Benefits of Individualized Lifecycle Investing:

The Impact of Individual Wage Profile & Housing Wealth

MASTER THESIS BY

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ABSTRACT

In this thesis we study the added value of individualizing DC lifecycle investments, in the context of the transition taking place in the Dutch pension system. We individualize lifecycle portfolios with respect to the individual's wage profile and housing wealth. Similar to the work of Munk (2016), the optimal portfolios are derived explicitly from the mean-variance analysis, instead of the much more complicated dynamic programming. The closed-form solution captures both the leverage effect and the riskiness of human capital and housing wealth, in the sense that they correlate with stock markets. We show that considering the heterogeneity of individuals provides higher welfare for those very different from the average person. The welfare gains, relative to the typically offered default strategies, are substantial when the lifecycles are individualized in terms of risk aversion, stock-income and stock-house correlations.

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Contents

1 Introduction

According to the 2015 Melbourne Mercer Global Pension Index, the highest graded two pension systems in the world belong to the Netherlands and Denmark. The index is a complex indicator of 25 countries' pension systems, in terms of Adequacy, Sustainability and Integrity. It describes the pension system relative to the country's own economic development, society and regulation system, rather than directly comparing one country to another. According to the highest grade A, the Dutch pension system is "a first class and robust retirement income system that delivers good benefits, is sustainable and has a high level of integrity". It is often regarded as a role model for a well-functioning, efficient risk-sharing pension system, with its duality of the first pillar state pension (AOW) and the second pillar occupational pension funds. The success of the system can be measured in its high replacement ratios or the fact that there is no old-age poverty. According to the OECD Pensions at a Glance (2015), the median earner's gross replacement ratio in the Netherlands is one of the highest, 90.5% and the old-age poverty is the lowest among all OECD countries: 2% of the total 65+ population.

Even such well-functioning pension systems face challenges, which have become prevalent in the recent years. Due to the changing demographic, economic and labor market trends and the newly introduced regulations, there is a continuous shift from defined benefit (DB) to defined contribution (DC) pension plans in the Netherlands, and in other countries, too. The 2008 financial crisis and the prevailing low interest and return environment highlighted the weaknesses of DB schemes for second-pillar - often corporate - pension providers: high costs and risks, unsustainability due to the changed demographics, accounting standards and the more competitive markets, as discussed by Boeri et al. (2006). At the same time, the recent tendencies in society, demographics and labor market conditions led to deeper heterogeneity of individual life-courses, explained by Bovenberg (2008a, 2008b). As participants have become more heterogeneous, their background risks also vary to a greater extent, which originate from individual-specific sources such as family, marital status, career, tenure choice and health condition, of which several stay hidden for ethical reasons. These make people less willing to share the unknown risks of others, such that the role of inter- and intragenerational solidarity in pensions may diminish, according to Bovenberg (2008b). In such heterogeneous and individualistic societies there is a rising demand for more property rights, in form of DC individual pension accounts.

An obvious consequence of the change from DB to DC plans is the shifting of risks regarding pensions from providers to participants, which requires serious rethinking of several aspects of the pension system design. To emphasize the importance of this topic, the Dutch government launched an initiative called the National Pension Dialogue, in which the key issues of the reform were discussed. According to Van Ewijk et al. (2014a), these are:

- Risk sharing: whether collective or individual schemes provide better protection against risks due to low interest rates and returns, high inflation and increasing life-expectancy.
- Freedom of choice and tailoring in pension related issues.
- Transparency: whether the paid contributions match the received pension payments.

In this thesis we relate to the second point, by focusing on the need for tailored investment strategies for retirement savings in individual DC plans. The European Insurance and Occupational Pensions Authority (EIOPA 2015) also discuss the landscape of DC investments offered for plan members within the European Union. They find that in the majority of countries still the default options play the largest role, which are tailored to the collective as a whole. The individual characteristics that are occasionally taken into account are also limited to age and average salary.

Tailoring investments for more heterogeneous employees draws the attention to their background risks and individual-specific needs. The DC instrument we study in detail is lifecycle investing, which offers great room for individualizing the investment strategies. The individual factors used for tailoring lifecycles are wage profile and housing wealth, which also go beyond the currently considered individual characteristics. Considering the heterogeneity of pension plan participants and the flexibility of lifecycle investments for individualizing, the following research questions are specified:

- *What is the added value of individualizing the lifecycle strategy by making it dependent on a number of individual factors, relative to the case when participants are considered to be equal to the representative Dutch employee?*
- *What is the benefit of individualized lifecycle strategies, considering the individual-specific information, over the default lifecycles commonly used by pension funds?*
- *What are the most important drivers of the lifecycle asset allocation decision and the pension outcome, among the individual factors to be considered in this thesis?*

Due to the ongoing pension discussion and reform initiatives in the Netherlands, improving DC instruments, e.g. by individualizing lifecycle strategies, is currently on the agenda. The relevance of the issue is underlined by the fact that assets managed in the Dutch DC industry grew from zero to 3 bln Euros in less than five years, according to Van De Grift (2016). Therefore, the results of the thesis will have, first of all, practical use for pension providers who consider individualizing lifecycle investment strategies.

The thesis also contributes to the academic studies about lifecycle theory for a number of reasons. Firstly, by considering two individual factors - wage profile and housing wealth -, our research compliments several directions of lifecycle theory. By modeling human capital in three components, we provide a detailed analysis about the impact of labor income and human wealth on lifecycle strategies and the pension outcome. Human capital is only rarely combined with housing wealth in lifecycle models, due to their different nature and modeling. Therefore, the methodology used here is also innovative, besides the practical relevance of the topic.

Following the work of Claus Munk and his fellow researchers, we develop a model to derive the optimal dynamic asset allocation through an explicit closed-form solution, instead of the numerical dynamic programming method, which is the conventional way to solve lifecycle problems. Interestingly, the original solution of a lifecycle problem without human capital is identical with that of Markowitz's mean-variance optimization, as derived by Merton (1969, 1971) and Samuelson (1969). Taking this as a hint and the approach of Munk (2016), we use the mean-variance framework with time-dependent variables and individual factors to determine the optimal lifecycle portfolio choice.

Having determined the individualized lifecycles, we compare them to default strategies which are a popular topic of behavioral economics studies. There is a wide range of literature investigating the reasons for picking defaults, however, their welfare implications and optimality is not discussed. We simulate the processes underlying the accumulation of the invested capital and retirement wealth, in order to derive expected retirement consumption and welfare. By doing so, we go beyond the results of behavioral economics and try to answer the question whether choosing a default is suboptimal or not. By comparing the different lifecycle strategies for different profiles, we provide answers for the research questions of the thesis as well.

The rest of the thesis is structured as follows. Chapter 2 introduces the institutional background behind the concept of lifecycle investing. Chapter 3 gives an overview of the related literature, first on standard lifecycle theory. Then the extensive academic evidence on the importance of defaults is introduced, often driven by "predictably irrational" reasons, as defined by Dan Ariely, one of the pioneers of behavioral economics. Lastly, the individual-specific factors to tailor lifecycle investments are described: their special features and impact on the lifecycle strategy and pension outcome. Chapter 4 summarizes the specifications of our model and describes the approach used to derive the individualized lifecycles. Chapter 5 describes the data series and the used benchmark parameters. Next, the typical default lifecycle strategies are introduced, as well as the individualized profiles, distinguished by different individual-specific characteristics of labor income and housing wealth. Chapter 6 discusses the results of the simulations for various individual profiles in terms of certainty equivalent consumption, to capture the welfare impact of individualizing lifecycle investments. Several other evaluation criteria will be introduced to get a better view on the lifecycle strategies. Chapter 7 concludes with discussing the limitations of our approach and specifying possible extensions of the model, for further research.

2 Institutional background

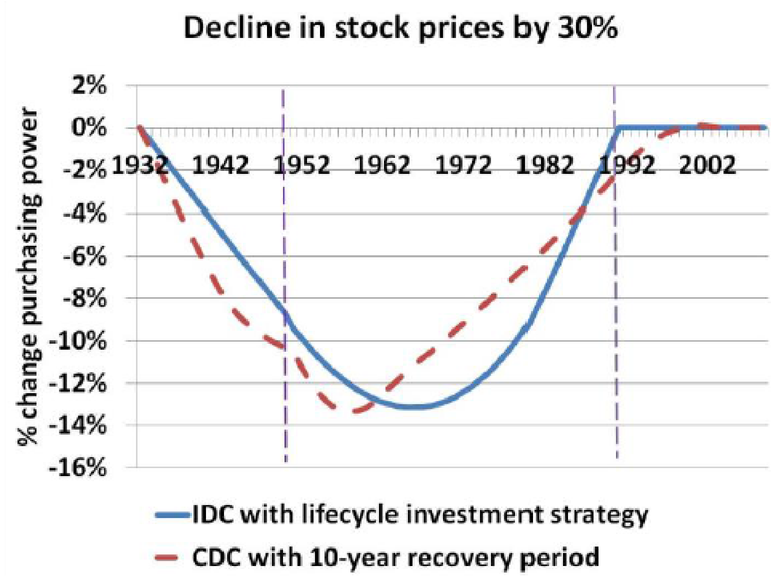
2.1 From Defined Benefit to Defined Contribution

The current tendency of shifting from DB to DC plans has two parallel driving forces, one from the providers and the other from the plan-members. For pension providers, both pension funds and corporate sponsors, running defined benefit schemes became too costly and risky following the 2008 crisis, with ever decreasing interest rates. In addition, there has been a gradual shift in demographics, leading to increasing old-age dependency ratios. The compounded effect of these changes has led to extremely low funding ratios and increasing costs of DB pensions.

In defined contribution plans, however, participants accumulate their pension on individual accounts, where they bear the risks of pension accumulation themselves. The pension benefits are accumulated based on financial market returns, so investment risk is the most obvious source of risk. Other risks borne by participants are interest rate risk and inflation risk, while both micro and macro longevity is covered by insurers. These together make the accumulation of DC pensions risky, since there are no guarantees on the benefits, as it would be in an ideal DB system. Broeders and Rijsbergen (2010) compare the critical features of the two systems, highlighting their sensitivities for the key risks: while in a defined benefit plan the funding ratio is affected negatively by the low interest rates and asset returns, making the liabilities hard to meet, in a DC system replacement ratios are exposed to the same factors and show great variations.

Another problem with DB plans is the opaque accumulation of pension benefits, due to its collective feature. Since DB plans use inter- and intragenerational risk sharing tools, the transparency of property rights over the accumulated pension wealth gets blurred. At the same time, individual heterogeneity is increasing as people lead more varied life-courses than ever, as described by Bovenberg (2008a, 2008b). The feminization of labor force, the more varied careers with several employers over the working life and the new family models are sources of heterogeneity between individuals. The diversity of life-courses, together with societies getting more individualistic, leads to the increasing importance of clear property rights and more tailored products, which are ensured by individual pension accounts of DC plans.

Besides the unclear property rights over accumulated pensions, the benefits of risk sharing within a collective are also questioned. When considering defined contribution plans, we distinguish between collective and individual DC (CDC and IDC henceforth) schemes: in CDC schemes participants share risks within the collective, e.g. in form of



Source: Boelaars et al. (2015)

Figure 2.1: The impact of intergenerational risk sharing

This figure presents the impact of a 30% draw-down in stock returns on the purchasing power of individual and collective DC pensions. The reason for the difference is the intergenerational risk sharing feature of the CDC. The %-change in purchasing power is plotted against the birth year of each cohort, showing that the actual redistribution effect of the collective contract, from older generations to those born after 1990, is relatively small. The biggest losses in purchasing power are incurred by the generations close to retirement in both contracts.

smoothing shocks between generations, while in IDC schemes fully individual accounts are maintained and there are no features of risk pooling. Figure 2.1 from Boelaars et al. (2015) illustrates the difference between collective and individual DC contracts due to intergenerational risk sharing. The change in the purchasing power of pensions is presented by birth year of participants after a 30% draw-down in stock returns. Assuming that the equity shock happens in current time, the largest loss is suffered by the generations close to retirement, having accumulated substantial amount of pension wealth already. As a result of intergenerational risk sharing in the collective contract, some of the equity risks are redistributed from the old to the generations born after 1990. In the IDC contract, young generations entering the labor markets and starting to accumulate their pensions now or in the future experience no such negative impact.

Van Ewijk et al. (2014a) and Boelaars et al. (2015) also argue that, although the collective element of second pillar pensions is typical of the Dutch system, the benefit from sharing risks with future generations is limited, due to the short recovery periods allowed for pension funds by solvency regulations. The extra certainty equivalent consumption gained over life, on average, is not more than 1%, calculated by Van Ewijk et al. (2014b). Further on in the thesis, we consider IDC schemes only, hence, no intergenerational risk sharing, and model a hypothetical second pillar pension fund offering lifecycle investment plans with fully individual accounts for pension accumulation.

2.2 What is lifecycle investing?

IDC plans, even though they do not offer risk sharing tools within a collective, do have solutions to mitigate the risks of pension accumulation. Lifecycle investing is typical of individual DC plans, where participants' contributions are dynamically invested in risky and risk-free assets, to match their risk preferences and risk capacity. The British National Employment Savings Trust (NEST) provides definitions for the concepts of risk preference and risk capacity in their 2012 report. Risk preference is the attitude of the individual to savings and risks, while risk capacity is the ability of the members to take investment risk, as a function of demographic characteristics, earnings, wealth, financial literacy, etc. According to NEST, one's risk capacity is what determines the ability to deal with investment losses too.

Morin and Suarez (1983) argue the positive relation between risk aversion level and age, however, standard lifecycle theory assumes constant relative risk aversion. In the first lifecycle models of Merton (1969, 1971) and Samuelson (1969), the optimal lifecycle strategy is in fact constant over time. The decreasing lifecycle patterns are derived from model 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 $(100 - age)\%$.

Lifecycle 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, in theory.

Since there is no collective or intergenerational risk sharing, the issue of macro longevity is not covered in a lifecycle fund. In the Netherlands, Boelaars et al. (2015) argue that neither is inflation risk, since in the Euro area, similar to most countries, it is a non-traded risk factor, due to the insufficient depth of markets for inflation-linked bonds. The conversion to the annuity depends on the risk-free interest rate available at retirement age. Due to their stochastic nature and the long horizon of the investment, interest rate risk is also relevant and substantial in the accumulation phase. It can be hedged by matching the duration of the risk-free portfolio to the duration of the pension liability.

Although efficient in the accumulation phase of pensions, lifecycles with fixed annuities are quite rigid in the decumulation during retirement. New initiatives, such as variable annuities and the idea to keep exposure to the risky asset in retirement, are introduced to make the decumulation phase more flexible and adapt to the current economic environment with low interest rates and equity returns.

2.3 The focus of our research

Modeling individual DC pension funds and lifecycle investments involves several risk factors and possible specifications. In this section we define what is applicable for our model and what is not. We limit the considered risk factors to the investment risk from the lifecycle strategies and the risks of the chosen individual factors: labor income and housing wealth. 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, as they are not the main focus of this research.

In our setting, we model a hypothetical IDC pension fund with individual accounts, exogenous contribution rates and participants are offered lifecycle investments that consist of two assets: a risky and a risk-free. The risky asset is in fact a stock-only portfolio, represented by a benchmark equity index. The accumulated capital is converted into a fixed annuity, with respect to the constant risk-free rate and fixed life expectancy. These specifications either serve the purpose of simplicity (e.g. only two asset classes in the lifecycle portfolio) or resemble the current regulatory framework (such as fixed annuities).

