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Individualized life-cycle investing

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Summary

This paper studies the added value of individualizing DC life-cycle investments with respect to the individual's labor income profile and housing wealth. Similar to the work of Munk (2016), optimal portfolios are derived explicitly from mean-variance analysis. Default life-cycle investment strategies are individualized in terms of risk aversion, and stock-income and stock-house price correlations. We find positive and substantial benefits of individualized life-cycle investment profiles in case of the stock-income correlation. Hence, considering heterogeneity in occupation sector is beneficial and provides better outcomes than one-size-fits-all life-cycle investment policies. In contrast, we conclude that individualizing life-cycle investments in terms of career path and idiosyncratic income risk has few benefits. The tailored life-cycle profile without considering housing wealth provides the highest welfare, even when the individual owns a house.

Samenvatting

In dit industry paper beschouwen we de mogelijkheden voor geïndividualiseerde default life-cycle beleggingen in DC pensioenregelingen. We bestuderen life-cycle beleggingsmixen die afhangen van leeftijd, inkomen en het eigen woningbezit. Geïndividualiseerde default life-cycle beleggingen geven een hogere welvaart en kleinere risico's dan standaardoplossingen, met name voor individuen die in een risicovolle sector werken, of die een andere risicohouding hebben dan de gemiddelde werknemer. Individualisatie van life-cycle beleggingen op basis van loopbaanprofiel en individu-specifiek loongroeirisico leidt tot weinig welvaartswinst. Het default life-cycle beleggingsprofiel dat geen rekening houdt met eigen huisbezit geeft de hoogste welvaart, ook voor huiseigenaren.

1. Introduction[1]

Collective pension systems face challenges, which have become prevalent in recent years. Due to changing demographic, economic and labor market trends and newly introduced regulations, there is an ongoing shift from defined benefit (DB) to defined contribution (DC) pension plans. At the same time, recent tendencies in society, demographics and labor market conditions lead to greater heterogeneity of individual life-courses, as explained for example by Bovenberg (2008a, 2008b). As participants become more heterogeneous, their background risks, originating from individual-specific sources such as family, marital status, education, career, house tenure choice and health condition, also vary more widely. In such heterogeneous and individualistic societies there is a growing demand for tailored individual DC pension products.

Tailoring investments to the heterogeneity of employees draws attention to their background risks and individual-specific needs. The DC instrument that we study in detail is life-cycle investing, as this offers much room for individualization of investment strategies. In this paper, we consider the added value of individualizing the life-cycle strategy by making it dependent on a number of factors, and we quantify the benefit of individualized life-cycle strategies, considering the individual-specific information, over the default life-cycles commonly used by pension providers. The individual factors used for tailoring life-cycles are wage profile and housing wealth.

We develop a model to obtain the optimal dynamic asset allocation through an explicit closed-form solution. Following the approach of Munk (2016), we use the mean-variance framework with time-dependent human capital and house value to determine the optimal life-cycle portfolio choice. Having determined the individualized life-cycles, we compare them to default strategies which are typically offered in the market. There is a wide range of literature that investigates the reasons for picking defaults, however, their welfare implications and optimality are not often discussed. We simulate the processes underlying the accumulation of invested capital and retirement wealth, in order to derive expected retirement consumption and welfare. We quantify the benefits of individualizing the life-cycle asset allocation (vis-'a-vis a one-size-fits-all-allocation) and the welfare losses of using defaults (vis-'a-vis optimized individual life-cycle strategies).

It is important to mention at this point that our work only models life-cycle investment decisions. As important (or perhaps even more so) are life-cycle savings and labour supply decisions. In this paper, however, we focus on the investment decisions only. This is obviously a limitation, and we leave default savings plans for further research. However, if interest rates are not (too) variable, then investment decisions can typically be decoupled from the savings decision. The present value of labor income and life-cycle wage patterns are taken into account, but treated as exogenously given.

The remainder of this paper is structured as follows. Section 2 discusses the role of lifecyle investing in individual pension plans. Section 3 sets up a model for the choice of indivudualized life-cycle investment. Section 4 presents the results of this model and discussed the optimality of various life-cycle strategies. Section 5 concludes.

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[1] This paper is based on the MSc thesis of Gréta Oleár, which was supervised by de Jong and Minderhoud. We thank Theo Nijman, Eduard Ponds, Peter Schotman and participants of the Netspar workshop "Vormgeving van opbouw- en uitkeringsfase in pensioenproducten" for useful comments.

2. Life-cycle investing

Individual Defined Contribution plans, even though they do not offer risk sharing tools within a collective, do have solutions to mitigate the risks of pension accumulation. Life-cycle investing is typical of such plans, where participants' contributions are dynamically invested in risky and risk-free assets, to match their risk preferences and risk capacity. In the classical life-cycle models of Merton (1969, 1971) and Samuelson (1969), the optimal life-cycle strategy is in fact constant over time. The decreasing life-cycle patterns are derived from models where labor income, thus, human capital is considered. The underlying assumption is that by aging, in general, individuals can absorb less risk due to their decreased risk capacity, in form of the depleted risk-free human capital. This is represented in the decreasing share of the risky asset over time: the closer to retirement age, the less equity exposure in the portfolio. The most intuitive rule to represent this is the so-called $(100 - age)\%$.

Life-cycle investments have long, often 30-40 years horizons, along which the exposure to the risky asset is gradually reduced. Hence, together with adjusting consumption, investment shocks can be mitigated. In the end of the accumulation phase, the total accrued capital is annuitized, to provide a life-time income stream starting from retirement age and covering micro longevity risk.

2.1. Classic models

The academic theory of the optimal life-cycle investment strategy originates from Merton (1969, 1971) and Samuelson (1969), even though these first results indicate a time-independent solution for the optimal portfolio weights, with no life-cycle implications. The constant solution for the risky asset share is the result of an optimization problem of a constant relative risk aversion (CRRA) life-time utility function over consumption, with no labor income in the model. The resulting formula is identical with the solution of Markowitz's myopic mean-variance analysis for the portfolio share invested in the risky asset:

$$\alpha_S = \frac{\mu_S - r_f}{\gamma \sigma_S^2} \tag{1}$$

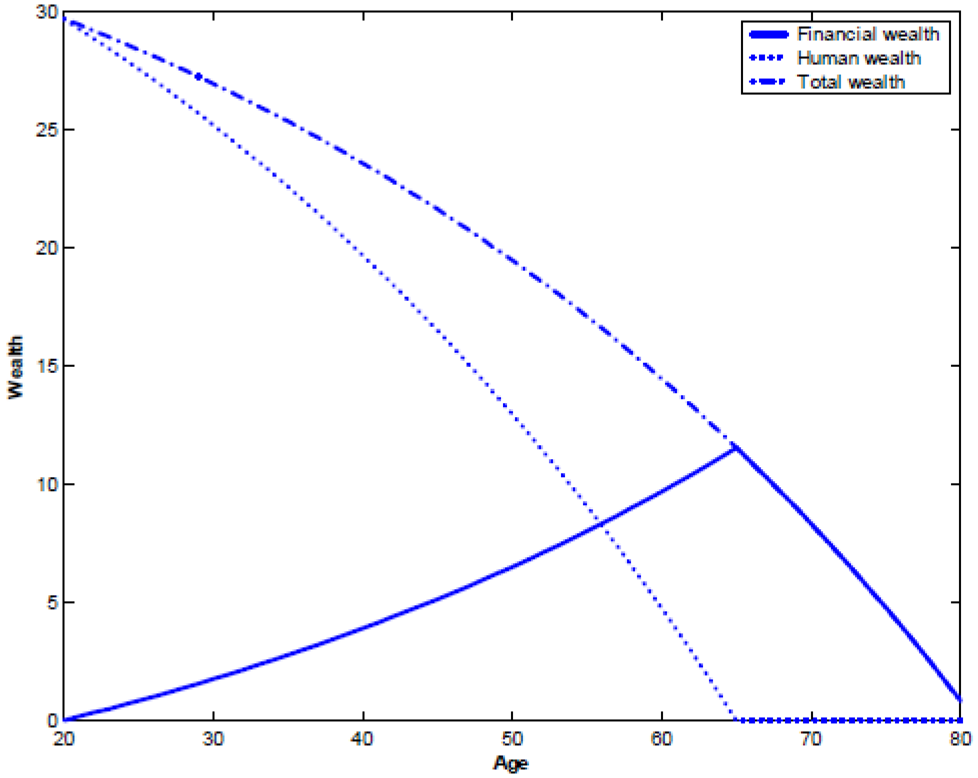
where α_S is the optimal share of risky asset, in our case a well-diversified pure equity index, within the investment portfolio, with μ_S expected return and σ_S^2 return variance of the equity index, r_f is the (long-term) risk-free interest rate and γ the investor's risk aversion, representing the only individual-specific information in the formula.

Further literature on life-cycle investing (e.g. Bodie et al. (1992), Campbell et al. (1999), Cocco et al. (2005)) incorporates human capital in the model, which became the basis of conventional life-cycle theory since it is well-known to generate the life-cycle effect. Human capital is traditionally defined as the discounted present value of the expected future labor income stream over the individual's remaining working life.

$$L_t = \mathrm{E_t}\left[\sum_{s=1}^{T-t} PV(Y_s)\right] = \sum_{s=1}^{T-t} \frac{1}{(1+r_f)^s} \cdot \mathrm{E}\left[Y_s\right], \tag{2}$$

with L_t human capital, Y_s annual labor income and $T - t$ marking the length of remaining working life in years. As represented by Bovenberg et al. (2007) in Figure 3.1, in young age the biggest component of wealth is human capital, which is gradually declining with age until reaching zero at retirement age. Financial wealth, on the other hand, is built up slowly during working life and consumed later in

Figure 1: Evolution of human, financial and total wealth over life



Source: Bovenberg et al. (2007)

retirement. The ratio of human capital over financial wealth decreases by age due to the two parallel processes and generates the life-cycle effect. This is also the idea behind smoothing investment shocks over the long investment horizon: young investors, with high human capital and still long time until retirement, can absorb more risk, have more time to recover the losses, hence, they have larger exposures to financial market risk, which implicitly leads to the assumption of risk-free human capital, in the sense that returns on labor income are not correlated with stock market returns.

