed-rate investments using a receiver interest rate swap. To that end, the pension fund agrees with a counterparty to pay the short-term rate for a certain principal in exchange for the long-term interest rate. Third, holding additional assets over the liabilities as a *buffer*. This solvency margin is intended to absorb the risks inherent in the possible changes in the value of assets and liabilities.

2.3. **Disclosure requirements.** Pension funds are generally required to disclosure information to their members on accrued or projected benefits. etc...

3. Model

We consider a pension plan in a 1-period model with two time points: time 0 and 1. At time 0 the pension contract already exists, i.e. it is not necessarily the issuance time of the plan. We consider a conditionally indexed defined benefit pension plan (a hybrid pension plan between defined benefit (DB) and defined contribution (DC) plan) to a representative beneficiary. At time 0, the asset value is A_0 and the outstanding liability is L_0. The asset value A_0 can be higher or lower than L_0. At time 1, the pension plan matures and it pays out a lump-sum payment (we can consider this payment as the time-1 value of all the possible future pension payments). This pension payment of the beneficiary can be defined as

$$\Psi(A_1) = \beta \cdot L_1 + (1 - \beta) \cdot A_1, \ \beta \in [0, 1] \tag{1}$$

with $[x]^+ := \max\{x, 0\}$. L_1 denotes the liability value at time 1 and A_1 the assets value of the pension fund at time 1. Note that

- For $\beta = 1$, the pension contract can be regarded as a defined benefit plan. The beneficiary obtains the defined benefit L_1.
- For $\beta = 0$, the pension contract can be regarded as a defined contribution plan because the beneficiary is not ensured with any certain pension benefits.
- For $\beta \in (0, 1)$, the pension contract can be regarded as a hybrid of DB and DC plan.

The payoff to the sponsoring company is determined residually:

$$\begin{aligned} \Psi_S(A_1) =& A_1 - (\beta \cdot L_1 + (1 - \beta) \cdot A_1) \\ =& \beta \cdot A_1 - \beta \cdot L_1. \end{aligned} \tag{2}$$

The above formulation allows to model the DB and DC plan in a unified framework.

Following the framework of Braun, Rymaszewski and Schmeiser (2010). In Bran, Rymaszewski and Schmeiser (2010), the asset A_1 is given by

$$A_1 = \exp\{r_A \cdot\}(A_0 + C_0 - B_0)$$

where r_A is the instantaneous rate of return from the asset. B_0 is the benefits paid between 0 and 1. The contribution between 0 and 1 can be decomposed into two parts:

$$C_0 = RC_0 + AC_0$$
$$\text{with } AC_0 = \gamma[L_0 - A_0]^+$$

where AC_0 is the additional contribution between 0 and 1 for the recovery of a deficit in $t = 0$ and γ is the fraction of the deficit in $t = 0$ which will be covered between 0 and 1. Conventionally in a DB plan, contributions are adjusted when there is some underfunding (in our framework $AC_0 \neq 0$, $B_0 = 0$). In a DC plan, the benefits will be adjusted given underfunding (here $AC_0 = 0$, $B_0 \neq 0$). The hybrid plans are a combination and they allow both the benefits and the contributions can be adjusted when there is some underfunding. Assuming a DB plan, the additional contributions need to satisfy two requirements:

- The first constraint is imposed on γ: $\gamma \geq \gamma^{min} := \frac{1}{\theta}$, where θ is the maximum length of years for the years for the elimination of the deficit of the pension fund. This parameter is set by the *regulator*. The minimum additional contribution is then given by $AC_0^{min} = \frac{1}{\theta}[L_0 - A_0]^+$.
- The second constraint concerns the initial asset value of the pension fund A_0, i.e. $A_0 \geq A_0^{min} = \eta L_0$. It leads to

$$AC_0 = \gamma[L_0 - A_0]^+ \leq \gamma[L_0 - \eta L_0]^+ := AC_0^{max},$$

  where $\eta = A_0^{min}/L_0$ is the lowest acceptable coverage ratio and set by the *regulator. In Braun, Rymaszewski and Schmeiser (2010), AC_0^{max} is defined without the parameter γ.*

REMARK 3.1. Through the above two requirements, the pension regulator can choose the maximal number of years θ and the minimum initial asset requirement (characterized by the parameter η) to stipulate the strictness of regulation. Furthermore, AC_0^{max} is not necessarily larger than AC_0^{min}. AC_0^{min} is larger than AC_0^{max} if η is allowed to be set larger than 1.