To individualize lifecycle investments, we consider two individual factors: wage profile and housing wealth, and derive a closed-form solution from the mean-variance framework, instead of solving the typical dynamic programming problem of lifecycle 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 lifecycles. 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 lifecycle.

Our research is designed to compare lifecycle 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 lifecycle 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 lifecycles to provide larger welfare gains for profiles far from this benchmark.

Collecting the individual information takes time and resources to develop adequate and efficient surveys. The risk of getting false or no information at all is also significant. To derive a cost-benefit analysis, the costs of both the providers and the participants need to be quantified similar to the benefits, in terms of certainty equivalent consumption. However, in this thesis no such analysis is considered, we do not derive net-of-costs or break-even welfare gains.

3 Literature overview

3.1 Lifecycle theory

The academic theory of the optimal lifecycle investment strategy originates from Merton (1969, 1971) and Samuelson (1971), even though these first results indicate a time-independent solution for the optimal portfolio weights, with no lifecycle 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:

$$\alpha_S = \frac{\mu_S - r_f}{\gamma \sigma_S^2} \tag{3.1}$$

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. Despite the same solution, the two models - mean-variance analysis and lifecycle model with CRRA utility function - are considerably different. Firstly, the mean-variance problem optimizes the weight invested in the risky asset, while lifecycle models determine the optimal consumption rate and, thus, the amount of wealth to be invested, and also optimize the asset allocation strategy of the invested amount. They also differ in the investment horizon: while a mean-variance investor is myopic, considering his end-of-period wealth, lifecycle investments optimize for a long period, and define dynamic asset allocation strategies. It is, however, not a coincidence that the two models lead to the same formula: Campbell and Viceira (2002) show that under certain assumptions, the two optimization problems are equivalent for the single- and multi-period models. Assuming independent and identically distributed (i.i.d.) lognormal returns and power utility function over wealth, Campbell and Viceira transform the objective CRRA function into the mean-variance utility function, resulting in the same solution for the myopic case. Further assumptions on re-balancing lead to the same, identical solutions for multi-period models too, although we do not consider these in further detail. When consumption is included in the lifecycle model, with power utility function and i.i.d. returns, Campbell and Viceira show that the myopic, time-invariant portfolio choice is the optimal for constant consumption-wealth ratios (Campbell & Viceira (2002), Ch. 2.2.3, p. 33). In the mean-variance problem, consumption is not a decision variable at all, only the optimal portfolio weight is. Given the idea of the constant consumption-wealth ratio, by using exogenous contribution rates, we define periodic consumption during the investment horizon as the remainder of the periodic income after paying the fixed contribution to the pension plan. In this way, there is no need to determine optimal consumption, only the optimal portfolio choice, where the invested wealth is the capital accumulating on the IDC account.

Further literature on lifecycle 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 lifecycle theory, since it is well-known to generate the lifecycle 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.

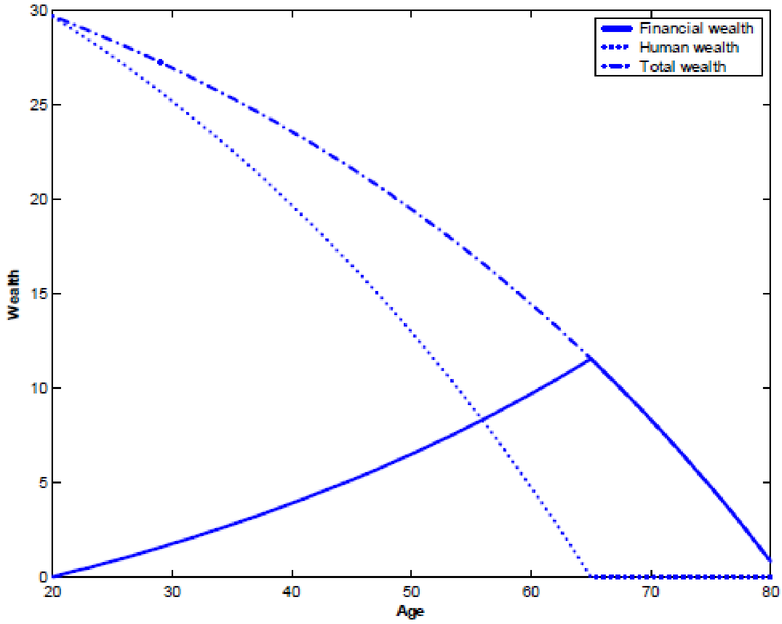
$$L_t = \mathrm{E_t}\left[\sum_{s=1}^{T-t} PV(Y_s)\right] = \sum_{s=1}^{T-t} \frac{1}{(1+r_f)^s} \cdot \mathrm{E}\left[Y_s\right], \tag{3.2}$$

with L_t human capital, Y_s annual labor income and $T-t$ marking the length of remaining working life in years. In standard lifecycle theory, besides financial wealth, it is the other component of one's total wealth. 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 retirement. The ratio of human capital over financial wealth decreases by age due to the two parallel processes and generates the lifecycle 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) extended the initial solution (3.1) 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:

$$\alpha_{S,t} = \frac{\mu_S - r_f}{\gamma \sigma_S^2}\left(1 + \frac{L_t}{F_t}\right) \tag{3.3}$$

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



Source: Bovenberg et al. (2007)

Figure 3.1: Evolution of human, financial and total wealth over life

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, markets 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 capped at 100% maximum. Constraints like this make the strategies differ from the actual optimal lifecycles and therefore, question the optimality of results from such truncated strategies.

Other studies elaborate on the individual-specific aspects of human capital and its impact on the lifecycle asset allocation decision. Campbell et al. (1999) and Cocco et al. (2005) (henceforth CCGM and CGM) study stochastic labor income of different profiles. Although assuming stochastic labor income, it is still considered to mimic the risk-free asset closer than the risky, which means the decreasing risky asset allocation still holds. They distinguish individuals on the basis of education and the industry of their occupation to describe the riskiness of one's labor income. The cross-sectional variation of individuals in these factors is reflected in their lifecycle asset allocation strategies too.

In spite of the theory recommending young participants to allocate most of their investments to risky assets, the empirical evidence shows the opposite, young investors hardly exposed to risky assets, which increases by age. Sablik (2014) summarizes the possible reasons for this puzzle: other risks that young individuals face, like labor and housing market risks, and the high costs of entering equity markets.

Another approach in lifecycle theory considers human capital a more stock-like asset, depending on the correlation between labor income and stock returns. So far this was assumed to be zero, however, Benzoni, Collin-Dufresne and Goldstein (2007) study the long-run co-integration of dividend yields and labor income, and suggest non-zero correlation between stocks and labor income. In this case, young investors, having most of their wealth in form of their human capital, are already exposed implicitly to stock market risk to a great extent, thus, they should have low, even negative positions in equity, which should evolve in a hump shape during later life.

However, the approach could not take over the role of conventional lifecycle theory, and was proved to be empirically insignificant. Bikker et al. (2009) investigate whether Dutch occupational pension funds, with typically collective arrangements, follow lifecycle patterns in their investment portfolios, namely by age decreasing or hump-shaped risky asset share. They find statistically significant results for the negative relationship between average participant age and asset allocation, but reject the approach of Benzoni et al. Similarly, Inkmann and Shi (2014) find significant results for decreasing risky asset share with age, when studying the default investment policies of Australian DC pension funds. In this thesis we also follow the standard lifecycle approach with the risky asset share declining by age.

3.2 Defaults versus Individualization

We argued that the development of greater heterogeneity in individual lifecourses, based on Bovenberg (2008a, 2008b), supports the concept of individual accounts of the IDC scheme. For the same reason, in parallel with the disappearing solidarity and benefits of collective risk sharing, there is also an increasing demand for more tailored, individualized solutions in the pension system. Due to the shift of risks to pension fund participants, attention needs to be directed to their own preferences and needs, which vary with the diversity of individuals and their background risks. This increases the importance of individualized products against default solutions designed for the average, representative plan member. It has been empirically proven by Inkmann and Shi (2014) that greater heterogeneity of the participant-base leads to a drop in the relative importance of default funds within a DC scheme. They study the role of default strategies in Australian DC pension funds, and find significant results in support of the hypothesis that the share of total plan assets allocated to the default fund declines as the age dispersion of participants increases. 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.

3.2.1 Participant's point of view

Uniform default options in pension funds have their own advantages both for participants and providers. There is extensive literature on participants' financial decisions related to their pensions. These decisions often originate from mental shortcuts, to simplify complex decisions by substituting them with a simpler idea, labeled as the availability heuristic by Kahneman and Tversky (1973), which often lead to systematic deviations from the optimal choice in form of biases. 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. The empirical study of Iyengar, Huberman and Jiang (2003) reveals that 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. Iyengar et al. find that as the number of investment choices, here the number of available U.S. 401(k) plans, increased, the participation rate declined.

When facing the choice of lifecycle strategy, participants often rely on typical heuristics, such as the fifty-fifty split or the diversification heuristic of the "$1/n$ rule" with n being the number of assets, allocating weights evenly across them, as discussed by Benartzi and Thaler (2007). The "$1/n$"diversification was captured in several experiments with varying results. Huberman and Jiang (2006) find statistically significant but economically negligible results for the explanatory power of the number of funds offered, on the chosen equity allocation. Therefore, the hypothesis that participants act rationally in presence of this framing effect cannot be rejected. On the other hand, Benartzi and Thaler (2007) find significant positive correlations between the relative number of equity funds among total funds offered and the percentage invested in equities. Too much choice, thus, leads to either less willingness to participate in the market, see Iyengar et al. (2003), or to the tendency to choose simpler outcomes, e.g. driven by the diversification heuristic as in the experiment of Benartzi and Thaler (2007). Iyengar and Kamenica (2010) draw their conclusion consistent with the previous two observations: as the number of available funds increases, the decision becomes more complex and the final asset allocation is affected so that the exposure to equities declines. The underlying intuition may well be that investing in relatively low-risk assets like money-market funds or bonds is regarded as the simple alternative with the least regret. However, these examples are only valid for pension systems where the portfolio is chosen entirely by the participant, such as in the U.S. 401(k) DC plans.

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 too much regret due to making a wrong decision. It is closely related to prospect theory and the concept of loss aversion by Kahneman and Tversky (1979): bad outcomes have a larger negative psychological impact on us than an equally good outcome's positive impact, measured from a fixed reference point. This explains why we have a tendency to strongly prefer avoiding losses against incurring gains.

Further, phenomena like inertia and endowment effect highlight the importance of well-designed defaults, since individuals tend to stick with their choice and do not pick again, having chosen a default. Inertia describes the fact that after making the first choice, individuals do not tend to change, while endowment effect explains the reason for it: facing a possible bad outcome as a result of an own, active decision is valued as worse than incurring losses passively, due to not changing.

Default options attract even more interest among financially illiterate plan members, as confirmed by the empirical findings of Agnew and Szykman (2005). The fact that most plan-members have no financial background knowledge might explain not only the tendency to pick default options too often, but also other behavioral biases, such as avoiding active decision. Defaults often stand for the choice of not choosing or following the "path of least resistance". This is a form of procrastination according to Inkmann and Shi (2014), typical of participants who are not aware of the importance of starting early with retirement savings and therefore, delay the decision. Lastly, according to Choi et al. (2003), employees might interpret the offered defaults as an implicit investment advice from the pension fund. When considering the social responsibility of pension providers and financial institutions, this argument becomes highly relevant.

The mentioned literature only studies the driving forces that make participants choose the defaults. This research, however, investigates the optimality and welfare implications of choosing default strategies, which is a considerable added value to the literature on defaults. Based on Choi et al. (2003) and Inkmann and Shi (2014), we expect larger welfare dispersion, resulting from the same default strategy, across individuals when the participant-base is more heterogeneous. Further, for individuals far from the representative profile, the defaults should perform worse than for close-to-average profiles.

3.2.2 Provider's point of view

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 they provide adequate level of welfare, satisfying the criteria for socially responsible pension providers. By deriving the certainty equivalent consumption for each studied lifecycle strategy, we show whether the welfare implications of defaults are in line with the discussed advantages of choosing and offering them.

3.3 New risk factors in the lifecycle asset allocation

Supported by 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 lifecycle asset allocation. The individual characteristics that we describe and model are individual wage 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 lifecycle model to quantify the impact of changes in marital status and family composition, on the lifecycle 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 thesis.

3.3.1 Individual wage profiles

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 lifecycle theory. In CCGM (1999) and CGM (2005)[3], 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. approach about hump-shaped lifecycles, 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 lifecycles that do not

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

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.

3.3.2 Housing wealth

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 4^{th} pillar of pensions, as by Holzmann and Hinz (2005) from the World Bank. Arts and Ponds (2016) discuss the role of flexibility to capitalize housing wealth into consumable retirement income, regarding the Dutch case. Here, we consider its role at the lifecycle 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. As we will study homeownership, we only consider private residential real estate as an asset in the individual's total wealth. The Norges Bank Investment Management (NBIM) (2015) discusses the risk-return profile of private residential real estate and its relation to other assets within a portfolio: most importantly, it is the diversification benefits, due to its low correlations with other assets, that make it attractive for portfolios. Besides the asset-specific risks, homeownership comes with house price risk, while it provides housing services to consume. According to Sinai and Souleles (2002), house price risk becomes relevant for households only when the house is sold, while it is a hedge against the constant fluctuation of rent prices, that is continuously sensed by renters. On the other hand, according to Rouwendal (2007), households do consider house price fluctuations, in order to determine their wealth position, which consequently will affect consumption, and in our case the lifecycle asset allocation decision.

As for the impact of housing on the asset allocation, 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 of individuals regarding their house-value-to-wealth ratios, to show the lifecycle 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. Ignoring labor income and only considering housing wealth, thus, leads to the so-called inverted lifecycles, similar to that of Benzoni et al. (2007), and could explain the puzzle of young people investing less in risky assets than theory dictates, as argued by Sablik (2014).

There is a small branch of lifecycle 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 lifecycle patterns suggested by the standard theory on lifecycle 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.

4 Model specifications and evaluation

Having introduced the related literature, now we specify the details of our model. First, we define the stochastic processes underlying the pension accumulation and evolution of individual wealth. Next, the utility function is specified so that the welfare from each investment strategy can be quantified in terms of their provided certainty equivalent consumption. The special focus of this thesis is individualizing lifecycle strategies, by considering certain individual-specific factors in the portfolio choice. Therefore, we need a model to incorporate the individual information in the asset allocation decision, which is also introduced in this chapter.

4.1 Model specifications

Our setup models a hypothetical individual DC pension plan with lifecycle investments. 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 lifecycle investment period is at age 66. The model simulates the pension outcome of various lifecycle strategies for different individual profiles. The lifecycle 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 lifecycle 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.

4.1.1 Labor income process

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

$$Y_{i,t+1} = Y_{i,t} \cdot (1 + \underbrace{w_{i,t+1}}_{\text{career path}} + \underbrace{\nu_{t+1}}_{\text{aggregate shock}} + \underbrace{\varepsilon_{i,t+1}}_{\text{idiosyncratic shock}}), \tag{4.1}$$

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.