Bodie, Merton and Samuelson (1992) extend the initial solution of equation (1) with such time-dependent, risk-free human capital and showed its leverage effect. The optimal portfolio share of risky asset as a fraction of financial wealth can be increased when human capital is considered:

$$\alpha_{S,t} = \frac{\mu_S - r_f}{\gamma \sigma_S^2} \left(1 + \frac{L_t}{F_t}\right) \tag{3}$$

Due to human capital and its leverage effect, the investment strategy is not constant anymore, the decrease of $\alpha_{S,t}$ is driven by two factors: the gradual depletion of human capital L_t and the accumulation of financial wealth F_t. It suggests that young investors should leverage up their portfolios by investing over 100% in risky assets, when markets are complete. However, market completeness is an unrealistic assumption and human capital is a non-tradable asset: due to moral hazard, it is difficult to borrow against it and the portfolio weight of the risky asset is typically capped at 100%. Constraints like this make the strategies differ from the actual optimal life-cycles and therefore, question the optimality of results from such truncated strategies.

2.2. New risk factors in life-cycle asset allocation

Considering the fact that increased heterogeneity among participants makes defaults less attractive, now we take a look at recent research about the link between individual factors and the life-cycle asset allocation. The individual characteristics that we describe and model are individual labor income profile and housing wealth. Other individual factors that also drive the asset allocation decision are (without completeness) age, gender and marital status, with substantial empirical evidence on their asset allocation tilting effect. Sundén and Surette (1998) and Hanna and Yao (2005) study the effect of gender and marital status on financial risk tolerance, and find that the interaction of the two significantly explains the portfolio choice of DC plan members. Love (2009) uses a life-cycle model to quantify the impact of changes in marital status and family composition, on the life-cycle portfolio choice. He finds that changes in marital status, especially divorce and widowhood, lead to large ex post adjustments in the asset allocation. However, the empirical findings do not always coincide with the simulation results of the model. The relevant definition of marital status, its modeling and the changes in it, are rather dependent on the modeler's choice, for which reason we do not consider it further in this paper.

The role of individual labor income and its risk features were already discussed to some extent: it determines human capital, which is the main driver of standard life-cycle theory. In CCGM (1999) and CGM (2005)[2], the volatility of labor income depends on individual-specific characteristics as education level, age, the sector of employment and idiosyncratic risks, besides aggregate, macro shocks. Following the Benzoni et al. (2007) approach about hump-shaped life-cycles, Bagliano et al. (2014) distinguish individuals based on the correlation of their labor income with stock markets, and measure the losses in certainty equivalent consumption from typical default life-cycles that do not consider labor income. Bodie et al. (1992) include the flexibility of labor supply as a determinant of labor income's risk profile too. With the ability to vary labor supply ex post, employees take greater risks in investment portfolios ex ante. The extent to which individuals can vary their labor supply depends on features of their human capital, such as age, industry of occupation or career level. They also highlight the large leverage effect of especially young investors' human capital, which has the most important impact on the asset allocation path: resulting in high, often over 100% risky asset weights at early stages of the investment period. Further on, we model individual labor income similar to CCGM (1999), by three components that capture the heterogeneity of individuals.

Housing wealth is the biggest investment decision for most households during their life-course. Furthermore, it is an alternative source of pension income: an important feature of financial security in retirement, according to the Melbourne Mercer Global Pension Index (2015) or often called the 4th pillar of pensions, as by Holzmann and Hinz (2005) from the World Bank. Here, we consider its role at the life-cycle investment decision and impact on the pension outcome. Housing wealth involves special aspects due to its dual nature: being an investment and a consumption good at the same time. Flavin and Yamashita (2002) show that housing has a tendency to crowd young investors out of stocks, because of the riskiness of the leveraged position in their homes. They derive the optimal weights for stocks, conditional on housing constraints by their owner-occupied homes, from the mean-variance framework, without considering labor income at all. House-value-to-wealth ratio, $h_t = \frac{H_t}{W_t}$, is also a variable that captures life-cycle effect: with the continuous accumulation of financial and total wealth, the ratio is decreasing by age, similar to human capital. They study the cross-sectional heterogeneity

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[2] Campbell et al. (1999) and Cocco et al. (2005)

of individuals regarding their house-value-to-wealth ratios, to show the life-cycle effect: the young with high h_t, leveraged up by mortgages, take less exposure to risky assets, depending on their risk aversion. By aging, h_t is assumed to decline and the risky asset share will increase.

There is a small branch of life-cycle research that models human capital and housing wealth together, and tries to find explicit closed-form solutions instead of the numerical dynamic programming. Van Hemert et al. (2007), Kraft and Munk (2011) and Kraft et al. (2015) all derive explicit formulas for the portfolio weight, similar to that of a mean-variance model. Munk (2016) in fact shows that the mean-variance framework with housing wealth and human capital is able to capture the life-cycle patterns suggested by the standard theory on life-cycle models. He derives the optimal shares of stocks and housing in the portfolio for complete markets without constraints, and cross-sectionally compares profiles with different levels of human capital and housing-to-financial-wealth. Similar to Flavin and Yamashita, they all argue that housing wealth, due to its risk profile, lowers the optimal exposure to risky assets, especially in young years. They consider housing riskier than stocks due to the underlying mortgage loans, which is usually substantial within total wealth of young people, relative to their low financial wealth.

2.3. Default Life-cycles

Our research is designed to compare life-cycle strategies that consider the mentioned individual-specific information to default asset allocation rules, typically offered by pension funds. We examine the pension outcome and welfare provided by each life-cycle for various individual profiles. Intuitively, we expect the defaults to perform well for individuals who are similar to the representative Dutch employee, and the individualized life-cycles to provide larger welfare gains for profiles far from this benchmark.

The role of defaults designed for the representative participant is undoubtedly questioned. Choi et al. (2003) argue that for a homogeneous group of participants, pension funds are more likely to design optimal defaults, whereas with greater heterogeneity, it is easier to motivate active choice from participants by offering ”bad”, far-from-optimal defaults. Uniform default options in pension funds have their own advantages both for participants and providers. The big advantage of defaults for most participants is the option of easy passive choice. There are various examples of defaults regarding DC pension plans: from the issues of participation and contribution rates to the asset allocation strategy. Choice overload might imply too much complexity and makes active decision harder. As a result, participants often stay with the default option, whether it is the default in case of voluntary participation, the pre-determined contribution rate or the default investment portfolio.

In the Netherlands, the free choice of participants is limited to choose between offered default asset allocations which are pre-designed for the representative Dutch employee. The preference of participants for default options is well documented in the academic literature. The large number of choice options have a discouraging effect in this case as well, but defaults are picked most often to avoid complicated decisions and the regret due to making a wrong decision. An additional advantage of default investment strategies is that these can be offered at low cost by professional pension providers. The low costs originate from scale advantages in the operational management and from the low turnover that one needs if cohorts of different ages are pooled in the investment portfolio of the pension provider. This is what, for example, the Swedish default pension fund discussed in Dahlquist, Setty and Vestman (2017) does.

From a provider’s point of view, retrieving individual-specific information is costly, as they need to confront clients with questionnaires and obtain data from different sources. The risk of getting no or false answers is also relevant: individuals do not intend to reveal everything about themselves, especially the information that might raise ethical issues. A common example is the pricing of annuities for different genders and different life-expectancies, where the actuarially fair price is regarded as price discrimination and the actuarially unfair, equal price leads to the adverse selection of clients. Designing defaults does not require the costly information, although it needs well-founded assumptions based on reliable statistics.

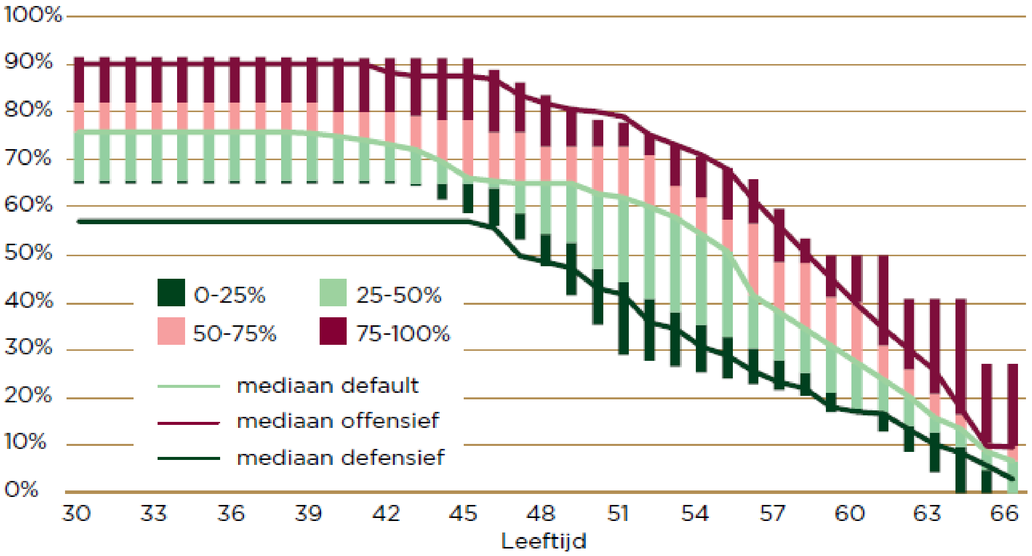
As pensions are a pillar of social security, pension funds are responsible for providing prudent investment vehicles and reliable defaults. Previously, we saw the biases that often drive participants in their financial decisions, regarding pensions too. The vulnerability of participants shifts the responsibility to regulators and to pension providers to design adequate pension products and defaults for them. Thaler and Sunstein (2003) established the concept of 'libertarian paternalism' which stands for the idea of "a policy selected with the goal of influencing the choices of affected parties in a way that will make those parties better off". Although given some level of free choice, individuals need to be guided by appropriate choices offered to them, in order to be protected from themselves and the mistakes they would make led by cognitive biases. This is executed by regulators setting out main policies and pension funds designing retirement plans in line with the regulations. By taking over the responsibility, pension providers must be aware of the outcomes of their investment plans, even though the final choice is with the client. According to Thaler and Sunstein, it "preserves freedom of choice, but authorizes (...) institutions to steer people in directions that will promote their welfare".

