Consumer protection and the design of the default option of a pan-European pension product

A. Berardi C. Tebaldi F. Trojani

Foreword by John Y. Campbell

This version: Milano, February 1st, 2018. The present paper has been commissioned to SDA Bocconi School of Management by the European Fund and Asset Management Association (EFAMA). Corresponding Author: Claudio Tebaldi (claudio.tebaldi@unibocconi.it) is affiliated with the Department of Finance at Bocconi University, IGIER and Baffi-CAREFIN Milano, Italy. Fabio Trojani, is affiliated to Università Bocconi Department of Finance, University of Geneva and Swiss Finance Institute, Andrea Berardi is affiliated to Università di Venezia Ca' Foscari. We are grateful to EFAMA delegates, A. Beltratti, M. Briere, E. Castagnoli, P. Colla, G. Corvino, M. Di Giacinto, C. Favero, N. Gennaioli, M. Guidolin, G. Meruzzi, G. Nocera, F. Ortu, S. Paci, E. Pitacco for helpful comments. Special thanks to J. Campbell and B. Delbecque for their insightful comments, the usual disclaimer applies.

ABSTRACT

We address potential strengths and weaknesses of alternative protection schemes, which can be adopted as a default option in a private, third pillar, pension product. In light of the observed behavior of savers adopting the default option at international level, we perform a comparative analysis aimed at quantifying the costs and the benefits of two different risk mitigation techniques and market-standard investment products available to European consumers. We make the case for eligibility of life-cycle target-date funds as default option for the pan-European pension products

FOREWORD

There is growing evidence that households need help with their financial decisions. Modern economies have evolved in a way that requires individuals to make more difficult decisions with bigger consequences. People are living longer, while traditional defined-benefit retirement systems that provide guaranteed income streams are being supplemented with defined-contribution systems that require people to accumulate and invest their own retirement savings. Improving information technology has made simple financial transactions cheaper and easier, but it has also permitted the development of more complex and confusing financial products. Academic research in the emerging field of household finance has documented apparent mistakes made by many households—particularly those with lower income, wealth, and education—as they struggle to manage their financial affairs.

Household financial mistakes not only hurt the households making them, but can have broader consequences for the economy. For example, wealth inequality is exacerbated if poorer people invest ineffectively and borrow expensively. Also, the mistakes of naïve consumers create rents that can distort competition. To attract naïve consumers, financial institutions may lower the up-front costs and raise the hidden costs of financial products, effectively subsidizing consumers who are sophisticated enough to avoid the hidden costs. Such subsidies to natural early adopters make it hard to market easier-to-use financial products. An additional problem is that common household mistakes create endogenous systemic risk, for example prepayment risk and default risk in mortgage markets. Finally, the exploitation of household mistakes by financial institutions can lead to corrosive mistrust of the financial system and the institutions that govern the economy. This evidence creates a powerful case for financial regulation to mitigate consumer mistakes and recreate the decisions that households would make if they were financially sophisticated. Research in household finance can guide the form of this regulation. Consumer financial protection must start from an understanding of the principles of optimal portfolio choice and must apply these principles in the complex environment faced by households, with income and expenses varying over the lifecycle, taxation and borrowing constraints, and random shocks that must be managed through insurance and saving. Only when one understands the properties of an optimal household financial strategy can regulation be designed to encourage it.

While the details are necessarily complicated, some basic principles can be stated simply. First, the positive reward for taking risk in financial markets implies that retirement savings vehicles should not be entirely riskfree. No matter how risk-averse a person is, he or she should be willing to take at least a modest amount of risk to earn a higher return. Quantitatively, the reward for risk is large enough, and most households have sufficiently stable labor income, that allocations to risky assets should be substantial for all but ultra-conservative households.

Second, an investment strategy of rolling over short-term safe assets is not riskfree over the long run because real interest rates vary over time. Retirees who followed this strategy over the past 20 years have suffered a severe loss of purchasing power as real interest rates have declined. A safe retirement income, of the sort provided by a defined-benefit pension plan, requires an investment strategy based on long-term inflation-indexed bonds. Long-term real assets such as equities and real estate, while not riskfree at any horizon, also generate relatively stable streams of real income over the long run.

Third, the preservation of nominal value is not an appropriate measure of safety because the inflation rate is uncertain. Inflation risk cumulates over time and becomes relatively more important at long horizons. This implies that long-term nominal bonds should be used with caution in a retirement portfolio because they are exposed to inflation risk; and portfolio guarantees stated in nominal terms are ineffective at controlling long-term risk exposure. Finally, it should not be presumed that households necessarily benefit by interacting with financial markets indirectly, through financial intermediaries, rather than by buying financial products that pass through capital market risks directly. Claims on banks and insurance companies involve credit risk that can be hard for ordinary households to assess, particularly in the context of a long-lasting financial relationship. The fees charged by intermediaries are also hard to measure. Claims to portfolios of financial assets, of the sort provided by target-date mutual funds, reduce counterparty risk and charge relatively transparent fees in forms that can be regulated to encourage price competition.

The study by Andrea Berardi, Claudio Tebaldi, and Fabio Trojani is an excellent application of these principles and an illustration of the power of household finance theory to assist the design task faced by European financial regulators.

John Y. Campbell,
Harvard University, February 1, 2018.

EXECUTIVE SUMMARY

The European Commissions legislative proposal on a pan-European Personal Pension product (PEPP) has led to a debate about the nature of the investment default option that should be offered by the PEPP. Some people are in favor of a default option with a guarantee on capital, while others consider that the life-cycling technique provides a more efficient protection against the risks associated with financial investment. The main goal of this study is to contribute to this debate by highlighting the risks and advantages of different kinds of life-cycle strategies, and by comparing the outcomes of those strategies with the potential returns offered by life-insurance products with minimum guarantee and upside participation.

Household finance and portfolio rebalancing over the life-cycle

In the past 15 years, household finance has developed into a growing field of academic research that studies how households use financial instruments and markets to achieve their objectives. Reasons explaining this development include the shift in responsibility for pension provision, from the government to individuals, which makes household saving a key policy issue. In studying financial investment and portfolio choice, the household finance literature has reached two important conclusions that validate the view that default options should offer households the possibility to save in a diversified portfolio of pension assets.

- First, households should take into account their human capital when deciding how much they invest in risky assets markets. Indeed, for the vast majority of households, human capital represents a large fraction of their total wealth when they are young because their accumulated financial assets are low. As households age and hold a larger share of financial assets, the relative importance of human capital declines. Consequently, because human capital can be viewed as a bond-like asset, **households should invest in equity when they are young, and they should increase the proportion of fixed-income assets as they become older.**[1]

- Second, more sophisticated (especially more educated and richer) households tend to behave closer to the prescriptions of theoretical models, i.e. they hold a much larger share of their financial wealth in stocks than less advantaged households. One implication of this finding is that **the regulatory design of the default option should**

[1] Even if this conclusion must be nuanced in light of the risk profile of the profession and the correlation of the household income with the stock market, there is a large body of research predicting that households should participate in risky assets early in life.

aim at protecting less sophisticated households from holding too much of their pension savings in under-diversified, low-risk and low-return asset portfolios. Instead, regulators should give more importance to the benefits of asset diversification, which constitutes an effective tool to mitigate credit and inflation risks.

Life-cycle investment strategies: performance and risk

Building on the household optimal portfolio rebalancing predicted in the academic literature, the study provides an analysis of three life-cycle investment strategies, which differ according to two key factors: firstly, the initial allocation of the pension plan that is invested in equity, and secondly, the pace at which the share of equity declines over time.

In the base model, it is assumed that the individual starts to contribute to the pension plan at the age of 25. The retirement age is 65, so that the accumulation period is 40 years. The assumption is that yearly contributions are equal to 10% of salary, which starts at 18,000 and grows annually at a rate of 2%. The management fee is set at 1%. The model simulates the accumulated pension wealth over 5,000 return paths drawn from historical returns of cash, risk-free government bonds, defaultable government bonds and equities.

The main results of the simulations can be summarized as follows:

- **Life-cycle strategies allow savers to recoup the capital invested with a probability well above 99%.** Even though this probability will decline over a shorter savings period, it remains greater than 99% for a 20-year accumulation period, indicating that life-cycling continues to provide robust downside protection even under shorter accumulation periods.

- **In 95% of the cases, the pension wealth accumulated is at least 1.8 times larger than the total contributions made to the pension plan.** In 50% of the cases, savers can expect a pension wealth at least 4.4 times greater.

Life-cycle versus guaranteed strategies

To compare the outcomes of life-cycle strategies with the potential returns of pension products with a minimum return guarantee, the study has developed a model of the asset-liability management procedure followed by an insurance company offering such products.

It is assumed that the insurer dynamically adjusts its balance sheet in order to service the policyholders, compensate its shareholders for providing sufficient funding, and to comply with solvency requirements.

The simulations are based on historical returns data for the period 1969-2012, which was marked by the two oil shocks, with interest rates and inflation rates going up, then down, as well as for the period 1992-2012, which was characterized by falling interest rates and inflation rates. The first period is referred to as the old normal, and the second period the new normal, as the economic and financial landscape that emerged following the financial crisis of 2007-2008 appears fundamentally different from the pre-crisis context. The period 2012-2017 is not considered in order to avoid that results are biased by the ECBs asset purchase program.

The simulations show that the nominal guaranteed rate of return consistent with market conditions and solvency constraints reaches 4.25% under the old normal, compared to 1.5% under the new normal assuming that 90% of the insurers portfolio is invested in bonds for regulatory reasons.

Using the same assumptions about the income path and contribution rate as described above, the study shows the following results for a 40-year accumulation period.

- In the old normal scenario, the minimum guarantee product with upside participation generates a real rate of return at least equal to 1.9% in 95% of the cases, and to 3.3% in 50% of the cases. On the other hand, the real rate of return under the life-cycle strategies is greater than 2.8% in 95% of the cases, and greater than 5.9% in 50% of the cases.

- **In the new normal scenario, the real rate of return of the product with a guarantee falls to 0.8% in 95% of the cases, and to 1.2% in 50% of the cases. Instead, life-cycle strategies continue to result in relatively high real returns, i.e. at least 2.8% in 95% of the cases, and 5.1% in 50% of the cases.**

- Shortening the length of the accumulation period does not alter the results significantly. By way of illustration, under the new normal scenario, the real return of the guaranteed strategy reaches 1.4% in 50% of the cases, compared to 5.8% for life-cycle strategies.

- **Each of the life-cycle strategies in the new normal ensures that 99.9% of the savers end up with a pension accumulated wealth greater than the inflation-adjusted capital invested, under both a 40- and 20-year accumulation period.**

Asset diversification and de-risking explain the solid results achieved by life-cycle strategies. Asset diversification is a powerful tool against inflation and market risks, whereas de-risking ensures return generation during most of the accumulation period and a reduction of investment risk some time before retirement.

Policy considerations

The study shows that the inclusion of life-cycle investment strategies as default options in the PEPP framework is economically desirable for savers, in order to increase their pension wealth at comparatively very low risk over a long investment horizon.

Allowing life-cycle strategies as a default option is even more desirable in light of their social and economic implications and the CMU project, as life-cycle strategies would:

- allow PEPP savers to diversify their pension savings towards equity when they are young, at a time in their lives when their financial wealth tend to be low and their human capital high;
- help channel more retirement saving capital towards investment opportunities, thus fueling growth and a more efficient allocation of capital in the EU;
- offer an efficient way of diversifying retirement saving assets at geographical and sectorial basis, thanks to their exposure to the equity market;
- mitigate the financial risk engendered by guaranteed strategies, which create long-term liabilities for life insurers and potential funding gaps, especially in the current low interest rates and low growth environment.

Contents

I. Introduction

Contributors to a pension plan must make a decision on how to allocate assets across various investment vehicles. Often regulation gives a prescription on the characteristics that an investment plan must have to be eligible as default option. The importance of the default option in observed choice on retirement savings has been discussed extensively, starting with the contribution of Beshears et al. (2009) and is known to play an important role in directing investor decisions.

This paper makes the case for the eligibility of a Life-Cycle Target-Date investment as default option in the PEPP regulation currently under discussion. First, we compare the capital protection capacity of a Life-Cycle Target-Date Fund with a proper selection of the 'glide path' and compare it with the one offered by a contractually guaranteed minimum nominal rate of return. Then we quantify the relative cost that this protection implies in terms of the investment performance reduction. Last but not least we assess the ability of various regulatory solutions about alternative investment schemes in the PEPP default option to reconcile individual protection targets with social stability concerns.

A good starting point to understand the motivations of our analysis is the simple observation that the relevance of the default option is per se already an indication that the behavior and the decisions of households are often directed by forces, like e.g. inertia, that are hard to reconcile with rational decision making. These features pose a serious question to regulators who are expected to incentivize the conditions for a responsible choice that is beneficial both at individual and social level.

Our analysis is organized as follows. In the remaining part of this section we first review the basic principles underlying the Regulation proposal that is in preparation. Then, following a consolidated tradition in the emerging field of household finance, we explore in Section II the stylized features of 'default' investors, in order to capture the situation 'as it is' to identify the 'symptoms' of bad or good habits that the regulation should fight or incentivize. Section III reviews the basic theory of life-cycle investing, 'how it should be'. Section IV quantifies the performance that a standard life-cycle target-date investment plan can achieve and discusses in a number of realistic examples the impact on the levels of capital protection and on the resulting risk-return tradeoff of alternative selections of investment opportunities and 'glide paths'. Section V is dedicated to the discussion of a popular alternative risk mitigation scheme, a guaranteed minimum rate that is usually embedded in insurance products. Section VI performs a comparative analysis between a life-cycle target-date fund with an extended accumulation period option and a participating life insurance policy, in order to assess their capacity to fulfill the institutional goals of a default option pension plan. Section VII concludes and draws a number of important policy implications at individual and social level, which support the introduction of a Life-Cycle Target-Date vehicle as a viable default option in the Pan European Pension Product. The Appendix includes additional Tables and Figures and all the technical foundations for the quantitative assessments discussed in the main text.

The proposal for a regulation of the European Parliament and of the Council on a pan-European Personal Pension Product (PEPP hereafter) "*is intended to establish a level-playing field between providers, whilst ensuring consumer protection. Comparative information would be available between different products, thus incentivising competitive pricing with full transparency on costs and fees related to the investment.*"

The creation of a PEPP is part of the regulatory effort announced by the Commission's Action Plan on building a Capital Markets Union (CMU): "*The Commission will assess the case for a policy framework to establish a successful European market for simple, efficient and competitive personal pensions ... One of the main objectives of the CMU is to increase investment and choices for retail investors by putting European savings to better use ... in fact personal pensions are important in linking long-term savers with long-term investment opportunities. A larger, European market for personal pensions will ... meet the challenges posed by population ageing and low interest rates ... (and) support the supply of funds for institutional investors (thus driving) ... more investment into capital markets ... and the real economy* ".

As part of the CMU initiative, the creation of a PEPP is intended to play a central role at the social level as well. Broadly speaking, it is expected to:

- Improve the matching between demand and supply of capital, thus raising the EU economic growth potential with a more efficient capital allocation;
- Improve the EU financial stability with a third pillar retirement protection scheme, which may alleviate the pressure on social security and public debt resulting from population aging and labour market changes.

II. Empirical evidence on households' retirement saving decisions

This section reviews some of the empirical evidence on household investment behaviour and on pension contributors adopting the default option, emphasizing possible causes for a deviation from theoretically optimal behaviour.

A. General aspects

The process of accumulating wealth for retirement when young and transforming wealth into consumption when older involves large long-term financial commitments that are consequential for most households. In a typical defined contribution plan, employees face various key choices: whether and how much to contribute; how to invest account balances and at what rate to withdraw their accumulations at retirement. Recent empirical evidence has shown that consumers face mounting difficulties in appropriately dealing with these decisions.

More precisely, a new research field studying how households use financial instruments to attain their objectives has recently emerged. J. Campbell, in his 2006 Presidential AFA address, called this field Household Finance, since its goal is to perform a descriptive and normative analysis of household financial decisions (see also Campbell (2006), Campbell et al. (2011), Calvet, Campbell, and Sodini (2007), Calvet, Campbell, and Sodini (2009a), Calvet, Campbell, and Sodini (2009b), Campbell (2016) and the CEPR review by Guiso and Sodini (2013) for a discussion of more recent findings).

Recent empirical evidence in this research area shows that the determination of an efficient retirement saving scheme is a difficult problem for households, in which mistakes due to financial illiteracy are frequent and potentially very costly. Therefore, regulators have also promoted a protection discipline to safeguard consumer interest. Given these premises, financial advisory and investment delegation, as suggested by Gennaioli, Shleifer, and Vishny (2015), must play the role of 'Money Doctors' and help alleviating the costs of suboptimal investment decisions.[2] One important element further complicating the discipline of investing for retirement is the long term nature of such decisions. For instance, the determination of relevant risk exposures requires the difficult identification of slow moving economic trends (see e.g. Ortu, Tamoni, and Tebaldi (2013)) that may require intertemporal hedging portfolio policies. Similarly, the adoption of risk mitigation schemes is necessary to balance the amplification of risk exposures resulting from the long term nature of the investment.

B. Household finance: broad empirical evidence on households' financial decisions

Recent research has highlighted the special challenges faced by households planning their saving for retirement decisions. First, long horizon investing amplifies the potential adverse

[2] However, any delegation scheme implies new costs and incentives, which have to be carefully balanced by regulators, in order to shape a new discipline on pension investments and to align money managers incentives with the welfare maximization goal of future pensioners.

effects due to uncertain future asset prices. Second, the planning problem needs to incorporate key non-traded assets, such as human capital, housing property or entrepreneurial firms, as essential elements of the investment decision process. The empirical evidence also documents that households face various constraints reducing their ability to borrow and participate in equity markets. These constraints are to a good extent the consequence of information barriers and other more direct transaction costs. A range of papers in the household finance literature, see e.g. Guiso and Sodini (2013), highlights the recent '*widespread finding that more sophisticated (especially more educated and richer) households seem to behave closer to the prescriptions of normative models*'. One of the implications of this finding is that regulatory frameworks should aim at protecting less sophisticated households from making portfolio allocation mistakes.

The most striking observed features on portfolio allocations from a life-cycle investment choice perspective are as follows:

- Observed portfolio allocations imply a much lower equity share and leverage than what predicted by theoretical models. Indeed, while it is true that young generations tend to possess more levered portfolios, only a few of them report portfolio shares that can even get close to those recommended by these models.[3]

- Equity portfolio shares increase steadily with investors' wealth, while cash portfolio shares clearly decline. To illustrate, for households in the bottom wealth decile cash accounts for over 80% of financial wealth and equity for less than 5%. In contrast, for households in the top wealth decile, cash amounts for only 20% and equity for 50% of financial wealth.

C. Household finance: "default option" investors

Dahlquist, Setty, and Vestman (2017) construct a dataset of Swedish investors' detailed asset holdings inside and outside the pension system. An important goal of their study is to characterize investors that implement default funds. Thus, while their empirical evidence is consistent with the findings of the previous literature, it also provides a more detailed profile of the inertial approach to portfolio allocation of investors selecting the default option in the Swedish pension system. They document that these investors are on average younger, poorer and less financially literate. More precisely, they report:

[3]Consistently with this evidence, the US Survey of Consumer Finance shows that only 12% of participating young households, with age between 20 and 30 years, have a share in risky assets exceeding 80%.

- A median default investor five year younger than the median active investor;
- An average labour income (wealth) of default investors that is only 68% (56%) of the average labour income (wealth) of active investors;
- A financial wealth of default investors participating in the stock market that is roughly three times the financial wealth of default investors not participating in the stock market;
- A degree of stock market participation of default investors outside the pension system that is 37% lower than the participation rate of active (non-default) investors;
- A gap in stock market participation between active and default investors that cannot be explained by differences in individual characteristics explaining investment decisions in benchmark life-cycle portfolio choice models.

In practice the adoption of a default plan seems to indicate a number of stylized features in the decision making of the investor. He/She seems to manifest an 'inertial behavior' taming risk exposure and market participation. The above evidence can be motivated in various ways, based on behavioural arguments. Generally speaking, it documents that default investors are less financially sophisticated agents that are trying ex-ante to limit the cost of their potential allocation mistakes. This information suggests that for this class of investors there's a barrier to entry that limits their capacity to profit from the upside potential of a well diversified controlled exposure to market risk.