First, we derive the processes for the three correlated random variables by using the Cholesky-decomposition of the 3×3 correlation matrix R, following the approach of Ascheberg et al. (2013) with unspanned labor income risks. The three correlated random variables are stock returns $\frac{dS_t}{S_t}$, house price returns $\frac{dH_t}{H_t}$ and returns on the aggregate wage series $\nu_{t+1} = \frac{dY_t}{Y_t}$:

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

where $\hat{\rho}_{YH} = \frac{\rho_{YH} - \rho_{SH}\rho_{SY}}{\sqrt{1-\rho_{SH}^2}}$. 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 (4.1) to derive the next-period labor income of individual i, with a fourth, independent random variable, $\varepsilon_{i,t+1}$. The stochastic processes are simulated for 2000 scenarios, but the risk-free interest rate and inflation are considered to be constant, since we do not consider the interest rate and inflation risk of the pension accumulation in our model, as specified previously.

4.1.2 Individual total wealth before retirement

To derive total wealth relevant for the lifecycle investment, we use a dynamic balance sheet approach to present the assets and liabilities of the individual for any time t, as in Table 4.1. Financial wealth, $F_{i,t}$ is the actual amount accumulated on the IDC account, thus, only the retirement savings. We assume the individual has no other financial wealth or savings accounts.

Assets at time t	Liabilities at time t
F_t financial wealth	Mortgage balance
H_t house	
PV(mortgage installments)	
PV(contributions)	

Table 4.1: Balance sheet of the individual's total wealth at time t

The academic literature concludes that the impact of an owner-occupied house on the lifecycle portfolio strongly depends on its riskiness due to the mortgage debt. Therefore, housing wealth is modeled as two discrete components in the total wealth: firstly, the actual market value of the owner-occupied dwelling, $H_{i,t}$ on the asset side and secondly, the underlying mortgage loan on the home, in form of a short bond on the liability side. Most individuals, when purchasing a home, do not have sufficient savings, especially among the young. Above their initial savings of down-payments, they can request a mortgage loan backed by the house as collateral. New regulations regarding mortgages lower the maximal loan-to-value, as discussed by Arts and Ponds (2016). Nevertheless, in our setup we allow for $\kappa = 100\%$ maximal loan-to-value (LTV). While market prices of houses are changing over time according to the process specified in Section 4.1.1., correlated with stock prices and labor income, the face value of the mortgage is determined at the time of the house-purchase. The loan is defined as a linear mortgage with fixed interest rate, equal to the long-term expectation on risk-free rate, for the whole life of the loan with maturity $T = 30$ years. Therefore, it is considered to be a risk-free bond issued by the individual, being payed back gradually in 30 equal I installments of principal and interest. By each installment-repayment, the liability exposure to the mortgage is decreasing until it reaches zero at maturity.

$$SB_{i,0} = -\kappa \cdot H_{i,0} = -\sum_{t=1}^{T} \frac{I}{(1+r_f)^t} = -\left(I \cdot \frac{1-(1+r_f)^{-T}}{r_f} \right)$$

$$I = \kappa \cdot H_{i,0} \cdot \frac{1}{\frac{1-(1+r_f)^{-T}}{r_f}}$$

The value of the mortgage balance, $SB_{i,t}$, at any year t before the maturity of the mortgage is equal to the discounted sum of the remaining installments to be paid until maturity:

$$SB_{i,t} = \begin{cases} -\left(\sum\limits_{s=1}^{30-t} \frac{I}{(1+r_f)^s}\right) & \text{if } 0 \leq t < 30 \\ 0 & \text{if } t = 30 \end{cases}$$

From which, the next-period mortgage balance is $SB_{i,t+1} = SB_{i,t} \cdot (1 + r_f) + I$, detailed in Appendix A1.

The last source of individual wealth is human capital, which is derived from labor income. Labor income at any time t is used for three purposes. First, to pay contributions for pensions in form of the FR_t franchise to the state pension system and, from the remaining $Y_{i,t} - FR_t$ amount, to the DC pension plan to the extent of the exogenous c_t contribution rate. Since the contributions are determined by law, the remaining income, left for consumption is also fixed, there is no endogenous decision about it, in contrast to typical lifecycle models. The remaining income is $(1 - c_t) \cdot (Y_{i,t} - FR_t)$, from which the periodic mortgage installment I is repaid and the rest is assumed to be fully consumed.

Analogously, human capital, as the discounted sum of expected future labor income, can be decomposed into three similar terms: the present value of the contributions to be paid to the IDC account for the remaining years of the pension accumulation, the present value of the future mortgage arrangements to repay the loan and the discounted sum of the consumption stream during the investment period, a.k.a. working life. However, consumption is not presented in the balance sheet, since it is not an asset and we do not optimize it in the investment decision either. The discounted sum of the to-be-paid mortgage arrangements on the asset side has to be equal to the actual mortgage balance on the liability side. After these are canceled out, human capital consists of the remaining present value of the contribution-stream to be paid to the DC pension plan:

$$L_{i,t} = \mathrm{E_t}\left[\sum_{s=1}^{T-t} PV(c_s \cdot (Y_{i,s} - FR_s))\right] = \sum_{s=1}^{T-t} \frac{c_s \cdot \mathrm{E}[Y_{i,s} - FR_s]}{(1 + r_f)^s}, \tag{4.2}$$

where $T = 30$ years, as the length of the remaining working life for a 37 years old employee. Similar to the mortgage position, next-period human capital is derived as: $L_{i,t+1} = L_{i,t} \cdot (1 + r_f) - c_{t+1} \cdot (Y_{i,t+1} - FR_{t+1})$, explained in detail in Appendix A1. The periodic return over human capital is expressed as $\frac{L_{i,t+1}}{L_{i,t}} - 1 = \mu_{L,t+1}$.

The individual's total wealth relevant for the lifecycle 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 $L_{i,t}$:

$$W_{i,t} = F_{i,t} + H_{i,t} + L_{i,t} \tag{4.3}$$

Consequently, next-period wealth is derived from the returns on the lifecycle portfolio, the house prices and from the expectations on labor income:

$$W_{i,t+1} = F_{i,t} \cdot (1 + r^{IDC}_{i,t+1}) + H_{i,t} \cdot (1 + r_H) + L_{i,t+1}$$

$$W_{i,t+1} = F_{i,t}(1 + r^{IDC}_{i,t+1}) + H_{i,t}(1 + r_H) + L_{i,t}(1 + r_f) - c_{t+1}(Y_{i,t+1} - FR_{t+1}) \tag{4.4}$$

4.1.3 Accumulation of DC capital

The modeled hypothetical individual DC plan offers individual accounts for participants, where pre-determined contributions are paid on an annual basis. The contribution rates, c_t, are increasing by age, but they follow the same increase for every employee. Due to the rapidly growing DC industry, we assume that the IDC account, as the financial wealth in equation (4.3) and (4.4), stands for the entire second pillar pension of the individual, hence, we do not consider any collective or DB type of pension accumulation. The contribution base is equal to the annual earnings net of first-pillar pension premiums, the AOW Franchise FR_t, regardless of taxes, bonuses and other costs or benefits to it.[4]

The investment policy of the pension fund is specified in lifecycle 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 lifecycle portfolio is the linear combination of the two asset returns. The evolution of the capital invested in the DC pension fund, which is identical with $F_{i,t}$, is determined as:

$$F_{i,t+1} = DCC_{i,t+1} = (DCC_{i,t} + c_t \cdot (Y_{it} - FR_t)) \cdot (1 + r^{IDC}_{i,t+1}), \tag{4.5}$$

where $r^{IDC}_{i,t+1} = \alpha_{S,t} \cdot r_S + (1 - \alpha_{S,t}) \cdot r_f$ is the lifecycle portfolio return depending on the time t allocation between the risky and risk-free assets, with $\alpha_{S,t}$ share of the risky asset.

[4] The annual Franchise is 12 953 €, as of 2016 data by the Belastingdienst, and together with the first-pillar AOW pension, it is linked to the statutory minimum wage and assumed to grow with the aggregate wage growth rate in nominal terms: $AOW_{t+1} = AOW_t \cdot (1 + \nu_{t+1})$.

4.1.4 Annuitization

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 until the end of the participant's life, which is assumed to last at maximum until the age of $D = 110$. In the Netherlands, full annuitization is compulsory by law, currently only to a fixed annuity, based on the risk-free interest rate available at the moment of conversion. The unfavorable impact of the low interest rate environment on the DC annuity is intended to be changed and improved by the introduction of variable annuities. However, we consider the case of fixed annuities, with an actuarial factor defined as a function of the risk-free rate and the appropriate survival-probabilities. The actuarial factor is calculated for a 67 year-old male, assuming that the participant survives until retirement with a probability of 1.

$$A_{x,t}^{(g)} = 1 + \mathrm{E_t}\left[\sum_{\tau \geq 1}^{D} \frac{1_{i,t+\tau}}{(1+r_f)^\tau}\right] = 1 + \sum_{\tau \geq 1}^{D} {}_\tau p_{x,t}^{(g)} \cdot \frac{1}{(1+r_f)^\tau} \tag{4.6}$$

The value of the described annuity is the τ-year survival probability-weighted discounted present value of periodic payments of unity. The appropriate τ-year survival probabilities are derived from mortality rates of the Dutch population. In this case, it is the price of an annuity for an $x = 67$ years old, g =male at the $t = 31^{\text{st}}$ year of the model and it is used to convert the DC capital into equal periodic pension payments of a today 37-year old participant, entering his IDC contract now, at $t = 1$. The nominal amount of the DC pension payment after purchasing the annuity is:

$$DCP_i = \frac{DCC_{i,R}}{A_{x,R}^{(g)}} \tag{4.7}$$

per year, for the remaining lifetime of the participant.

4.1.5 Retirement wealth and pension income

We determine the individualized lifecycle strategies conditional on the wealth composition of the employee in working life, which makes it reasonable to consider total wealth similarly in retirement too. 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.

$$W_{i,R} = DCC_{i,R} + H_{i,R} \tag{4.8}$$

In the analysis, first-pillar state pensions are not considered since we assume that the AOW provides the subsistence consumption level for every participant, therefore, we only focus on the pure DC pension outcome of different lifecycle investment strategies.[5]

The pension outcome of the second-pillar DC plan is the annuitized capital, which serves as liquid consumable income above the AOW pensions. Housing wealth, on the other hand, is a substantial part of retirement wealth but locked-up in an illiquid asset. With riskier pension accumulation of DC plans, parallel with new regulations on safer annuity-mortgages, Arts and Ponds (2016) argue that future pensioners need more flexibility to retrieve additional pension income by capitalizing their homes. The higher uncertainty of future DC pensions could be offset, but at least mitigated by gaining access to this large, illiquid part of their wealth. The possible tool recommended by Arts and Ponds, is a reverse mortgage against the capital built up in the home. Our evaluation approach also implicitly considers and suggests the capitalization of housing wealth into a liquid consumable stream of income. The reverse mortgage in form of periodic payments from the lender can serve as a supplement to the pension income from the other two sources. The conditions of the reverse mortgage can vary across individuals, in terms of maturity, loan-to-value, interests, etc. In our setting, it is considered to be an annuity: equal payments received until the end of one's life, with 100% LTV assuming no bequests at all, thus capitalizing the entire value of the house. The interest is equal to the risk free rate. Such a loan is "repaid" from the proceeds of selling the house after the borrower passes away. Therefore, the annual pension income, excluding AOW state pensions, consists of the equal periodic payments of the purchased annuity and installments paid by the reverse mortgage.

$$Y_i^R = DCP_i + Reverse\ mortgage_i \tag{4.9}$$

4.2 Welfare evaluation

We defined 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

[5] First pillar pension rights are accrued to all residents between the age 17 and 67 in the Netherlands, but full AOW pension rights are entitled for those who spent all the 50 years here with a resident status. The full amount of annual AOW benefit in January, 2016 was 9 715€ for a married retiree, as of the Belastingdienst.

constant relative risk aversion utility function, as of CCGM (1999):

$$E_R[U(C)] = E_R\left[\sum_{t=1}^{D=110} \delta^{t-1}\left(\prod_{j=0}^{t-1} p_j\right)\frac{C^{1-\gamma}}{1-\gamma}\right] \tag{4.10}$$

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. Bovenberg et al. (2007) specify the most important features of CRRA preferences: firstly, utility always increases in consumption, but at a diminishing rate of marginal utility, at higher levels of consumption. The positive and constant relative risk aversion implies that individuals prefer consumption smoothing over time or across contingencies. They have a taste for stable rather than volatile consumption streams. Since no bequest motives are assumed, the periodic consumption of the retiree equals his pension income: $C = Y_i^R$.

The CRRA utility function captures the expected consumption-volatility trade-off conditional on the individual's risk aversion level. However, instead of comparing utility levels, annual certainty equivalent consumptions (CEC) are derived to evaluate each strategy, as they have a more intuitive interpretation. Over 2000 scenarios, the outcome of the lifecycle strategies is simulated, resulting in a wide range of possible retirement consumption levels and $U(C)$ utilities. The expected utility and consumption levels for each lifecycle strategy are derived by Monte-Carlo simulations, as the average of the 2000 simulated scenarios, and the CE consumption is calculated from $\mathrm{E}[U(C)]$.

$$E[U(C)] = U(CEC)$$

$$U(CEC) = \sum_{t=1}^{D=110} \delta^{t-1}\left(\prod_{j=0}^{t-1} p_j\right)\frac{CEC^{1-\gamma}}{1-\gamma}$$

$$CEC = \left(\frac{E[U(C)]\cdot(1-\gamma)}{\sum_{t=1}^{D=110} \delta^{t-1}\left(\prod_{j=0}^{t-1} p_j\right)}\right)^{\frac{1}{1-\gamma}} \tag{4.11}$$

Intuitively, risk aversion and the riskiness of the outcome will affect the CEC: for higher risk aversions and volatilities, the CEC will be lower, while higher volatilities also yield higher $\mathrm{E}[C]$. The difference $\mathrm{E}[C] - CEC$ is the risk premium that is given up from the risky expected consumption, to trade risk for certainty. Thus, the risk premium is higher for more volatile consumption streams and for more risk averse individuals, who are willing to give up more from the risky expected consumption for certainty. Besides the welfare evaluation, replacement ratios and downside measures will be also used to compare the different lifecycles and their pension outcomes.

4.3 Individualized lifecycles

By individualizing lifecycles, we mean including individual-specific characteristics in the investor's optimization problem. In standard lifecyle theory, the objective is to maximize life-time utility over consumption, by determining the optimal consumption rate and the share of savings invested in risky assets versus risk-free, which is solved by dynamic programming. Instead of dynamic programming, however, we follow the idea 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. Their models, however, ignore consumption as a decision variable, which is also an important tool to mitigate investment shocks in standard lifecycle models, besides the optimal portfolio choice. By assuming exogenous contribution rates and no savings beyond the IDC account, we resolve the lack of consumption in our model.

Our model, although builds on their approach, substantially differs in certain aspects. Flavin and Yamashita (2002) and Munk (2016) follow the myopic framework of the mean-variance theory to determine the optimal asset allocation for separate individuals with a given amount of human capital and housing. This cross-sectional comparison of individuals with different $\frac{L_{i,t}}{F_{i,t}}$ and $\frac{H_{i,t}}{F_{i,t}}$ ratios does yield results consistent with lifecycle theory, however, it does not provide complete lifecycle strategies to be able to simulate the evolution of the investment. We go beyond their work, by using the mean-variance approach, together with time-dependent variables and long-term capital market expectations, to derive a time-dependent, multi-period lifecycle strategy and follow how the invested capital evolves.