Our research investigates whether the cost-efficiency of defaults pays off and whether they provide adequate level of welfare, satisfying the criteria for socially responsible pension providers. By deriving the certainty equivalent consumption for each studied life-cycle strategy, we show whether the welfare implications of defaults are in line with the discussed advantages of choosing and offering them.

Some of the default life-cycle asset allocations offered by pension funds are found in the academic literature, regarded as simple approximations of the optimal asset allocation rules e.g. the "100-age% rule", the '$1/n$" rule of naive diversification and the typical strategy of Target-Date Funds, which is designed to adapt the risky asset share by declining to a given level of exposure. These defaults follow the idea of standard life-cycle theory with decreasing the exposure to investment risk as retirement age comes closer, and they are easy to interpret, even by clients. LCP Netherlands (2016) provides a detailed overview of the available life-cycles and thirteen funds offering them in the Netherlands. Figure 2 presents the variation of the risky asset exposure per participant age, decomposed into four quartiles, each with three pension funds in it. The three 'median' lines represent the 50th percentile of the allocation to risky assets for each of the risk profiles offensive, default (neutral) and defensive based on the life-cycle allocations of twelve Dutch pension providers. The range of the portfolio-share variation differs by age cohort. For age-groups below 42, the range is about 25%-points, while at age 51 it is almost 50%-points, where funds deviate from each other to the largest extent.

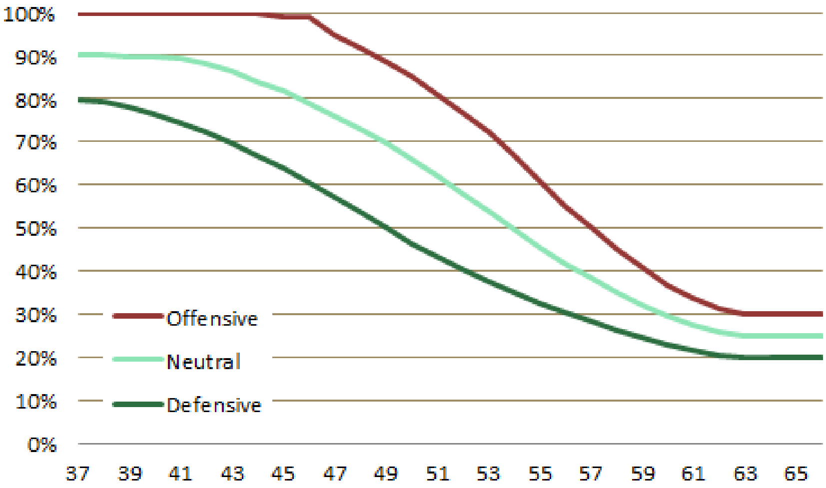
Figure 3 represents the default life-cycles used in our analysis. Assuming that the investment period is exactly 30 years long, the age of the employee entering the fund is 37. The risky asset shares are 80%, 90% and 100% at age 37, for the Defensive, Neutral and Offensive strategies. By age 66, the exposure declines to 20%, 25% and 30%, respectively. The asset allocation in younger years is assumed to be the same as in age 37, since young investors are assumed to take the maximal exposure of their risk capacity and appetite, according to standard life-cycle theory. Therefore, we do not look at younger participants. The Neutral life-cycle is considered to be the ultimate default option of the three, representing the completely passive choice.

Figure 2: Default life-cycle asset allocations of Dutch DC pension providers



Source: LCP Netherlands (2016)

Figure 3: Default life-cycles offered by the hypothetical pension provider



Source: NN Investment Partners (2016)

3. Model specification

Modeling individual DC pension funds and life-cycle investments involves several risk factors and possible specifications. We limit the considered risk factors to the investment risk from the life-cycle strategies and the risks of labor income, housing wealth and idiosyncratic income risk. Interest rates and inflation are considered to be constant in our model, while longevity is also specified in a maximal age. Therefore, we ignore these aspects, as they are not the main focus of this research.

To individualize life-cycle investments, we consider two individual factors: labor income profile and housing wealth, and derive a closed-form solution from the mean-variance framework, instead of solving the typical dynamic programming problem of life-cycle theory. The time-invariant risky asset share, as the solution of the 1969 Merton-model, provided motivation for studies like Campbell and Viceira (2002) or Munk (2016), on the link between the mean-variance framework and life-cycles. Munk (2016) discusses and confirms the optimality of the asset allocation from a mean-variance problem, with human capital and housing, for investments in complete markets. With borrowing constraints and incomplete markets, we are aware that the solution is truncated, but as an approximation, we consider it as the ”optimal” individualized life-cycle.

Our setup models a hypothetical individual DC pension plan with life-cycle investments. Each participant has his or her individual account, but the investments in the life-cycle funds can be done collectively to save on operational costs. However, due to the individualized accounts, there is no risk sharing among participants. We model the capital accumulation of a 37 year-old employee *i* with annual individual labor income $Y_{i,t}$ with $i = \{1, ..., N\}$ and $t = \{1, ..., 30\}$, since the end of working life and the life-cycle investment period is at age 66. The model simulates the pension outcome of various life-cycle strategies for different individual profiles. The life-cycle asset allocations, both individualized and defaults, are evaluated to determine which strategy suits a certain profile the best, based on different evaluation criteria. In this section we specify the assumptions and the processes that drive labor income, DC capital accumulation, retirement wealth and pension income. The derivation of the individualized life-cycle strategies is also introduced here. Instead of solving a dynamic programming problem, we follow the approach of Munk (2016) who tries to find closed-form, analytical solutions, very similar to that of a mean-variance investor.

3.1. Income and wealth dynamics

Individual labor income is a key factor in our model: it determines human capital and its riskiness, which drives the individualized life-cycle strategies and the paid contributions for the DC account. We rely on CCGM (1999) in modeling the labor income process, with three different components:

$$Y_{i,t+1} = Y_{i,t} \cdot (1 + \underbrace{w_{i,t+1}}_{\text{career path}} + \underbrace{\nu_{t+1}}_{\text{aggregate shock}} + \underbrace{\varepsilon_{i,t+1}}_{\text{idiosyncratic shock}}), \tag{4}$$

where $w_{i,t+1}$ is a deterministic component, a function of age, education, gender and other individual characteristics, labeled as individual career path. $\varepsilon_{i,t+1}$ is an idiosyncratic risk term, with a distribution of $N(0, \sigma_\varepsilon^2)$. Lastly, ν_{t+1} stands for macro level, aggregate shocks that affect all employees and capture the impact of economic shocks, since it is modeled as correlated with other economic variables relevant in our setup, namely with stocks and housing returns.

Notice that we do not model large risks such as unemployment or disability. These shocks are difficult to capture with a normal distribution,a s they happen with relatively small probability but have large, and often persistent, impact. Modeling such shocks is not trivial within the mean-variance framework and we shall therefore refrain from including such events.

First, we derive the processes for the three correlated random variables: stock returns $\frac{dS_t}{S_t}$, house price returns $\frac{dH_t}{H_t}$ and returns on the aggregate wage series $\nu_{t+1} = \frac{dY_t}{Y_t}$:

$$\begin{aligned}
\frac{dS_t}{S_t} =& (r_f + \mu_S^e)dt + \sigma_S dW_{St} \\
\frac{dH_t}{H_t} =& (r_f + \mu_H^e)dt + \sigma_H \left(\rho_{HS} dW_{St} + \sqrt{1 - \rho_{HS}^2} dW_{Ht} \right) \\
\frac{dY_t}{Y_t} =& \mu_\nu dt + \sigma_\nu \left(\rho_{YS} dW_{St} + \widehat{\rho}_{YH} dW_{Ht} + \sqrt{1 - \rho_{YS}^2 - \widehat{\rho}^2{}_{YH}} dW_{\nu t} \right)
\end{aligned}$$

where $\widehat{\rho}_{YH} = \frac{\rho_{YH} - \rho_{SH}\rho_{SY}}{\sqrt{1-\rho_{SH}^2}}$. The three processes are driven by three independent Geometric Brownian motions, dW_{St}, dW_{Ht}, $dW_{\nu t}$, each distributed as $N(0, t)$. The presence of an independent GBM for labor income, $dW_{\nu t}$, suggests that markets are incomplete, just like in a realistic setting, with labor income risk not fully spanned by other traded assets. All the three processes have a deterministic drift component, a function of dt and their own mean (expected excess return and risk-free rate) μ_S, μ_H and μ_ν. The stochastic components depend on each series' volatility, σ_S, σ_H or σ_ν, the pairwise correlations, corrected by the Cholesky-decomposition terms and lastly, the GBMs. Having derived the three correlated processes, the aggregate wage growth rate, $\nu_{t+1} = \frac{dY_t}{Y_t}$ is used in equation (4) to derive the next-period labor income of individual i, with a fourth, independent random variable, $\varepsilon_{i,t+1}$.