An important takeaway from this empirical evidence is that, when designing a default option, regulators should address a second, not less relevant, problem in addition to risk mitigation: the problem of easing a controlled access to risky market investments in order to avoid that a share of population does not participate to equity markets and is excluded from the upside potential of risky investing. Note that this issue is relevant both at an individual and at the social level.

III. Life-cycle investment strategies

In this section, we benchmark the above empirical evidence on household investment behaviour to some of the key predictions of theoretical life-cycle portfolio allocation models.[4]

[4]These models usually rely on utility maximization schemes that largely abstract from (i) potential distortions due to behavioural biases and (ii) the broad cost-benefit tradeoffs associated with financial advisory or investment delegation schemes.

The goal of life-cycle portfolio allocation problems is to determine the optimal consumption and investment choices of an investor with total wealth consisting of human capital, financial wealth and other real assets, such as housing property. Therefore, the selection of the optimal asset allocation in these settings incorporates also the illiquid and the real components of investors' wealth.

Formally, human wealth is the present value of all future (uncertain) labor income earned over the remaining lifetime. Alternatively, one can consider labor income as the liquid dividend of an illiquid stock of capital, which endows the newborn and eventually grows by investing in education. Given the inalienable, intangible and at least partially idiosyncratic nature of human capital, the quantitative description of its risk and return profile is both a challenge and essential to shape the overall allocation strategy over the life-cycle.

A. *Normative household finance: basic principles underlying life-cycle investing*

One of the reasons to hold liquid financial wealth over the life-cycle is to partially hedge the systematic and predictable variations of human wealth. To illustrate, consider the benchmark advice that the amount of equity held in the portfolio should decline with age. This advice has a simple foundation in Samuelson (1969) and Merton (1971) model settings. Indeed, Merton shows that the risky portfolio share of an investor with constant relative risk aversion and constant opportunity set is constant. Therefore, assuming for simplicity that human capital has a bond-like structure decreasing with age, the amount of equity in the portfolio has to decrease to keep the equity ratio constant.[5] Modern research has developed further this benchmark intuition in many important directions, using more realistic models of household's investment behaviour. In such settings, the different costs that may influence stock market participation and the asset selection have also been quantified.

Bodie, Merton, and Samuelson (1992) study the hedging potential of financial wealth for risky human wealth, under the assumption that exogenous labour income shocks are perfectly spanned by traded asset return shocks. In their model, households are able to fully hedge the effects of exogenous labour income shocks on their total wealth, if they are not constrained by short-selling or borrowing constraints. However, in reality an important fraction of labor income risk is idiosyncratic and thus unhedgeable. Moreover, labour income and human capital investment are endogenous choice variables for households. Therefore, households may also actively react to weak financial wealth performance by adjusting their labour supply and retirement date.

[5]Under a deterministic labor income, a bond-like structure of human capital decreasing with age can be motivated by the fact that human wealth is progressively liquidated through labor income.

This additional degree of flexibility appears essential (i) for more broadly describing households' risk-return tradeoff during the disinvestment phase of their life-cycle portfolio allocation and (ii) in order to allow households to sustain sufficient financial risk exposures during the last part of their life-cycle. Disinvestment and annuitization risks, i.e., the risks that in the immediacy of the retirement age liquidation and eventually annuitization of the retirement savings become too costly due to the contingent market conditions, are well-recognized risks also in the actuarial literature. Existing approaches to mitigate these risks include, e.g., the option available in many countries of deferring the annuitization of retirement wealth.[6]

The risk-return properties of endogenous labour income have been addressed by a second direction in the literature. Cocco and Maenhout (2005) argue that labour income is similar to an implicit holding of safe assets, whereas Benzoni, Collin-Dufresne, and Goldstein (2007) document that labour and capital income are positively correlated in the long run. Under various assumptions on the correlation between liquid and illiquid wealth shocks, Schwartz and Tebaldi (2006) study optimal portfolio allocations in a model where human capital risk is not fully hedgeable. Importantly, housing property is both a consumption and an investment asset to the household. Moreover, its share of total wealth is extremely costly to adjust due to its intrinsic illiquidity. Kaplan and Violante (2014) introduce the notion of "Wealthy Hand-to-Mouth" investor to characterize households with substantial assets in the form of housing and retirement accounts, but with little liquid wealth or credit facilities to offset short-term income falls. Pension investment is the main component of financial investment for most households. Hence, it is an essential instrument to diversify risk over the life-cycle, e.g., by hedging intertemporal variations in human wealth or other illiquid components of households' wealth. From this perspective, the approach pioneered in Swanson (2012), allowing households' to more flexibly adjust their pension allocations to risky assets during the last part of their life-cycle, in accordance with their risk tolerance and their total wealth composition, seems very reasonable.[7]

[6]See also Di Giacinto and Vigna (2012). Meanwhile, pension funds are invested in financial assets after retirement and the pensioner withdraws periodic amounts until annuitization occurs (if ever). This option is named "income drawdown option" in the UK, "phased withdrawals" or "programmed withdrawals" in the US. By taking it, reinvestment risk and annuitization risks are shifted from the retirement date to the post-retirement period.

[7]Note that the asset allocation should depend on the ratio of financial wealth to human capital. While this ratio does depend on age, it also depends on the financial wealth that has been accumulated at each point in time (which depends in turn on past contribution rates and realized rates of return on risky assets). Thus, as emphasized by Dahlquist, Setty, and Vestman (2017) age-dependent rules can only ever approximate the normatively recommended asset allocation.

B. Welfare costs of suboptimal life-cycle allocations

Various authors have tried to characterize quantitatively the optimal portfolio strategies and the welfare implications of life-cycle allocations.

Under different assumptions, Cocco and Maenhout (2005), Gomes and Michaelides (2005) and Gomes, Kotlikoff, and Viceira (2008), show that the empirically observed stock market participation rates and asset allocations can be reproduced by a calibrated life-cycle model with plausible specifications of uninsurable labour income risk and risk aversion. Using a large sample of Norwegian households, Fagereng, Gottlieb, and Guiso (2017) provide related empirical support on life-cycle portfolio allocations, by documenting a double (optimal) adjustment as households age: a rebalancing of the portfolio composition away from stocks as they approach retirement and a stock market exit after retirement.

In a life-cycle model similar to Cocco and Maenhout (2005), but with flexible labour supply, Gomes, Kotlikoff, and Viceira (2008) investigate optimal consumption, asset accumulation and portfolio decisions. Importantly, they quantify the welfare costs of suboptimal life-cycle allocations that mimic popular default investment choices in defined-contribution pension plans. They document that life-cycle funds designed to match investor risk tolerance and investment horizon have small welfare costs, i.e. a small reduction in the utility of the household. In contrast, all other policies induce substantial welfare costs. For instance, a time-invariant 100% bond allocation can result in a welfare loss as large as 46% (no less than 22%) of income at the beginning of the life-cycle for a relative risk aversion of 5 (risk aversions lower than 2 or higher than 8). Similarly, a constant 50-50 allocation rule between bonds and stocks results in a welfare loss of 15% (87%) of income for investors with risk aversion of 2 (risk aversion of 8).

In summary, this literature documents potentially large welfare costs of popular default investment choices in defined-contribution pension plans that deviate from optimal life-cycle allocations and instead rely on investments in fixed income or in other 'safe' instruments with low yields.

IV. The performance of a defined contribution life-cycle investment: a quantitative assessment

The value of the assets accumulated in a defined contribution (DC) pension plan at retirement depends primarily on the contribution rate, the length of the contribution period, the investment policy and the random shocks to risky asset returns during the accumulation phase of the life cycle. In this section, we compute under various scenarios the expected retirement wealth of a worker/investor that adopts a DC pension plan relying on a life-cycle investment strategy.[8] The main purpose of the exercise is to analyze the risk/return properties of different risky portfolio strategies implementable during the accumulation phase of the life-cycle strategy.

We fix a contribution (wealth accumulation) phase of 40 years, i.e., the worker joins the DC pension plan at age 25 and leaves it after retirement at age 65. In order to consider different disinvestment policies after retirement, we also allow for a 7-year early-retirement phase, during which the worker/investor can decide to keep the portfolio invested until age 72.[9] For simplicity, we abstract from annuitization risk and assume that under particularly unfavourable market conditions the worker can simply delay her/his retirement to accumulate more assets for a period of time between 65 and 72 years, which are conventionally considered as upper and lower retirement age limits. The following assumptions of pension contributions and wage evolution further underly our computations:

- An annual initial wage of €18,000, which corresponds approximately to the current Euro area average net income;
- An annual wage growth rate of 2%, consistently with a deterministic wage growth rate compatible with Euro area inflation and productivity growth rates;[10]
- A monthly wage contribution of 10% to the DC pension plan;

Under these assumptions, the worker/investor starts contributing €150, i.e., 10% of her initial monthly wage, to the DC pension plan. Every following month, the wage increases by 2% on an annual basis, implying a final annual salary at the retirement date of about €40,000. Therefore, at the retirement date the fix percentage contributions of 10% of monthly salaries give rise to total contributions of about €110,000 for the DC pension plan.

A. *Mean-variance portfolio optimization*

[8]In this section our empirical analysis combines static mean-variance portfolio optimization with Monte Carlo and bootstrap simulation methods.

[9]See again the discussion in the preceding Footnote 6.

[10]Assuming that the inflation rate and the productivity growth rate are stochastic or that wages increase at a different annual rate does not alter the main results of our analysis. Therefore, for the sake of simplicity, we keep the growth rate of wages fixed at 2%, which is approximately equal to the sum of the average inflation rate in the Euro area since 1999 (1.5%) and the current productivity growth rate in advanced economies, which was recently estimated at a value around 0.3% (see Lagarde (2017)).

Table IV.1 – Initial portfolio allocation

	Cash	RF Bonds	DEF Bonds	Equity
Portfolio 1	0%	25%	25%	50%
Portfolio 2	0%	12.5%	12.5%	75%
Portfolio 3	0%	0%	0%	100%

Contributions to the DC plan are invested in portfolios consisting of different initial allocations to four asset class: cash and cash-equivalent assets, risk-free government bonds, defaultable government bonds, i.e., government bonds yielding a risk premium for sovereign risk, and equities.

We consider only European Euro-denominated assets to emphasize the opportunities arising in the internal capital market. The beneficial role that is also played by international diversification of investment will be discussed later. Precisely, we proxy the return on cash by the total return index on German T-Bills and the return on risk-free government bonds by the total return index on German 10-year government bonds.[11] Similarly, we proxy the return on defaultable government bonds by the total return index on Italian 10-year government bonds and the return on equity by the total return MSCI Europe equity index.

We estimate average returns and the variance-covariance of our return series using a 30-year period of monthly observations from January 1988 to November 2017. Table A.1 reports corresponding annualized summary statistics for monthly returns. We allocate wealth to the four asset classes according to a standard mean-variance optimization approach, in which the portfolio return volatility is minimized for any target level of average portfolio return $\overline{\mu}$. Moreover, we impose a no-short selling constraint on each asset classes.

Formally, we solve the following quadratic optimization problem with respect to the vector $\mathbf{w} := (w_1, w_2, w_3, w_4)'$ of portfolio weights:[12]

$$\begin{aligned} &\min_{\mathbf{w}} \mathbf{w}'\Sigma\mathbf{w} \\ \text{s.t.:} \quad &\mathbf{w}'\mathbf{1} = 1 \ ; \ \mathbf{w}'\mu = \overline{\mu} \ ; \ \mathbf{w} \geq \mathbf{0} \ , \end{aligned}$$

where Σ is the sample variance-covariance matrix of asset returns, $\mu := (\mu_1, \ldots, \mu_4)'$ the

[11] We also carried our analysis including as a fifth asset class German corporate bonds, in order to address extra return components reflecting corporate risk. However, the main results of our analysis did not change significantly. More generally, the choice of the assets is purely illustrative as life-cycle strategies can be built on different types of bond and equity exposures.

[12] Given our monthly estimates of Σ and μ in Table A.1, the resulting optimal portfolio allocations are mean-variance efficient in a one-period (monthly) context.

vector of asset average returns, $\mathbf{1} := (1,1,1,1)'$ a vector of ones and $\mathbf{0} := (0,0,0,0)'$ a vector of zeros. Panel A of Figure A.1 reports the efficient mean-variance frontier obtained by solving for various levels of target return $\overline{\mu}$ the above optimization problem. Note that besides the short selling constraints, the optimal portfolios underlying the efficient frontier in Panel A of Figure A.1 do not incorporate other investment restrictions. Therefore, in order to compute optimal portfolios and efficient frontiers that are more compatible with realistic portfolio allocations of typical DC systems, we introduce additional constraints in our mean-variance optimization. Precisely, we bound the investment in cash to no more than 5% of the initial wealth and we force the investment in the defaultable government bond to be no more than the investment in the risk-free government bond.

The mean variance efficient frontier obtained by incorporating these additional portfolio constraints is reported in Panel B of Figure A.1. In the same figure, we also highlight the average return and the volatility of three different efficient portfolios (portfolios 1, 2 and 3) with portfolio weights detailed in Table IV.1. We take these three portfolio allocations as three different possible benchmarks to initialize our life-cycle portfolio strategies.

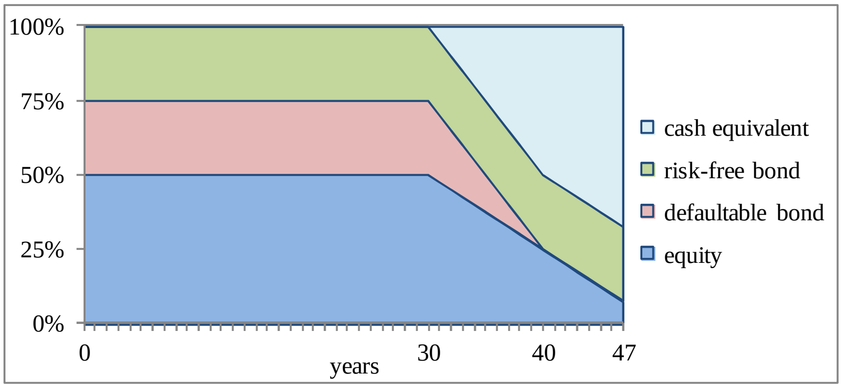
Intuitively, these portfolios correspond to the investment profile of investors with different attitudes towards risk. Given the long-term investment period, Portfolio 1 corresponds to a relatively prudent investment profile, implying an equal-weighted allocation to stocks and bonds (25% risk-free and 25% defaultable). Portfolio 2 corresponds to a less conservative investment profile, implying a 75% allocation to stocks and an equal-weighted residual allocation to risk-free and defaultable government bonds. Finally, Portfolio 3 corresponds to an aggressive investment profile fully invested in equities.

B. Life cycle investment strategies

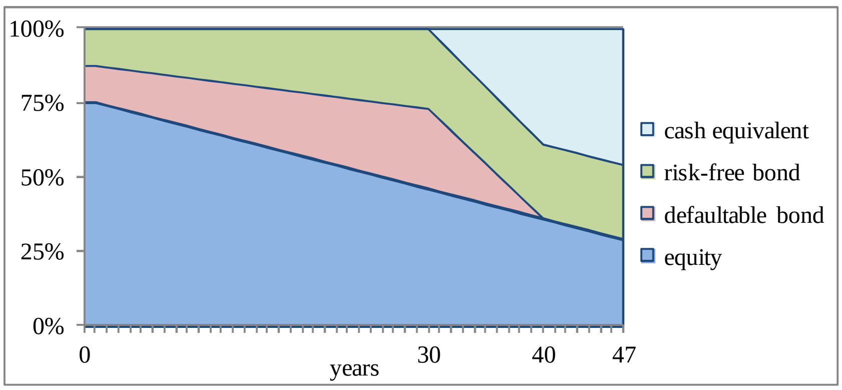
We implement various life-cycle investment strategies for a wealth accumulation phase of 40 years, under three different assumptions about the decrease in portfolio exposure to equity assets in dependence of investors' age. Precisely, we assume that 10 years before retirement, i.e., after age 55, portfolio allocations are progressively adjusted to target a less aggressive investment profile, in order to reduce the volatility of future wealth at the retirement date. The portfolios' asset allocation glide paths underlying the three life-cycle strategies we consider are summarized in Figure IV.1.

Panel A of Figure IV.1 illustrates the allocation glide path of our first life-cycle strategy. It reports the initial allocations of 25% in risk-free bonds, 25% in defaultable bonds and 50%

Panel A: Portfolio 1 (50% bonds – 50% equity)



Panel B: Portfolio 2 (Poterba scheme)



Panel C: Portfolio 3 (All equity)

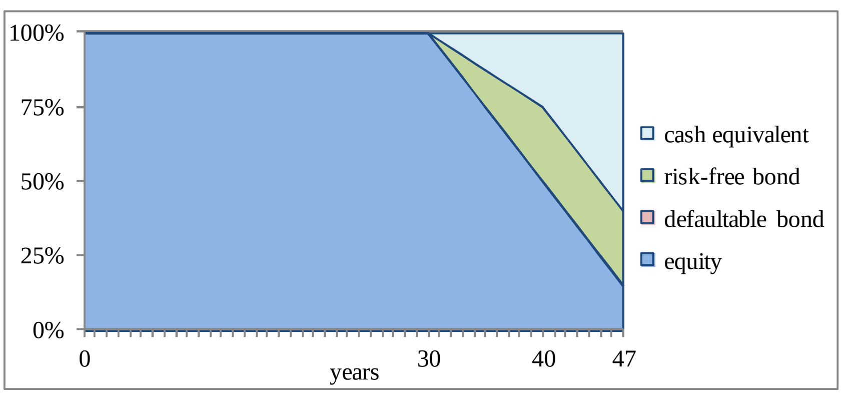


Figure IV.1 – Portfolio allocation

in equity, which are kept fixed for the first 30 years of the wealth accumulation phase. In the last 10 years of the wealth accumulation phase, the allocation to defaultable bonds is reduced linearly, in order to fully eliminate the exposure to default-sensitive assets at the retirement date. In parallel, the allocation to equity is reduced by 5% every year, so that at retirement the residual equity allocation is 25% of total wealth. All disinvestment from equity and defaultable bonds in this period is allocated to cash, so that the investment in risk-free bonds and cash at the retirement date is 25% and 50%, respectively. After the retirement date, the allocation to stocks during the early retirement period of 7 years is further reduced by 5% every year, yielding an equity exposure of only 7.5% and a cash allocation of 67.5% at age 72.

Panel B of Figure IV.1 illustrates the allocation glide path of a life-cycle strategy following the so-called 'Poterba age-based scheme'; see Poterba et al. (2006). This scheme dictates a percentage wealth allocation to stocks equal to 100% minus investor's age. Therefore, under this scheme the initial wealth allocation to stocks at age 25 is 75%, while the stock allocation at the retirement age of 65 is 35%. During the first 30 years of the wealth accumulation phase, the wealth not invested in stocks is fully invested in risk-free and defaultable bonds, with equal weights. Therefore, the allocation to risk-free and defaultable bonds is 12.5% at the initial date and 27.5% just 10 years before retirement. 10 years before retirement, the strategy is starting to reduce the allocation to risk-free bonds and to progressively eliminate the allocation to defaultable bonds, by reallocating wealth to cash at a linear annual rate that implies a zero allocation to defaultable bonds and a 25% allocation to risk-free bonds at the retirement date. In parallel, the disinvestment in stocks under the Poterba scheme after the first 30 years of wealth accumulation is also fully allocated to cash. Therefore, while the portfolio cash allocation 10 years before retirement equals 0%, it is 40% at the retirement date and 47% at the end of the early retirement phase.

Panel C of Figure IV.1 illustrates the allocation glide path of our third life-cycle strategy, which implies an initial all-equity allocation kept fixed for the first 30 years. After this period, the stock allocation is reduced each year by 5%, while the allocation to risk-free bonds is increased annually by 2.5%, up to a maximal allocation of 25%. Therefore, the portfolio allocations at the retirement date are 25% for cash, 25% for risk-free bonds and 50% for equity. In contrast, at the end of the early retirement period in year 47, the allocations to cash and equity are 60% and 15%, respectively.