To do so, we optimize the return over periodic wealth, defined in equation (4.4), taking the time t expected value of human capital and housing wealth, the two time-dependent individual-specific factors. The mean-variance utility, as our objective function, is:

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

With the expected return over wealth and its variance specified as:

$$\frac{W_{i,t+1}}{W_{i,t}} = \frac{F_{i,t+1} + H_{i,t+1} + L_{i,t+1}}{W_{i,t}}$$

$$\mathrm{E}\left[\frac{W_{i,t+1}}{W_{i,t}}\right] = \frac{F_{i,t}}{W_{i,t}}(1 + r_f + \alpha_{S,t+1}(\mu_S - r_f)) + \frac{H_{i,t}}{W_{i,t}}(1+\mu_H) + \frac{L_{i,t}}{W_{i,t}}(1+\mu_L)$$

$$\mathrm{Var}\left[\frac{W_{i,t+1}}{W_{i,t}}\right] = \left(\frac{F_{i,t}}{W_{i,t}}\right)^2\cdot\alpha_{S,t+1}^2\cdot\sigma_S^2 + \left(\frac{H_{i,t}}{W_{i,t}}\right)^2\cdot\sigma_H^2 + \left(\frac{L_{i,t}}{W_{i,t}}\right)^2\cdot\sigma_L^2 +$$

$$+2 \cdot \frac{F_{i,t} L_{i,t}}{W_{i,t}} \cdot \alpha_{S,t+1} \cdot \sigma_{S,L} + 2 \cdot \frac{F_{i,t} H_{i,t}}{W_{i,t}} \cdot \alpha_{S,t+1} \cdot \sigma_{S,H} + 2 \cdot \frac{L_{i,t} H_{i,t}}{W_{i,t}} \cdot \sigma_{L,H},$$

with $\sigma_{i,j}$ covariance between assets i and j. σ_L^2 represents the variance of human capital (4.2), which is driven by the individual labor income process (4.1), while the risk-free rate is constant. Therefore, the only 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.

In contrast to the literature, housing wealth is considered as an exogenously given asset in the individual's wealth, which is not optimized by pension providers. The only decision variable is the optimal risky asset share for time $t+1$, which is[6]:

$$\alpha_{S,t+1} = \underbrace{\frac{\mu_S - r_f}{\gamma \sigma_S^2}}_{\text{Merton-solution}} \cdot \underbrace{\left(1 + \frac{L_{i,t} + H_{i,t}}{F_{i,t}}\right)}_{\text{leverage effect}} \underbrace{- \frac{L_{i,t}}{F_{i,t}} \cdot \frac{\sigma_{S,Y}}{\sigma_S^2} - \frac{H_{i,t}}{F_{i,t}} \cdot \frac{\sigma_{S,H}}{\sigma_S^2}}_{\text{hedging demand terms}} \tag{4.12}$$

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 lifecycle 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. As defined in the balance sheet of Table 4.1, the outstanding mortgage is canceled out, and housing wealth is only represented by the time t market value of the owner-occupied home. Therefore, housing provides leverage even if there is mortgage debt behind it, in contrast to the related literature. The leverage from human capital is decreasing by time, while in case of housing, it is uncertain. Under certain scenarios, house prices can increase by more than stocks, and hence, than financial wealth, although this also depends on the assumed stock-house correlations. Due to the pairwise 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 lifecycle 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

[6] The first order condition of the objective function and the detailed derivation of the optimal asset allocation can be found in Appendix A1.

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 lifecycle 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 lifecycles.

5 Data and Research Design

This chapter will summarize the data used to parametrize our model and simulate the pension accumulation of a participant of the hypothetical individual DC pension fund. It provides both historical and forward-looking long-term summary statistics on the previously specified stochastic and deterministic variables. Next, we proceed to describe the different directions of our research, which is based on the comparison of various individuals and their pension outcome via several lifecycle investment strategies. Individuals are compared based on the features of their labor income and housing wealth. The default lifecycles will be also introduced in this chapter.

5.1 Baseline parameter values

When specifying the process underlying the individual labor income, the stochastic aggregate wage growth rate, ν_{t+1} is modeled as a random variable correlated with two other market processes, stock and house price returns. The parameters for the correlated processes were estimated from three time-series of annual data from 1970 to 2015 and then used to simulate the variables for the next 50-year period, with 2000 scenarios each.

5.1.1 Stock investments

For stock markets the MSCI World Index is taken, hedged and denominated in EUR, since we use Dutch, EUR denominated data for every other market variable. The MSCI World Index represents a well-diversified, pure equity portfolio, which we assume to be the risky asset in the lifecycle portfolio. It captures large and mid cap companies, diversified across 23 developed market countries, with the largest, roughly 60% weight of the US in it, and covering various sectors. In real-life pension funds, the risky asset, so-called Return Fund, consists of more asset classes than only equities, resulting from strategic asset allocation models. Even though this implies a more diversified Return Fund, we neglect the benefits of diversification as it is not the objective of our research. Similar to the related literature, we investigate the asset allocation simply between risky and risk-free assets within the portfolio.

5.1.2 Private residential real estate

The Bank of International Settlements (BIS) constructed long series on nominal residential property prices based on quarterly information for 18 advanced and 5 developing economies, documented by Scatigna et al. (2014). These series capture the evolution of private residential real estate prices since 1970. However, they have several imperfections due to the scarcity of data and the fact that they are constructed from shorter data sets available for different time periods from a variety of sources. There is a wide range of statistical methods used to harmonize the series but the types of dwellings and geographical areas the data cover are so varied that it makes the comparability of countries questionable. For our analysis, we take the Dutch series of BIS as a starting point for private residential property prices. This is constructed from the following sources: between 1995 and 2015 quarterly data is available on residential property prices, including all dwellings, provided by Statistics Netherlands. From 1976 until 1995 prices of existing dwellings are recorded and lastly, between 1970 and 1975, actual sales prices of houses and apartments brokered by real estate agents are available[7].

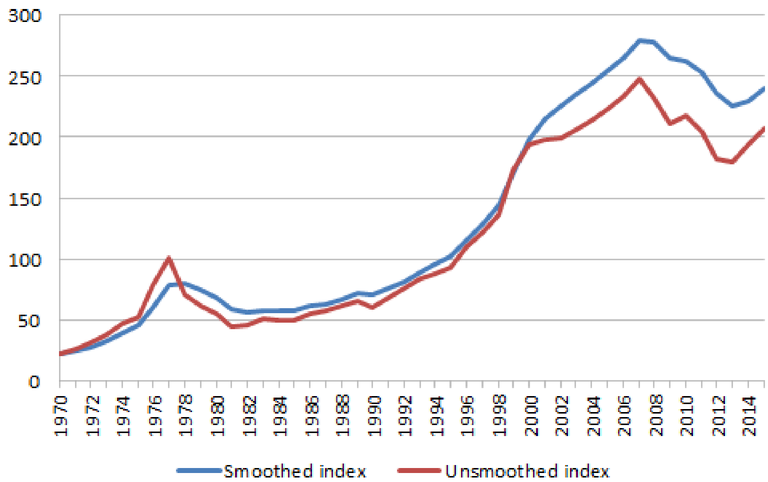
5.1.3 Aggregate wage series

The series on aggregate Dutch wages is provided by the International Monetary Fund (IMF). It represents the average, aggregate wage growth rate, lacking the individual-specific components of individual labor income. As the macro level wage growth rate, it is often interpreted as general wage inflation, affecting all employees and including price inflation.

5.1.4 Adjusting the raw data

The three time series are taken as raw data, which we adjust accordingly: historical data (mean returns, standard deviations and correlations) are estimated after unsmoothing house prices and the aggregate wage series, and forward-looking estimates are taken from the Dutch Advies Commissie Parameters of 2014, responsible for determining long-term capital market assumptions, also used by pension funds, among others. House price and wage series are smoothed because of the low-frequency and lagged data. Smoothing yields lower-than-expected volatilities, while it does not affect the means of the time series. We use the unsmoothing technique of Lizieri et al. (2010)

[7]By the Nederlandse Vereniging van Makelaars (Dutch Association of Real Estate Agents)



Source: BIS

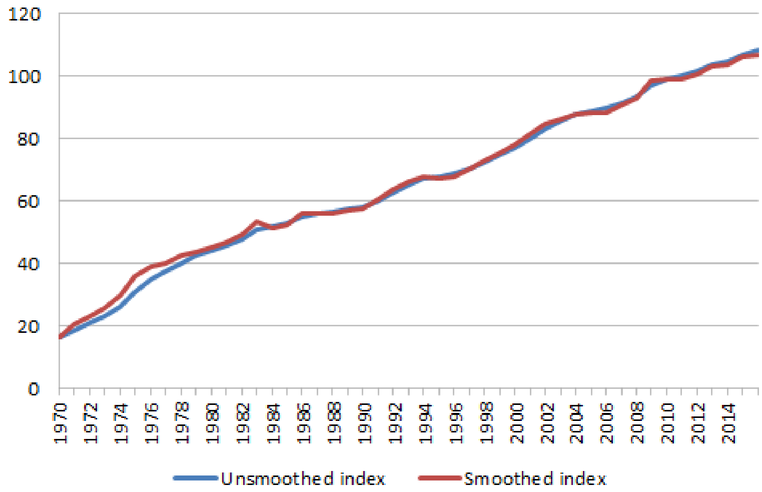
Figure 5.1: Smoothed and unsmoothed Dutch house price index

In case of house price returns, the popular appraisal-based indices are typically smoothed because of the low frequency and slow adaptation of new prices. In order to derive the more realistic series, with higher volatility, we unsmooth the index with the technique discussed in Appendix A2.

to derive the original arithmetic returns of the two series, using a smoothing parameter $a = 0.5$ in both cases. Further details on the unsmoothing technique can be found in Appendix A2, while the differences between the smoothed and unsmoothed series are presented in Figure 5.1 and 5.2.

As for returns on private real estate, Ruhmann and Woolston (2011, p. 11.) and the NBIM (2015) decompose total return on real estate investments into two sources: income and capital appreciation. Homeowners often realize only the returns due to capital appreciation, since they do not receive income from renting their property out. While the income stream is realized immediately, capital appreciation is relevant on the long-term, typical of owning a house. Ruhmann and Woolston define capital appreciation as "the change in market value of a property from one period to the next" (p. 10.). They present the relative importance of capital appreciation within total return to be between 14.3% and 15.0% for rolling returns on horizons from 1 to 5 years, while the standard deviation of capital appreciation takes up 90.32%-91.46% of the standard deviation of total returns.

Based on the assumptions about capital appreciation and using the suggested long-term, forward-looking parameters of the committee from 2014, Table 5.1 summarizes the capital market assumptions and Table 5.2 presents the correlation matrix that were used as benchmark. The forward-looking values, set by the Advies Commissie Pa-



Source: IMF

Figure 5.2: Smoothed and unsmoothed aggregate wages in the Netherlands

Similar to house price indices, wage series are also often tend to be smoothed. With the same unsmoothing technique we derive the more volatile unsmoothed returns for the wage series too.

rameters, are the maximum values for the market variables that financial institutions, including pension funds, can use for their calculations.

Variable	Expected return (μ)	Standard Deviation (σ)
Equities	7%	20%
Private Residential RE	1.13%	13.72%
Aggregate wages	2.5%	5.27%

The presented parameters were derived from the three, adjusted historical time series and the forward-looking estimations of the Dutch Advies Commissie Parameters (2014). Equities are represented by the MSCI World benchmark index, denominated in €. The house price index and the wage series are both unsmoothed in order to retrieve the more realistic series with higher volatilities, which were reduced by the initial smoothing of the data. By housing returns, we mean the capital appreciation of private residential real estate. To simulate the scenarios of the three correlated random variables, these parameters are applied together with the correlations of Table 5.2.

Table 5.1: Forward-looking capital market assumptions

Equity returns were adjusted from the high, historical 10.31% to a more forward-looking 7.00%, while a volatility of 20.00% is used instead of 17.00%. With the long-term assumption of 3.5% for risk-free interest rate, the equity premium is 3.5%. The historical average of wages is 4.30%, which is substituted by 2.50%, of the Commissie Parameters, with a volatility of 5.27% after unsmoothing the data. As for house price returns, we derive the capital appreciation and volatility from the total housing return of 7.50%, based on the proportions taken from Ruhmann and Woolston (2011).

	Stock	House	Wages
Stock	1	0.069	0
House	0.069	1	0.305
Wages	0	0.305	1

Table 5.2: Correlation matrix, baseline parameters

The three pairwise correlations are of key importance in modeling the processes driving stock, housing and aggregate labor income returns. The long-term correlation between stocks and house price returns is very low, confirmed by the NBIM (2015) emphasizing the diversification benefits of both public and private real estate due to their low positive correlations with other assets. Our results are consistent with their conclusions, namely that even though long-term correlations are low, these are not stable over time. The correlation between house prices and labor income is also positive, but not too strong on average. For stock-income correlations, the related academic literature provides mixed results: CCGM (1999) estimate slightly negative, insignificant correlations, while Davis and Willen (2000) find significantly different correlations for different gender-education groups. Their results vary from -0.25 for the least educated men to 0.25 for highly educated women. Most lifecycle-related studies, e.g. CGM (2005), Bagliano et al. (2009, 2014) and Kraft and Munk (2011) assume $\rho_{SY} = 0$ and carry out sensitivity analysis for different positive values of the coefficient. Since our data sets imply insignificantly negative correlation, in line with the literature, we set the stock-income correlation at zero as a benchmark.

5.2 Default Lifecycles

In Section 2.3. the role of default options was discussed regarding the cognitive biases of participants and the efficiency that they give to pension providers. Now we describe default lifecycles typically offered by pension funds, with special emphasis on Dutch providers.

Some of the default lifecycle asset allocations offered by pension funds are often found in the academic literature, regarded as simple approximations of the optimal asset allocation rules. Bagliano et al. (2014) list such default rules, ignoring the individual-specific factor labor income: 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 lifecycle theory with decreasing the exposure to investment risk as retirement age comes closer, and they are easy to interpret, even by clients. Another rule, worth mentioning, is the time-invariant solution of the 1969 Merton-model.

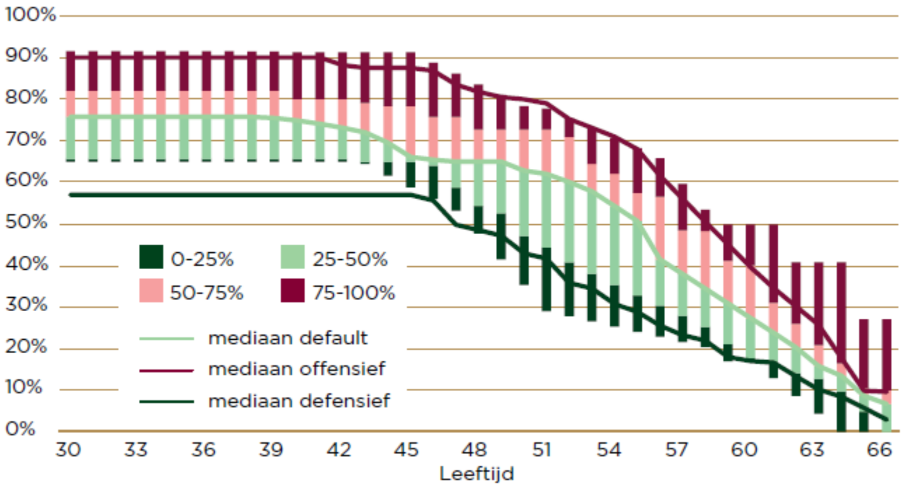
LCP Netherlands (2016) provide a detailed overview of the available lifecycles and thirteen funds offering them in the Netherlands. In recent years, mainly because of the introduction of the new DC pension providers, the PPI's (Premie Pensioen Instellingen), the market for lifecycle funds extended substantially. The number of participants, as more employers engage in contracts with DC funds, is increasing together with the types of lifecycle investments.