The individual's total wealth relevant for the life-cycle investment decision, consists of financial wealth as the accumulating DC capital, $F_{i,t} = DCC_{i,t}$, the owner-occupied house, $H_{i,t}$, and the derived human capital $L_{i,t}$:

$$W_{i,t} = F_{i,t} + H_{i,t} + L_{i,t} \tag{5}$$

Housing wealth is modeled as the actual market value of the owner-occupied dwelling, $H_{i,t}$. We assume that any mortgage loan on the home will be repaid in full before retirement, and hence we can leave the mortgage out of the analysis.[3] The second source of individual wealth is human capital, which is derived from labor income. Human capital consists of the remaining present value of the contribution-stream to be paid to the DC pension plan:

$$L_{i,t} = \mathrm{E_t} \left[\sum_{s=1}^{T-t} PV(c_s \cdot (Y_{i,s} - FR_s)) \right] = \sum_{s=1}^{T-t} \frac{c_s \cdot \mathrm{E}[Y_{i,s} - FR_s]}{(1 + r_f)^s}, \tag{6}$$

where $T = 30$ years, as the length of the remaining working life for a 37 years old employee. In this formula, Y_{it} is labor income at any time t, FR_t is the franchise of the state pension system and c_t is the contribution rate to the individual DC pension plan. The contribution rates, c_t, are increasing by age, but they follow the same increase for every employee. We assume that the IDC account stands

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[3] If we do not assume that the mortgage is fully repaid before retirement, we should include the net housing wealth (home value minus expected mortgage repayments until retirement) in the leverage effects. However, the full house value has to be used for the hedging demands.

for the entire second pillar pension of the individual, hence, we do not consider any collective or DB type of pension accumulation.

The investment policy of the pension fund is specified in life-cycle investment strategies, each different in the paths of the asset allocation, but with the same two assets available in all of them: a risky and a risk-free asset. The return on the life-cycle portfolio is the linear combination of the two asset returns:

$$r_{i,t+1}^{IDC} = \alpha_{S,t} \cdot r_S + (1 - \alpha_{S,t}) \cdot r_f$$

with $\alpha_{S,t}$ share of the risky asset.

The evolution of the capital invested in the DC pension fund, which is identical with $F_{i,t}$, is determined as:

$$F_{i,t+1} = (F_{i,t} + c_t \cdot (Y_{it} - FR_t)) \cdot (1 + r_{i,t+1}^{IDC}), \tag{7}$$

Next-period human capital is derived as

$$L_{i,t+1} = L_{i,t} \cdot (1 + r_f) - c_{t+1} \cdot (Y_{i,t+1} - FR_{t+1})$$

and next period's house price is given by the housing market return r_{t+1}^{H}, so that

$$H_{i,t+1} = H_{i,t}(1 + r_{t+1}^{H})$$

Retirement wealth at age $R = 67$ consists of the accumulated DC capital and the owner-occupied housing wealth, assuming no more mortgage debt after retirement and the complete depletion of human capital.

$$W_{i,R} = F_{i,R} + H_{i,R} \tag{8}$$

At retirement age the accumulation period is over and the DC capital is converted into an immediate nominal single-life annuity, which will pay periodic pension payments (denoted by DCP_i) until the end of the participant's life. Housing wealth, on the other hand, is locked-up in an illiquid asset. A possible tool to benefit from housing wealth, recommended by Arts and Ponds (2016), is a reverse mortgage against the capital built up in the home. Therefore, the annual pension income (above the AOW) consists of the equal periodic payments of the purchased annuity and installments paid by the reverse mortgage:

$$Y_i^R = DCP_i + \textit{Reverse mortgage}_i \tag{9}$$

For analytical convenience, we assume that the annuity purchased and the reverse mortgage provide a fixed stream of (cost of living adjusted) consumption. We do not explicitly consider the possibility of taking risky investments after retirement. de Jong (2009) provides some simple policy rules for the retirement phase.

3.2. Optimal life-cycle asset allocation

By individualizing life-cycles, we mean including individual-specific characteristics in the investor's optimization problem. We follow the setup of Flavin and Yamashita (2002) and Munk (2016) to derive an explicit formula for the optimal risky asset share, conditional on human capital and housing. We optimize the return over periodic wealth, defined in equation (4.4), taking the time t expected value of human capital and housing wealth as the two time-dependent individual-specific factors. The mean-variance utility, as our objective function, is:

$$max_{\alpha_S}\left\{ U(\alpha_S) = \mathrm{E}\left[\frac{W_{i,t+1}}{W_{i,t}}\right] - \frac{1}{2}\cdot\gamma\cdot\mathrm{Var}\left[\frac{W_{i,t+1}}{W_{i,t}}\right]\right\}$$

After some calculations, detailed in Oleár (2016), we find that the optimal risky asset share for the period t to $t+1$ is

$$\alpha_{S,t} = \underbrace{\frac{\mu_S - r_f}{\gamma\sigma_S^2}}_{\text{Merton-solution}} \cdot \underbrace{\left(1+\frac{L_{i,t}+H_{i,t}}{F_{i,t}}\right)}_{\text{leverage effect}} \underbrace{-\frac{L_{i,t}}{F_{i,t}}\cdot\frac{\sigma_{S,Y}}{\sigma_S^2} - \frac{H_{i,t}}{F_{i,t}}\cdot\frac{\sigma_{S,H}}{\sigma_S^2}}_{\text{hedging demand terms}} \tag{10}$$

with $\sigma_{i,j}$ covariance between assets i and j. σ_L^2 represents the variance of human capital, which is driven by the individual labor income process, while the risk-free rate is constant. [4] The formula, although the solution of a myopic problem, has two time-dependent components: $\frac{L_{i,t}}{F_{i,t}}$ and $\frac{H_{i,t}}{F_{i,t}}$, which capture the life-cycle effect and yield the dynamic strategy. Since the objective function is defined as utility over the returns on total wealth, both human capital and housing wealth provide leverage effect. The leverage from human capital is decreasing by time. Due to the correlations with stock markets, housing and labor income provide an implicit exposure to equities, for which the hedging demand terms correct. The two parallel effects will determine the overall impact of housing and human capital on the optimal portfolio choice.

As for the optimality of the derived formula, we rely on the work of Munk (2016), who confirms that in complete markets without borrowing constraints, the optimal solution of the life-cycle problem is in fact a mean-variance type of closed-form solution, with leverage effect from human capital and a labor income adjustment term, which stands for the hedging demand to correct for the implicit stock exposure. According to our specifications about the exogenous housing wealth, the optimal asset allocation was changed consistently. However, the assumption on the three correlated random variables violates the market completeness because of the unspanned risk of labor income. Furthermore, we do use borrowing constraints in the life-cycle portfolios, which inevitably truncates the assumed "optimal" strategies. Nevertheless, being aware of these deviations and distortions, we only aim to give an approximately optimal solution, conditional on the individual specific factors, instead of determining ad hoc life-cycles.

3.3. Individual profiles

Table 1 summarizes the baseline parameters used to analyze the pension outcomes of various life-cycle strategies, for the representative Dutch employee in the benchmark economic environment.[5] The information specified in Table 5.3 is tailored to the average Dutch employee. The average risk aversion of $\gamma = 5$ and idiosyncratic risks of labor income, $\sigma_\varepsilon = 5\%$ are based on academic studies, for example Cocco et al. (2005).

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[4] The risk of human capital is due to individual labor income, which has the previously discussed two components: macro and idiosyncratic shocks: $\sigma_L^2 = \sigma_Y^2 = \sigma_\nu^2 + \sigma_\varepsilon^2$. Since $\varepsilon_{i,t+1}$ does not correlate with any other asset, $\sigma_{S,L} = \sigma_{S,Y}$ and $\sigma_{H,L} = \sigma_{H,Y}$ in further notation.

[5] We refer to Oleár (2016) for an extensive motivation of these assumptions.

Table 1: Baseline parameter values

Parameter	Description	Value
r_f	risk-free rate	3.5%
π_{t+1}	price inflation	1.9%
μ_S	expected stock return	7%
σ_S	stock volatility	20%
μ_H	capital appreciation of private RE	1.13%
σ_H	house price volatility	13.72%
μ_Y	aggregate wage growth	2.5%
σ_Y	volatility of aggr. wage growth	5.27%
ρ_{SH}	stock-house correlation	0.069
ρ_{SY}	stock-income correlation	0
ρ_{HY}	income-house correlation	0.305
γ	risk aversion	5
R	retirement age	67
F_0	initial financial wealth in €	27 000
Y_1	salary at age 37 in €	44 900
H_1	purchase price of house in €	235 000
κ	loan-to-value of reverse mortgage	100%
T	life-cycle investment period in yrs	30
σ_ε	idiosyncratic labor income risk	5%

The individual profiles are designed to capture certain aspects of employee-heterogeneity, one at a time. The model makes it possible to fully individualize the life-cycle investment decision in terms of the investigated variables, by tailoring parameters for a chosen individual. However, the aim of this paper is to quantify the effects of the chosen individual-specific characteristics one by one. To capture the impact of individual labor income profile, we study three components of it: the individual-specific, real wage growth rate $w_{i,t}$; the correlation of labor income and stock returns ρ_{SY} and the idiosyncratic volatility σ_ε, partially describing the riskiness of one's labor income. Next, to study the role of housing wealth in life-cycle investing, we compare the cases when housing wealth is included as individual-specific information and when it is not.

We specify three possible career paths in Table 2, to capture individual heterogeneity: flat, moderate and steep. The flat career path indicates no growth rate in real wages, while the aggregate, nominal wage growth still applies here too. The steep career path is chosen to be the one defined by the Dutch legislation on wages: until the age of 35, a wage increase of 3% is taken, in the following 10 years 2% and in the next 10 years 1% is assumed, while starting from the age of 55, no further real increase is assumed in individual wages. It is chosen as the steepest career path since we aim to define representative groups of Dutch employees.

