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Designing and pricing guarantee options in defined contribution pension plans

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ABSTRACT

The shift from defined benefit (DB) to defined contribution (DC) is pervasive among pension funds, due to demographic changes and macroeconomic pressures. In DB all risks are borne by the provider, while in plain vanilla DC all risks are borne by the beneficiary. However, for DC to provide income security some kind of guarantee is required. A minimum guarantee clause can be modeled as a put option written on some underlying *reference portfolio* and we develop a discrete model that selects the reference portfolio to minimize the cost of a guarantee. While the relation DB–DC is typically viewed as a binary one, the model shows how to price a wide range of guarantees creating a continuum between DB and DC. Integrating guarantee pricing with asset allocation decision is useful to both pension fund managers and regulators. The former are given a yardstick to assess if a given asset portfolio is fit-for-purpose; the latter can assess differences of specific reference funds with respect to the optimal one, signaling possible cases of moral hazard. We develop the model and report numerical results to illustrate its uses.

1. Introduction

Developed and developing countries are currently debating comprehensive approaches for delivering adequate, sustainable and safe retirement incomes to their aging populations. Defined benefit (DB) pension plans, desirable as they may be for retirees, are not sustainable and shift all the risks to the provider, be it a corporate employer or future taxpayers. A consensus has emerged that retirees will "rely more on complementary retirement savings", European Commission (2012), and we are witnessing a trend favoring defined contribution (DC) that shift risks to retirees. To make DC politically acceptable, encourage participation and increase savings, the retirement income must be safe. Hence, some type of guarantee is needed and success of DC hinges upon the design of appropriate guarantees. However, the difficulty does not stop in designing the guarantee. We then need asset allocation decisions that deliver on the guarantee or appropriate insurance in case the guarantee cannot be met. These interrelated decisions need to be "optimized for their safety and performance" in the words of the European Commission report cited above. Given the interactions of financial, economic and demographic risks, a guarantee may fail after all, as much as a "defined benefit" may be modified by government legislation, World Bank (2000). Complementary retirement plans make failures less likely.

In core-DB the provider commits to a set of rigid promises and assumes all risks. In DC there is no promise made to the beneficiary, who assumes all the risks. This is a binary division. Complementary plans range from DB-lite, i.e., plans with a floor on minimum benefit, to DC-plus, i.e., defined contribution plans with some guarantee on the contribution made during the working life. However, "defined ambition" plans – a term coined during the Dutch pension reform debate of the 2000's and currently providing the basis for policy debates in the UK – argue that a tweak to the binary system cannot solve the problem and requires better risk sharing to ensure that DC is going to work and be sustainable. A comprehensive approach views pension plans as a hybrid of guarantees and ambitions: nominal annuities are guaranteed, but the degree to which pensions rise in line with prices and wages depends on the performance of investments of the pension funds. The Dutch reforms are discussed in Bovenberg and Nijman (2009), NAPF (2012) provides an overview of risk-sharing issues for the UK industry, and Smetters (2002) discusses the conversion of public pensions to DC in the United States.

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Our contribution is in modeling DC plans with alternative guarantee options to compute ex ante mark-to-market risk premia and facilitate risk sharing in the design of guarantees.

1.1. The pensions challenge

The US Census Bureau reports that before baby boomers started turning 65 in 2010, 11% of the total population was between the ages of 65 and 84. Thereafter, this age group is projected to reach 18% of the population by 2030, Colby and Ortman (2014). The US will experience a 45% increase of aging population by 2050. Data from the EC, European Commission (2012), and the IMF, Carone and Costello (2006), reveal even bigger challenges in Europe. Older Europeans are a significant and growing part of the EU population (24%) and by 2050 it is projected to grow by 77%. The fastest growing group in the EU are the very elderly (over 80) projected to grow by 174%, and the old-age dependency ratio is projected to double to 54%.

At the same period per capita growth rate slides to a projected 1.4%, Carone and Costello (2006) (these are pre-crisis estimates). Pensions represent a large share of public expenditure: more than 10% of GDP on average today, expected to rise to 12.5% by 2060 in the EU as a whole. Spending on public pensions ranges from 6% of GDP in Ireland to 15% in Italy, so countries are in different situations although they face similar demographic challenges. Projected changes between 2004 and 2050 ranges from −5.9% GDP in Poland to +12.9% GDP in Cyprus. Only three EU members experience a decrease and nine members expect increases over 5%.

According to the EC white paper for "adequate, safe and sustainable" pensions, European Commission (2012), a majority of member states have been reforming pension systems to put them on a more sustainable footing. Shifting from DB to DC is a significant component of the reforms. Velculescu (2010) reports that "on existing [pension] policies, the intertemporal net worth of the EU27 is deeply negative [....] Europe's current policies need to be significantly strengthened to bring future liabilities in line with the EU governments' capacity to generate assets".