Figure 5.3 presents the variation of the risky asset exposure per participant age, decomposed into four quartiles, each with three pension funds in it. The color-segments represent the quartiles: the red segment stands for the three funds with the highest weights in risky asset for each age group, and the dark green represents the three funds with the lowest risky asset shares for the given age cohort. At the beginning of the investment period, at age 30, the allocation to the risky asset is highest in all funds, varying between 65% and 90%. At the end of the investment period, just before retirement, the exposure to risky asset is, on average, about 7%, while the three funds with the highest percentages have still exposures between 10% and 27%.

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.

The lines in the figure plot typical defaults: "offensive" as the median of the most aggressive lifecycles of all the thirteen funds and "defensive" as the median of the lowest risky asset allocations per age cohorts. The light green line labeled as "median default" represents a lifecycle in between the two, which we will refer to as "neutral'.

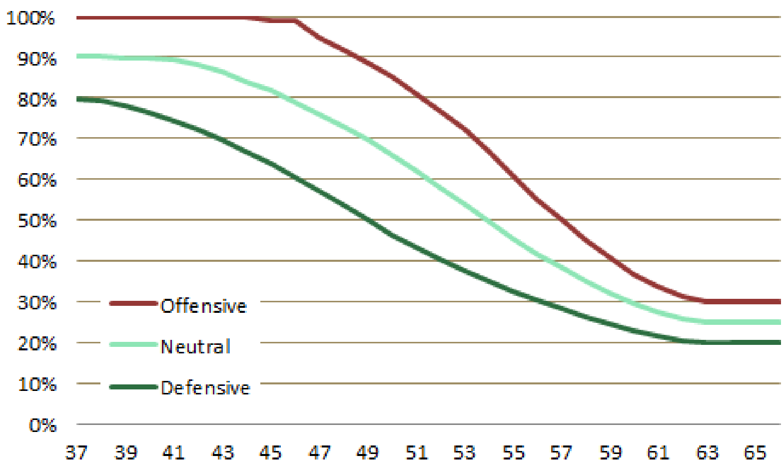
Figure 5.4 represents the default lifecycles used in our analysis. Assuming that the investment period is exactly 30 years long, the age of the employee entering the fund is 37. The risky asset shares are 80%, 90% and 100% at age 37, for the Defensive, Neutral and Offensive strategies. By age 66, the 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 lifecycle theory. Therefore, we do not look at younger participants. The Neutral lifecycle is considered to be the ultimate default option of the three, representing the completely passive choice.



Source: LCP Netherlands (2016)

Figure 5.3: Default lifecycle asset allocations of Dutch DC pension providers

This figure summarizes the default lifecycles offered by twelve Dutch DC pension providers. The variation of the risky asset exposure per participant age is presented, decomposed into four quartiles, each representing three pension funds. From the overall landscape of lifecycles offered in the Netherlands, three median lifecycles are constructed to represent the median defensive, offensive and between the two, the median default lifecycle.



Source: NN Investment Partners

Figure 5.4: Default lifecycles offered by the hypothetical pension provider

In our further research these three lifecycles are labeled as the defaults, among which the Neutral stands for the absolute default lifecycle. The initial risky asset shares are 100%, 90% and 80% for a 37 year-old participant. The asset allocation in younger years is assumed to be the same as in age 37. The final-year exposures are 30%, 25% and 20%, respectively.

5.3 Research design: Individual profiles

Table 5.3 summarizes the baseline parameters used to analyze the pension outcomes of various lifecycle strategies, for the representative Dutch employee in the benchmark economic environment. In our model, individuals with heterogeneous characteristics can be described in detail and assigned to strategies that better fit their profile. According to Choi et al. (2003), as the dispersion of participants increases in a pension fund, it becomes harder to design adequate defaults that suit most members. In fact, it is more likely that such defaults will force far-from-average members into active decision-making, which better resembles their individual-specific needs.

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	lifecycle investment period in yrs	30
σ_ε	idiosyncratic labor income risk	5%

Table 5.3: Baseline parameter values

The individual-specific information specified in Table 5.3 is, thus, 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. The age of the participant entering the plan and the reverse mortgage loan-to-value are given exogenously and can be changed arbitrarily. The salary at the moment of entering the pension plan, Y_1, and the purchase price of the owner-occupied house are from the Statistics Netherlands (CBS), while the initial financial wealth in form of earlier savings is assumed to be 27 000 €, conditional on the income stream and the exogenous contribution rates.

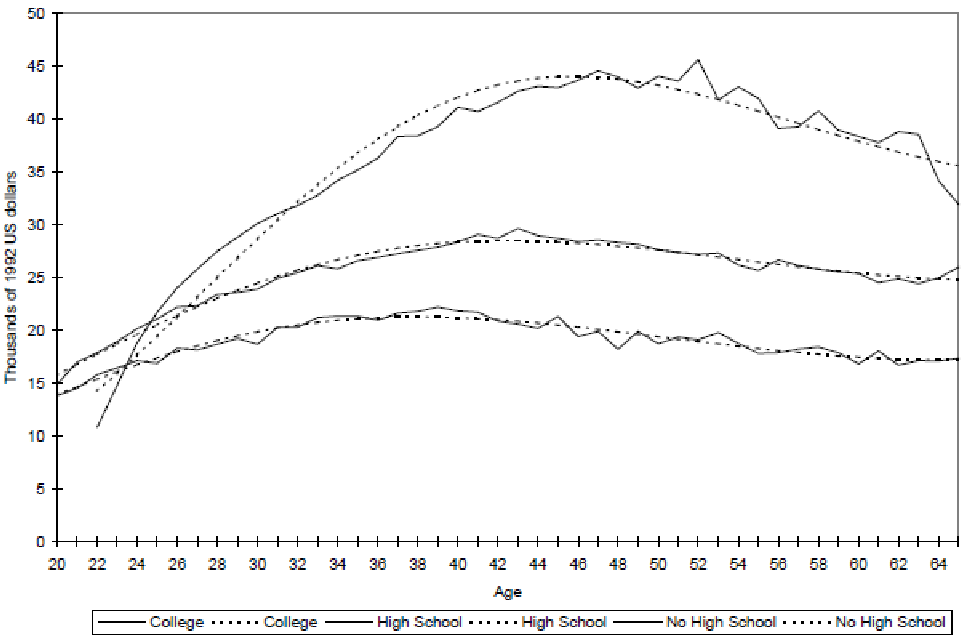
The individual profiles are designed to capture certain aspects of employee-heterogeneity, one at a time. The model makes it possible to fully individualize the lifecycle investment decision in terms of the investigated variables, by tailoring parameters for a chosen individual. However, the aim of this thesis is to quantify the effects of the chosen individual-specific characteristics one by one. To capture the impact of individual wage 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 lifecycle investing, we compare the cases when housing wealth is included as an individual-specific information and when it is not.

5.3.1 Individual wage profile

Individual labor income is a key indicator of an employee's savings and investment decisions and risk capacity. The wage level and growth rate of the income greatly determine the wealth position of the individual, while its risk profile is important for further risk taking and hedging in investments. We study in detail the impact of parameters which represent these features of individual labor income: the steepness of the individual wage growth rate and its riskiness in terms of idiosyncratic risk and its correlation with stock markets. Individual labor income as a whole, strongly depends on education, as studied by CCGM (1999). They find that higher educated employees not only have higher wage levels, but also steeper wage growth, as shown in Figure 5.5. Furthermore, education level is positively related to stock-income correlation and negatively to idiosyncratic shocks of income. In line with their assumptions, we compare individual profiles distinguished by these parameters in an intuitive way.

Career path

First, individuals are distinguished based on their deterministic wage growth rates, the so-called career path $w_{i,t+1}$. It is defined as a function of individual-specific factors like age, gender or education. Figure 5.5 represents not only the difference in steepness of labor income between education groups in the U.S., but also captures the fact, high-



Source: Campbell et al. (1999)

Figure 5.5: Wage profiles for different education groups, calibrated on U.S. data

lighted by Euwals et al. (2009), that Anglo-Saxon countries have usually hump-shaped wage profiles. On the other hand, continental European countries like the Netherlands, have steeper, by age increasing wage profiles for the whole working life. Besides the aggregate wage growth rate, a. k. a. aggregate wage inflation, it is this real wage growth that individual participants experience. We specify three possible career paths in Table 5.4, 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, from 1964[8]: 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. Steeper wage growth rates occur too, however, those apply for only a very small fraction of the population. The moderate career path was designed by deviating from the two extremes. Figure 5.6 plots the expectations on labor income in nominal and real terms for all the three career paths. In real terms, the only growth in expected wages

[8]Wet op de Loonbelasting 1964. Artikel 18a, derde lid, onderdeel b. Source: http://wetten.overheid.nl/BWBR0002471/2016-07-01

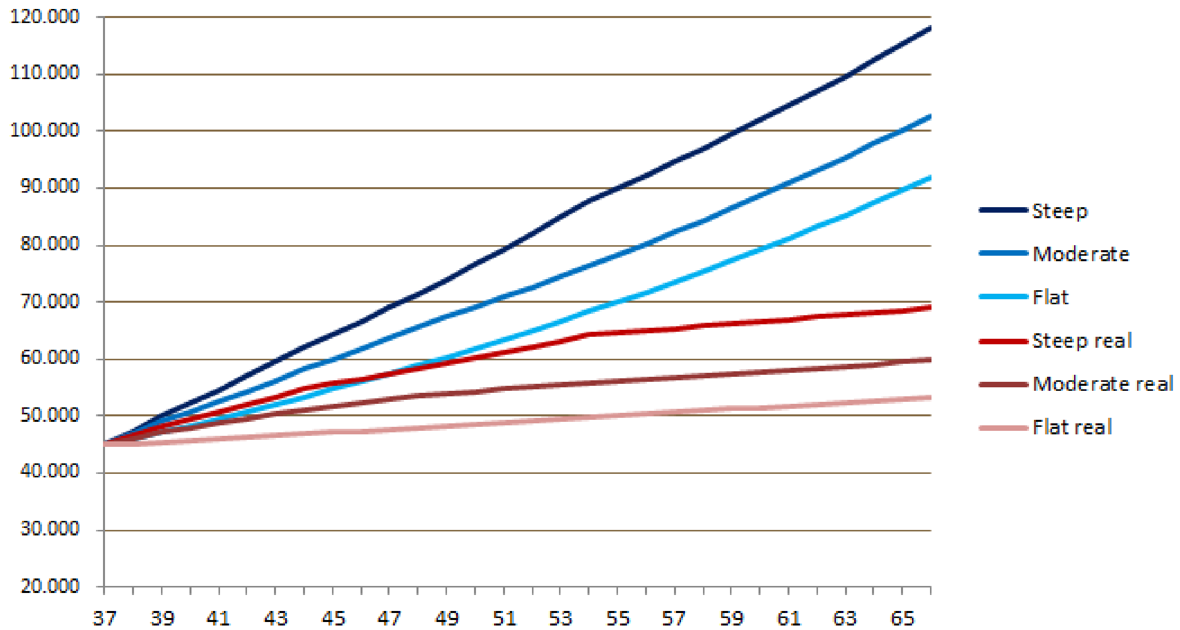


Figure 5.6: Expected wage growth in nominal and real terms

The figure plots the accumulation of expected nominal and real wages for the three career paths, each with an initial salary of 44 900 € at the age of 37. For nominal wage growth we account for both the aggregate wage inflation rate, ν_{t+1}, and the individual-specific career path term, $w_{i,t+1}$. Real wage growth is equal to the nominal rate net of aggregate price inflation, which is fixed at the level 1.9%: $wage^{real}_{i,t+1} = w_{i,t+1} + \nu_{t+1} - \pi_{t+1}$.

originates from the individual career paths and the 0.6% difference between aggregate wage inflation and price inflation. In nominal terms, thus with the aggregate wage inflation, on expectation the 3-2-1 steep career path results in 120 000 € wages at age 66, with other exceptionally high salaries appearing only at the 95$^{\text{th}}$ and 97.5$^{\text{th}}$, percentiles of the income distribution at age 66, with otherwise baseline parameter values.

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%

Table 5.4: Career path wage growth rates

The moderate career path is considered as the benchmark case, for example due to average education level. In the Netherlands, it is the last stage of compulsory public education until the age of 18[9]. According to CBS, in 2013 43.1% of the Dutch labor force belonged to this education group. On average, we conclude that employees with higher than average, thus, college or university education (35.1%) have the steep, while with below-average education (20.1%) have the flat career path. The intuition for the steep career path, even though the growth seems very strong, is the fact that highly educated individuals often do not start working until the age of 25 or later, or if they do, they often take only low-salary internship positions. When starting their working life, their salary usually jumps high compared to lower education groups, who start working right after high school, around the age of 18.

Individual-specific labor income risk

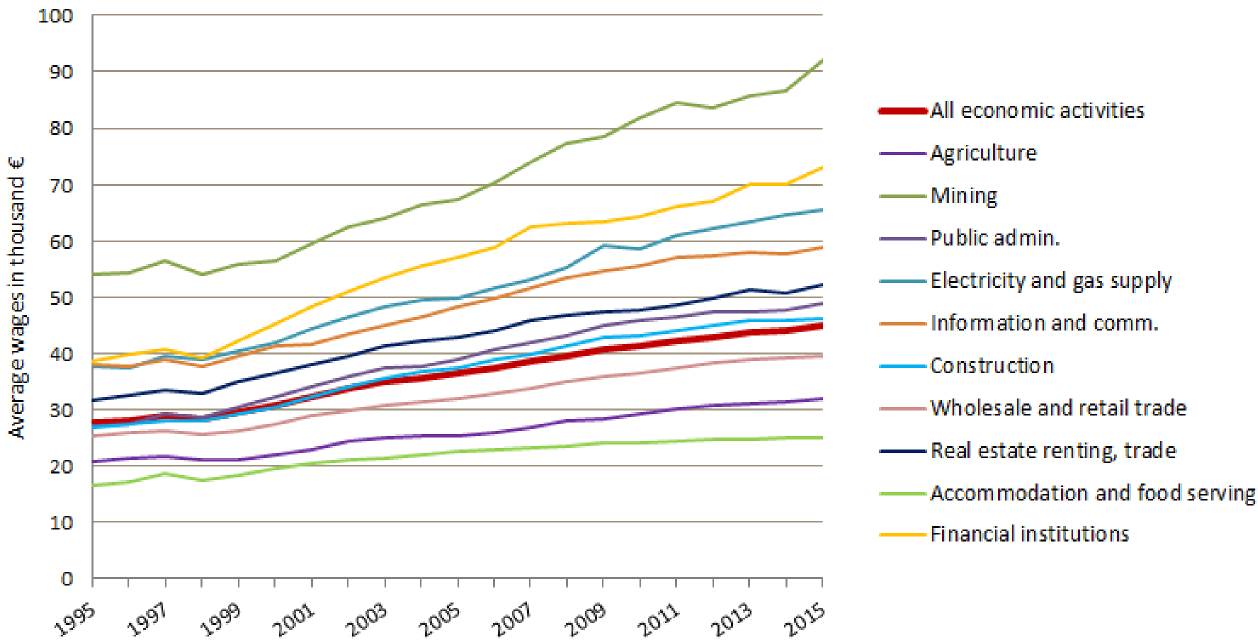
Assuming that the aggregate wage process drives all employees' labor income to the same extent, hence, correlations and aggregate wage volatility are identical across individuals, the only difference in labor income risk is due to idiosyncratic shocks. The estimations of CCGM reveal that the importance of idiosyncratic shocks, both in absolute and relative terms, is lower for the higher educated. However, education is not the only source of individual background risk. In Table 5.5 we distinguish individuals based on idiosyncratic volatilities: $\sigma_\varepsilon = 0.05$ for the benchmark case, $\sigma_\varepsilon = 0.03$ for below-average and 7% 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.