C. Life-cycle portfolio simulation

The goal of this section is to characterize the risk-return trade-off associated with the three life-cycle portfolio strategies introduced in the previous section. To this end, we follow a historical Monte Carlo simulation approach, which allows us to simulate the empirical distribution of retirement wealth under our life-cycle portfolio strategies.

Precisely, we simulate several time series of 47 years of multivariate monthly returns, by randomly drawing with uniform weights from the joint empirical distribution of returns in the sample period from January 1988 to November 2017.[13] In this way, we obtain several time series of four dimensional asset returns, consisting each of 564 time series observations. For each such time series, we compute the time series of monthly portfolio wealth realizations under the corresponding life-cycle portfolio strategy. By randomly repeating this procedures a large number of times, e.g., 5,000 times, we finally obtain a whole distribution of 5,000 simulated portfolio wealth realizations at the retirement date (year 40) and at the end of the retirement period (year 47). In order to simulate more realistic portfolio wealth processes, we apply everywhere an annual management fee of 1%.[14]

C.1 Wealth distribution at the retirement date

For the three life-cycle strategies under scrutiny, Figure IV.2 plots the simulated distribution of the ratios between accumulated retirement wealth and total contributions paid during the 40-year wealth accumulation period of the DC pension plan. For comparison, it also plots the distribution of these ratios for a 'risk-free strategy' investing each month all contributions in cash-equivalent assets. For all risky life-cycle strategies, we find that simulated ratio distributions are positively skewed, with median ratio between accumulated retirement wealth and total contributions higher than 4, which means that in 50% of the cases the contributors can expect to accumulate a retirement wealth four times the level of their contribution. Median ratio also seems to increase in the degree of riskiness of the underlying life-cycle strategy.[15] We quantify the downside risk of life-cycle strategies using the 5%th percentile of the ratio distribution, i.e., the threshold value of the ratio such that a lower outcome occurs with a probability not higher than 5%. Under this approach, a higher 5%th percentile indicates

[13]We sample from the joint distribution of asset returns to reproduce the (unconditional) return correlation structure in our data.

[14]According to Morningstar, the average management fee applied by European funds in 2016 is 1%, down from 1.09% in 2013. Hence it should be understood as reflecting an average European fund management fee and not as the likely fee for the management of a default fund, which could be lower.

[15]As all simulated ratio distributions are positively skewed, the probability of achieving a ratio not lower than the mean ratio is less than 50%.

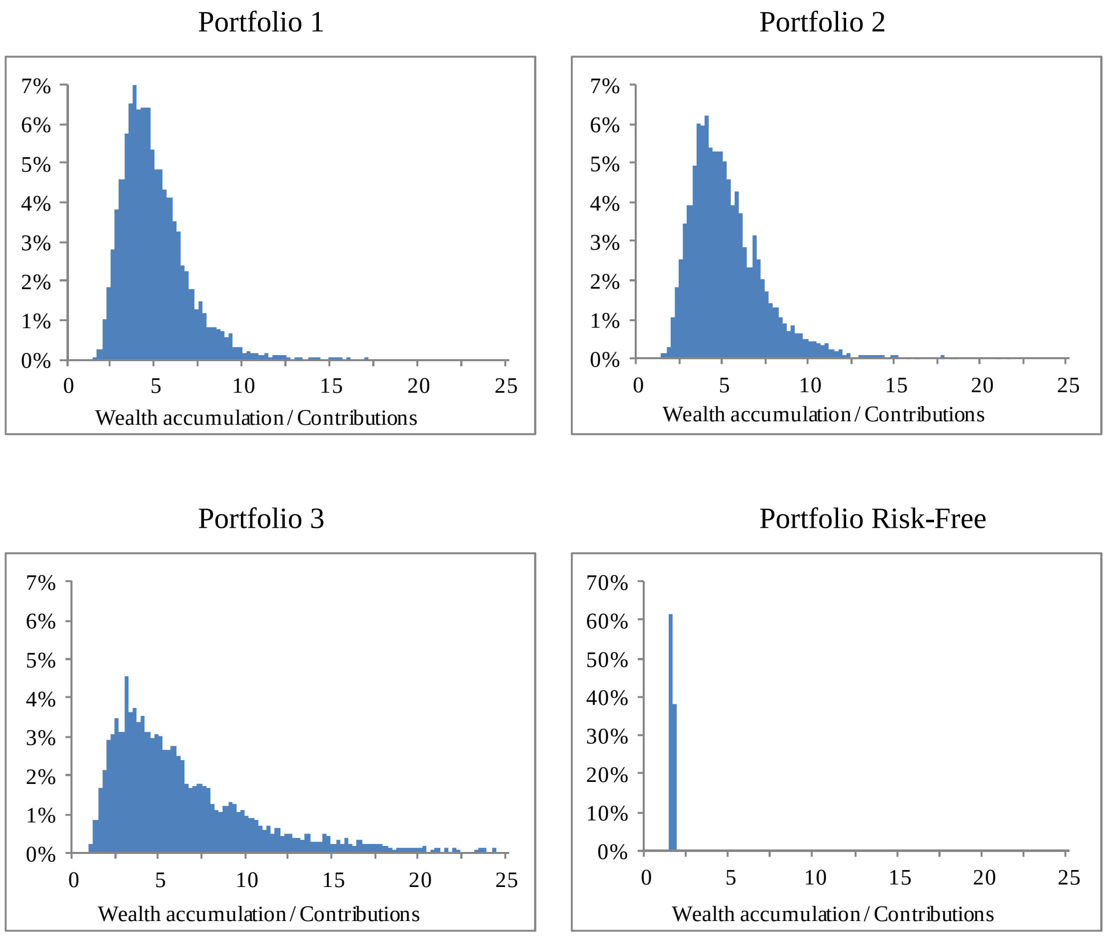


Figure IV.2 – Distribution function of the ratio wealth accumulation/contributions paid

a lower downside risk, very much in line with the well-known risk management practice of measuring downside risk with the Value-at-Risk (VaR).[16]

Consistently with this approach, Panel A of Figure A.2 shows that the median ratio of life-cycle strategies increases with the strategy downside risk, i.e., it decreases with the 5% quantile of the ratio distribution. Panel B of Figure A.2 provides a complementary description of the risk-return tradeoff of life-cycle strategies. To this end, we compute the distribution of the internal rates of return (IRR) corresponding to the investment plans generated by the paid contributions and the accumulated retirement wealth. Based on this distribution, we then compute median IRRs and 5% lower IRR quantiles as complementary measures of portfolio return and downside risk. Similar to Panel A, we find that the median IRR of life-cycle strategies decreases with the 5% quantile of the IRR distribution.

[16]Using alternative risk measures motivated by, e.g., expected shortfall or conditional VaR does not change the main results of our analysis. Therefore, we do not elaborate further on this topic.

The actual values of our proxies of risk and return for life-cycle strategies are reported in Table A.2.

In Panel A of Table A.2, we find for the first life-cycle strategy that the median investor retires with a wealth corresponding to 4.4 times the contributions paid. This multiple increases to 4.6 and 5.1, respectively, for the second and the third life-cycle strategies. At the same time, the 5% ratio percentile for the first and second strategy is 2.5 and it decreases to 1.8 for the third strategy, this means that under strategies 1 and 2, 95% of the savers can expect to accumulate at retirement a wealth at least equal to 2.5 times the level of their contributions. Panel B of Table A.2 similarly shows that the median IRR also increases with the equity allocation, from 6.9% to 7.5% for the first and third strategies. Accordingly, the 5% IRR percentile decreases from 4.4% to 2.9%.

While, as intuitively expected, we tend to obtain a tradeoff between the downside risk and the median return of life-cycle portfolio strategies, it is interesting to note that for some portfolio comparisons this tradeoff may be not excessively tight. More explicitly, we document the following evidence:

(i) The 5% ratio and IRR percentiles for life-cycle strategies 1 and 2, while different, are numerically almost identical.

(ii) Even the 5% IRR percentile of the all-equity life-cycle strategy 3 is higher than the median IRR of the risk-free strategy investing all contributions in cash.

Result (i) suggests that over a 40-year investment horizon life-cycle strategies 1 and 2 can provide a more favourable balance between risk and return than more conservative allocations. Result (ii) further highlights that excessively risk-averse strategies can be extremely penalising in the vast majority of wealth scenarios at the retirement date.

C.2 Retirement wealth and early-retirement investment

In order to better interpret the evidence highlighted in result (ii) of the previous section, it is useful to consider in more detail some of the 5% worst scenarios for retirement wealth arising under the life-cycle strategy 3. To this end, we focus on extremely unlikely adverse scenarios, in which the wealth accumulated at the retirement date does not exceed the sum of the contributions paid during the 40-year wealth accumulation period before retirement. Panel A of Table IV.2 shows that such scenarios can materialize only under the all-equity life-cycle portfolio strategy. Even in this case, the probability of such scenarios is only 0.28%.

Table IV.2 – Left tail of portfolios' distribution functions

Panel A: Wealth accumulation below total contributions paid

	Accumulation stage (40-year holding period)	Accumulation + Early-retirement stage (47-year holding period)
Portfolio 1	0.00 %	0.00 %
Portfolio 2	0.00 %	0.00 %
Portfolio 3	0.28 %	0.06 %

Panel B: Wealth accumulation below 5th percentile of the risk-free portfolio

	Accumulation stage (40-year holding period)	Accumulation + Early-retirement stage (47-year holding period)
Portfolio 1	0.04 %	0.02 %
Portfolio 2	0.14 %	0.04 %
Portfolio 3	2.26 %	1.06 %

Unlikely adverse scenarios for retirement wealth can materialize because of particularly negative realized market conditions shortly before the retirement date. Therefore, we next quantify the implications of a possible delay in the withdrawal of accumulated wealth during the retirement phase for such cases, by extending the investment period by seven years up to age 72, and assuming that the risk exposures to equities and bonds can be further reduced during this period as shown in Figure IV.1. Since the PEPP is a private pension (Pillar 3) product, it can be assumed that many savers/investors will have access to Pillars 1 and 2 pensions, allowing to an extended investment period in the PEPP.[17]

Panel A of Table IV.2 shows that by allowing for this extended investment period, the probability that the final value of the investment of the all-equity life-cycle strategy falls below the sum of the contributions paid is further reduced to 0.06%. For the other two life-cycle strategies all such probabilities in Table IV.2 are virtually zero.

In summary, our simulation evidence shows that life-cycle strategies generally provide a quite satisfactory risk/return profile for investment horizons of about 40 years, implying median IRR around 7% and a low probability for adverse states associated with an inability to recoup the contributions paid during the accumulation phase. In particular, we find that strategies 1 and 2 can produce relatively high median returns together with a virtually zero probability for extremely adverse outcomes.

[17] See for instance the descriptions of life-cycle investment solutions in Amundi (2017) and Donaldson et al. (2015).

C.3 The no-equity case

In order to better understand the portfolio implications of equity investment for the wealth accumulation phase in the life-cycle strategy, we reproduce the simulations in the previous sections for no-equity portfolios consisting only of cash-equivalent assets and government bonds. Panel A of Figure A.3 reports the efficient frontier for no-equity portfolios subject only to the no short selling constraints. This frontier is by definition dominated by the efficient frontier of portfolios including equities. By adding the portfolio constraints that (i) cash allocations cannot exceed 5% and that (ii) allocations to defaultable bonds cannot exceed those in the risk-free bonds, we obtain the efficient frontier in Panel B of Figure A.3. On this frontier, we finally select the portfolio with equal allocations of 50% in risk-free and defaultable government bonds, which we take as the initial portfolio for the implementation of a life-cycle strategy with no equities.

Panel A of Figure IV.3 shows the glide path of the asset allocations under the life-cycle strategy with no equities. Portfolio weights are kept constant during the first 30 years of the accumulation period. 10 years before the retirement date, the exposures to defaultable bonds is linearly progressively reduced, in order to ensure a completely vanishing credit-risk exposure at the retirement date. During the same period, the exposure to risk-free government bonds is also reduced linearly, in a way that implies a bond allocation of 25% at the retirement date.

Panel B of Figure IV.3 plots the simulated distribution of the 5,000 ratio between accumulated wealth at the retirement date and total contributions paid. We find that this distribution is only slightly positively skewed, in a very different way than in the cases of portfolios including equity discussed above. The risk/return characterization of the bond-only life-cycle strategy is reported in Panel C and Panel D of Figure IV.3. Interestingly, we obtain evidence that the bond-only life-cycle strategy is dominated by the life-cycle strategies 1 and 2 of the previous sections. Indeed, the bond-only life-cycle strategy exhibits a slightly higher downside risk and a clearly lower median return than both life-cycle strategies with equities. In particular, the median wealth accumulation of the bond-only strategy is about 3.26 times the total contributions paid, which is substantially below the 4.61 times of the second (Poterba-style) life-cycle strategy with equities.[18]

We conclude that bond-only portfolios can imply a lack of diversification, which adversely affects the risk/return tradeoff of the retirement wealth produced by a DC pension plan

[18]Similarly, the median IRR is only 5.65% versus a 7.09% median IRR of the Poterba-style strategy.

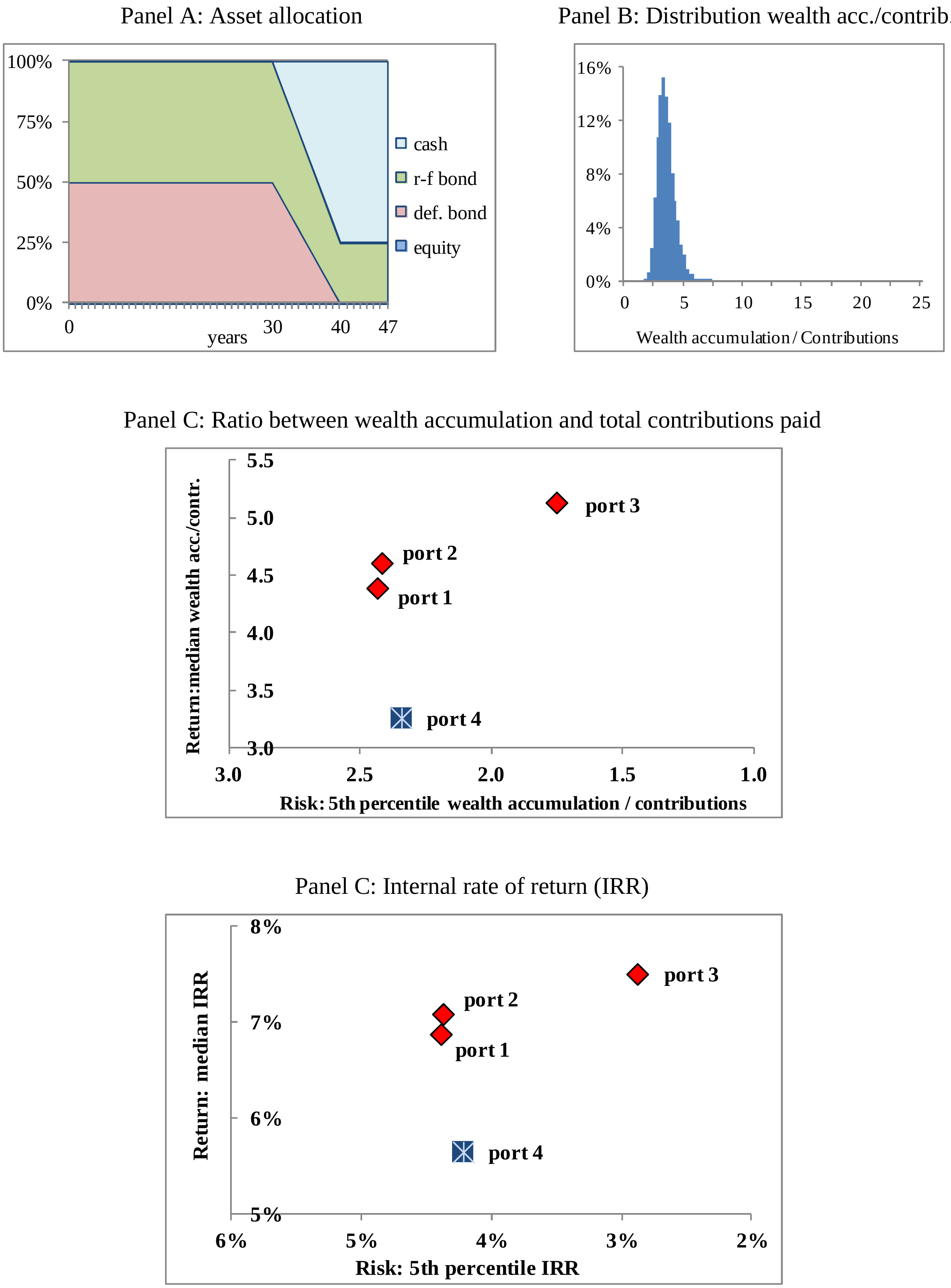


Figure IV.3 – Main features of bond-only portfolio

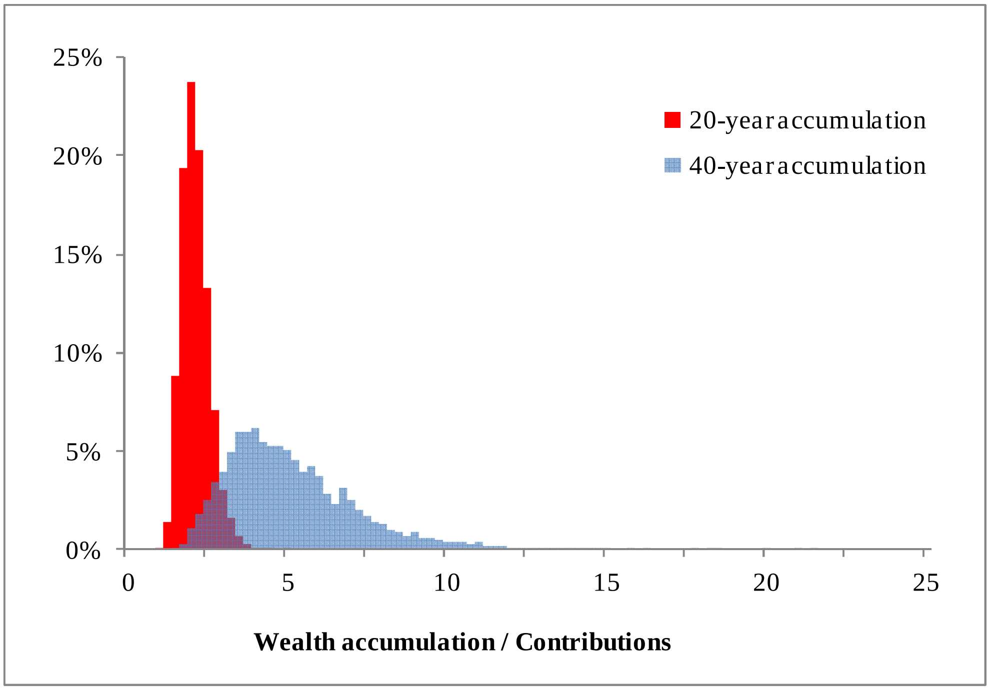


Figure IV.4 – Distribution function wealth accumulation/contributions for the 20-year case

adopting a corresponding life-cycle strategy.

C.4 Sensitivity to the retirement date

In this section, we study the sensitivity of our previous results to the choice of the retirement date. To this end, we compute the risk/return profile of the various life-cycle strategies under a shorter accumulation period of only 20 years. Equivalently, the worker/investor is assumed to start his/her investment in the fund at age 45. For this case, the initial annual salary is €26,747 and the total contributions paid over the 20-year accumulation period amounts to about €66,000.

We focus for brevity on the Poterba-style allocations, which are particularly suited for this type of sensitivity analysis, because they rely on equity allocations that decreases proportionally to age. Under this strategy, the initial equity allocation at age 45 is 55%. Consistently with the choices in strategy 2 of the previous sections, the residual wealth is allocated to risk-free and defaultable bonds with equal weights. Hence, the initial strategy allocation to risk-free and defaultable bonds is 22.5%.

Figure IV.4 plots the simulated distribution of the ratios between accumulated retirement wealth and total contributions paid over the 20-year accumulation period. For comparison, we report again also the simulated distribution of these ratio obtained under a 40-year accumulation period.