The defined benefit at time 1 can be constructed as

$$L_1 = \exp\{r_L\}(L_0 + RC_0 - B_0)$$

where r_L denotes the interest rate for the valuation of the liabilities. RC_0 the regulation contributions for the time period between $t = 0$ and $t = 1$. Assume CAPM holds for the rate of return r_A and r_L, i.e.

$$\begin{aligned} r_A =& r_f + \beta_{A,M}(r_m - r_f) + \varepsilon_A \\ r_L =& r_f + \beta_{L,M}(r_m - r_f) + \varepsilon_L \end{aligned}$$

where r_m is the rate of return of the market index, r_f is the risk-free interest rate. $\beta_{i,M} := Cov[r_i, r_m]/\sigma_m^2$, $i = A, L$. The residual terms ε_A and ε_L are idiosyncratic risk of the asset and liabilities, and they are independent of each other and of the market index. Assume r_m is normally distributed with (μ_m, σ_m^2) and ε_A and ε_L are normally distributed too, with $(0, \sigma_{\varepsilon_A}^2)$ and $(0, \sigma_{\varepsilon_L}^2)$. It allows us to calculate the mean and the variance of r_A and r_L immediately:

$$\begin{aligned} r_A \sim& N\left(r_f + \beta_{A,M}(\mu_m - r_f), \beta_{A,M}^2\sigma_m^2 + \sigma_{\varepsilon_A}^2\right) := N(\mu_A, \sigma_A^2) \\ r_L \sim& N\left(r_f + \beta_{A,M}(\mu_m - r_f), \beta_{L,M}^2\sigma_m^2 + \sigma_{\varepsilon_L}^2\right) := N(\mu_L, \sigma_L^2) \end{aligned}$$

The regulatory contribution RC_0 is determined by following the regulatory constraint, e.g. a shortfall probability constraint of 0.5% within one period. In other words, RC_0 is the critical regulatory contribution which makes the survival probability binding:

$$P\left(A_1 \geq \eta\Psi(A_1)\right) = P\left(A_1 \geq \eta(\beta L_1 + (1-\beta)A_1)\right) = 99.5\%$$

This probability equals

$$\begin{aligned} & P\left((1 - \eta(1-\beta))\exp\{r_A\cdot\}(A_0 + AC_0 + RC_0 - B_0) \geq \eta\beta\exp\{r_L\}(L_0 + RC_0 - B_0)\right) \\ =& P\left(r_A - r_L \geq \ln\frac{\eta\beta(L_0 + RC_0 - B_0)}{(1-\eta(1-\beta))(A_0 + AC_0 + RC_0 - B_0)}\right) \\ =& \Phi\left(\frac{\ln\frac{\eta\beta(L_0+RC_0-B_0)}{(1-\eta(1-\beta))(A_0+AC_0+RC_0-B_0)} - (\mu_A - \mu_L)}{\sqrt{\sigma_A^2 + \sigma_L^2 - 2\beta_{A,M}\beta_{L,M}\sigma_m^2}}\right) \end{aligned}$$

From the above equation we can numerically determine the critical amount of regulatory capital. There are several observations concerning the above survival probability.

- For $\beta = 0$, the hybrid plan is reduced to a DC plan (the regulatory parameter for DC plan is $\eta = 1$). In this case, the asset and liability match perfectly and the liability is fully covered by the asset. Hence, the survival probability is equal to 1.
- For $\beta = 1$, the hybrid form is reduced to a DB plan and the survival probability is $P(A_1 > \eta L_1)$. In this case, η is not restricted to be smaller than 1. The higher the η, the less likely the pension fund's assets value exceeds the value of the outstanding liability.
- For $\beta \in (0, 1)$, we have a real hybrid form. Since the fraction $\frac{\eta\beta}{1-\eta(1-\beta)}$ increases in β, the survival probability decreases in β. A high β indicates that DB plan is the dominant component in the payoff of the beneficiary.

4. Alternative model

In this section I follow an alternative approach. Assume a pension fund which is closed to new entrants and accrual of new benefits. We therefore consider a run off scenario. For now assume that longevity risk is absent. First define $Z_{t,i}$ as the benefits evaluated at time t the pension fund has to pay to the beneficiaries retiring in year i. In the next period these benefits evolve according to

$$Z_{t+1,i} = \exp(y_t) Z_{t,i}$$

Now we define

- For $y = R_p$, the pension plan is a DC plan with R_p the return on the pension fund's assets.
- For $y = R_f$, the pension plan is a DB plan with R_f the risk free rate.
- For $y = \alpha R_f + (1 - \alpha) R_p$, we have a hybrid pension plan as a linear combination of a DB and DC plan.
- For $y = \frac{1}{N} R_p$, we have a hybrid pension plan with smoothing of returns, where N represents the smoothing period in years.

If we for now assume a single benefit payment in year i the market consistent value at time t of this payment is

$$L_{t,i} = E_t(m_{t+1} Z_{t+1,i})$$

We therefore need to explore the pricing kernel.