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

We define three individual profiles distinguished by idiosyncratic income risk. All else equal, the total variance of labor income, $\sigma^2_{Yi} = \sigma^2_\nu + \sigma^2_\varepsilon$, is higher for individuals with higher background risks. According to CCGM (1999), idiosyncratic income risks are negatively related to education level, which implies higher relative importance of individual-specific risk, within total income variance, for the lower educated.

Table 5.5: Individual profiles with different idiosyncratic labor income risk

[9] These are the categories: MBO, HAVO and VWO



Source: CBS

Figure 5.7: Average annual wages per economic sector, in thousand €

Stock-income correlation

Lastly, heterogeneity in individual labor income is captured through the correlation between labor income and stock market returns. Similar to CCGM, Davis and Willen (2000) also conclude that correlation of labor income and stock returns increases with education, which implicitly increases the exposure to stock markets and the role of aggregate shocks within total labor income risk. Instead of analyzing the relation between education and stock-income correlation, we turn to another common, intuitive view on ρ_{SY}: an indicator of the sector of employment. Consequently, an analysis with respect to the stock-income correlation can reveal the sensitivity of different sectors' labor incomes to stock market movements.

CBS data are available on sector average wages and the number of workers they employed for the last 20 years. The concept of wages, according to CBS, include income taxes and social contributions even if they are withheld by the employer to be paid directly to tax authorities, social security and pension schemes. The evolution of wages in 10 sectors and the overall average for the last 20 years is plotted in Figure 5.7. The average wage in 2015 was 44 900 €, with a substantial cross-sectional variation within the range of 25 200 € in the Accommodation and food serving sector, and 92 000 € in the sector Mining and quarrying, which however, takes up only 0.2% of employees.

The second highest sector average wage of 73 200 € belongs to the sector of Financial Institutions, with 4.2% of all employees. The aggregate growth rate of sector wages is 2.46%, similar to the advised parameter of 2.5%. The big cross-sectional variation of sector averages suggests that the average of all economic activity will not be a good indicator for every single individual employee.

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.

5.3.2 Housing wealth

For every individual profile, default lifecycles and two individualized strategies are compared. The individualized lifecycles are distinguished by the fact whether they consider the impact of housing wealth or not. Housing wealth, similar to human capital, provides leverage effect to invest more in the risky asset than purely financial wealth would suggest. On the other hand, due to our model specifications on the stock-house correlation, it also has an implicit exposure to stock investments through the pairwise correlation. We investigate whether the extra exposure due to housing yields benefits or not. Our model captures the following aspects of housing wealth: size, $H_{i,t}$, correlation with stocks, ρ_{SH} and volatility, σ_H. The role and impact of stock-house correlations will be discussed in further detail.

6 Results

This chapter describes and analyzes the results in various aspects. The individualized lifecycles are introduced, which were derived analytically by considering two individual-specific factors: wage profile and housing wealth. The chapter explains how they differ from their default alternatives.

First, the benefits of tailoring lifecycles for heterogeneous individuals are quantified. We measure the welfare changes in certainty equivalent consumption, due to switching from a lifecycle 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 lifecycle investing provides benefits over the pre-designed defaults is concerned, by comparing lifecycles that consider individual factors to defaults which ignore such information, e.g. the 40%-60% rule. We analyze the results of eight lifecycle strategies in terms of various evaluation criteria, both in utility and practical measures, e.g. on the risk-return trade-off.

Lastly, a sensitivity analysis is carried out for alternative scenarios, risk preferences, and stock-house correlations.

6.1 Tailored lifecycles for heterogeneous individuals

First, we quantify the welfare change due to offering individualized lifecycles to heterogeneous employees, relative to the welfare when individual heterogeneity is not considered. This comparison aims to answer our first research question, by determining whether it is worth distinguishing individuals by their labor income process when deciding on the optimal portfolio. We compare the certainty equivalent consumption results for two cases: first, 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 Chapter 5.3.

6.1.1 Impact of career path

The career path variable causes substantial variation in the final-year labor income of otherwise identical employees, as presented in Figure 5.6. However, Figure 6.1

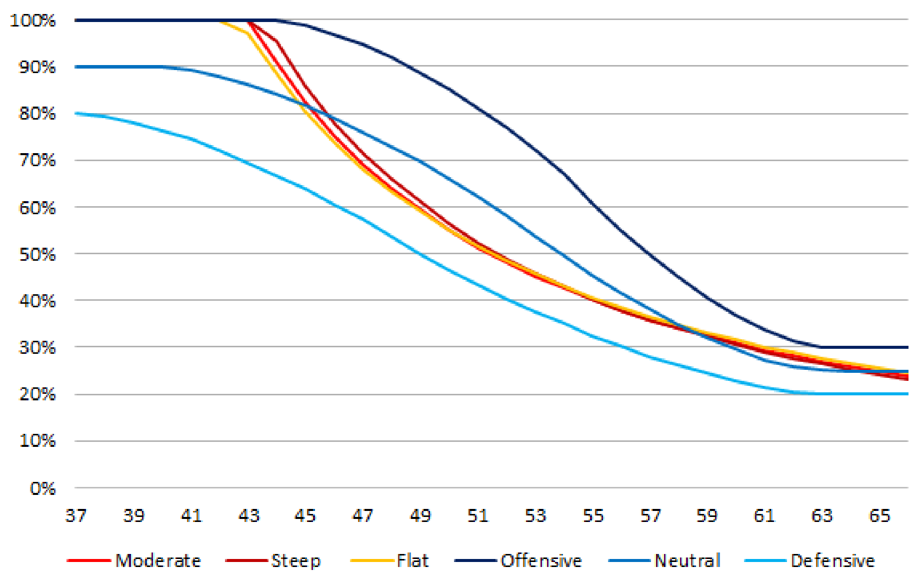


Figure 6.1: Individualized lifecycles for different career paths and the defaults

shows that lifecycles 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.

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. First, the case without tailored investment strategies is studied, 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. Panel A of Table 6.1 presents the results in annual, nominal certainty equivalent consumption for the three profiles.

Before tailoring lifecycles, 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 lifecycle 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 welfare enhancing effect of considering individual heterogeneity in the career path, we simulate the outcome when each profile is assigned to their own

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	Moderate	Steep	Flat	Moderate	Steep	Flat	Moderate	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 lifecycles, 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 lifecycle strategies for different career paths.

Table 6.1: Welfare analysis of individualizing lifecycles by career path

matching lifecycle strategies. The welfare changes are measured relative to each individual's initial CEC from the untailored lifecycle 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 lifecycles 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 lifecycles.

The direction of the changes is explained by the CRRA utility and the CE consumption: these measures capture the trade-off between expected value and volatility of the consumption stream, relative to the individual's risk aversion level. The welfare change can be decomposed into two parallel effects: the changes in E[C] and in the volatility of the retirement consumption, which are presented in Panel B of Table 6.1. The overall impact on welfare is captured by the change in the ratio $\frac{\sigma_C}{E[C]}$. If the relative importance of σ_C grows, the CE consumption decreases. Therefore, simply moving to a more defensive strategy will not necessarily increase the CEC outcome.

Since the ratio $\frac{\sigma_C}{E[C]}$ has decreased for the flat career path profile, as presented in Table 6.1.B, the welfare change is positive. For the employee with steep career path, the relative growth in expected consumption is lower than in σ_C, therefore, the overall impact is negative.

$$CEC \downarrow \text{when} \frac{\sigma_C}{E[C]} \uparrow \text{, if} \begin{cases} \sigma_C \uparrow \text{and E[C]} \uparrow \text{, with \%-change larger in } \sigma_C \\ \sigma_C \downarrow \text{and E[C]} \downarrow \text{, with \%-change smaller in } \sigma_C \end{cases}$$

We conclude when distinguishing individuals by their career path, the variation in CEC is caused mainly by the labor income process and not by the lifecycle strategies. When decomposing the difference into the two sources, we find that the added value of tailored lifecycles is negligible in magnitude and ambiguous in direction. The magnitude is explained by the small difference between the three individualized lifecycles, while the unclear welfare effect is due to the two driving forces of the CRRA utility and CE consumption: the expectation and volatility of the consumption stream. Therefore, we conclude tailoring lifecycles by career paths has only limited impact.

6.1.2 Employees of different sectors

The next component of labor income that we consider is the different sectors, captured by the correlation between income and stock returns. As plotted in Figure 6.2, higher stock-income correlations, meaning higher implicit exposures to stock markets, yield more defensive strategies than the benchmark $\rho_{SY} = 0$. As human capital is depleted, the hedging demand term and the difference between the three lifecycles are also diminishing. This implies the same, 24% 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 lifecycle asset allocation and the individual labor income process. Therefore, the analysis follows the same structure as before: we investigate the benefits of individualizing lifecycles 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 lifecycles distinguished by ρ_{SY} are substantially different, the distributions of final-year labor income of the three profiles do not show big variation, as summarized in Table B1 of Appendix B. Table B2 of Appendix B compares the retirement wealth distributions, as a result of investment strategies before and after tailoring,

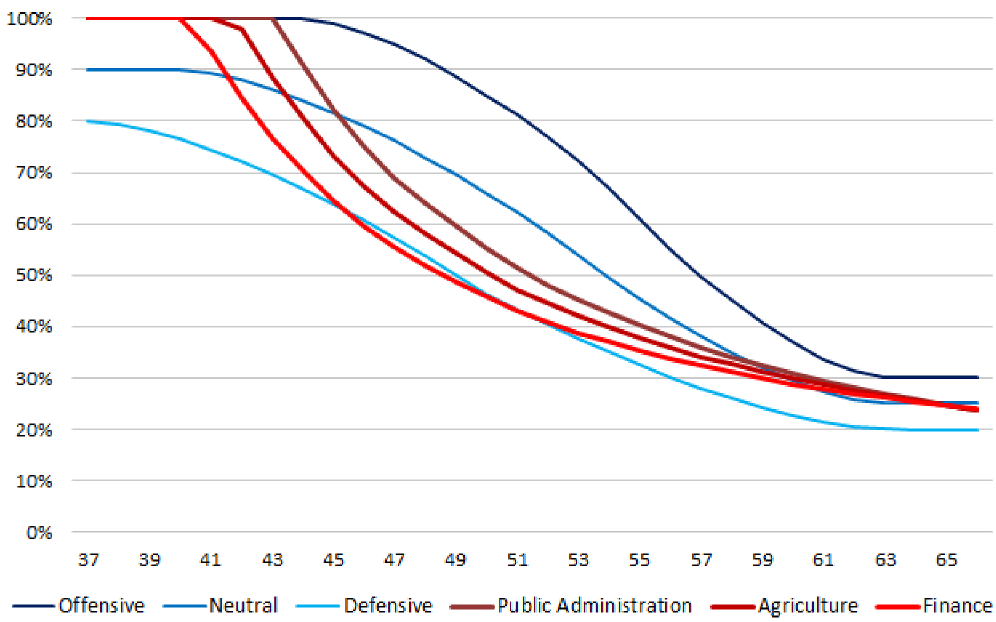


Figure 6.2: Individualized lifecycles for different income-stock correlations and the defaults

with retirement wealth defined in (4.8). Although the income processes are similar, retirement wealth does capture the impact of different stock-income correlations in its volatility. Before tailoring, the distribution reflects the sensitivity of sectors to stock market movements, while after tailoring, retirement wealth resembles how aggressive the tailored strategies are.

Panel A of Table 6.2 summarizes the CEC results before and after tailoring the lifecycles 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 lifecycles, when they are assigned to the strategy of the Public Administration employee, recalling that the income processes are very similar.

When lifecycles 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 6.2 shows the drivers of the welfare gains, as discussed previously. The $\frac{\sigma_C}{E[C]}$ ratio has improved for both sectors due to the more defensive strategies, increasing

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 lifecycles, 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 lifecycle strategies for different sectors.

Table 6.2: Welfare analysis of individualizing lifecycles by stock-income correlations

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 lifecycle 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 untailored lifecycles.

In conclusion, we quantify meaningful welfare gains due to individualizing lifecycle investing by stock-income correlations. The added value of tailoring by ρ_{SY} is larger than in case of career path, both in relative and absolute terms. The larger variation of the individualized lifecycle strategies also indicates the larger size of the welfare changes. Thus, larger deviations in the lifecycles lead to larger welfare effects. Any further variation in the welfare outcomes of the different profiles is not due to the strategies, but rather the underlying labor income profiles, which is not analyzed here further.

6.1.3 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

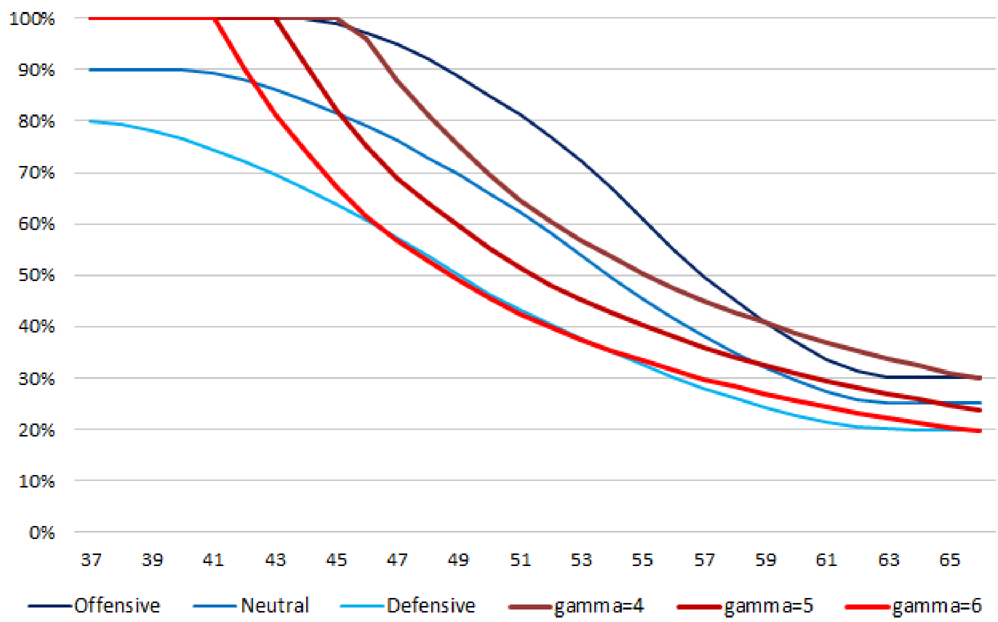


Figure 6.3: "Individualized" lifecycles for different idiosyncratic income risks and the defaults

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, for two reasons. First, it is not included in the closed-form solution and second, human capital is derived from the expectation on future labor income, where $\varepsilon_{i,t+1}$ is represented only by its zero expected value, regardless of its volatility. Consequently, this implies the same, default-parametrized lifecycle strategy for the three profiles with different σ_ε-s, both before and after tailoring.