The distribution obtained for the shorter accumulation period is significantly less positively skewed. The median ratio, reported in Panel A of Table A.3, is 1.96, compared to 4.61 under a 40-year accumulation period.[19] The shorter 20-year accumulation phase implies a small probability of 0.14% of not covering the total contributions paid with the accumulated wealth at the retirement date. This probability vanishes under an extended investment period of 7 years in the early retirement phase. This result confirms that the probability of not recouping the capital invested under a shorter accumulation period, 20 years, remain very low 0.14%.

V. Guaranteed investment strategies

A. Pension investment products with a minimum guaranteed rate of return.

Various financial intermediaries, often insurers, offer pension products with upside performance linked to the one of an equity benchmark and downside performance limited by a contractual long-term capital guarantee, in the form of a minimum nominal guaranteed rate of return.

Therefore, the payout of these products has a typical option-like form with respect to the benchmark investment: if the benchmark investment performance falls below a minimum floor level, the contract payoff equals the floor; if the benchmark investment produces a performance above the floor, then a fraction of the payout of the policy will raise with it. There are different categories of products explicitly designed to achieve this goal. The simplest one is an index-linked or unit-linked insurance contract, which guarantees to the policyholder a return that is the maximum between the index performance and a minimum guaranteed rate; see e.g. Hipp (1996).

From the point of view of the insurance, a policy with a minimum guaranteed rate induces a long term liability whose present value depends on the level of interest rates. When interest rates are low, the price of the liability raises and the buffer of capital that can be invested in riskier asset is reduced. This problem, known with the name of 'lock-in', limits the performance of an index-linked strategy in periods of low rates, inducing a payout similar to

[19] Similarly, the median IRR for the shorter accumulation period is only 6.38%, versus a median IRR of 7.07% under a 40-year accumulation phase.

the one offered by a long term bond. Such an allocation is known to be optimal (see Wachter (2003)) only for an investor with arbitrary low risk propensity.

A more advanced approach to structured products with minimum guarantees can be achieved by implementing an asset-liability management strategy. Following the traditional actuarial approach, insurance companies actively use their balance sheet to reconcile the targets of policyholders, who play the role of insurance liability holders, and shareholders, who provide funding to keep the adequate levels of risk capital required by regulators to minimize insolvency risk.[20] The provision of capital by shareholders is compensated through dividend distributions. The contributions paid by the policyholders of traditional guaranteed products, which may be sold in different years and for different guarantee levels, are pooled together and invested into a corresponding portfolio of assets. The cash flows generated by the insurer's asset portfolio in any given year can be then used to fulfil the obligations deriving from the portfolio of outstanding policies. As long as these cash flows exceed the sum of all existing minimum guarantees, all insurance contracts participate to the asset portfolio excess performance.

From a broader perspective, the organization and regulation of the insurance sector are explicitly designed to optimize the diversification of individual risks through pooling and collective management. In the specific case of market risk, which is undiversifiable, whether such a collective management can be beneficial is still a subject of debate. When comparing index-linked and traditional participating life-insurance contracts, the last one allows for additional flexibility, as temporary provisions of (costly) capital may reduce the lock-in effect determined by low interest rates. Similarly, when the asset portfolio performance is high, a bonus reserve can be created, which may be used to re-inject capital when needed in the future. The final effect of these dynamic adjustment, is to reduce the policyholder return volatility. This reduction is typically offered in a uniform way throughout the full policy life-cycle, not only in some proximity of the policy liquidation date. Therefore, these investment vehicles at least partly abstract from some of the insights of traditional financial advices on life-cycle and retirement investing.

In our analysis, we will largely abstract for simplicity from the economic reasons that may explain the policy provider's selection of a particular form of minimum guarantee investment and the corresponding asset portfolio.[21] Instead, we take the perspective of a potential policy

[20] In the Solvency II regulation, the risk capital required to limit the insurance's insolvency risk is determined by a VaR-type constraint.

[21] In this way, we also abstract from broader economic issues related to the management of the actuarial risks in the life insurance business. See van Bilsen, Laeven, and Nijman (2014) for a recent analysis of this interesting issue.

holder who wants to quantify the welfare tradeoffs of a choice between a given minimum guarantee investment policy and other benchmark life-cycle investment strategies, such as a Poterba life-cycle strategy. To achieve this purpose, we basically need to model plausible asset-liability management plans that are implementable by insurance companies in order to produce the contractual cash-flows of minimum guaranteed investment products.

B. Approach for quantifying the performance of minimum guaranteed investments

We will compare costs and benefits of minimum guarantee investments with a participation life insurance policy and life-cycle target-date investment funds. In such funds, each investor pays an upfront and a yearly management fee, in order to participate to the return of an asset allocation selected according to a corresponding life-cycle rule and investment mitigation scheme. We compare payout distributions assuming that insurance managers compensate equity capital at market prices and implement a regulatory solvency condition. They also require an upfront management fee from policy holders and pay a yearly asset management cost that is retroceded to policy holders. The quantification of the relative efficiency of the various investment approaches under consideration also requires a model that reproduces the key properties of security return dynamics, such as the dependence of risks, returns and correlations on the investment horizon, and their relation with relevant economic state variables. Therefore, we make use of a different Monte Carlo simulation approach from the one adopted in Section IV. We estimate a Vector Auto Regressive (VAR) model to describe and simulate the joint long-term dynamics of returns and economic state variables relevant to European investors; see also Campbell and Viceira (2005).[22]

VI. Simulation of payout distributions for minimum guarantee and life-cycle investment strategies

Our scenario simulation reproduces the joint dynamics for three tradable returns and three economic state variables. Tradeable returns include the return of a short-term cash investment (proxied by the 3-month German T-Bill), the return of a long-term, 10-year duration, investment (proxied by the 10-year German government bond) and the return of an aggregate stock market index (proxied by the MSCI Europe equity index).[23] The three economic state variables are the price-dividend ratio of a portfolio equity index, the term spread be-

[22] A more detailed formal description of this model is given in the Appendix.

[23] VAR estimations using the 10-year French government bond return produced similar implications of our analysis.

tween the 10-year and the 3-month yields on German T-bills, and the real 3-month yield of German T-bills, obtained by deflating the nominal yield by German CPI inflation. Note that this simulation keeps into account also the dependence of risks and correlations with respect to the horizon. Moreover, the inclusion of an inflation proxy in the estimated VAR dynamics allows us to obtain important information about the effective degree of long-term inflation protection offered by the risk mitigation schemes under scrutiny.

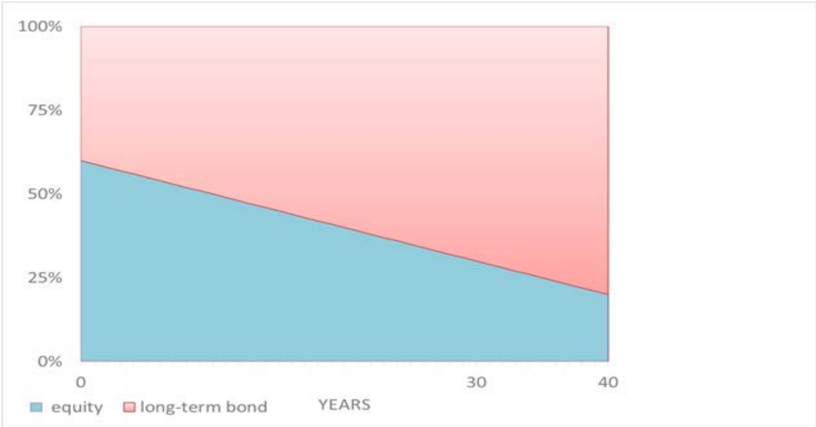
A. Specification of the economic scenarios and asset allocation strategies

This section specifies (i) minimum guarantee investments with a participation life insurance policy that can be offered at market prices in different economic scenarios and (ii) 'Poterba-style' life-cycle target-date investment funds.

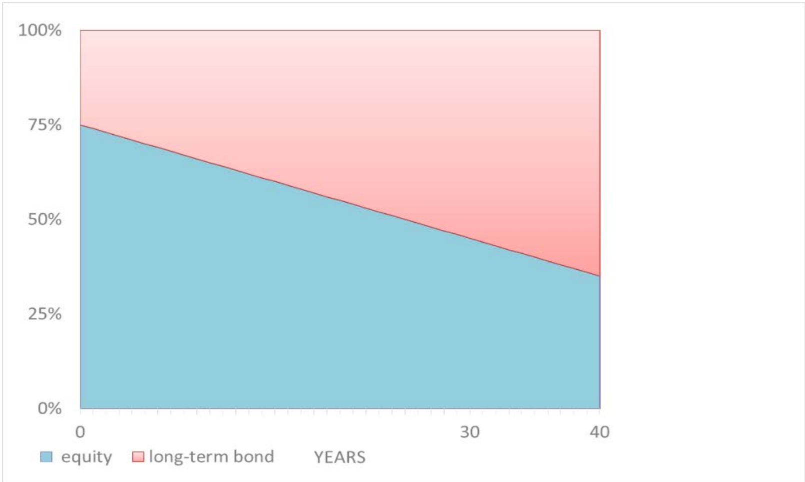
For the minimum guaranteed investment contracts, we analyze the performance of three static asset allocations A, B and C relying on two distinct simulation scenarios. Allocation A and B are supported by a set of scenarios generated by a monthly VAR simulation that has been estimated on the 1992-2012 sample period, reflecting the economic conditions experienced after the EU Maastricht treaty and truncated before the start of the ECB Outright Monetary Transaction program. This scenario corresponds to estimated interest rates and equity VAR dynamics characterized by low unconditional real and nominal rates, a relatively flat unconditional yield curve and an unconditional inflation rate of about 1.5%, slightly below the ECB institutional target rate of 2%.

This simulation setting is the most similar to the so called 'new normal', a term which often refers to financial conditions that characterized the economies after the financial crises, with low rates and low inflation. Allocation C is supported by an estimated VAR dynamics for the longer sample 1969-2012, which includes the two oil shocks and periods of clearly higher inflation rates and interest rates. This sample reflects interest rates that are initially low, subsequently increase to clearly higher levels and finally mean revert. Ideally, this scenario is more similar to the 'old normal' and is expected to be more favourable for an asset liability management strategy that may profit from a higher level of long term rates to offer higher guaranteed rates.

Low Equity



Medium Equity



High Equity

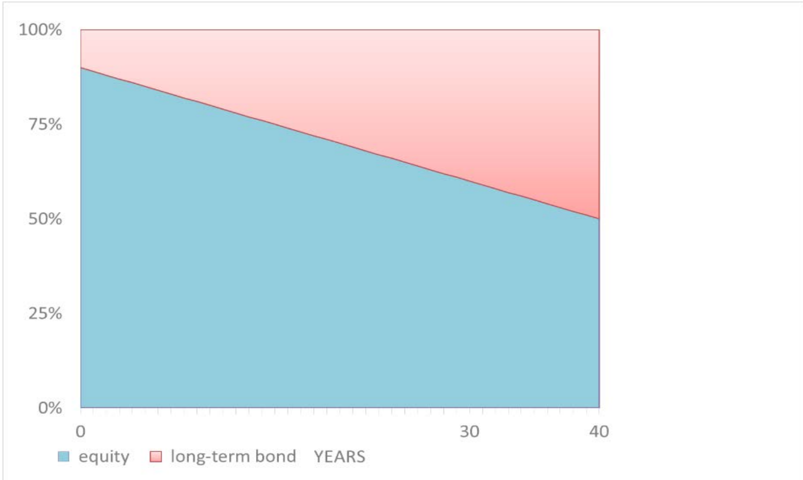


Figure VI.5 – Glide path for Low, Medium and High equity Poterba-style investment strategies

The detailed asset allocation A, B and C are:[24]

$$\begin{aligned}
\text{Allocation } A &: \pi_t^{Equity} = 0.05 \ ; \ \pi_t^{LongB} = 0.95 \ , \\
\text{Allocation } B &: \pi_t^{Equity} = 0.10 \ ; \ \pi_t^{LongB} = 0.90 \ , \\
\text{Allocation } C &: \pi_t^{Equity} = 0.05 \ ; \ \pi_t^{LongB} = 0.95 \ ,
\end{aligned}$$

where π_t^{Equity} and π_t^{LongB} are constant percentage wealth allocations to equities and long-term bonds, respectively. Allocation B is a slightly tilted version of allocation A, which is applied for the same historical scenario to analyze the sensitivity of the results under allocation A with respect to a moderate increase in the equity allocation.

Note that in practice there are structural reasons that force an insurer who sells a guaranteed product to allocate most of his wealth in long term bonds and thus to reduce the diversification of the asset allocation. First, the principle of duration matching: in order to lower the exposure of the balance sheet to interest rate volatility risk, the duration of assets must be close to the duration of liabilities, which is high due to the presence of the guarantee on the liability side. Second, capital requirements for equity are higher than those for bonds according to Solvency II regulation.

For comparison with the minimum guaranteed investment strategies supported by allocations A, B and C above, we consider three 'Poterba-style' life-cycle strategies with the following time-varying allocations to equities and long-term bonds only:

$$\begin{aligned}
\text{Low Equity:} \quad & \pi_t^{Equity} = \frac{85-\tau}{100} \ ; \ \pi_t^{LongB} = 1 - \pi_t^{Equity} \ , \\
\text{Medium Equity:} \quad & \pi_t^{Equity} = \frac{100-\tau}{100} \ ; \ \pi_t^{LongB} = 1 - \pi_t^{Equity} \ , \\
\text{High Equity:} \quad & \pi_t^{Equity} = \frac{115-\tau}{100} \ ; \ \pi_t^{LongB} = 1 - \pi_t^{Equity} \ ,
\end{aligned}$$

where τ is the age of the life-cycle investor, ranging from an initial age of 25, when starting the life-cycle strategy, and an age of 72 at the end of the early retirement period, seven years after the date of retirement, as in Section IV. Glide paths corresponding to these allocations are illustrated in Figure VI.5. The choice to focus on zero allocations to cash also in the life-cycle strategy is taken in order to make the comparison more consistent with the implication of allocations A, B and C for minimum guaranteed investment products. In

[24] See Graf, Kling, and Ruß (2011) and Hieber, Korn, and Scherer (2015), for an extended discussion on the optimality conditions used to set the allocation strategies in this context. Our allocations are broadly in line with most of the allocations often adopted in the insurance industry.

this way, we can focus on a comparison with the long-term risk-return tradeoff resulting only from a time-varying allocation to equity and long-term bonds in the life-cycle strategy.

B. Specification of insurer's balance sheet and computation of minimum guarantees affordable under fair market conditions

For simplicity, we assume an insurer's balance sheet that is regulated on a yearly basis. Therefore, the random yearly return R^{Π}_{t+1} on the insurer's asset portfolio, for each of the allocation scenarios introduced in the previous section, is capitalized in the account with a yearly frequency. Moreover, a fee of 50 basis points is charged up-front on every policy contribution to cover administrative costs. Finally, the yearly asset return credited to policy holders is reduced by 50 basis points to cover asset management fees.[25] In the Appendix, we detail the asset-liabilities management procedure followed by the insurance company to dynamically adjust the balance sheet, in order to (i) service the policy holders, (ii) fulfill the regulatory requirements and (iii) compensate the shareholders. In essence, this procedure aims at calculating the minimum guaranteed rates that an insurer can offer to comply with these three objectives.

The minimum guaranteed rates depend on market conditions, i.e., the simulated VAR scenarios, and the asset allocation policies A, B or C applied. A numerical procedure allows us to determine the following minimum annual guaranteed rates G^i ($i = A, B, C$), affordable by the insurance company in each scenario:

$$G^A = 1.25\% \ ; \ G^B = 1.5\% \ ; \ G^C = 4.25\% \ .$$

As intuitively expected, given the properties of the different economic scenarios underlying asset allocations A, B and C, the affordable minimum guarantee associated with asset allocation C, the 'old normal', is substantially higher. Similarly, the slightly more risky asset allocation B yields a higher affordable minimum guaranteed rate than allocation A under an identical historical scenario.

C. Performance assessment of a participating life-insurance policies with minimum guaranteed rate

[25] In this comparison, for both strategies, we assume a more realistic fee of 50 b.p. since we are requiring only passive replication of index benchmarks

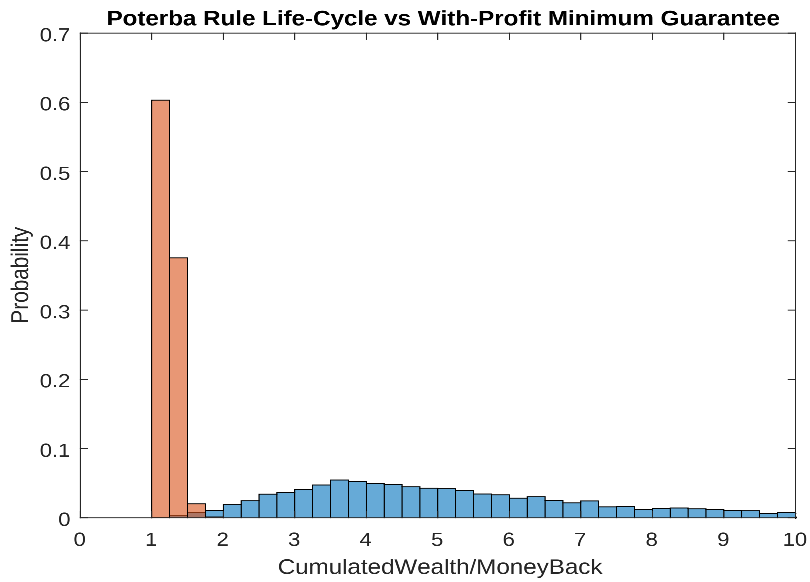


Figure VI.6 – Comparison of Guaranteed Strategies (Orange) vs Medium equity Life Cycle (Blue) Payoff Distributions Configuration A

For each allocation scenario A, B and C and corresponding minimum nominal guaranteed rates G^A, G^B and G^C, we simulate the asset-liabilities management strategy implemented by the insurance company, in order to compute the simulated distribution of total final payout produced by the investment policy with minimum guarantee. Finally, in order to obtain a distribution of proxies of final effective policy payouts, we compute the distribution of the ratio between the inflation-deflated final total policy payouts and the nominal final total contributions paid.

We call the ratio between final total policy payouts and final total contributions paid the Payoff/MoneyBack (PMB) ratio hereafter.[26] The scale is chosen in such a way that a PMB higher than 1 implies that the nominal rate of return guaranteed each year by the investment of the contributions is at least sufficient to compensate the loss in value due to the ex-post observed inflation rate. In other words, a unit PMB ratios ensures that the investment strategy generates a final wealth equal to the inflation-indexed value of the total contributions paid during the accumulation period.

Orange histograms in Figures VI.6–VI.8 plot the simulated distribution of PMB ratio of minimum guaranteed strategies (hereafter GS) under allocation scenarios A, B and C. In order to produce a direct comparison with life-cycle Poterba-style strategies, we also report with blue histograms the simulated distributions of PMB ratios for Poterba-style life-cycle

[26]The denominator of the PMB ratio is equal to the contributions capitalized at zero ex-post real rate.

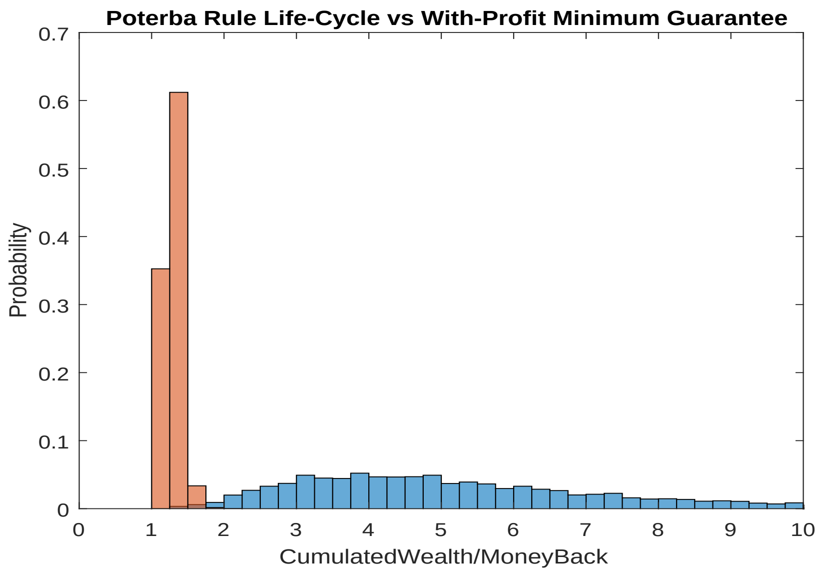


Figure VI.7 – Comparison of Guaranteed Strategies (Orange) vs High equity Life Cycle (Blue) Payoff Distributions Configuration B

investment strategies (hereafter LCS strategies). To ensure a meaningful comparison, for each GS–allocation scenario A, B and C, the payouts of GS and LCS are simulated path-by-path under identical economic conditions.