Assuming that the aggregate wage process drives all employees' labor income to the same extent, hence, correlations and aggregate wage volatility are identical across individuals, the only difference in labor income risk is due to idiosyncratic shocks. In Table 3 we distinguish individuals based on

Table 2: Career path wage growth rates

Age	0-34	35-39	40-44	45-49	50-54	55-59	60-66
Flat	0%	0%	0%	0%	0%	0%	0%
Moderate	2%	1%	1%	0.5%	0%	0%	0%
Steep	3%	2%	2%	1%	1%	0%	0%

idiosyncratic volatilities: $\sigma_\varepsilon = 0.05$ for the benchmark case, $\sigma_\varepsilon = 0.03$ for below-average and $\sigma_\varepsilon = 0.07$ for above-average individual-specific income risk. However, these parameters are not estimated, it is rather a sensitivity analysis by considering several values for σ_ε.

Table 3: Individual profiles with different idiosyncratic labor income risk

Profile	σ_Y	σ_ε	Total variance	Idiosyncr./Total
Above-average	5.27%	7%	0.0077	0.638
Benchmark	5.27%	5%	0.0053	0.474
Below-average	5.27%	3%	0.0037	0.245

Lastly, heterogeneity in individual labor income is captured through the correlation between labor income and stock market returns. Following Cocco et al. (2005), we vary this correlation by considering values that are representative for the sector of employment. The benchmark case of $\rho_{SY} = 0$ is interpreted as the sector of Public Administration. Wages here are considered to depend rather on the government and politics than on financial markets. The labor income of Financial sector employees is conventionally assumed to be more sensitive to financial market movements than those in Public Administration, thus Financial sector employees are assumed to have an income-stock correlation as high as $\rho_{SY} = 0.4$. Between the two, Agriculture sector employees are studied with an assumed $\rho_{SY} = 0.2$, since it is a sector moderately influenced by stock markets.

For every individual profile, default life-cycles and two individualized strategies are compared. The individualized life-cycles are distinguished by the fact whether they consider the impact of housing wealth or not.

4. Results

This chapter describes and analyzes the results in various aspects. First, the benefits of tailoring life-cycles for heterogeneous individuals are quantified. We measure the welfare changes in certainty equivalent consumption, due to switching from a life-cycle tailored with the parameters of the representative employee to another truely individualized one. We distinguish individuals ceteris paribus by one labor income characteristic at a time. Next, the question whether individualized life-cycle investing provides benefits over the pre-designed defaults is concerned, by comparing life-cycles that consider individual factors to defaults which ignore such information, e.g. the 40%-60% rule. We analyze the results of eight life-cycle strategies in terms of various evaluation criteria, both in utility and practical measures, e.g. on the risk-return trade-off.

Throughout this section, we define wealth at retirement age and also the periodic pension income in retirement years, with the purpose to derive utility from these. The expected utility at retirement is derived from the sum of the discounted, survival probability-weighted expected consumption stream for the remaining retirement life. It is calculated from a constant relative risk aversion utility function, as of CCGM (1999):

$$E_R[U(C)] = E_R\left[\sum_{t=1}^{D=110} \delta^{t-1}\left(\prod_{j=0}^{t-1} p_j\right)\frac{C^{1-\gamma}}{1-\gamma}\right] \tag{11}$$

with δ subjective discount factor equivalent to that of r_f, the product of p_j one-year survival probabilities and γ positive constant relative risk aversion. For higher levels of risk aversion and volatility of the resulting consumption levels, the certainty equivalent consumption (CEC) will be lower, while higher volatilities also yield higher expected consumption levels. The difference $\mathrm{E}[C] - CEC$ reflects the risk premium that is given up from the risky expected consumption, to trade risk for certainty. Besides the welfare evaluation, replacement ratios and downside measures will be also used to compare the different life-cycles and their pension outcomes.

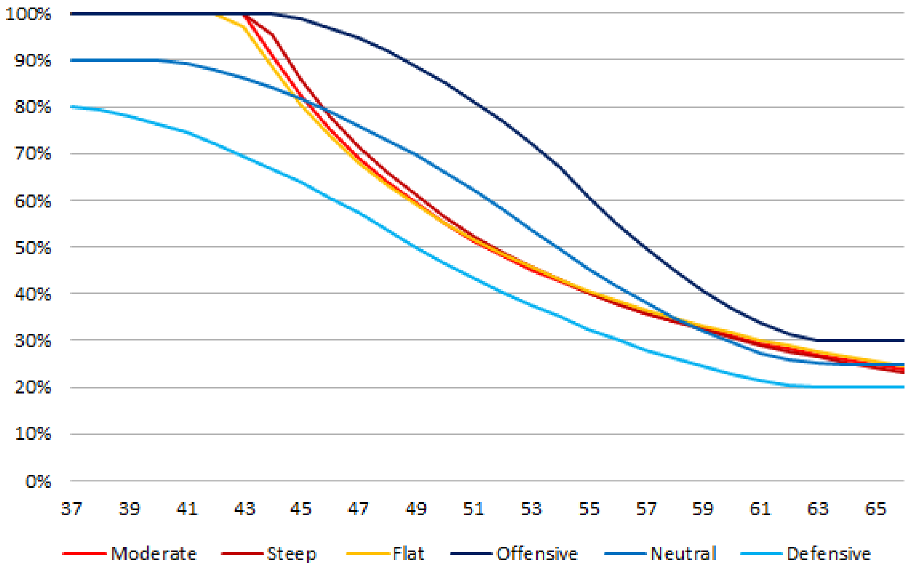
4.1. Tailored life-cycles for heterogeneous individuals

First, we quantify the benefits of offering individualized life-cycles to heterogeneous employees, relative to the welfare when individual heterogeneity is not considered. This comparison aims to determine whether it is worth distinguishing individuals by their labor income process when deciding on the optimal portfolio. We compare the certainty equivalent consumption (CEC) results for two cases: when the individual-specific parameters in the asset allocation formula are not tailored for the individual, i.e. when heterogeneity of participants is not considered; and second, when the derived asset allocation formula is parametrized with respect to the different labor income processes of employees. We study the welfare changes in case of the three labor income parameters, along which we distinguished individuals in Section 3.2.

4.1.1. Impact of career path

Figure 4 shows that life-cycles distinguished by career path do not deviate substantially from each other, since the differences in the labor income processes and human capitals are heavily mitigated in the asset allocation formula. The three tailored strategies follow each other closely, with differences only in the year when the decrease to the risky asset share starts and in the final positions. However, our simulation results show that the career path variable causes substantial variation in the final-year labor income of otherwise identical employees.

Figure 4: Individualized life-cycles for different career paths and the defaults



The career path drives the pension outcome in two different ways: through the evolution of labor income, in form of the paid contributions, and through the investment strategy due to the human capital of different income profiles. Table 4 shows the welfare effects in the case without tailored investment strategies, to capture the effect of heterogeneous income profiles in the pension outcome. Otherwise identical employees of different career paths have their own labor income processes, but the investment strategy is based on the moderate one for all. Before tailoring life-cycles, there is great variation in the CEC due to the magnitude of the underlying labor income: the flat career path yields 8.53% lower, while the steep one 8.78% higher CEC than the moderate career path, in spite of the identical life-cycle strategies. Clearly, steeper career path yields higher level of labor income, higher contributions in Euros, which lead to higher DC capital and expected consumption.

To determine the benefits of considering individual heterogeneity in the career path, we simulate the outcome when each profile is assigned to their own matching life-cycle strategies. The welfare changes are measured relative to each individual's initial CEC from the untailored life-cycle strategy. The aim is to quantify welfare gains on an individual level, and not to compare the pension outcome of heterogeneous participants to each other.

Firstly, we conclude that the variation of CEC-s across the three profiles has decreased, thus, tailoring life-cycles does mitigate the impact of labor income on the welfare distribution. However, the welfare enhancing effect and the economic impact are unclear: while the profile with flat career path gains 0.06% of his initially untailored annual CEC, the one with steep loses 0.14% of it. The economic significance of these changes is negligible, only a couple of Euros per month, which is explained by the slight differences between the three individualized life-cycles.

4.1.2. Employees of different sectors

The next component of labor income that we consider is the correlation between income and stock returns, captured by the different sectors in which the individual can be employed. As plotted in Figure 5, higher stock-income correlations, meaning higher implicit exposures to stock markets, yield

Table 4: Welfare analysis of individualizing life-cycles by career path

Panel A

	Before tailoring		After tailoring		
Career path	CEC	diff. from Moderate	CEC	diff. from Moderate	Welfare change
Flat	44 756	-8.53%	44 782	-8.48%	+0.06%
Moderate	48 932	0.00%	48 932	0.00%	0.00%
Steep	53 226	8.78%	53 151	8.62%	-0.14%

Panel B

	Before tailoring			After tailoring			Relative change		
	Flat	Mod.	Steep	Flat	Mod.	Steep	Flat	Mod.	Steep
E[C]	65 908	70.850	75.478	65.946	70.850	75.583	+0.06%	0.00%	+0.14%
σ_C	26.881	28.157	29.060	26.889	28.157	29.214	+0.03%	0.00%	+0.53%
$\frac{\sigma_C}{E[C]}$	40.79%	39.74%	38.50%	40.77%	39.74%	38.65%	-0.04%	0.00%	+0.39%
CEC	44 756	48.932	53.226	44.782	48.932	53.151	+0.06%	0.00%	-0.14%

Panel A. CEC outcomes for the three, career path-distinguished profiles before and after individualizing the life-cycles, and the individual welfare gains. Panel B. The two parallel factors driving the change in CEC: Expected retirement consumption and its volatility in €, before and after tailoring life-cycle strategies for different career paths.

more defensive strategies than the benchmark $\rho_{SY} = 0$. As human capital is depleted, the hedging demand term and the difference between the three life-cycles are also diminishing. This implies the same equity exposure for all the three profiles in the final year of the investment period.