4.1. **Pricing kernel.** We define independent equity and interest rate risk in the following manner.

$$\begin{bmatrix} e_{t+1} \\ \Delta r_{t+1} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_e^2 & 0 \\ 0 & \sigma_r^2 \end{bmatrix} \right)$$

The return on equities is represented by

$$\frac{S_{t+1}}{S_t} = R_{t+1} = \exp\left(\mu - \frac{1}{2}\sigma_e^2 + e_{t+1}\right)$$

Alternatively we define the expected return on equities as the risk free rate plus a risk premium

$$\mu = r + \lambda_e \sigma_e$$

The market price of risk is equal to

$$\lambda_e = \frac{\mu - r}{\sigma_e}$$

The return on equities can therefore also be expressed as

$$R_{t+1} = \exp\left(r_t + \lambda_e \sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right)$$

Now we take the usual specification of the deflator in a Black and Scholes world and define m_t as the log of the pricing kernel as

$$m_{t+1} = -r_t - \lambda_e \frac{e_{t+1}}{\sigma_e} - \frac{1}{2}\lambda_e^2 - \lambda_r \frac{\Delta r_{t+1}}{\sigma_r} - \frac{1}{2}\lambda_r^2$$

As a check note that

$$\begin{aligned}
&E_t\left[\exp(m_{t+1})R_{t+1}\right] \\
&= E_t\left[\exp(m_{t+1})\exp\left(r_t + \lambda_e\sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right)\right] \\
&= E_t\left[\exp\left(-r_t - \lambda_e \frac{e_{t+1}}{\sigma_e} - \frac{1}{2}\lambda_e^2\right)\exp\left(r_t + \lambda_e\sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right)\right] \\
&= E_t\left[\exp\left(\left[1 - \frac{\lambda_e}{\sigma_e}\right] e_{t+1} - \frac{1}{2}\lambda_e^2 + \lambda_e\sigma_e - \frac{1}{2}\sigma_e^2\right)\right] \\
&= \exp\left(\frac{1}{2}\left[1 - \frac{\lambda_e}{\sigma_e}\right]^2 \sigma_e^2 - \frac{1}{2}\lambda_e^2 + \lambda_e\sigma_e - \frac{1}{2}\sigma_e^2\right) \\
&= 1
\end{aligned}$$

YET TO BE INSERTED: AN INTEREST RATE MODEL. VASICEK??

4.2. **Evolution of assets.** Suppose the pension fund invests a fixed percentage w in equities and $1 - w$ in bonds. The pension funds is continuously rebalancing its portfolio. The return on the portfolio by consequence is

$$R_{p,t+1} = \exp\left(r_t + w\left[\lambda_e\sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right] + (1-w)D_{A,t}\Delta r_{t+1}\right)$$

Where $D_{A,t}$ is the duration of the bond portfolio at the beginning of the year. Taking into account that the pension funds has cash pay outs, the value of the assets at time $t+1$ is equal to

$$A_{t+1} = (A_t - Z_{t,1})\exp\left(r_t + w\left[\lambda_e\sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right] + (1-w)D_{A,t}\Delta r_{t+1}\right)$$

Note that we have assumed in this expression that all pension benefit payments $(Z_{t,1})$ occur at the beginning of the year.

4.3. **Evolution of liabilities.** The evolution of the liabilities from t to time $t+1$ is influenced by the benefit payments ($Z_{t,1}$) and the accrual rate in benefits as defined by y_t. To find the market consistent value of the liabilities we need to discount the expected benefit payments Z at the appropriate discount rate. We define $\delta_t(h)$ as the market consistent discount rate for a pension liability due in year h.

$$\begin{aligned} L_{t+1,h} &= \exp(-h\delta_{t+1}(h))Z_{t+1,i} \\ &= \exp(-h\delta_{t+1}(h))\exp(y_t)Z_{t,i} \end{aligned}$$

Or

$$\delta_{t+1}(h) = -\frac{1}{h}\log E_t\left[\exp(y_{t+1} + m_{t+1]}\right]$$

It can be shown that

$$L_{t+1,h} = \exp\left(y_t + r_t + w\left[\lambda_e\sigma_e - \frac{1}{2}\sigma_e^2\right]\right)[L_t - Z_{t,1}]\exp(-D_{L,t}\Delta r_{t+1})$$

4.4. **Funding ratio.** We now can determine the funding ratio as

$$F_{t+1} = \frac{A_{t+1}}{L_{t+1}} = \frac{(A_t - Z_{t,1})\exp\left(r_t + w\left[\lambda_e\sigma_e - \frac{1}{2}\sigma_e^2 + e_{t+1}\right]\right)\exp((1-w)D_{A,t}\Delta r_{t+1})}{(L_t - Z_{t,1})\exp\left(y_t + r_t + w\left[\lambda_e\sigma_e - \frac{1}{2}\sigma_e^2\right]\right)\exp(-D_{L,t}\Delta r_{t+1})}$$

To simplify this expression of the funding ratio we define the duration mismatch of the funding ratio as

$$D_{F,t} = D_{L,t} - (1-w)D_{A,t}$$

The funding ratio one period ahead reads

$$F_{t+1} = F_t\frac{1 - Z_{t,1}/A_t}{1 - Z_{t,1}/L_t}\exp\left(-y_t + we_{t+1} + D_{F,t}\Delta r_{t+1}\right)$$

5. Analysis of different pension plans

First assume a DC plan, so that $y = R_{p,t+1}$. The value of the liabilities is

$$L_t = E_t(m_{t+1} Z_{t+1,i})$$

5.1. **Regulation.** We now turn to regulation and define two parameters which can be set by the regulator. Thirst the regulator can put a maximum on the smoothing period N. Second the regulator may require the pension fund to hold additional assets as a buffer such that the probability that y drops below a certain threshold $\overline{y}$ is equal to α.