Tables VI.3–VI.5 show that all strategies offer a real capital protection with a very high probability. Indeed under allocation scenarios A and B, both GS and LCS achieve the goal of a real capital protection with a probability higher than 99.9%. Similarly, Table VI.5 shows that under scenario C this probability is larger than 99.9%, for the GS and the LCS–Low equity and larger than 99.84% and 99.80% for the other two life-cycle strategies.

Therefore, the risk mitigation approach underlying all GS and LCS appears as quite effective in truncating the lower tail of the distribution of PMB ratio. Figures VI.6–VI.8 also highlight a key difference in the distribution of GS– and LCS–PMB ratio, as LCS produce a clearly more positively skewed distribution, i.e., a thicker right tail and a practically absent left tail because of the risk-mitigation, together with a clearly higher upside return potential for a wide range of simulated economic scenarios.

Given such strong asymmetries in payout-distributions, a risk and return tradeoff comparison based on symmetric measures of average return and risk, such as, e.g., means and volatilities, is inappropriate.[27] Therefore, we follow Antolin et al. (2009) in the OECD re-

[27]Symmetric measure of dispersion like volatility do not distinguish between losses and gains. Similarly, the sample mean does not measure a typical investment performance in presence of strongly skewed distributions. To illustrate this point, consider an investment of 10000 Euros for one year in a security producing each week

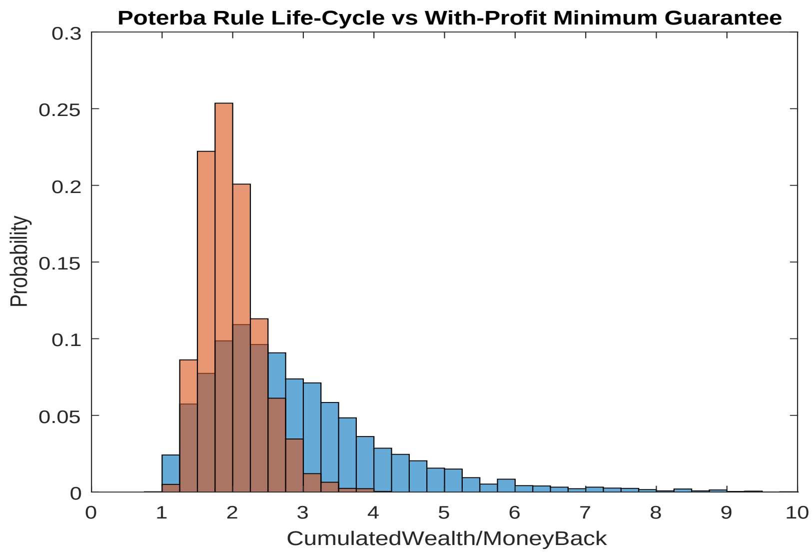


Figure VI.8 – Comparison of Guaranteed Strategies (Orange) vs Low equity Life Cycle Strategies (Blue) Payoff Distributions Configuration C

port on investment regulations on defined contribution pensions, by adopting quantile based measures of risk and performance.

Table VI.3 – Guaranteed Strategy Scenario A Monthly Sample 1992-2012. Nominal Guaranteed rate $G = 1.25$. Allocation: $\pi_A^{LongBond} = 0.95$ $\pi_A^{Equity} = 0.05$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	$GS\ A$	$LCS\ Low$	$LCS\ Medium$	$LCS\ High$
$Reward-Ratio$	1.09	1.69	2.00	2.33
$Median_{50\%}IRR$	1.17% (0.18%)	5.14% (0.78%)	6.31% (1.11%)	7.04% (1.38%)
$LwR_{5\%}IRR$	0.72% (0.17%)	2.79% (0.77%)	3.31% (0.91%)	3.43% (1.08%)
$MoneyBack$	$> 99.9\%$ $PS(5.2\%)$	$> 99.9\%$ (0.1%)	$> 99.9\%$ (0.1%)	$> 99.9\%$ (0.1%)

We measure the downside risk of a payout distribution using the IRR corresponding to the 5% percentile (denoted by $LwR_{5\%}IRR$). Similarly, we measure the 'typical' payout in

a capital gain of 80% or a loss of 60% with equal probability. The mean weekly payout is $5,000 \cdot (1.8 + 0.4) =$ 11000 Euros, which may naively suggest an attractive investment opportunity. However, the most likely end-of-year payout after reinvesting the initial capital every week is:

$$10,000 \cdot (1.8)^{26} (0.4)^{26} = 1.952 \text{ Euros} ,$$

i.e., less than 0.02% of the initial capital.

Table VI.4 – **Guaranteed Strategy Scenario B** Monthly Sample 1992-2012. Nominal guaranteed rate $G = 1.50$ GS Allocation: $\pi_B^{LongBond} = 0.9$ $\pi_B^{Equity} = 0.1$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	$GS\ B$	$LCS\ Low$	$LCS\ Medium$	$LCS\ High$
$Reward - Ratio$	1.09	1.69	2.00	2.33
$Median_{50\%}IRR$	1.20% (0.39%)	5.14% (0.78%)	6.31% (1.11%)	7.04% (1.38%)
$LwR_{5\%}IRR$	0.80% (0.28%)	2.79% (0.77%)	3.31% (0.91%)	3.43% (1.08%)
$MoneyBack$	> 99.9% PS(4.5%)	> 99.9% (0.1%)	> 99.9% (0.1%)	> 99.9% (0.1%)

a payout distribution using the median IRR (denoted by $Median_{50\%}IRR$).[28] Finally, we compute a measure of upside performance using the ratio of the median payout and the 5% percentile payout (denoted by RR):

$$RR := \frac{Median_{50\%}}{LwR_{5\%}}.$$

These indicators of downside risk and return performance are reported in Tables VI.3–VI.5 for all strategies and economic scenarios considered.

Tables VI.3–VI.5 show that the median IRR generated by guaranteed strategies is significantly lower than the pension wealth accumulated under each of the three life-cycle strategies, including for the 5% worse-off individuals.

The Reward-Ratio, RR, is introduced to compare the level of performance offered to the median investor for a given level of payout performance granted to 95% of the population sample.[29]

We find in Tables VI.3–VI.4 that under allocation scenarios A and B, which correspond to an historical economic period more similar to the recent economic context of low interest rates and inflation rates, GS are clearly dominated by LCS. Indeed, given a probability higher than 99.9% of achieving a capital protection in real terms by all strategies, both GS A and B are dominated by all LCS, with respect to any metric. This reflects the fact that the nominal minimal guarantee affordable at fair market conditions is only $G^A = 1.25\%$, i.e. less than the inflation rate.[30] Note however that, as detailed in the Appendix, when the asset

[28]Since payouts are deflated, also IRR in this section provide information depurated from the effect of inflation.

[29]Given two pension plans say x and y, y has to be preferred to x if $LwR_y \geq LwR_x$ and $RR_y \geq RR_x$

[30]Under allocation scenario B, the affordable minimum guarantee $G^B = 1.5\%$ is also below the institutional ECB inflation target.

performance is sufficiently good, GS credits to policyholders a nominal target return that is higher than the minimum guaranteed rate. This explains why the GS is able to achieve a positive rate of return in real terms also in Scenario A.

Table VI.5 – Guaranteed Strategy Scenario C Annual Sample 1969-2012. Nominal guaranteed rate $G = 4.125$ GS Allocation: $\pi_C^{LongBond} = 0.95$ $\pi_C^{Equity} = 0.05$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	GS C	*LCS Low*	*LCS Medium*	*LCS High*
$Reward - Ratio$	1.34	1.86	2.16	2.38
$Median_{50\%}IRR$	3.33% (0.09%)	5.92% (0.65%)	6.55% (0.76%)	7.19% (0.9%)
$LwR_{5\%}IRR$	1.89% (0.09%)	2.83% (0.53%)	2.94% (0.63%)	3.10% (0.73%)
$MoneyBack$	> 99.9% $PS(4.6\%)$	> 99.9% (0.2%)	> 99.84% (0.2%)	> 99.8% (0.2%)

In Table VI.5, which corresponds to an economic scenario including phases of higher interest rates and inflation shocks ('old normal'), the difference in the risk and return comparison between GS and LCS is less striking. Low equity LCS meets the 99.9% capital protection threshold while the level of protection for the other two LCS equals to 99.84% and 99.80%. Even though under this scenario the affordable nominal minimal guarantee at fair market conditions is equal to 4.25%, the truncation of the upside is still so relevant that its reward-risk ratio RR is 38% lower (GS 1.34 vs LCS 1.86) than the RR of the Low equity LCS, which grants an equivalent level of capital protection.

C.1 Sensitivity to retirement date

In order to test the robustness of the above results with respect to the length of the period of accumulation, the same analysis as above is repeated for a shortened investment horizon, based on a 20 year accumulation period and an option to defer disinvestment by 7 years.[31] Results are shown in tables A.4–A.6 and are in line with the findings already discussed. The shortening of the accumulation period slightly reduces the level of protection, which in the case of GS is signalled by a raise in the probability of shortfall. While the level of protection offered by LCS remains 99.9% in the 'new normal' scenarios (99.5% for the GS), it is lowered to 99.6% in the 'old normal' scenario, still above the benchmark level set, e.g.,

[31] In glide paths adopted for this shorter accumulation period adopt a starting allocation of equity which is higher by 7.5% with respect to the corresponding 40 years version. This change raises the performance and the protection w.r.t inflation while leaving essentially unaffected the probability of moneyback.

by Solvency II regulation, which prescribes a safety level of 99.5%. The return protection offered for the 95% of the sample by GS and LCS are comparable, in contrast the IRR for the median investor offered by the GS is substantially lower than the one granted by LCS. Finally, median return performances are close to those achieved by the 40 year accumulation period investment strategy.

Our findings highlight a number of important aspects in the comparison of guaranteed and life-cycle strategies. First, GS–type investments are likely to produce weak performance results under a scenario of persistent low interest rates.[32] Here, LCS appear to offer both a high level of capital protection and a high expected return, thanks to the potential return that equity investment can generate over the savers' life-cycle. Second, in economic scenarios characterized by higher inflation and interest rate levels, when GS–type investments are able to offer a sizeable minimum nominal guaranteed return rate, LCS also score better in terms of risk-reward ratio. The limited capacity of the GS to capture upside performance is structurally related to the limitations imposed on the asset allocations of the insurance company to keep under control the risk of insolvency.

In summary, our analysis shows that the inclusion of a LCS-type investment as default option in the PEPP scheme is economically desirable, in order to increase pension wealth at comparatively very low risk. In this context, a minimum guarantee requirement in the PEPP default option finds little economic support, as the above findings show that this type of protection has a small value over the relevant investment horizon and that it is extremely costly to the pensioner. Especially if interest rates should remain low for a long period, it may induce a substantial reduction of pension wealth. Indeed, our findings imply that GS default investment solutions generate a significant reduction in retirement wealth without achieving any relevant additional reduction of risk. While this investment approach is likely to generate high individual welfare losses, it can also imply important long-term social costs, e.g., by contributing to raise social inequality, as young unsophisticated investors who are likely to opt for the default option do not sufficiently profit from reasonable long-term investment opportunities in financial markets.

VII. Conclusions and main policy considerations

Our qualitative and quantitative considerations provide strong support for the adoption of a life-cycle target-date fund strategy offered as a default option for the PEPP, which would be very beneficial to improve welfare for households. First of all a target date fund would offer

[32] We discuss below in more detail these aspects related to the recent secular stagnation.

a level of risk taking adequate to account for the stock of human capital of each individual and offering great diversification opportunities across different asset classes, as discussed in Section III. The definition of a suitable glide path and a smooth de-risking strategy toward the retirement phase provides a reliable risk mitigation technique.

The quantitative comparison of (i) a simple Poterba-style life-cycle strategy with an extended accumulation phase and (ii) a traditional participating life insurance with minimum guaranteed rate, offered at market conditions, highlights that the capital protection offered by the two contracts is comparable, while the cost of the protection is much lower for life-cycle strategies. The comparative advantage of life-cycle with respect to minimum guarantee can be quantified by considering the change in the reward-ratio for a fixed level of downside protection. The simulation results show that the level of upside performance for the majority of savers is at least 38% higher under life-cycle strategies than under a guaranteed strategy offered at the same market conditions.

While the above findings consider only the individual welfare point of view, the adoption of life cycle investment strategies as a default option is even more desirable for its social and economic implications in light of the Capital Market Union project. This would promote a higher participation of households in the stock market and thus generate a more efficient matching between the retirement saving capital and risky investment opportunities, thus fueling growth and a more efficient allocation of capital in the EU. An investment in equity also offers a natural channel to diversify the portfolio at international level, above and beyond the EU and across sectors. On the other hand, the current macroeconomic conditions justify the introduction of risk mitigation techniques other than minimum guarantees, in order to alleviate the pressure on insurance companies that derives from the persistent low level of interest rates.

In our framework the problem generated by low interest rates on minimum guarantees contracts is well exemplified by the poor performance of participating contracts under the 'new normal' scenario, which is the result of the long trend shown in Figure VII.9. These conditions lead economists to raise concerns about the possibility that the European economy has entered in a new era characterized by low rates, which would persist in the future[33]. In particular, Jimeno, Smets, and Yiangou (2014) note: "When thinking about secular stagnation (in Europe), in our view the key point is not so much whether such trends exist, but whether they are truly "secular". Put differently, how much potential is there for policy to reverse the downward drift in the equilibrium real rate?" It is difficult to give a definite

[33] see, for example, "Secular Stagnation: Facts, Causes, and Cures", the CEPR VOX E-book edited by Teulings and Baldwin

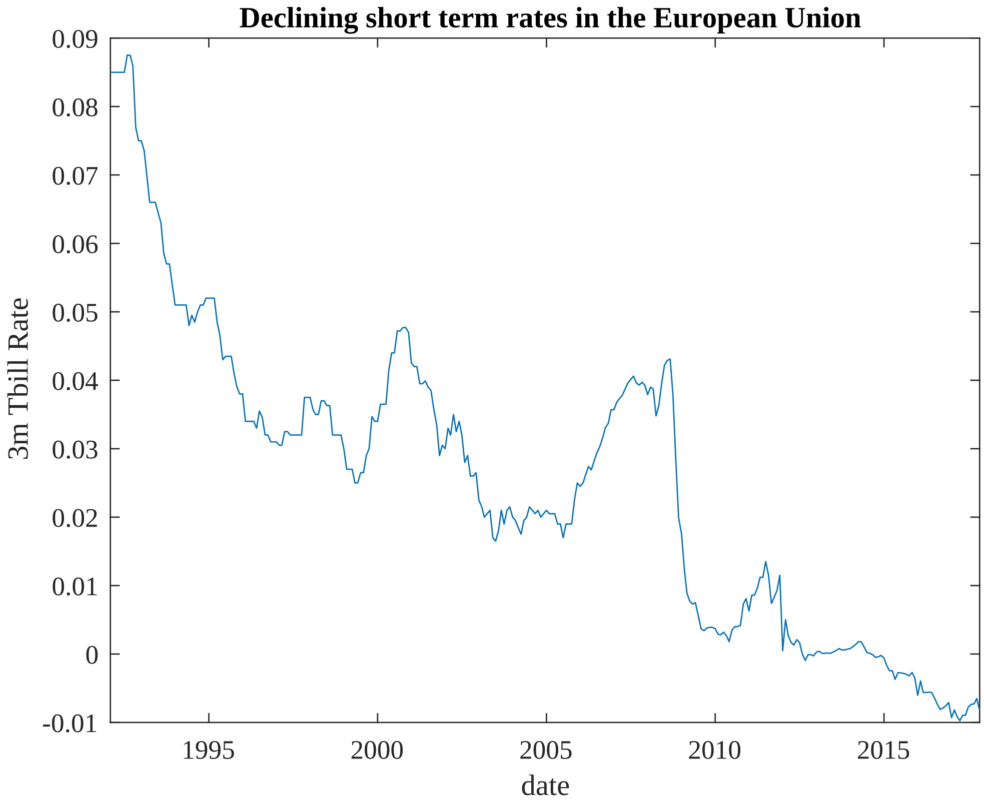


Figure VII.9 – Monthly Time Series of the 3m German T-Bill yearly rate in the period 1992-2016

answer to this question, but the rise of life expectancy, combined with uncertainty about future pension benefits, can be expected to lead to a significant increase in savings per capita, both of workers and the retired population, thus inducing low interest rates for a long period. In this context, the development of a Capital Market Union should improve the provision of risk capital to firms, and thus a life-cycle solution would help shifting savings from bond to equity markets.

Although the scenario of a raising inflation currently appears unlikely, the necessity to preserve the standards of living of the pensioner requires a specific assessment of the exposure of pension savings to inflation risk. From this point of view our analysis highlights that both life-cycle and guaranteed life policies should be designed to react promptly in case of an inflation burst. For such scenarios, a concentrated exposure on bond portfolios, as implied by minimum guarantees, is very risky. In contrast life-cycle strategies offer a higher protection thanks to a better well-diversified portfolio and equity exposure. Importantly, an excessive focus on investment risk may come at the expense of a weaker protection with respect to other risks. From this point of view, a more balanced attitude toward consumer protection should be based on the broader notions of risk mitigation and diversification which is more robust and consistent with the fact that it is impossible to eliminate all risks completely.

References

Amundi (2017). *Life cycle solutions*. Tech. rep.

Antolin, Pablo, Gerhard F Scheuenstuhl, Sandra Blome, David Karim, Stéphanie Payet, and Juan Yermo (2009). "Investment regulations and defined contribution pensions".

Barberis, Nicholas (2000). "Investing for the Long Run when Returns are Predictable". *The Journal of Finance* 55.1, pp. 225–264.

Benzoni, Luca, Pierre Collin-Dufresne, and Robert S. Goldstein (2007). "Portfolio choice over the life-cycle when the stock and labor markets are cointegrated". *The Journal of Finance* 62.5, pp. 2123–2167.

Beshears, John, James J Choi, David Laibson, and Brigitte C Madrian (2009). "The importance of default options for retirement saving outcomes: Evidence from the United States". *Social security policy in a changing environment*. University of Chicago Press, pp. 167–195.

Bisetti, Emilio, Carlo A Favero, Giacomo Nocera, and Claudio Tebaldi (2017). "A multivariate model of strategic asset allocation with longevity risk". *Journal of Financial and Quantitative Analysis* 52.5, pp. 2251–2275.

Bodie, Zvi, Robert C Merton, and William F Samuelson (1992). "Labor supply flexibility and portfolio choice in a life cycle model". *Journal of economic dynamics and control* 16.3-4, pp. 427–449.

Brière, Marie and Ombretta Signori (2012). "Inflation-hedging portfolios: Economic regimes matter". *Journal of Portfolio Management* 38.4, p. 43.

Calvet, Laurent E, John Y Campbell, and Paolo Sodini (2007). "Down or out: Assessing the welfare costs of household investment mistakes". *Journal of Political Economy* 115.5, pp. 707–747.

— (2009a). "Fight or flight? Portfolio rebalancing by individual investors". *The Quarterly journal of economics* 124.1, pp. 301–348.

— (2009b). *Measuring the financial sophistication of households*. Tech. rep. National Bureau of Economic Research.

Campbell, John Y (2006). "Household finance". *The Journal of Finance* 61.4, pp. 1553–1604.

— (2016). "Restoring rational choice: The challenge of consumer financial regulation". *American Economic Review* 106.5, pp. 1–30.

Campbell, John Y, Adi Sunderam, and Luis M Viceira (2009). *Inflation bets or deflation hedges? The changing risks of nominal bonds*. Tech. rep. National Bureau of Economic Research.

Campbell, John Y. and Louis M. Viceira (2002). *Strategic Asset Allocation: Portfolio Choice for Long-Term Investors*. New York, NY: Oxford University Press.