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, for instance. 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 lifecycle, 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" lifecycles were derived by using the benchmark risk aversion of $\gamma = 5$. The three

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 lifecycles, 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 lifecycle strategies for different background risks.

Table 6.3: Welfare analysis of individualizing lifecycles by idiosyncratic income risk

lifecycles are compared to each other and to the defaults in Figure 6.3.

Table B1 in Appendix B presents the impact of different individual-specific shocks on the distribution of final-year labor income. The expected values of final-year income suggest that the simulated processes are all driven by the moderate career path, although with large deviations in the tail-values due to the idiosyncratic shocks. Larger σ_ε leads to higher total variance of labor income ($\sigma_Y^2 = \sigma_\nu^2 + \sigma_\varepsilon^2$), which is also reflected in the welfare distribution, before tailoring the lifecycles. The riskier ($\sigma_\varepsilon = 7\%$) labor income profile accrues 4.78% lower, and the less risky one 4.85% higher CEC than the benchmark, as presented in Panel A of Table 6.3.

After assigning strategies to the profiles which better resemble their labor income features, the dispersion in welfare decreases. 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 two parallel changes driving the CEC, summarized in Panel B of Table 6.3. For the profile with lower background risks and a more aggressive lifecycle, the increase in the volatility of consumption 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" lifecycles, with respect to idiosyncratic labor income risk, depends strongly on the lifecycles we choose as "individualized". Since σ_ε has no effect on the optimal individualized strategies, the "tailored" lifecycles, which reflect the riskiness of each profile, are chosen based on intuition and economic logic, but not on quantitative basis. Idiosyncratic risk is proved to be responsible for dispersion in labor income and thus, in CEC outcomes, however, to define σ_ε still requires further research. 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 lifecycle investment yields welfare losses.

6.2 Individualized lifecycles vs. Defaults

So far, we quantified the added value of individualizing lifecycles for heterogeneous employees, in terms of three characteristics of the labor income process. Regardless of the results of Section 6.1, now we compare the individualized lifecycles to default strategies in order to answer our second research question. The considered defaults are either used by pension funds, 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.

6.2.1 The evaluation criteria

For every strategy, we analyze the CE consumption, as described earlier to represent a utility-based measure. Furthermore, other, more practical measures will be used to capture the down-side risk features and risk-return trade-off for the analyzed lifecycles. These are: replacement ratios (RR-s) including and excluding first pillar pensions; their standard deviation and the 2.5^{th} percentile of the replacement ratio across scenarios to define the pension outcome in the 2.5% worst case scenarios. The replacement ratios are defined as the pension income from the DC annuity with or without the AOW benefit, relative to final-year labor income.

The maximum draw-downs are considered only until the age of 45, after which there is still sufficient amount of time for recovery. The median of maximum draw-downs across 2000 scenarios is calculated for each lifecycle to describe the strategy in general. To capture the volatility - expected RR trade-off, the performance evaluation measure Sharpe-ratio is derived. Since the evaluation criteria capture different, sometimes controversial aspects of the investment strategies, none of the studied lifecycles will perform best in each of them. Although some are more complex than the others, they are all necessary to draw a well-founded conclusion.

6.2.2 Results from baseline parametrization

Having concluded the welfare enhancing effect of lifecycles individualized by the stock-income correlation, now we investigate whether they perform better than the default strategies, for two profiles: the benchmark, representative Dutch employee and the Finance sector one with $\rho_{SY} = 0.4$.

The individualized lifecycles

Figure 6.4 presents their individualized lifecycles and the three defaults of the hypothetical pension fund. The two individualized lifecycles 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 in formula (4.13). 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 lifecycles, distinguished by the presence of housing in the formula, relate to each other always in the same way. The lifecycle with housing wealth is more aggressive, unless,

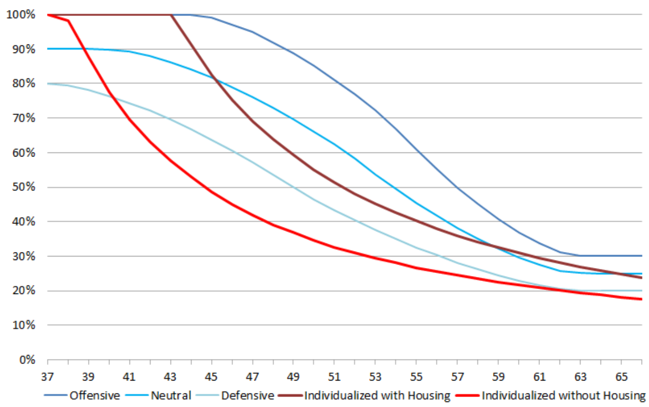


Figure A. Benchmark profile

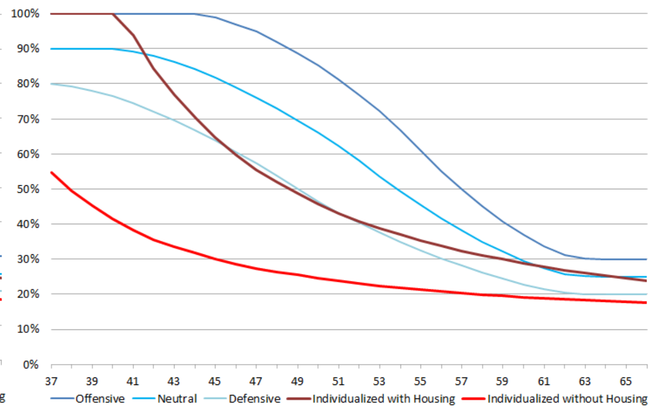


Figure B. Finance sector profile

Figure 6.4: Individualized lifecycles for the benchmark and the Finance sector employee, relative to the defaults

for instance, certain regions with higher house-stock correlations are considered.

In Figure 6.4.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 lifecycles, in Figure B, are more defensive than in Figure A, due to the higher stock-income correlation.

The lifecycles of the two profiles differ in the starting year of the asset allocation adjustment to the risk-free asset, while the final positions at age 66, are the same with 23.8% and 17.50% remaining in risky assets. The individualized lifecycles do not only start allocating to the risk-free asset earlier, but they also adjust to the risk-free asset at a larger speed than the defaults. The steeper adjustments involve larger transaction costs than gradual decline of the risky asset allocation, while starting the adjustment earlier means giving up potential returns, although for less volatile outcomes.

Welfare analysis

Table 6.4 presents the simulation results for the compared lifecycle 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.

Utility and the CEC are derived from the same CRRA utility function (3.10) as before, over retirement consumption defined in (4.9). Even though housing wealth is not considered in most strategies, it is still taken into account in retirement consumption, assuming this to be the fair comparison of lifecycles.

Interestingly, for the baseline economic scenario and individual parameters, the individualized lifecycles without housing wealth perform the best in terms of CEC, instead of the supposedly optimal lifecycles with housing. At moderate levels of risk aversion, individuals prefer the more defensive of the two individualized lifecycles. The welfare gain from the optimal individualized lifecycle, 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 fact that the default was initially designed for this participant. The Finance sector employee incurs 4.46% higher CEC by individualizing his lifecycle, which means an additional retirement consumption of 2080 € annually. This confirms the welfare enhancing impact of considering ρ_{SY} when tailoring lifecycles. The welfare gains are substantial for employees from sectors where labor income is highly sensitive for stock

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

Table 6.4: Various evaluation criteria for the benchmark and the Finance sector profile

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 controversial that this model-suggested optimal strategy is inferior, relative to the other individualized lifecycle. The reason may be the calibration of the baseline economic scenario set, based on the forward-looking assumptions about capital market variables. Equities, in this parametrization, are remarkably unattractive, with a Sharpe ratio as low as $\frac{\mu_S - r_f}{\sigma_S} = 17.5\%$ compared to the 30-40% level commonly used in practice. Furthermore, participants with certain characteristics, such as low risk aversion or high stock-house correlation, may prefer the lifecycle considering housing wealth, even in the scenarios with such low equity Sharpe ratios. We discuss the role of the three variables, equity Sharpe ratio, risk aversion and stock-house correlation in the sensitivity analysis below.

Risk-return analysis

Table 6.4 also compares features of the lifecycles, other than welfare. The ratio $\frac{\sigma_C}{E[C]}$ only 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 lifecycles. 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 lifecycle with housing wealth. Their 2.5% worst case RR-s are not substantially different from those of the more defensive lifecycles, but their potential for better mean RR-s is much higher. The maximal draw-downs show big variation across the eight lifecycles too. The differences between the pairs of individualized lifecycles are remarkably large, 6 and 12.7%-points.

Figure 6.5 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 $\frac{\mu_S - r_f}{\gamma \sigma_S^2} = 17.5\%$ to the risky assets during the entire investment period, when parametrized for these profiles. Although it seems to be an unlikely strategy to follow, it performs well and has theoretical importance, being the solution of a basic lifecycle 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 lifecycles 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 RR. The risk-return trade-off, in terms of RR-s, is also plotted in the standard mean-variance graph in

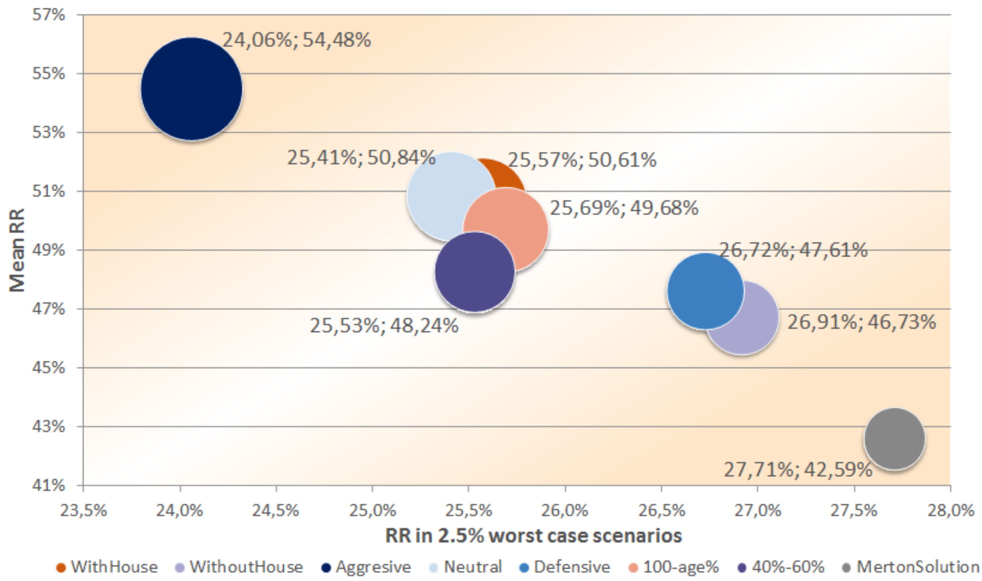


Figure A. Benchmark profile

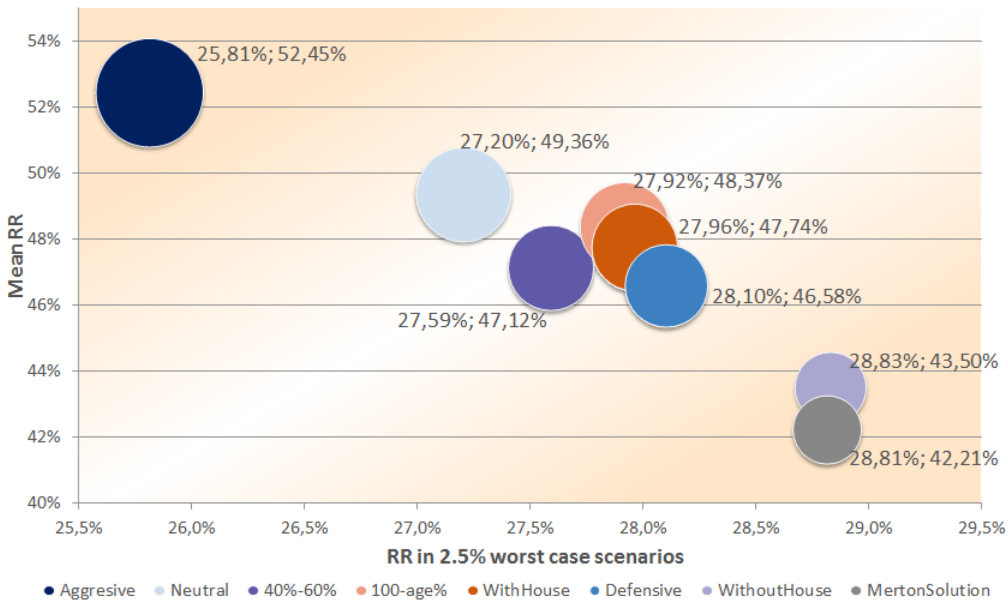


Figure B. Finance sector profile

Figure 6.5: Expected and 2.5% worst Replacement Rates. The size of the bubbles represents the volatility of the replacement rates.

The figures plot the expected replacement ratio of every investment strategy against its 2.5% worst case RR. While the difference in the worst case outcomes is not more than 4%-points between the most aggressive and most defensive strategies, the expected replacement rate can be 10-12%-points higher. However, the volatility of the RR, represented by the size of the bubbles, increases with the mean.

Figure B1 of Appendix B.

Housing wealth in retirement

As for the relative importance of housing wealth in retirement, Figure 6.7 presents the composition of retirement wealth for the benchmark profile. Retirement wealth, defined in (4.8), is made up of the market value of the owner-occupied house at age 67 and the accumulated DC capital, which consists of the paid contributions and the returns. The value of the house and the paid contributions are the same in case of every investment strategy, since the same scenarios were used in each simulation. The only difference is due to the returns which come from the portfolio choice. We conclude, housing and the contributions have a larger weight in retirement wealth, on average, for more defensive strategies, where less is allocated to the return-generating risky asset. It suggests that capitalizing housing wealth is also more important for the defensive strategies.