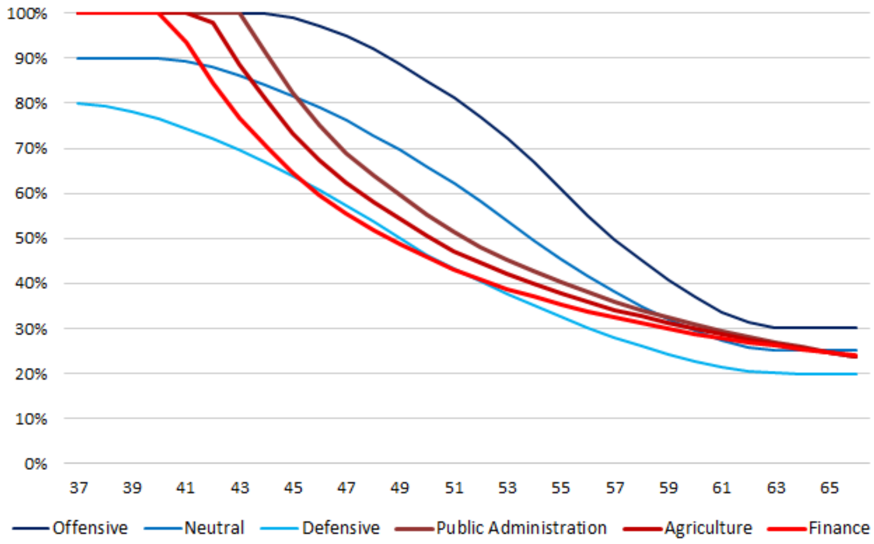
Similar to the career path, ρ_{SY} affects both the life-cycle asset allocation and the individual labor income process. Therefore, the analysis follows the same structure as before: we investigate the benefits of individualizing life-cycles with respect to stock-income correlation, by first assigning the same, benchmark asset allocation to the different profiles and then their matching, tailored ones.

While the life-cycles distinguished by ρ_{SY} are substantially different, the distributions of final-year labor income of the three profiles do not show big variation. Panel A of Table 5 summarizes the CEC results before and after tailoring the life-cycles by ρ_{SY}. Following the untailored strategy, there is substantial dispersion in the welfare of the three sectors. Intuitively, the reason for the big variation in CEC is the large deviation from their optimal, true individualized life-cycles, when they are assigned to the strategy of the Public Administration employee, recalling that the income processes are very similar.

When life-cycles are tailored for the different ρ_{SY} values, the dispersion in welfare decreases, meaning that the non-zero correlation profiles gained additional consumption relative to their initial, untailored results. The Agriculture employee gained 0.78% of his original CEC, while the Finance sector employee gains 1.73%, which translates into an € 812 annual increase in the pension income. Decomposed into the two parallel effects, Panel B of Table 5 shows the drivers of the welfare gains. The $\frac{\sigma_C}{E[C]}$ ratio has improved for both sectors due to the more defensive strategies, increasing the CEC-s.

As for the variation in welfare, both non-zero correlation sectors accrue lower CEC-s than the Public Administration. The reason for the lower welfare is their individual-specific wage profile and not the inadequacy of the life-cycle strategy. Also, the aim of our analysis is not to provide equal welfare for every plan member, but to improve the individual outcomes relative to the welfare of the untai-

Figure 5: Individualized life-cycles for different income-stock correlations and the defaults



lored life-cycles. In conclusion, we quantify meaningful welfare gains due to individualizing life-cycle investing by stock-income correlations.

4.1.3. Individual-specific income risk

Lastly, the distinction between individuals with different idiosyncratic labor income risk, σ_ε is analyzed. σ_ε describes the volatility of one's labor income process due to fully individual factors, i.e. background risks, which leads to great variation in final-year labor income. On the other hand, it is a factor that is not incorporated in the asset allocation decision of Section 3.2. Nevertheless, idiosyncratic risks have an impact on individual behavior and decisions: assuming more background risks makes individuals behave more carefully, as if they were more risk averse. Although it is not possible to individualize directly in terms of σ_ε, we assign different strategies to the two non-average profiles, considering their riskiness, based on intuition and economic logic. Therefore, the profile with above-average idiosyncratic income risk (7%) is assigned a safer strategy, derived by assuming higher $\gamma = 6$ risk aversion. The below-average (3%) idiosyncratic risk profile gets a more aggressive life-cycle, based on $\gamma = 4$. The risk aversions, to determine these ”tailored” lifecyles, were chosen based on economic intuition, so that they only slightly deviate from the benchmark $\gamma = 5$. However, the CEC-s from the ”tailored” life-cycles were derived by using the benchmark risk aversion of $\gamma = 5$. The three life-cycles are compared to each other and to the defaults in Figure 6.

After assigning strategies to the profiles which better resemble their labor income features, the dispersion in welfare decreases, see Table 6. The less risky profile, with the more aggressive $\gamma = 3$ strategy, loses 1.44% of his initial CEC, while the employee with more background risks and, therefore, the more defensive $\gamma = 6$ strategy, gains 0.69% relative to the welfare outcome of the untailored strategy.

The ambivalent results in terms of welfare are due to the change in $E[C]$ and σ_C, and their relative change compared to each other. These are summarized in Panel B of Table 6. For the profile with lower background risks and a more aggressive life-cycle, the increase in the volatility of consumption

Table 5: Welfare analysis of individualizing life-cycles by stock-income correlations

Panel A

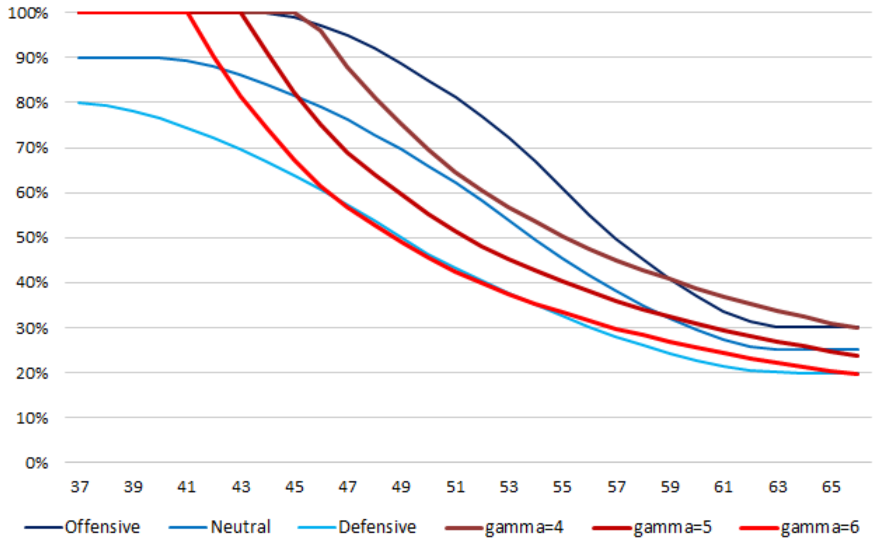
	Before tailoring		After tailoring		
ρ_{SY}	CEC	diff. from $\rho_{SY} = 0$	CEC	diff. from $\rho_{SY} = 0$	Welfare change
0	48 932	0.00%	48 932	0.00%	0.00%
0.2	47 977	-1.95%	48 350	-1.19%	+0.78%
0.4	46 994	-3.96%	47 806	-2.30%	+1.73%

Panel B

	Before tailoring			After tailoring			Relative change		
ρ_{SY}	0	0.2	0.4	0	0.2	0.4	0	0.2	0.4
E[C]	70 850	70 820	70 887	70 850	70 084	69 341	0.00%	-1.04%	-2.18%
σ_C	28 157	28 734	29 444	28 157	27 837	27 554	0.00%	-3.12%	-6.42%
$\frac{\sigma_C}{E[C]}$	39.74%	40.57%	41.54%	39.74%	39.72%	39.74%	0.00%	-2.11%	-4.33%
CEC	48 932	47 977	46 994	48 932	48 350	47 806	0.00%	+0.78%	+1.73%

Panel A. CEC outcomes for the three, stock-income correlation-distinguished profiles before and after individualizing the life-cycles, and the individual welfare gains. Panel B. The two parallel factors driving the change in CEC: Expected retirement consumption and its volatility in €, before and after tailoring life-cycle strategies for different sectors.

Figure 6: "Individualized" life-cycles for different idiosyncratic income risks and the defaults



is higher than in the expectation itself, hence, the welfare change is negative. Whereas the individual with higher background risks and more defensive strategy, accrues lower retirement consumption on average, but also lower volatility, which yields an overall welfare gain.

In conclusion, the added value of "individualizing" life-cycles, with respect to idiosyncratic labor income risk, depends strongly on the life-cycles we choose as "individualized". Our results support the argument that individuals with higher background risks should behave as more risk averse in their investments, since it increases welfare. For lower-background-risk profiles, however, taking additional risk exposure in the life-cycle investment yields welfare losses.

Table 6: Welfare analysis of individualizing life-cycles by idiosyncratic income risk

Panel A

	Before tailoring		After tailoring		
σ_ε	CEC	diff. from $\sigma_\varepsilon = 5\%$	CEC	diff. from $\sigma_\varepsilon = 5\%$	Welfare change
3%	51 305	4.85%	50 564	3.34%	-1.44%
5%	48 932	0.00%	48 932	0.00%	0.00%
7%	46 595	-4.78%	46 918	-4.12%	+0.69%

Panel B

	Before tailoring			After tailoring			Relative change		
σ_ε	3%	5%	7%	3%	5%	7%	3%	5%	7%
E[C]	70 301	70 850	70 336	72 974	70 850	68 415	+3.08%	0.00%	-2.73%
σ_C	26 993	28 157	29 340	30 234	28 157	27 471	+12.01%	0.00%	-6.37%
$\frac{\sigma_C}{E[C]}$	38.40%	39.74%	41.71%	41.43%	39.74%	40.15%	+7.89%	0.00%	-3.74%
CEC	51 305	48 932	46 595	50 564	48 932	46 918	-1.44%	0.00%	+0.69%

Panel A. CEC outcomes for the three idiosyncratic risk-distinguished profiles before and after individualizing the life-cycles, and the individual welfare gains. Panel B. The two parallel factors driving the change in CEC: Expected retirement consumption and its volatility in €, before and after tailoring life-cycle strategies for different background risks.