— (2005). “The Term Structure of the Risk-Return Tradeoff”. *Financial Analysts Journal* 61.1, pp. 34–44.

Campbell, John Y, Howell E Jackson, Brigitte C Madrian, and Peter Tufano (2011). “Consumer financial protection”. *The Journal of Economic Perspectives* 25.1, pp. 91–113.

Cocco Joao F and, Francisco J and Pascal J Maenhout (2005). “Consumption and portfolio choice over the life cycle”. *The Review of Financial Studies* 18.2, pp. 491–533.

Dahlquist, Magnus, Ofer Setty, and Roine Vestman (2017). “On the asset allocation of a default pension fund”.

David, Alexander and Pietro Veronesi (2013). “What ties return volatilities to price valuations and fundamentals?” *Journal of Political Economy* 121.4, pp. 682–746.

Di Giacinto, Marina and Elena Vigna (2012). “On the sub-optimality cost of immediate annuitization in DC pension funds”. *Central European Journal of Operations Research*, pp. 1–31.

Donaldson, Scott, Francis Kinniry, Vytautas Maciulis, Andrew Patterson, and Michael DiJoseph (2015). *Vanguard’s approach to target-date funds*. Tech. rep.

Eling, Martin and Stefan Holder (2013). “The value of interest rate guarantees in participating life insurance contracts: Status quo and alternative product design”. *Insurance: Mathematics and Economics* 53.3, pp. 491–503.

Fagereng, Andreas, Charles Gottlieb, and Luigi Guiso (2017). “Asset Market Participation and Portfolio Choice over the Life-Cycle”. *The Journal of Finance* 72.2, pp. 705–750.

Fugazza, Carolina, Massimo Guidolin, and Giovanna Nicodano (2007). “Investing for the long-run in European real estate”. *The Journal of Real Estate Finance and Economics* 34.1, pp. 35–80.

Gennaioli, Nicola, Andrei Shleifer, and Robert Vishny (2015). “Money doctors”. *The Journal of Finance* 70.1, pp. 91–114.

Gomes, Francisco, Laurence Kotlikoff, and Luis M Viceira (2008). “Optimal Life-Cycle Investing with Flexible Labor Supply: A Welfare Analysis”. *of Life-Cycle Funds, American Economic Review: Papers & Proceedings*. Citeseer.

Gomes, Francisco and Alexander Michaelides (2005). “Optimal Life-Cycle Asset Allocation: Understanding the Empirical Evidence”. *The Journal of Finance* 60.2, pp. 869–904.

Graf, Stefan, Alexander Kling, and Jochen Ruß (2011). “Risk analysis and valuation of life insurance contracts: Combining actuarial and financial approaches”. *Insurance: Mathematics and Economics* 49.1, pp. 115–125.

Guiso, Luigi and Paolo Sodini (2013). "Household finance". *An Emerging Field. in the Handbook of the Economics of Finance, 2nd Edition, edited by Constandinides, G., M. Harris and R. Stulz, Elsevier Science*, pp. 1398–1532.

Hieber, Peter, Ralf Korn, and Matthias Scherer (2015). "Analyzing the effect of low interest rates on the surplus participation of life insurance policies with different annual interest rate guarantees". *European Actuarial Journal* 5.1, pp. 11–28.

Hipp, Christian (1996). "Options for guaranteed index-linked life insurance". *Proceedings AFIR* 2, pp. 1463–1482.

Jimeno, Juan F, Frank Smets, and Jonathan Yiangou (2014). "Secular stagnation: A view from the Eurozone1". *Secular Stagnation: Facts, Causes and Cures*, p. 153.

Kaplan, Greg and Giovanni L Violante (2014). "A model of the consumption response to fiscal stimulus payments". *Econometrica* 82.4, pp. 1199–1239.

Lagarde, Christine (2017). *Reinvigorating productivity growth*. Tech. rep. IMF.

Merton, Robert C (1971). "Optimum consumption and portfolio rules in a continuous-time model". *Journal of economic theory* 3.4, pp. 373–413.

Ortu, Fulvio, Andrea Tamoni, and Claudio Tebaldi (2013). "Long-run risk and the persistence of consumption shocks". *The Review of Financial Studies* 26.11, pp. 2876–2915.

Poterba, James, Joshua Rauh, Steven Venti, and David Wise (2006). *Lifecycle asset allocation strategies and the distribution of 401 (k) retirement wealth*. Tech. rep. National Bureau of Economic Research.

Samuelson, Paul A (1969). "Lifetime portfolio selection by dynamic stochastic programming". *The review of economics and statistics*, pp. 239–246.

Schwartz, Eduardo S and Claudio Tebaldi (2006). *Illiquid assets and optimal portfolio choice*. Tech. rep. National Bureau of Economic Research.

Swanson, Eric T (2012). "Risk aversion and the labor margin in dynamic equilibrium models". *The American Economic Review* 102.4, pp. 1663–1691.

Van Bilsen, Servaas, Roger JA Laeven, and Theo Nijman (2014). "Consumption and portfolio choice under loss aversion and endogenous updating of the reference level".

Wachter, Jessica A (2003). "Risk aversion and allocation to long-term bonds". *Journal of Economic Theory* 112.2, pp. 325–333.

A. Figures and Tables

Table A.1 – Basic statistics of the asset classes

Panel A: Mean and standard deviation

	Return	Volatility
Cash	3.11%	0.74%
Risk-free (RF) Bonds	6.22%	5.53%
Defaultable (DEF) Bonds	8.71%	7.82%
Equity	9.84%	17.22%

Panel B: Correlation matrix

	Cash	RF Bonds	DEF Bonds	Equity
Cash	1.00	0.07	0.09	-0.06
RF Bonds	0.07	1.00	0.52	-0.16
DEF Bonds	0.09	0.52	1.00	0.19
Equity	-0.06	-0.16	0.19	1.00

Table A.2 – **Risk/return profile of life cycle portfolios**

Panel A: Ratio between wealth accumulation and total contributions paid

	Median	5^{th} percentile
Portfolio 1	4.39	2.44
Portfolio 2	4.61	2.42
Portfolio 3	5.13	1.75
Portfolio risk-free	1.49	1.42

Panel B: Internal rate of return

	Internal rate of return	
	Median	5^{th} percentile
Portfolio 1	6.88 %	4.39 %
Portfolio 2	7.07 %	4.36 %
Portfolio 3	7.51 %	2.88 %
Portfolio risk-free	2.09 %	1.86 %

Table A.3 – Risk/return profile 20-year accumulation case

Panel A: Return and risk measures of Portfolio 2 (Poterba-style) in the 20-year case

	Median	5^{th} percentile
Wealth accumulation / contributions	1.96	1.40
IRR	6.38 %	3.28 %

Panel B: Wealth accumulation below contributions for Portfolio 2 in the 20-year case

Accumulation stage (20-year holding period)	Accumulation + Early-retirement stage (27-year holding period)
0.14 %	0.00 %

Table A.4 – **Guaranteed Strategy Scenario A** Monthly Sample 1992-2012. Nominal guaranteed rate $G = 1.25$. Allocation: $\pi_A^{LongBond} = 0.95$ $\pi_A^{Equity} = 0.05$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	$GS\ A$	$LCS\ Low$	$LCS\ Medium$	$LCS\ High$
$Reward - Ratio$	1.06	1.54	1.69	1.88
$Median_{50\%}IRR$	1.18% (0.18%)	5.81% (1.01%)	6.66% (1.32%)	7.63% (1.69%)
$LwR_{5\%}IRR$	0.60% (0.18%)	1.74% (0.66%)	1.77% (0.86%)	2.06% (1.03%)
$MoneyBack$	99.7% PS(7.8%)	> 99.9% (0.1%)	> 99.9% (0.1%)	> 99.9% (0.1%)

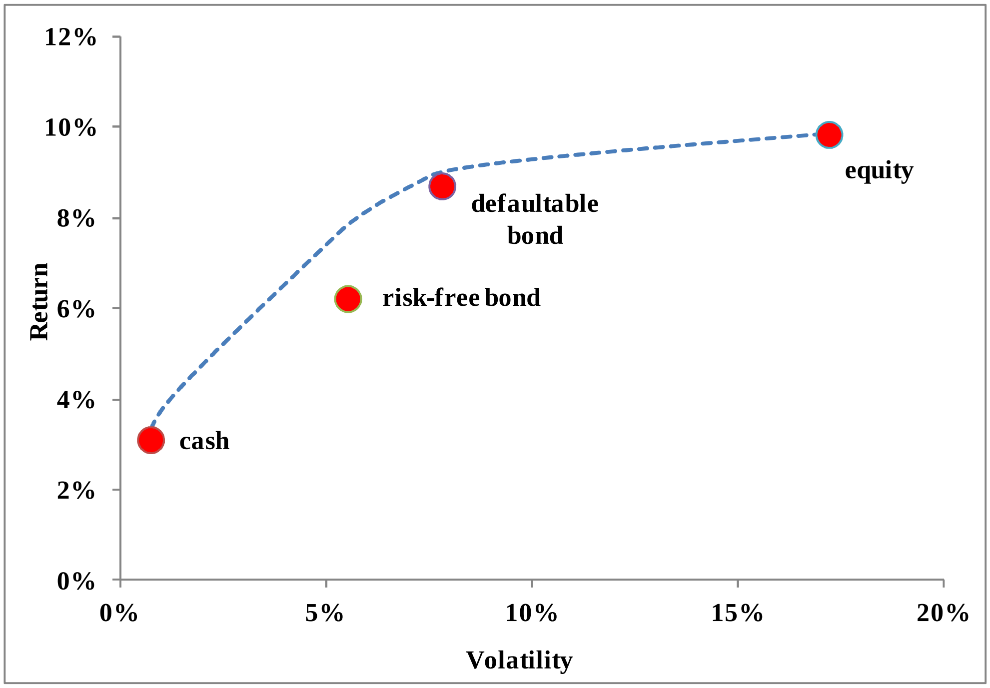
Table A.5 – **Guaranteed Strategy Scenario B** Monthly Sample 1992-2012. Nominal guaranteed rate $G = 1.50$ GS Allocation: $\pi_B^{LongBond} = 0.9$ $\pi_B^{Equity} = 0.1$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	$GS\ B$	$LCS\ Low$	$LCS\ Medium$	$LCS\ High$
$Reward - Ratio$	1.06	1.54	1.69	1.88
$Median_{50\%}IRR$	1.35% (0.16%)	5.81% (1.01%)	6.66% (1.32%)	7.63% (1.69%)
$LwR_{5\%}IRR$	0.78% (0.15%)	1.74% (0.66%)	1.77% (0.86%)	2.06% (1.03%)
$MoneyBack$	> 99.9% PS(7.9%)	> 99.9% (0.1%)	> 99.9% (0.1%)	> 99.9% (0.1%)

Table A.6 – **Guaranteed Strategy Scenario C** Annual Sample 1969-2012. Nominal guaranteed rate $G = 4.125$ GS Allocation: $\pi_C^{LongBond} = 0.95$ $\pi_C^{Equity} = 0.05$. Internal Rate of Return (IRR) standard deviations are reported in brackets. Moneyback indicator reports $\mathbb{P}(Payoff/MoneyBack > 1)$.

	$GS\ C$	$LCS\ Low$	$LCS\ Medium$	$LCS\ High$
$Reward - Ratio$	1.19	1.68	1.80	1.99
$Median_{50\%}IRR$	3.09% (0.09%)	6.20% (0.79%)	6.96% (0.93%)	7.50% (1.06%)
$LwR_{5\%}IRR$	1.44% (0.09%)	1.33% (0.41%)	1.46% (0.48%)	1.52% (0.52%)
$MoneyBack$	> 99.9% PS(7%)	> 99.6% (0.2%)	99.36% (0.2%)	> 99.17% (0.2%)

Panel A: Unconstrained efficient frontier



Panel B: Constrained efficient frontier

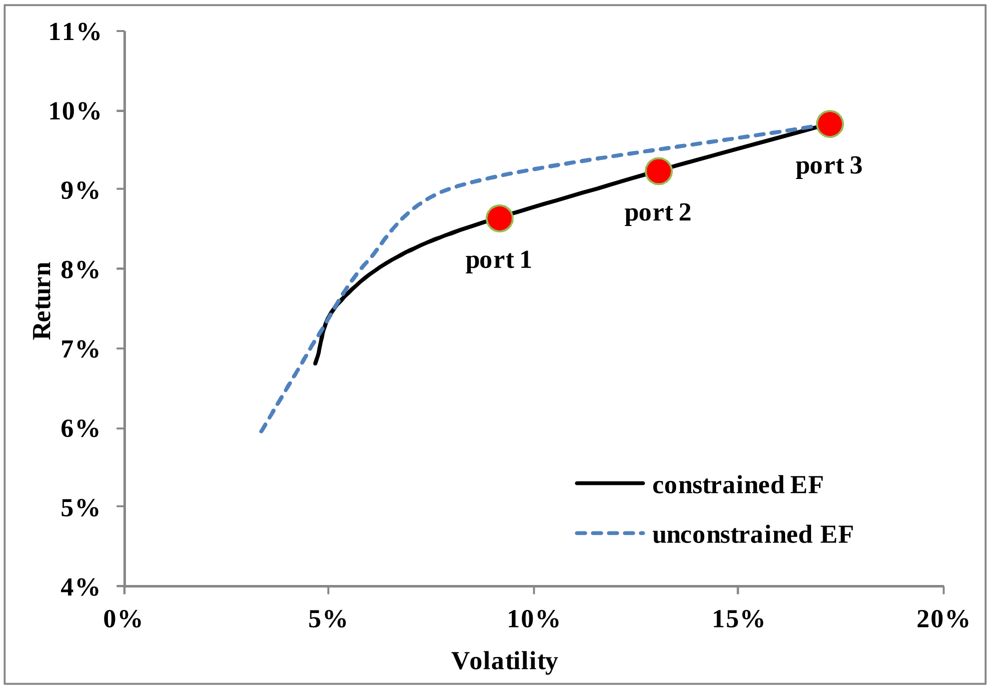
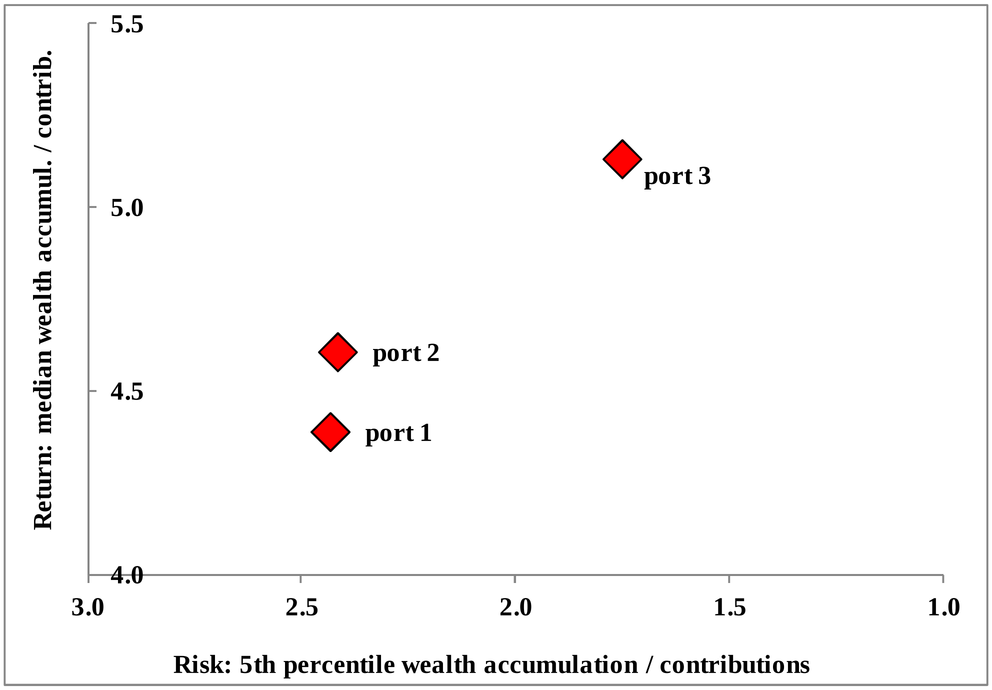


Figure A.1 – Efficient frontier with 4 asset classes

Panel A: Ratio between wealth accumulation and total contributions paid



Panel B: Internal rate of return (IRR)

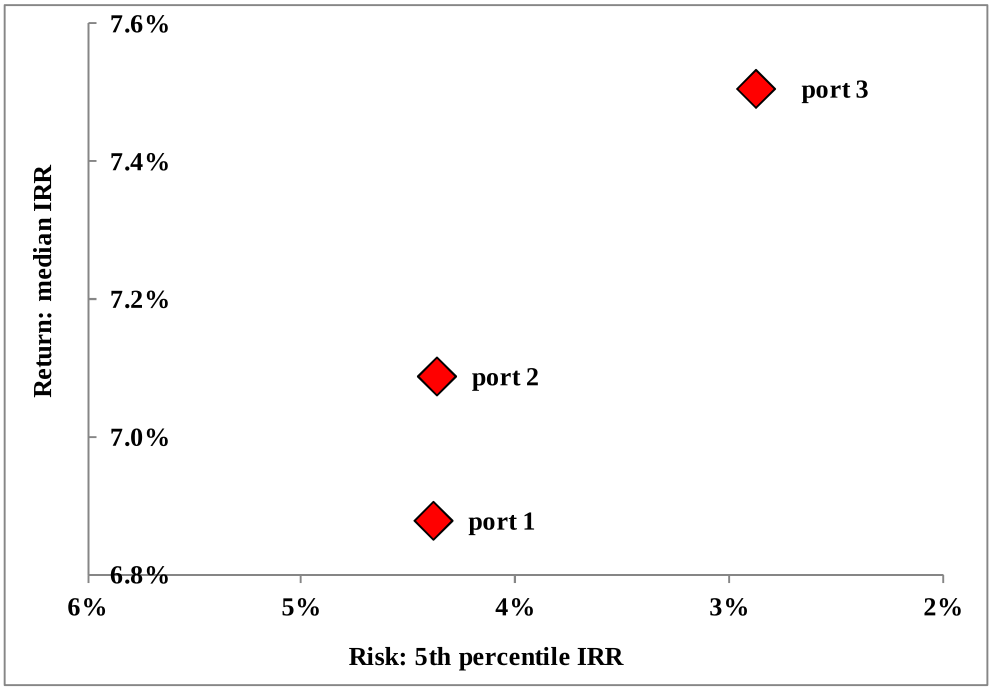
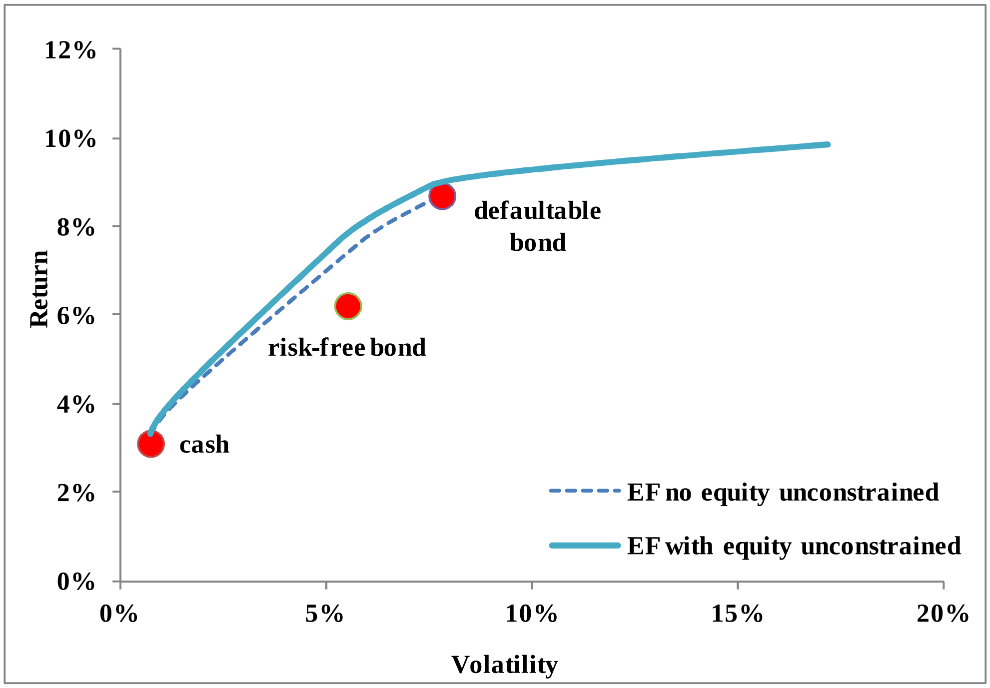