The challenges are not restricted to the US and EU. Latin American countries were pioneers in pension reforms in the 1990's; the pricing literature reviewed below was motivated by DC plans introduced in Uruguay, Chile and Colombia. In India, DB plans were closed by the Government in 2004 and were replaced by a two-tier DC system. The introduction of DC plans in China appears to be modest but it represents a very recent and ongoing trend.

The challenges are addressed with a variety of policy tools: balancing time spent in work and retirement, enhancing productivity, indexing replacement rates, supporting the development of complementary retirement savings to enhance retirement incomes. Shifting away from DB is a way to develop complementary retirement savings and we focus now on DC plans.

1.2. Type of guarantees

A survey of 1700 organizations in the nine largest EU economies, found 22% of the respondent's undergoing pension reforms and 42% mentioned sustainability as a reason, Hewitt (2007). In the UK, 88% of DB schemes were open to new members in 2000 but by 2011 this had dropped to 19%, NAPF (2012). Shifting from DB to DC addresses sustainability issues, but shifts all risks to the beneficiaries. To mitigate risks DC plans typically offer some type of guarantee. In the core DB, the provider commits to a set of rigid promises and takes all the risk. A plain vanilla DC guarantees the nominal value of the contribution.

However, we are not restricted to a binary classification and hybrid forms met with success in Sweden, Denmark or Holland. Hybrid schemes come with a variety of guarantees, such as a return guarantee on the pension pot but no guarantee an what that will buy in terms of income. From the Hewitt survey 50% of the plans were DB, 32% DC and 18% hybrid. From the NAPFA data 8% define themselves as hybrid. In a paper pricing the cost of public pension liabilities in the US, Biggs (2011) uses the database from the National Association of State Retirement Administrators covering 125 mostly state-level programs and finds that around 80% of the employees have a DB pension, 14% DC and 6% have both. Fig. 1 illustrates the prevalence of DC and hybrid plans in OECD countries.

Guarantees come in various forms, see, e.g., Antolín et al. (2011). There are significant legislative differences among countries on who backs the guarantee, such as the Government, the provider, a public pension protection fund, a collective DC trust and so on. We define a *risk sharing ladder* based on the level of protection to the beneficiary and the risks to the provider:

Rung 1. Money-safe accounts, that guarantee the contribution, either in nominal or real value upon retirement.
Rung 2. Guaranteed return plans, that guarantee a fixed rate of return on contribution, upon retirement.
Rung 3. Guaranteed return to match some industry average upon retirement.
Rung 4. Guaranteed return for each time period until retirement.
Rung 5. Guaranteed income past retirement.

Note an important distinction between the first four and the fifth level of protection. The first four provide the beneficiary with guarantees on level of wealth attained upon retirement while the fifth guarantees retirement income. Of course, wealth accumulation provides the means to buy an income upon retirement, but the connection between the two is not trivial. Plans with the first four levels of protection are focusing on the volatility of assets and returns rather than the risk of not realizing inflation-protected incomes. The "Defined Ambitions" debate climbs this risk ladder, offering some protection in the form of guarantees and some in the form of soft guarantees (ambitions).

Deciding how far to climb the risk ladder offers possibilities for risk-sharing, but this requires fair valuation of the risks. For instance, if the employer – or a public protection fund or a collective trust – provides asset volatility insurance for the retirees, the insurance premium should be determined ex-ante and priced using the markets. Risk transfers should be valued on a mark-to-market basis and whoever underwrites the guarantee – employer, future taxpayers or members of a collective trust – must be compensated (NAPF, 2012, pp. 25–30). We turn therefore to the pricing literature.

1.3. Pricing and asset management literature

A minimum guarantee clause can be modeled as a put option written on an underlying *reference portfolio* of assets whose returns determine the return on the contribution. Valuation of the guarantee option has attracted significant interest from academics and practitioners. The seminal papers, developed independently and simultaneously, are Pennacchi (1999) and Fischer (1999). Pennacchi used continuous martingale theory to price the guarantees offered in Uruguay and Chile, respectively; these lie on the second and third rung of our risk ladder. Fischer values Colombia's guarantees using a discrete martingale model and obtained qualitatively similar results to Pennacchi. An interesting feature of Fischer's model is the existence of a ceiling on the guarantee. Pennacchi recognized the similarity between pension guarantees and insurance participating products with embedded options, as priced by Brennan and Schwartz (1979); Boyle and Hardy (1997), see also Embrechts (2000). Advances in this field generated numerous studies extending the framework to