4.2. Individualized life-cycles vs. Defaults

So far, we quantified the added value of individualizing life-cycles for heterogeneous employees in terms of three characteristics of the labor income process. Regardless of the results of the previous sub-section, we now compare the individualized life-cycles to simple default strategies. The considered defaults are either used by pension providers, because of their simplicity and easy interpretations, e.g. the 100-age% rule, or often found in academic papers, like the time-invariant Merton-solution. Specifically, we investigate whether the individually optimized strategies perform better than the default strategies for two profiles: the benchmark, representative Dutch employee and the Finance sector employee with $\rho_{SY} = 0.4$.

Figure 7 presents the individualized life-cycle asset allocations and the three defaults of the hypothetical pension fund. The two individualized life-cycles are distinguished by the fact whether they consider the impact of a house purchased for € 235 000 at age 37, or not. The strategy without housing assumes H_t to be zero for any t year. Due to the close-to-zero ($\rho_{SH} = 0.069$) correlation between house prices and stocks, the impact of housing is negligible in the hedging demand and the effect from housing translates mainly into the leverage effect in the speculative demand term. Irrespective of the parametrization of the wage profile and the risk aversion, the two individualized life-cycles, distinguished by the presence of housing in the formula, relate to each other always in the same way. The life-cycle with housing wealth is more aggressive, unless, for instance, certain regions with higher house-stock correlations are considered.

In Figure 7.A, the tailored strategies of the benchmark profile are remarkably close to the Defensive and Neutral default strategies. Not surprisingly, tailoring strategies for representative employees yields outcomes similar to the defaults which were originally calibrated for them. As expected, the Financial sector employee's individualized life-cycles, in Figure 7.B, are more defensive than in Figure 7.A, due to the higher stock-income correlation.

Table 7 presents the simulation results for the compared life-cycle strategies of the two profiles. Although the defaults follow the same asset allocation rules for both profiles, they do perform differently because of the different labor income processes.

Interestingly, for the baseline economic scenario and individual parameters, the individualized life-cycles without housing wealth perform the best in terms of CEC, instead of the supposedly optimal life-cycles with housing. At moderate levels of risk aversion, individuals prefer the more defensive of the two individualized life-cycles. The welfare gain from the optimal individualized life-cycle, without housing, is measured from the absolute default Neutral strategy. Tailoring the strategy for the representative employee yields a welfare gain of 2.44% in CEC, which is not negligible, considering the

Figure 7: Individualized life-cycles for the benchmark and the Finance sector employee, relative to the defaults

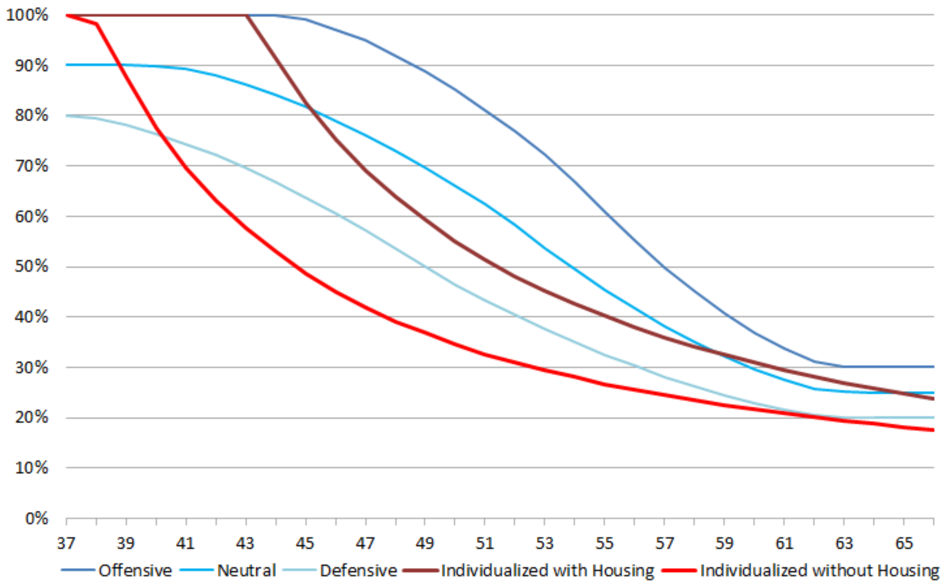


Figure A. Benchmark profile

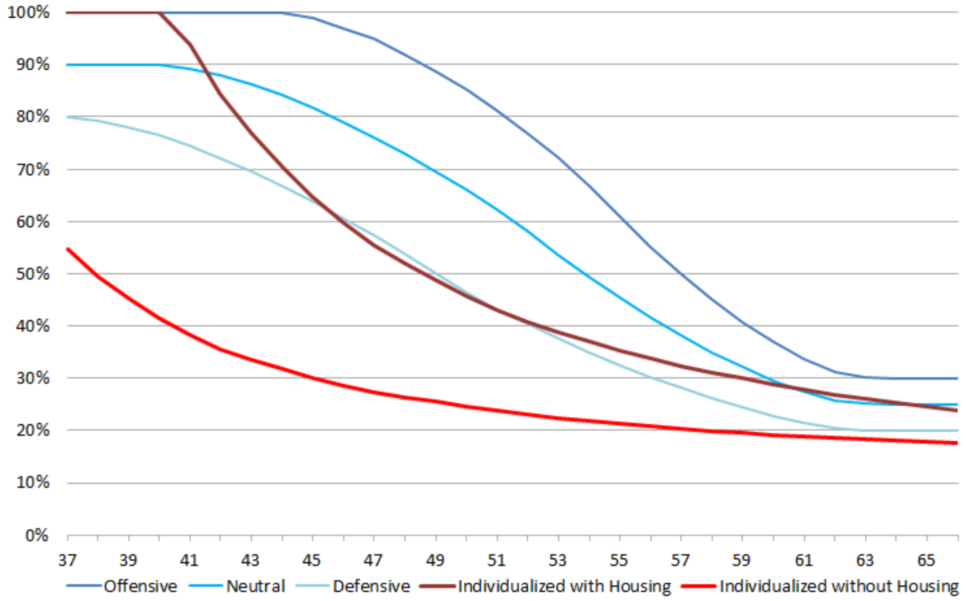


Figure B. Finance sector profile

Table 7: Various evaluation criteria for the benchmark and the Finance sector profile

Panel A: Benchmark profile								
	1.	2.	3.	4.	5.	6.	7.	8.
CEC	48 932	49 920	47 152	48 732	49 588	49 146	49 184	49 208
$\frac{\sigma_C}{E[C]}$	39.74%	36.60%	44.65%	40.05%	37.22%	38.93%	38.21%	35.66%
Mean RR excl. AOW	50.61%	46.73%	54.48%	50.84%	47.61%	49.68%	48.24%	42.59%
Std. dev. RR	19.87%	14.14%	26.66%	20.12%	15.27%	18.21%	16.62%	10.03%
2.5% VaR	25.57%	26.91%	24.06%	25.41%	26.72%	25.69%	25.53%	27.71%
Pension Sharpe	2.55	3.30	2.04	2.53	3.12	2.73	2.90	4.25
Mean/2.5% VaR	1.98	1.74	2.26	2.00	1.78	1.93	1.89	1.54
Max Drawdown age 45	-22.24%	-16.23%	-22.56%	-19.58%	-15.59%	-11.82%	-6.81%	-0.85%
Mean RR incl. AOW	71.13%	67.25%	74.99%	71.36%	68.15%	70.20%	68.76%	63.11%
Panel B: Finance sector employee								
	1.	2.	3.	4.	5.	6.	7.	8.
CEC	47 806	48 727	44 765	46 647	47 983	47 365	47 698	48 511
$\frac{\sigma_C}{E[C]}$	39.74%	36.67%	46.96%	42.03%	38.81%	40.60%	39.62%	36.36%
Mean RR excl. AOW	47.74%	43.50%	52.45%	49.36%	46.58%	48.37%	47.12%	42.21%
Std. dev. RR	13.77%	9.24%	21.45%	16.20%	12.37%	14.47%	13.23%	8.50%
2.5% VaR	27.96%	28.83%	25.81%	27.20%	28.10%	27.92%	27.59%	28.81%
Pension Sharpe	3.47	4.71	2.44	3.05	3.77	3.34	3.56	4.97
Mean/2.5% VaR	1.71	1.51	2.03	1.81	1.66	1.73	1.71	1.46
Max Drawdown age 45	-18.99%	-6.32%	-22.51%	-19.55%	-15.55%	-11.81%	-6.80%	-0.85%
Mean RR incl. AOW	68.25%	64.01%	72.96%	69.87%	67.09%	68.88%	67.63%	62.72%

This table presents the simulation results of the eight strategies, for both individual profiles, in various evaluation measures. The CEC is derived from the expected utility over the periodic pension income from the DC annuity and the reverse mortgage. Further, we analyze the resulting replacement ratios, their volatilities and the down-side risk features of each strategy. 1. With Housing; 2. Without Housing; 3. Offensive; 4. Neutral; 5. Defensive; 6. 100-age%; 7. 40%-60%; 8. Merton-solution

fact that the default was initially designed for this participant. The Finance sector employee incurs 4.46% higher CEC by individualizing his life-cycle, which means an additional retirement consumption of € 2080 annually. This confirms the welfare enhancing impact of considering ρ_{SY} when tailoring life-cycles. The welfare gains are substantial for employees from sectors where labor income is highly sensitive for stock market movements. On the other hand, considering housing wealth at the investment decision leads to 1.98% and 1.89% CEC-loss, respectively for the benchmark and the Finance profile, relative to the strategy without housing. It is surprising that this model-suggested optimal strategy is inferior, relative to the other individualized life-cycle.