Figure A.2 – Risk/return profile of life cycle portfolios

Panel A: Unconstrained efficient frontier



Panel B: Constrained efficient frontier

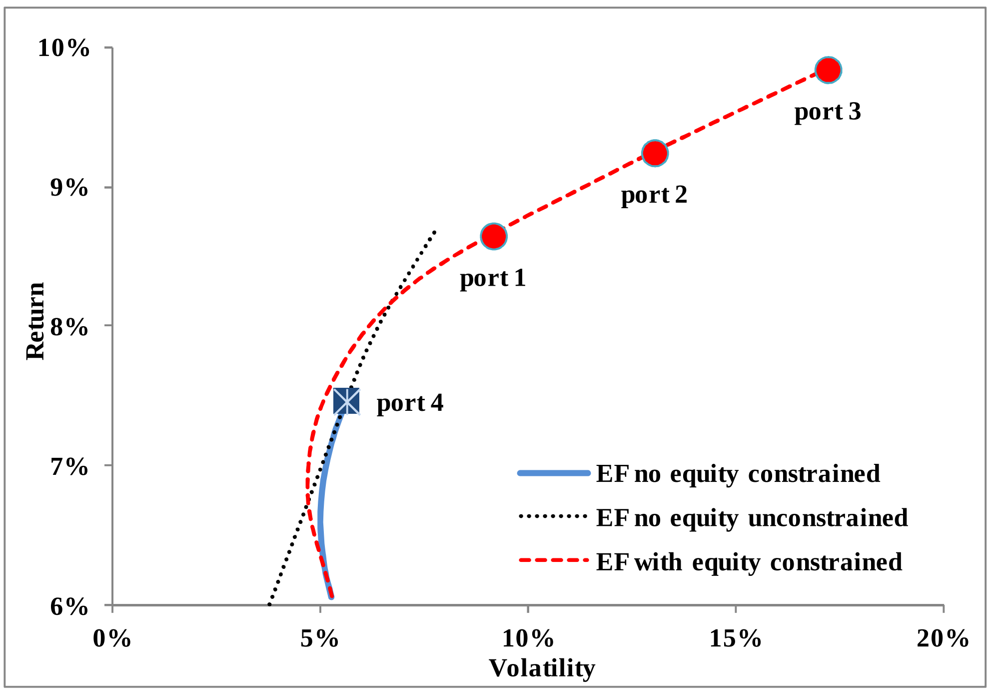


Figure A.3 – Efficient frontier with no equity

B. Estimation and simulation of a stylized European Capital Market model

In order to produce a realistic dynamic scenario analysis we assume that both the investment firm and the insurance company can invest in a common, stylized model of European capital market. Following the approach to strategic asset allocation pursued by Campbell and Viceira (2005), CV hereafter, dynamic simulation of asset returns is performed using a conditional Vector Auto Regression (VAR hereafter) model estimated on European data. See also Bisetti et al. (2017) for an updated and extended analysis based on US data, Fugazza, Guidolin, and Nicodano (2007) and Brière and Signori (2012) for an extended analysis including returns from real estate and commodities in the European market. Its construction and basic properties are reviewed below. We construct the vector $\mathbf{z}_t^{Mkt}$ using the following information set:

- The returns from 3 reference securities for our conditional analysis are:
  - Short Rate: Total Return on a strategy investing in 3-month German T-Bills.
  - Long Term Rate: Total Return of an investment in Government 10-year Securities (German and French as a robustness check).
  - Stock Market Total Return of an investment in MSCI Europe.
- Conditioning state variables
  - German 3-month T-Bill Yield.
  - log(Dividend-Price Ratio) for a European benchmark securities portfolio.
  - Spread between Yields of German 10-year Bund and 3-month T-Bill.

The presence of the conditioning state variables is necessary to keep into account the modification of the long term risk-return generated by asset return predictability. The vector $\mathbf{z}_t^{Mkt}$ is given by:

$$\mathbf{z}_t^{Mkt} := \left[r_{0,t}, xR_t, xB_t, y_t^{3M}, dp, y_t^{10y} - y_t^{3M}\right]$$

where:

- $r_{0,t}$ real log-return of the 3-month T-Bill.
- xR_t denotes the excess log-return of MSCI over the log-return of the 3-month T-Bill.

- xB_t denotes the excess log-return of the 10-year bond investment over the log-return of the 3-Month T-Bill.
- y_t^{3M} denotes the nominal yield of the 3-month T-Bill.
- dp denotes the log dividend-price ratio.
- $y_t^{10y} - y_t^{3M}$ denotes the spread between the 10-year Bund over the 3-month T-Bill.

We estimate the model on two different data samples: a sample of yearly observations for the period 1969-2012 that includes also a high inflation period and a monthly sample starting in Jan-1992 ending Dec-2012 describing asset dynamics after that European Community has been created before and after the introduction of the Euro. In both samples the data have been truncated to Dec-2012 to avoid extreme interest rate scenarios possibly driven by the OMT purchase program carried out by the ECB. Differences arising between the monthly and the yearly sample reflect the different economic conditions underlying alternative estimation samples and will be used in our discussion to assess the robustness of results with respect to changing economic conditions.

Table **B.1**, reports the unconditional risk and return characteristics for the asset classes and the predictors in the estimation samples.

Figures **B.1, B.2, B.3, B.4,** plot the term structure of risks and of correlations for the two samples, i.e. the variation with the horizon of the riskiness, measured by the standard deviation of ex post real rate of returns measured on a yearly basis, and of correlation for the three asset classes under consideration: long, short term bonds and stock market index. Term structures of risks do not present relevant differences compared to the original CV results and are quite homogeneous across different samples, the term structure of correlations in the two samples shows remarkable differences and in particular the correlation between stocks and bonds is quite unstable when changing the estimation sample. As discussed by Campbell, Sunderam, and Viceira (2009) and David and Veronesi (2013), the correlation between fixed income and equity investment returns may vary across different economic regimes and is difficult to capture within the present linear homoscedastic modeling approach. On the other hand we use the VAR simply as a scenario generator, thus the heterogeneity of the correlation structure across the two selected two samples will be useful to test robustness of the results with respect to different correlation structures. In order to reduce the impact of the lowering trend of interest rates on the simulation results, in Tables VI.3–VI.5, A.4–A.6 we report sample statistics, mean and standard deviation, corresponding to a sample of initial conditions extracted randomly over the period of 6 years 2006-2012. For each initial condition we generate a set of $5,000$ paths and compute the relevant statistics. Illustrations have been produced considering as initial condition the real data corresponding to the last calendar date of the estimation sample.

Tables **B.4** , **B.5** report the unconditional risk and return characteristics for the asset classes and the predictors in the simulated samples.

A. Financial asset returns and their predictors: the basic specification of the VAR model for traditional financial investments

Consider the continuously compounded security market returns from time t to time $t+1$, $\mathbf{r}_{t+1}$. Define μ, the conditional expected log return given information up to time t as follows:

$$\mathbf{r}_{t+1} = \mu + \mathbf{u}_{t+1},$$

where $\mathbf{u}_{t+1}$ is the unexpected log return. Define the τ-period cumulative return from period $t+1$ through period $t+\tau$, as

$$\mathbf{r}_{t,t+\tau} = \sum_{i=1}^{\tau} \mathbf{r}_{t+i}.$$

The term structure of risk is defined as the conditional variance of cumulative returns, given the investor's information set, scaled by the investment horizon

$$\Sigma_r(\tau) \equiv \frac{1}{\tau}\mathrm{Var}(\mathbf{r}_{t,t+\tau} \mid D_t), \tag{1}$$

where $D_t^{\mathrm{Mkt}} \equiv \sigma\{z_\tau^{\mathrm{Mkt}} : \tau \leq t\}$ consists of the full histories of returns as well as predictors that investors use in forecasting returns. Following Barberis (2000) and Campbell and Viceira (2002), we describe asset return dynamics by means of a first-order vector autoregressive or VAR(1) model. We choose a VAR(1) as the inclusion of additional lags, even if easily implemented, would reduce the precision of the estimates:

$$\mathbf{z}_t^{\mathrm{Mkt}} = \Phi_0^{\mathrm{Mkt}} + \Phi_1^{\mathrm{Mkt}}\mathbf{z}_{t-1}^{\mathrm{Mkt}} + \nu_t^{\mathrm{Mkt}}, \tag{2}$$

where

$$\mathbf{z}_t^{\mathrm{Mkt}} = \begin{bmatrix} r_{0t} \\ \mathbf{x}_t^{\mathrm{Mkt}} \\ \mathbf{s}_t^{\mathrm{Mkt}} \end{bmatrix}$$

is a $(m \times 1)$ vector, with r_{0t} being the log real return on the asset used as a benchmark to compute excess returns on all other asset classes, $\mathbf{x}_t^{\text{Mkt}}$ being the $(n \times 1)$ vector of log excess returns on all other asset classes with respects to the benchmark, and $\mathbf{s}_t^{\text{Mkt}}$ is the $((m-n-1) \times 1)$ vector of returns predictors. In the VAR(1) specification, Φ_0^{Mkt} is a $(m \times 1)$ vector of intercepts and Φ_1^{Mkt} is a $(m \times m)$ matrix of slopes. Finally, ν_t^{Mkt} is a $(m \times 1)$ vector of innovations in asset returns and returns' predictors for which standard assumptions apply, i.e.

$$\nu_t^{\text{Mkt}} \sim \mathcal{N}(0, \Sigma_\nu^{\text{Mkt}}), \tag{3}$$

where Σ_ν^{Mkt} is the $(m \times m)$ variance-covariance matrix. Note that

$$\Sigma_\nu^{\text{Mkt}} = \begin{bmatrix} \sigma_0^2 & \sigma_{0x}' & \sigma_{0s}' \\ \sigma_{0x} & \Sigma_{xx} & \Sigma_{xs}' \\ \sigma_{0s} & \Sigma_{xs} & \Sigma_{ss} \end{bmatrix}$$

and the unconditional mean and variances-covariance matrix of $\mathbf{z}_t$, assuming that the VAR is stationary end therefore that this moments are well-defined, can be represented as follows:

$$\begin{aligned} \mu_z^{\text{Mkt}} &= \left(I_m - \Phi_1^{\text{Mkt}}\right)^{-1} \Phi_0^{\text{Mkt}} \\ vec\left(\Sigma_{zz}^{\text{Mkt}}\right) &= \left(I_{m^2} - \Phi_1^{\text{Mkt}} \otimes \Phi_1^{\text{Mkt}}\right)^{-1} vec\left(\Sigma_\nu^{\text{Mkt}}\right). \end{aligned}$$

The conditional mean of the cumulative asset returns at different horizons are instead

$$E_t(z_{t+1}^{\text{Mkt}} + ... + z_{t+\tau}^{\text{Mkt}}) = \left(\sum_{i=0}^{\tau-1} (\tau - i) \left(\Phi_1^{\text{Mkt}}\right)^i\right) \Phi_0^{\text{Mkt}} + \left(\sum_{j=0}^{\tau} \left(\Phi_1^{\text{Mkt}}\right)^j\right) \mathbf{z}_t^{\text{Mkt}},$$

and their variance is:

$$\begin{aligned} \text{Var}_t(z_{t+1}^{\text{Mkt}} + ... + z_{t+\tau}^{\text{Mkt}}) &= \Sigma_\nu^{\text{Mkt}} + (I + \Phi_1^{\text{Mkt}})\Sigma_\nu^{\text{Mkt}}(I + \Phi_1^{\text{Mkt}})' + \\ &\quad (I + \Phi_1^{\text{Mkt}} + \left(\Phi_1^{\text{Mkt}}\right)^2)\Sigma_\nu^{\text{Mkt}}(I + \Phi_1^{\text{Mkt}} + \left(\Phi_1^{\text{Mkt}}\right)^2)' + ... \\ &\quad +(I + \Phi_1^{\text{Mkt}} + ... + \left(\Phi_1^{\text{Mkt}}\right)^{\tau-1})\Sigma_\nu(I + \Phi_1^{\text{Mkt}} + ... + \left(\Phi_1^{\text{Mkt}}\right)^{\tau-1})'. \end{aligned} \tag{4}$$

Once the conditional moments of excess returns are available the following selector matrix extracts for each period, τ-period conditional moments of log real returns

$$M_r = \begin{bmatrix} 1 & 0_{1\times n} & 0_{1\times(m-n-1)} \\ \iota_{n\times 1} & I_{n\times n} & 0_{n\times(m-n-1)} \end{bmatrix}$$

which implies

$$\frac{1}{\tau}\begin{bmatrix} E_t\left(r^{\tau}_{0,t+1}\right) \\ E_t\left(\mathbf{r}^{\tau}_{t+1}\right) \end{bmatrix} = \frac{1}{\tau} M_r E_t(z^{\text{Mkt}}_{t+1} + ... + z^{\text{Mkt}}_{t+\tau})$$

$$\frac{1}{\tau}\begin{bmatrix} \text{Var}_t\left(r^{\tau}_{0,t+1}\right) \\ \text{Var}_t\left(\mathbf{r}^{\tau}_{t+1}\right) \end{bmatrix} = \frac{1}{\tau} M_r \text{Var}_t(z^{\text{Mkt}}_{t+1} + ... + z^{\text{Mkt}}_{t+\tau}) M_r'.$$

Therefore after the estimation of the VAR it is possible to derive unconditional and conditional moments for returns and excess returns at all different investment horizons. These moments deliver the dynamics of returns and the risk of different assets across investment horizons. This information forms the input for portfolio allocation. Following Campbell and Viceira (2005), we consider a benchmark portfolio to be obtained by attributing optimal weights to bond, stock and T-Bills. Therefore we include in $\mathbf{x}^{\text{Mkt}}_t$ excess returns on stocks and bonds, real returns on T-Bills, while we include in $\mathbf{s}^{\text{Mkt}}_t$ three factors commonly recognized as good predictors of these assets' returns. In particular, the predictors are the nominal short-term interest rate, the dividend price ratio and the yield spread between long-term and short term bonds.

B. The simulation approach

Contribution scheme. We consider the same convention adopted in the previous section,

- The initial annual wage of the worker/investor is equal to €$18,000$, which corresponds approximately to the current Euro area average net income;
- The wage grows by 2% annually, according to a non-stochastic growth rate including inflation and productivity growth rates;
- Each month, the investor contributes 10% of the wage to the DC plan;

We exemplify the performance of different allocation strategies comparing the performance of different pension products using the same set of initial condition and the same set of simulation scenarios.

Asset return dynamics. The first step to set up the simulation approach is common to both life-cycle and life-insurance investment analysis. In each simulation run we use the Vector Auto-Regression Model described in the Appendix to generate $5,000$ possible scenarios of the random evolution of market returns and of the state variables. For both monthly and yearly samples, our input data will be the annual rates of returns produced by a set of tradable instruments for a number of years sufficient to determine the final performance of the alternative strategies. Available securities include a short term fixed income security, cash, a long term bond with 10 year duration and a fund that replicates the behavior of MSCI Europe index. The state variables determine information on inflation rate, on the dividend-price ratio and on the yield spread.

From each simulation we compute the time series of real returns for each of the three tradable asset classes:

$$R_{t+1} := \left(r_{t+1}^{ShortB}\left(\omega\right), r_{t+1}^{Equity}\left(\omega\right), r_{t+1}^{LongB}\left(\omega\right) \right)$$

where $\omega = 1, ..., NoPaths$ while $t = 0, .., T-1$.

Differently from previous analysis, in order to analyze the exposure to inflation of pension investment, this comparison will be performed in real terms to take into account the erosion of portfolio value driven by inflation.

Portfolio strategies. An asset allocation strategy $\Pi_t = \left(\pi_t^{ShortB}, \pi_t^{Equity}, \pi_t^{LongB} \right)$ produces a return between time t and time $t+1$ along path ω, $R_{t+1}^{\Pi}\left(\omega\right)$, given by:

$$R_{t+1}^{\Pi}\left(\omega\right) = \pi_t^{ShortB} r_{t+1}^{ShortB}\left(\omega\right) + \pi_t^{Equity} r_{t+1}^{Equity}\left(\omega\right) + \pi_t^{LongB} r_{t+1}^{LongB}\left(\omega\right), \ t = 0, .., T-1.$$

We assume that account balance is regulated on a yearly basis. Hence the return $R_{t+1}^{\Pi}\left(\omega\right)$ is capitalized in the account on a yearly basis. Administrative costs are charged up-front and correspond to 0.5% of the contributions and each year asset management fees are assumed to be equal to 0.5%.

In the following we sketch the main steps necessary to compute the investment performance for each path of asset returns and for each investment approach.

C. Participating life insurance with capital guarantee: how it works

We quantify the performance of the minimum guarantee strategy implementing a traditional participating life insurance contract. We concentrate solely on the analysis of financial risk abstracting from the actuarial one in order to avoid reference to biometric data. The following procedure builds on the approach proposed by Graf, Kling, and Ruß (2011) and Eling and Holder (2013) and combines a risk neutral and an historical risk measure analysis to simultaneously analyze the performance of the strategy from the point of view of the insurance company, of the policyholder and of the regulator.

In order to compute the benefit $L_T(\omega)$ distributed to the policyholder it is necessary to simulate a simplified model of the insurer balance sheet and of its dynamic evolution.

When a policy of type is sold, the policy-holder agrees to pay the annual contribution and in exchange the intermediary, i.e. an insurance company, commits to credit the policyholder's account with a minimum nominal interest rate G each year. Since we intend to analyze the real return to the policyholder, the effective guaranteed real rate is the level G net of the ex-post inflation rate π_t measured during year t, $\widetilde{G}_t := G - \pi_t$ Both policyholders and shareholders participate in the investment performance and receive a fraction of the annual surplus. To align interest of shareholders to those of policyholders, the annual dividend d_t credited to shareholders is usually assumed equal to a fraction α of the surplus credited to policyholders. Single period asset performance dynamics is determined by the equation:

$$A_{t+1}^{-} = \left(1 + R_{t+1}^{\Pi}(\omega)\right) A_t^{+}$$

where $A_t^{-}(A_t^{+})$ are the time t assets prior (posterior) to the distribution of the dividends and investment of collected premium:

$$A_t^{+} = \max\left\{A_t^{-} - d_t, L_t\right\} + P_t$$

Notice that in case the accumulated asset net of dividends falls short of the liabilities, a capital injection is required

$$c_t = \max\left\{L_t - A_t^{-} + d_t, 0\right\}$$

and shareholders must be compensated for its provision.

The liabilities evolve as follows:

$$L_{t+1} = (1 + G_t)\, L_t + Surplus_t$$

where $Surplus_t$ is an additional distribution whose exact expression is detailed in eq.(2) pg.193 of Eling and Holder (2013) implements the German legal requirements and the traditional surplus distribution policy described below.

The exact value credited by the insurance company to the policyholder's is determined by a target rate z as long as the reserve quota $x_t := \frac{A_t^{-} - d_t - L_t}{L_t}$ lies within a predetermined region $x_t \in [a, b]$. If the reserve quota falls below a the interest rate credited to the policyholder's is the maximum between the guaranteed interest rate and the level of participation rate that restores x_t to the minimum capital requirement value a. If crediting the target rate z leads to a reserve quota above b, then the company credits exactly the rate necessary to set $x_t = b$. In our analysis we will assume $a = 0.05$ and $b = 0.30$. In the simulations the target rate z was set in the range 3-5%.

According to German legislation, at least $\delta = 90\%$ of the earnings on book values must be distributed to the policyholders. Hence we assume that a fraction $y = 0.7$ of the market value $A^-_{t+1} - A^+_t$ is distributed to the policyholder. Hence the final participation to the surplus is given by:

$$\delta y \left(A^-_{t+1} - A^+_t\right)$$

while the dividend distributed to the shareholders is a fraction $\alpha = 0.05$ of this surplus:

$$\alpha \delta y \left(A^-_{t+1} - A^+_t\right)$$

Pricing fairness is guaranteed by ensuring that risk neutral present value of the dividend distributed to the shareholder $d_t(\omega)$ is sufficient to compensate capital provisions $c_t(\omega)$, i.e. it must be larger or equal than the risk-neutral discounted value of future capital provisions net of the total change in capital reserve:

$$E^{\mathbb{Q}}\left[\sum_{t=1}^{T} \frac{d_t - c_t}{B_t}\right] + \left\{E^{\mathbb{Q}}\left[\frac{R_T}{B_T}\right] - R_0\right\} \simeq 0 \tag{5}$$

where $R_t = A^-_t - L_t - d_t$ denotes the residual value of the reserve account at time t.