Table 7 also compares features of the life-cycles other than welfare. The ratio $\frac{\sigma_C}{E[C]}$ captures the trade-off between the expected retirement consumption and its volatility, regardless of the risk preferences, therefore, the results show different order of the life-cycles. According to the ratio, the Merton-solution has the lowest volatility in terms of its expected consumption for both profiles. The optimal strategies of the two profiles provide DC annuities with mean replacement rates of 46.73% for the benchmark and 43.50% for the Finance employee. Higher RR-s are paired with higher volatilities too, resulting in lower Sharpe ratios in terms of the replacement rates. However, the relation between down-side risk and expected replacement ratios is better for more aggressive strategies, like the individualized life-cycle with housing wealth. Their 2.5% worst case RR-s are not substantially different from those of the more defensive life-cycles, but their potential for better mean RR-s is much higher. The maximal draw-downs show big variation across the eight life-cycles too. The differences between the pairs of individualized life-cycles are remarkably large, 6 and 12.7%-points.

Figure 8 visualizes the trade-off between the mean and the 2.5% worst RR and the volatility of the RR-s, represented by the size of the bubbles. Clearly, the most volatile strategy is the Offensive default in both figures, while the least risky is the time-invariant Merton-solution, which allocates 17.5% to the risky assets during the entire investment period. Although it seems to be an unlikely strategy to follow, it performs well and has theoretical importance, being the solution of a basic life-cycle model, without labor income. The negative relation between 2.5% worst and mean replacement rates is clearly captured: for giving up roughly 3-4% of the replacement rate in the 2.5% worst case scenarios, approximately 10-12% higher expected RR can be earned, by changing from the Merton-strategy to the Offensive default. The life-cycles also follow the higher return-higher risk principle of portfolio theory, as the size of the bubbles, representing the standard deviation of the replacement rates, grows with the mean replacement rate.

4.3. Summary of results

In general, we found that tailored life-cycles provide larger welfare gains when employees deviate more from the benchmark. However, the optimal asset allocation and the pension outcome are more sensitive for some characteristics than for others. We conclude that distinguishing individuals by their stock-income correlation can yield substantial welfare gains, relative to default strategies, for individuals with non-zero values of ρ_{SY}. For example, for the Finance sector employee, with a stock-income correlation of $\rho_{SY} = 0.4$, the welfare gain was € 812 in annual nominal certainty equivalent retirement consumption, relative to the welfare from the untailored strategy. Clearly, the greater the dispersion of employees in terms of stock-income correlation is, the bigger the participant-base who will benefit from tailoring, with larger welfare gains too.

Besides the welfare analysis, other evaluation metrics were also derived to capture the risk-return and down-side features of each strategy. As expected, none of the life-cycles performs as the best in all of the criteria. Life-cycles that provide high replacement ratios also have higher volatilities, with larger draw-downs and lower replacement rates in the worst case scenarios. The criterion which considers the most information and provides the most tangible result is the certainty equivalent consumption, expressed in annual, nominal consumption, in Euros. Therefore, in our final decision to choose the optimal strategy, we rely on this metric. We conclude that in the baseline economic scenarios, for the modeled individuals, the optimal investment strategy is the individualized life-cycle without housing wealth. It provides 2.44% higher CEC than the ultimate default for the benchmark profile and an annual welfare gain of € 2080 for the Finance sector employee.

Figure 8: Expected and 2.5% worst Replacement Rates.

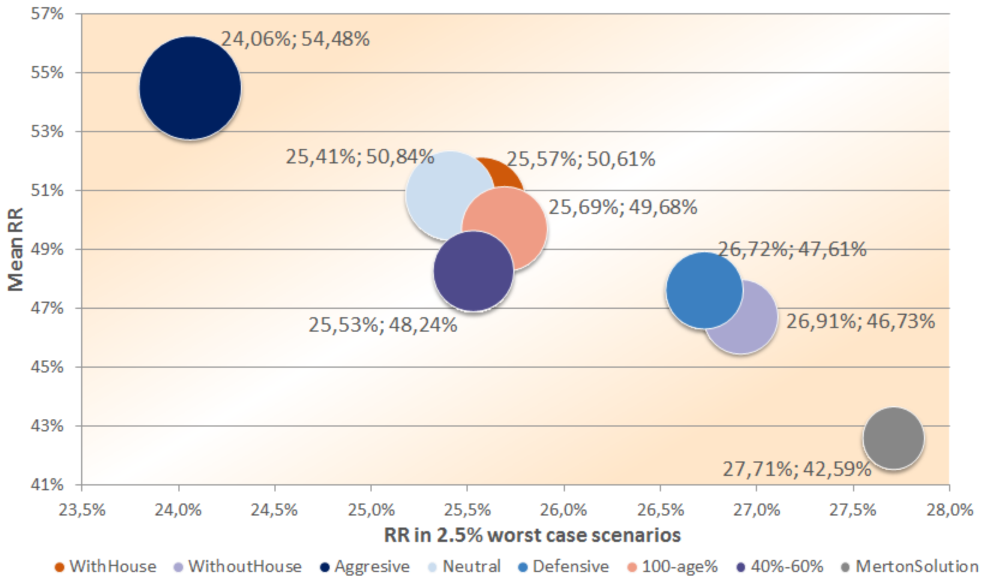


Figure A. Benchmark profile

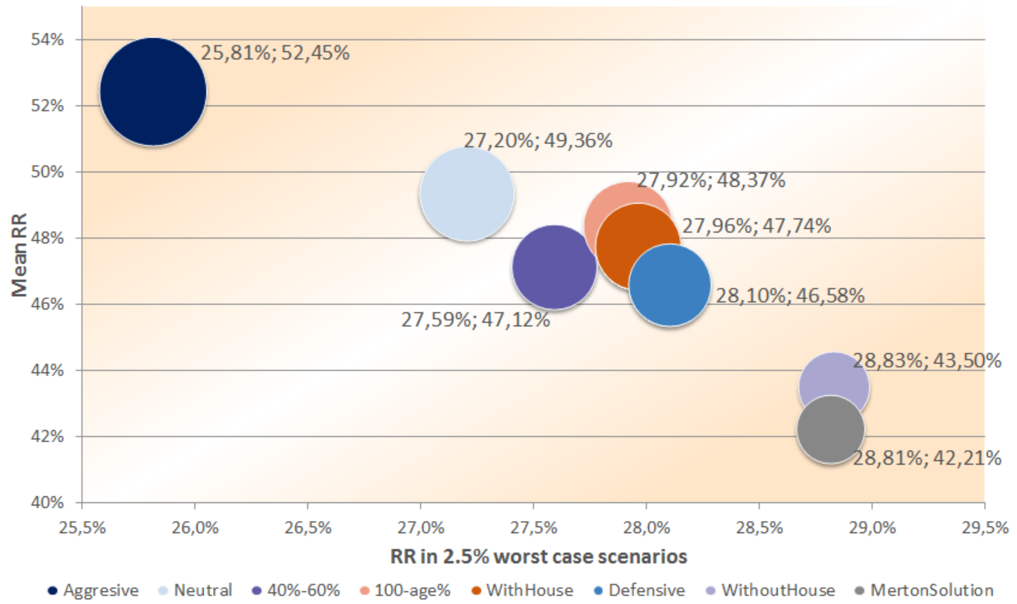


Figure B. Finance sector profile

The size of the bubbles represents the volatility of the replacement rates.

5. Conclusions

The Dutch pension system is going through considerable changes recently. The shift from defined benefit systems to defined contribution plans in the second pillar involves several aspects which need rethinking for the evolving new pension paradigm. In this paper we focus on the need for tailored retirement investment strategies for heterogeneous individuals. By deriving an explicit formula for the optimal asset allocation conditional on two individual factors, namely wage profile and housing wealth, we obtain individualized life-cycles. To conclude on their welfare enhancing effect, they are analyzed in several experiments for different individual profiles.

We find positive and substantial benefits of individualized life-cycle investment profiles in case of the stock-income correlation, which represents the sector of employment. Considering heterogeneity in occupation sector-wise, thus, has added value for individuals versus when they are treated as the representative individual. In contrast, we conclude that individualizing life-cycle investments in terms of career path and idiosyncratic income risk yields little welfare benefit. We find that the tailored life-cycle profile without housing wealth provides the highest welfare, which is, however, not the optimal strategy according to our model.

Our results confirm the importance and welfare enhancing effect of individualization of life-cycles, although there is still room for further extension. Firstly, the individual characteristics considered are not always clearly defined and some are hard to estimate. An obvious extension of this paper would be a deeper study of these characteristics, such as risk aversion, idiosyncratic income risks, stock-income correlation per sector, and stock-house correlation per region. Better understanding and estimation of these can improve the quality of the analysis and contribute to a better description of individual heterogeneity.

Studying other individual factors, such as marital status, family composition or tenure choice, and their role in asset allocation can further deepen our knowledge about individualization of life-cycles. Besides the necessary specifications to model these within the life-cycle framework, empirical evidence about their impact on portfolio choice is often controversial or lacking. Modeling the housing tenure choice of renting or owning is also a possible extension of this research.

Life-cycle investing is a flexible instrument, with much room for further individualization for heterogeneous clients. Our research has confirmed the welfare enhancing effect of tailoring life-cycles with respect to risk aversion and stock-income correlation. The results suggest that exploration of further individual characteristics may also yield additional benefits. Besides the welfare implications of our research, new regulations on DC life-cycle investing also call for the introduction of tailored instruments and these can increase the practical use of our results and the relevance of individualization of life-cycles.

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