In order to compute the risk neutral probability of different scenarios, we assume a stochastic discount factor driven by the VAR innovations for the stock market and long term bond excess returns:

$$-\log(m_{t+1}) = r_{0,t} + \frac{1}{2}\left[S_{EQ}, S_{LTB}\right]\Omega_{2x2}\left[S_{EQ}, S_{LTB}\right]' + \left[S_{EQ}, S_{LTB}\right]\left[\varepsilon^{xr}_{t+1}, \varepsilon^{xb}_{t+1}\right]'$$

while $r_{0,t}$ is the rate of return on the short term bond as determined by the VAR dynamics. Market prices of risk are assumed to be constant and set equal to the historical values in the sample used to estimate the VAR; Ω_{2x2} is extracted from the variance covariance matrix of the VAR residuals selecting the variances and covariances between equity and long term bond excess returns.

The risk that the management strategy of the guarantee is unsuccessful and the account balance does not break even is then quantified considering two risk measures: the Probability of Shortfall (PS):

$$PS := \mathbb{P}\left(A\left(T\right) < L\left(T\right)\right)$$

and the Expected Shortfall (ES):

$$ES := \mathbb{E}^{\mathbb{P}}\left[\mathbb{I}_{\{A(T)<L(T)\}}\left(L\left(T\right) - A\left(T\right)\right)\right] \tag{6}$$

To simplify the analysis, we will consider acceptable a management strategy if the relative ES, i.e. the ratio between the ES and the present value of future contributions is smaller than 0.5%:

$$\frac{ES}{NPV_C} < 0.5\% \tag{7}$$

The probability of shortfall is reported in the tables as a reference measure to assess the frequency of the paths where the insurance management of the policy does not break even.

The level of the minimum guarantee is computed imposing: i) condition (5), i.e. contract fairness and ii) condition (6), i.e. a solvency condition.

D. Life-cycle Poterba- style investment strategy

In this investment strategy the individual account A_t is updated following the same rule of total assets under management:

$$A_{t+1} = \left(1 + R^{\Pi}_{t+1}\left(\omega\right) - apf\right)\left(A_t + P_t\right)$$

where P_t is the individual contribution at time t net of the management fee and in order to keep into account the costs of trading we apply a fee of 50 basis points on the annual performance, $apf = 0.0050$.

In order to reduce the disinvestment risk we assume that the pensioner stops the contributions at the age of 65 and then may choose to liquidate the investment either at 65, if the amount is higher than the money back or wait until the age of 72. This simplified scheme is assumed to mimic the role of more sophisticate disinvestment options that are known in the literature.

Table B.1 – Summary Statistics Monthly Sample

Mean returns is computed including the Jensen correction term, thus are computed as $\mu + 0.5\sigma^2$. Sharpe ratio is computed as the ratio between mean and standard deviation. R^{TB} = ex post real T-Bill rate, xR = excess stock return, xB = excess bond return, dp = log dividend–price ratio, y = nominal T-Bill yield, spr = yield spread.

Variable	R^{TB}	xR	xB	y	dp	spr
MONTHLY SAMPLE						
Mean	0.009652	0.069603	0.0411	0.0245	−3.5127	0.0137
Std. dev.	0.0119	0.1967	0.0580	0.652	0.188	0.0288
Sharpe ratio	—	0.353	0.709	—	—	—
ANNUAL SAMPLE						
Mean	0.0139	0.0770	0.0345	0.0412	−3.3012	0.0160
Std. dev.	0.0179	0.2027	0.0726	0.0244	0.381	0.0112
Sharpe ratio	—	0.3839	0.4752	—	—	—

Table B.2 – VAR(1) coefficients with relative t-statistics and Cross-Correlations of Residuals. rtb_t = ex post real T-Bill rate, xr_t = excess stock return, xb_t = excess bond return, $(d-p)_t$ = log dividend-price ratio, y_t = nominal T-bill yield, spr_t = yield spread.

VAR(1) - Matrix Φ_1 - Monthly Sample 1992-2012. Original Financial Variables

	rtb_t	xr_t	xb_t	y_t	$(d-p)_t$	spr_t	R^2	$adjR^2$
	(t)	(t)	(t)	(t)	(t)	(t)		
rtb_{t+1}	-0.205	-0.008	-0.001	1.078	-0.001	0.047	0.188	0.169
	(-2.493)	(-2.277)	(-0.108)	(6.799)	(-0.985)	(1.924)		
xr_{t+1}	-0.495	0.086	0.193	-2.567	0.011	0.616	0.036	0.013
	(-0.428)	(1.166)	(0.904)	(-0.999)	(0.541)	(1.490)		
xb_{t+1}	0.216	-0.031	0.016	0.525	0.009	0.230	0.042	0.019
	(0.651)	(-1.469)	(0.238)	(0.507)	(1.736)	(1.600)		
y_{t+1}	-0.002	0.000	-0.001	0.997	-0.000	0.002	0.990	0.990
	(-0.806)	(0.834)	(-2.046)	(120.966)	(-4.027)	(1.655)		
$(d-p)_{t+1}$	-0.091	-0.057	-0.333	0.451	0.962	-0.704	0.939	0.937
	(-0.093)	(-0.905)	(-1.837)	(0.192)	(55.617)	(-1.773)		
spr_{t+1}	0.007	0.004	0.012	-0.063	0.002	0.952	0.943	0.941
	(0.204)	(1.710)	(1.437)	(-0.560)	(2.826)	(51.379)		

Cross-Correlations of Residuals

	rtb	xr	xb	y	$(d-p)$	spr
rtb	0.302	-0.104	0.071	0.042	0.041	-0.110
xr	-	5.800	-0.137	0.278	-0.812	-0.033
xb	-	-	1.642	-0.412	0.092	-0.468
y	-	-	-	0.016	-0.255	-0.514
$(d-p)$	-	-	-	-	4.987	0.056
spr	-	-	-	-	-	0.208

Table B.3 – VAR(1) coefficients with relative t-statistics and Cross-Correlations of Residuals. rtb_t = ex post real T-Bill rate, xr_t = excess stock return, xb_t = excess bond return, $(d-p)_t$ = log dividend-price ratio, y_t = nominal T-bill yield, spr_t = yield spread.

VAR(1) - Matrix Φ_1 - Yearly Sample 1969-2012. Original Financial Variables

	rtb_t	xr_t	xb_t	y_t	$(d-p)_t$	spr_t	R^2	$adjR^2$
	(t)	(t)	(t)	(t)	(t)	(t)		
rtb_{t+1}	0.674	0.030	0.007	0.249	-0.007	0.312	0.596	0.526
	(3.899)	(3.432)	(0.310)	(2.327)	(-1.843)	(1.604)		
xr_{t+1}	5.763	-0.364	0.874	-3.674	0.258	0.849	0.266	0.140
	(1.587)	(-2.618)	(2.457)	(-2.006)	(2.791)	(0.206)		
xb_{t+1}	-0.584	-0.065	-0.081	-0.417	0.025	-3.148	0.195	0.057
	(-0.796)	(-0.851)	(-0.437)	(-0.559)	(0.606)	(-3.359)		
y_{t+1}	0.155	0.016	-0.039	0.927	0.000	0.875	0.807	0.774
	(0.870)	(2.194)	(-1.864)	(8.372)	(0.044)	(4.668)		
$(d-p)_{t+1}$	2.489	-1.518	0.457	-2.056	1.095	1.292	0.862	0.838
	(0.765)	(-13.564)	(1.544)	(-1.515)	(13.907)	(0.381)		
spr_{t+1}	-0.121	-0.014	0.042	0.022	0.001	0.301	0.294	0.172
	(-0.750)	(-1.988)	(2.114)	(0.241)	(0.107)	(1.724)		

Cross-Correlations of Residuals

	rtb	xr	xb	y	$(d-p)$	spr
rtb	1.090	-0.030	-0.328	0.554	0.178	-0.476
xr	-	18.025	0.036	0.065	0.792	0.130
xb	-	-	6.611	-0.636	-0.134	0.238
y	-	-	-	0.978	0.253	-0.697
$(d-p)$	-	-	-	-	14.730	-0.018
spr	-	-	-	-	-	0.961

Table B.4 – **Monthly Sample** Basic Statistics in the simulated sample. Initial condition is set to October 2012.

Monthly Sample Simulation	R^{TB}	xR	xB	y	dp	spr
Mean	-0.017	0.0927	0.0200	0.0125	-3.5813	0.0157
Std Dev.	0.0116	0.22045	0.0578	0.0051	0.6069	0.0285

Table B.5 – **Annual Sample** Basic Statistics in the simulated sample. Initial condition is set to December 2012

	R^{TB}	xR	xB	y	dp	spr
Mean	-0.0054	0.0658	0.0459	0.0149	-3.2271	0.0201
Std Dev.	0.0248	0.2118	0.0750	0.0313	0.3998	0.0118

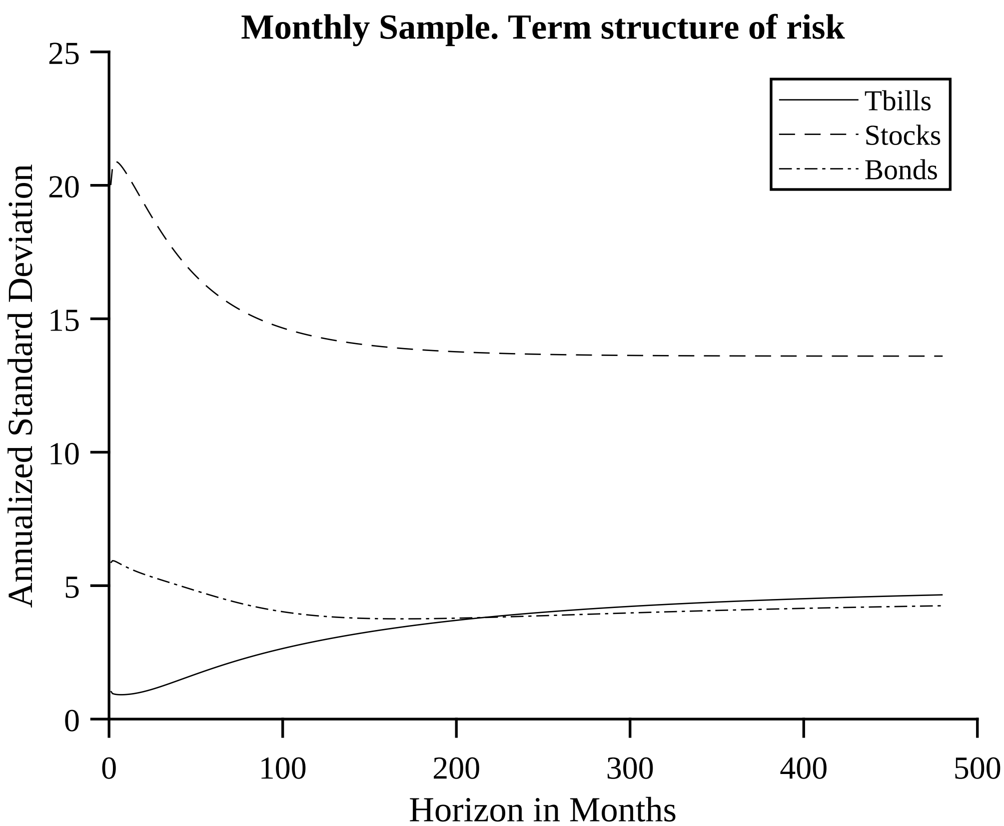


Figure B.1 – Term Structure of risk. Monthly Sample.

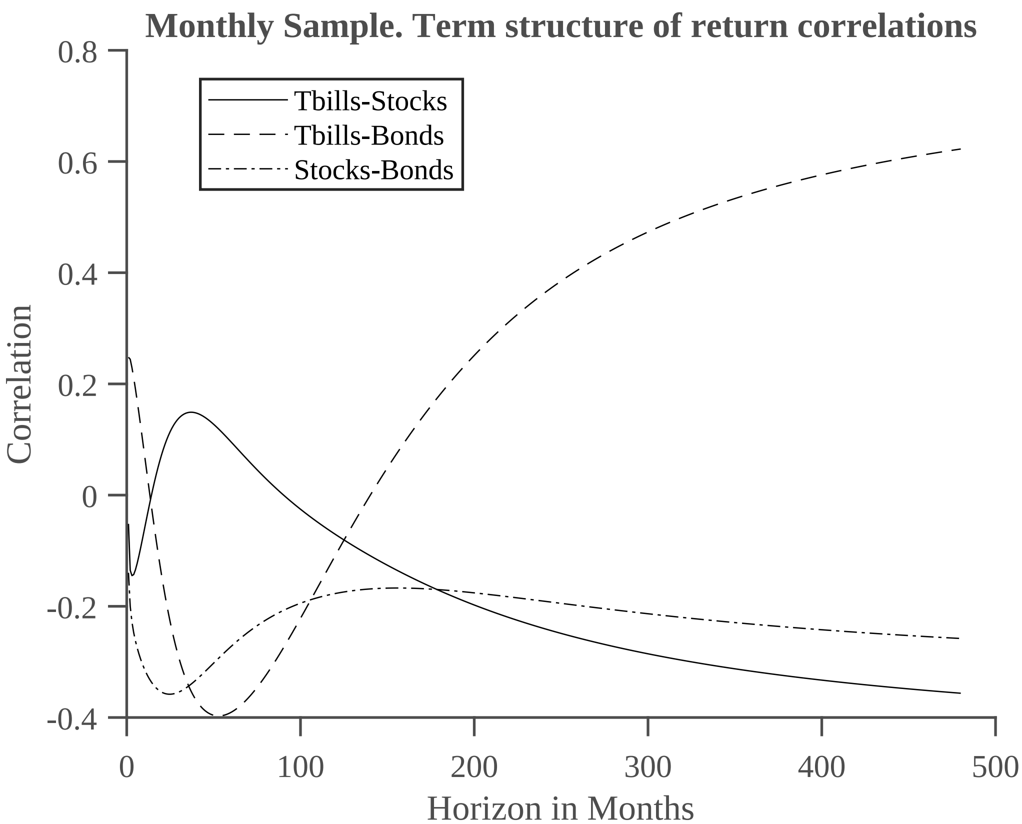


Figure B.2 – Term Structure of return correlations between financial securities included in the VAR model. Monthly Sample.

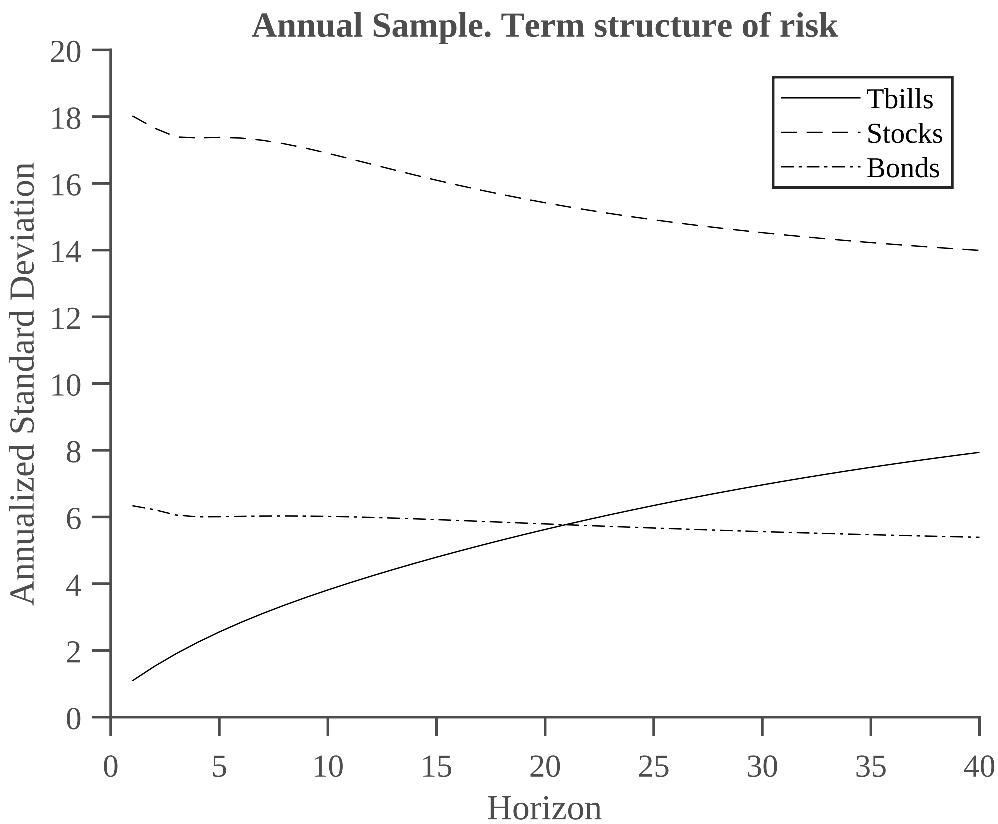


Figure B.3 – Term Structure of risk. Annual Sample.

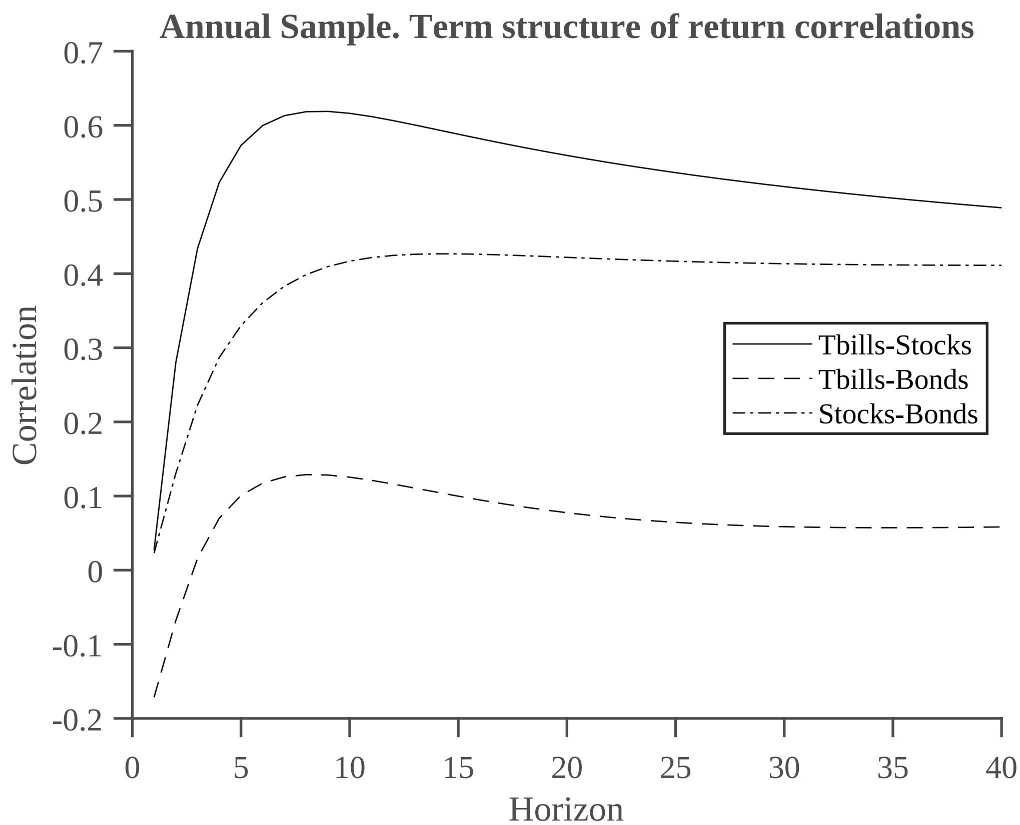


Figure B.4 – Term Structure of return correlations between financial securities included in the VAR model. Annual Sample.