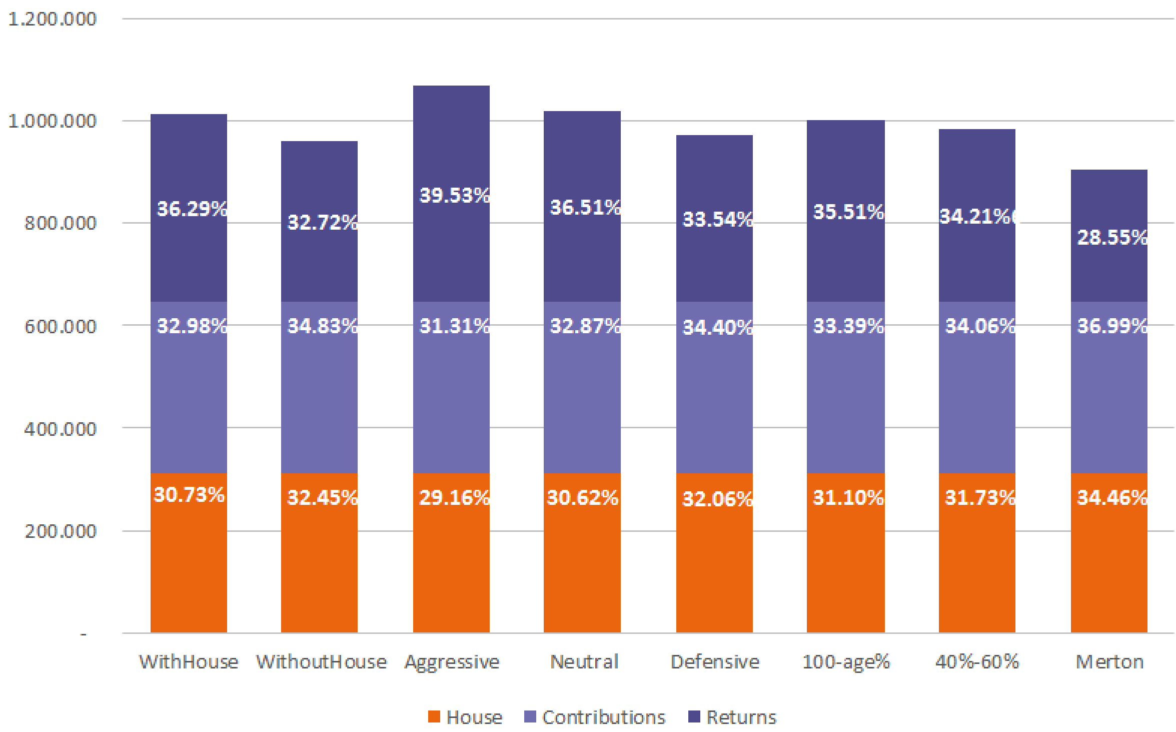


Figure 6.6: Composition of retirement wealth

The graph shows the retirement wealth resulting from the eight strategies, for the benchmark individual. Retirement wealth is decomposed into House Value and DC Capital, in form of contributions and returns.

In general, we assumed that tailored lifecycles provide larger welfare gains when employees deviate more from the benchmark. However, the welfare change strongly depends on the certain individual factor, meaning that 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 yields substantial welfare gains, relative to default strategies, for individuals with non-zero values of ρ_{SY}. 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 lifecycles performs as the best in all of the criteria. Lifecycles that provide high replacement ratios, also have higher volatilities, with larger draw-downs and lower RR-s in the worst case scenarios, for instance. The criteria 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. We conclude that in the baseline economic scenarios, for the modeled individuals, the optimal investment strategy is the individualized lifecycle 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.

6.3 Sensitivity Analysis

The optimal asset allocation of the mean-variance analysis, considering two individual factors, turns out to be inferior in the baseline parametrization, while the individualized lifecycle without housing is the optimal. Therefore, in the sensitivity analysis, we investigate the drivers of this result. Due to the specifications of our model, the optimal individualized asset allocation is highly sensitive to the following variables: equity Sharpe ratio, risk aversion and stock-house correlation.

One could assume that the idiosyncratic risks of the underlying labor income cause the preference for more defensive strategies. However, we find that the individual with no idiosyncratic income risks also prefers the more defensive lifecycle, without housing wealth, as presented in Table B3 of Appendix B. Therefore, the reason must be another underlying risk factor.

6.3.1 Improved equity performance

The first building block of the optimal asset allocation formula is the time-invariant solution of the 1969 Merton-model, determined by the excess return of the risky asset, its variance and the risk aversion level. In our specification, the risky asset in the lifecycle investment is assumed to be a stock-only portfolio, therefore the risk-return profile of equities becomes very important. The Merton-strategy and, thus, the individualized lifecycles in general become more aggressive as the risk-return trade-off of stocks improves, or the risk aversion decreases.

In this section, we investigate the sensitivity of the lifecycles and the pension outcome for the equity Sharpe ratio. We follow the work of Poterba et al. (2006), who study the distribution of retirement wealth resulting from different investment strategies, for two different scenario sets. Retirement wealth and certainty equivalent wealth in their work are equivalent to our definitions of retirement consumption and CEC. They assume stock returns to be the historical average over the period 1960-2002, which is around 10%, and a sensitivity check of 3% lower equity returns. While in their high-return scenario, stock-only portfolios perform the best, in case of lower stock returns, the more defensive strategies yield the highest certainty equivalent retirement wealth.

In the benchmark calibration, the view is very pessimistic on equities, with expected returns lower than the historical averages and volatilities higher. This results in a Sharpe ratio as low as 17.5%, which is far below the commonly assumed 30-40% for stocks. Furthermore, lifecycle investments typically have well-diversified Return Fund portfolios including other asset classes besides stocks, with balanced risk-return profiles and higher Sharpe ratios. Such a low Sharpe ratio for stocks might well explain why the more defensive strategy, without housing wealth, is preferred instead of the model-suggested one.

Based on the results of Poterba et al., we expect the individualized lifecycles with housing to improve when the equity Sharpe ratio is higher. Similarly, in the alternative scenarios we use the historical time series estimates of stocks, with $\mu_S = 10.31\%$, $\sigma_S = 16.99\%$ and a Sharpe ratio of 40%, while all the other parameters are kept at the benchmark values.

Table 6.5 summarizes the welfare results for the benchmark and the Finance sector profiles. As expected and suggested by the mean-variance analysis, in an economic environment with better prospects for the risky asset, the individualized lifecycle with housing is the optimal. Therefore, the pessimistic view on stocks is a reason for the

	1.	2.	3.	4.	5.	6.	7.	8.
Benchmark $\rho_{SY} = 0$	67 134	67 016	65 229	63 363	60 510	62 638	60 845	62 672
Finance sector $\rho_{SY} = 0.4$	41 491	39 938	39 057	36 702	33 952	35 666	34 082	35 645

CEC outcomes in € for the individualized and default lifecycles, in the alternative economic scenario set. 1. With Housing; 2. Without Housing; 3. Offensive; 4. Neutral; 5. Defensive; 6. 100-age%; 7. 40%-60%; 8. Merton-solution

Table 6.5: Welfare analysis in the alternative economic scenario set.

initial tilt towards the more defensive individualized strategy.

The sensitivity analysis also reveals that in scenarios with better prospects for the risky asset, the welfare gains of individualizing lifecycles are also considerably higher. The benchmark profile wins almost 6% in CEC by following the individualized lifecycle with housing wealth, instead of the Neutral default, which is equivalent to a 314 € extra consumption per month. The gain for the Finance sector employee is even higher, 13.05% relative to the CEC provided by the Neutral default.

Furthermore, this comparison also highlights why the Merton-strategy performs so well, compared to other strategies in the baseline parametrization. Being very defensive and providing low volatilities of consumption and replacement rates are great advantages when stocks are volatile with low Sharpe ratios. When equities have a better risk-return profile, the highly defensive Merton-strategy loses its attractiveness and yields higher welfare losses of 6.65% and 14.09% relative to the optimal lifecycle.

Therefore, we conclude that the simplifying assumption about the stock-only Return Fund as risky asset has serious implications for the optimality of the individualized lifecycles and their relation to the defaults. In scenarios of low equity Sharpe ratios, the aggressive strategies, with high exposure to the unattractive stock investments, tend to perform poorly, which is also reflected in the optimality of the less aggressive lifecycle, without housing. The sensitivity analysis proved that the performance of the individualized lifecycles strongly depends on the current economic environment and our assumptions on it. Assuming better risk-return profile of the risky asset, the lifecycle considering housing wealth does become optimal, as suggested by the mean-variance model.

6.3.2 Risk preferences

Besides improving the Sharpe ratio of equities, certain individual-specific features, such as low risk aversion levels, can also lead to the optimality of the individualized lifecycle with housing wealth, even in the baseline economic setting. In this case, however, the result is explained by the special risk preferences of the individual.

Given the original Merton-solution (3.1), risk aversion also has a strong impact on the derived lifecycle strategies and, through the CRRA utility, on the CEC outcomes. Therefore, we derive results for the risk aversion levels of 2, 7 and 10, similar to CGM (2005) or Bagliano et al. (2014), to analyze the sensitivity of the pension outcome with respect to γ. The scenarios and the individual factors are unchanged in this experiment and regardless of these, increasing risk aversion will always result in the "shift" towards more defensive strategies. Thus, the conclusions of Section 6.1 on the added value of distinguishing lifecycles by the characteristics of labor income, hold for other risk aversion levels too.

Table 6.6 presents the results of the welfare analysis. On average, we conclude that the individual with lower risk aversion level has higher CEC-s, in spite of the identical underlying labor income process of the three profiles. The expected consumptions resulting from the default strategies are the same for the three profiles, however, the risk premiums depend on the risk aversion levels. For risk seekers, the paid premium for certainty is lower, therefore, the remaining CEC is higher, while highly risk averse people are willing to give up more of the expected, risky consumptions.

For the extremely risk-seeking individual with $\gamma = 2\%$, the lifecycle with housing is the optimal, since that is the most aggressive strategy of all. The welfare gain is 3.4%, when compared to the Neutral default. For individuals with $\gamma = 7$, the individualized lifecycle without housing wealth remains the optimal strategy. It is very close to the simple Merton-strategy in this case, which is in fact tailored for the individual's risk aversion. The similar welfare outcome, however, also depends on the economic scenario set. As discussed in Section 6.3.1, the Merton-strategy is driven by the expectation and volatility of stock markets, besides risk aversion.

The highly risk averse individual in the given baseline economic environment,

	1.	2.	3.	4.	5.	6.	7.	8.
$\gamma = 2$	63 552	63 271	62 522	61 470	60 040	60 997	60 153	60 603
$\gamma = 7$	43 943	45 026	38 804	41 307	43 454	42 301	42 881	44 913
$\gamma = 10$	38 913	39 854	30 498	33 171	36 007	34 746	35 746	40 285

CEC outcomes in € for the individualized and default lifecycles, for three profiles with different risk aversion levels. 1. With Housing; 2. Without Housing; 3. Offensive; 4. Neutral; 5. Defensive; 6. 100-age%; 7. 40%-60%; 8. Merton-solution

Table 6.6: Welfare analysis for different risk aversion profiles

accrues the highest welfare by following the extremely defensive Merton-strategy, which allocates only 8.75% to the risky asset. His individualized lifecycle without housing wealth resembles this strategy the closest, with the lowest welfare loss of 1.07%. The CEC-loss from the ultimate default lifecycle of the pension fund is 17.66%, which translates into 593 € per month, only originating from individualizing by risk aversion in the Merton-strategy.

To sum up, we conclude that risk aversion is the factor that generates the largest changes in the optimal asset allocation, as well as in the provided welfare. Considering the dispersion of individual risk aversion, we quantify substantial added value of individualizing by this factor. The results confirm the importance of the time-invariant Merton-strategy, which is in fact tailored by this most important individual factor. However, its optimality also depends on the performance of equities.

6.3.3 Stock-house correlation

So far, we concluded that considering housing wealth is not beneficial in the baseline parametrization. The stock-house correlation has a similar role as the stock-income correlation, which is already concluded to be an important factor in tailoring lifecycles. Therefore, now we show the sensitivity of the asset allocation and the pension outcome for ρ_{SH}.

The correlation used so far was derived from the data series describing Dutch private residential properties and global equity. However, stock-house correlations vary heavily and across different geographical regions, as shown by Flavin and Yamashita (2002). They find big variation in the correlations of stocks and house prices across four big American cities. Similarly, we assume different stock-house correlations across different regions of the Netherlands and analyze the results for $\rho_{SH} = 0.2$ and 0.4.

As for the individualized lifecycles, increasing the stock-house correlation makes the strategy considering housing wealth more defensive through the hedging demand term, while the lifecycle without housing is obviously unchanged. Table 6.7 presents the results of the welfare analysis for two, otherwise identical, benchmark profiles with $\rho_{SH} = 0.2$ and 0.4.

Firstly, the welfare provided by the default strategies differs per individual, since the underlying labor income processes vary by the stock-house correlations. For $\rho_{SH} = 0.2$, the lifecycle without housing wealth is still optimal, since the lifecycle with housing is still more aggressive than its alternative without housing wealth.

In case of $\rho_{SH} = 0.4$, the individualized lifecycle with housing is more defensive

	1.	2.	3.	4.	5.	6.	7.	8.
$\rho_{SH} = 0.2$	48 813	49 071	45 703	47 499	48 691	48 06	48 176	48 735
$\rho_{SH} = 0.4$	48 102	47 835	43 748	45 812	47 323	46 438	46 781	48 060

CEC outcomes for the individualized and default lifecycles, for three profiles with different stock-house correlations. 1. With Housing, 2. Without Housing, 3. Offensive, 4. Neutral, 5. Defensive, 6. 100-age%, 7. 40%-60%, 8. Merton-solution

Table 6.7: Welfare analysis for different stock-house correlations

than its alternative, without housing wealth. As expected and suggested by the mean-variance analysis, it becomes optimal for such high level of stock-house correlation. The welfare gain from following the optimal strategy, instead of the lifecycle without housing, is still limited, only 0.56% in CEC, but compared to the Neutral default, it is 5%. The welfare gains are even larger, when the impact of high stock-house correlation is enhanced by non-zero stock-income correlations, for instance.

In this section we showed the impact of stock-house correlations on the optimal individualized lifecycle strategy, which is similar to that of the stock-income correlation. Higher correlations lower the optimal stock exposure through the hedging demand terms, while their magnitude depends on the size of human capital and housing wealth relative to financial wealth. The correlations affect our model in two ways: through the correlated stochastic processes and in the hedging demand term of the optimal asset allocation formula.

Besides the magnitude of the welfare effect, the direction becomes important when we study individual profiles deviating from the benchmark in several ways. Our preliminary expectation, that profiles further from the benchmark will yield larger welfare gains from the individualized strategies, is not necessarily true. Due to the complex nature of the optimal asset allocation formula, changing multiple individual factors at the same time can result in mitigated or fully offset impact. It is important to understand the driving forces and mechanics of the formula, before drawing conclusions on specific factors.

7 Conclusions

7.1 Summary

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 paradigm in pensions. In this thesis we focus on one of the focal points of the Dutch pension discussion: 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, wage profile and housing wealth, we obtain so-called individualized lifecycles. To conclude their welfare enhancing effect, they are analyzed in several experiments for different individual profiles.

To answer our first research question, we quantify the added value of distinguishing individuals by their labor income characteristics, namely career path, stock-income correlation and individual specific income risk. The welfare changes are interpreted in certainty equivalent consumption, as the improvement compared to the initial, untailored outcome. After individualizing the lifecycles, the remaining dispersion in the welfare results is credited to the underlying labor income processes. We find positive and substantial welfare gains in case of the stock-income correlation, which represents the sector where the employee works. 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. Considering heterogeneity in occupation sector-wise, hence, has added value for individuals versus when they are treated as the representative individual. However, career path and idiosyncratic risk yield ambiguous results. Therefore, we conclude that individualizing lifecycle investments in terms of these has no relevant welfare enhancing effect.

The second research question broadens the scope of the analysis, since the results of the individualized strategies are compared to those of the typically used defaults, to answer the question whether tailoring provides welfare gains over defaults. We find that in the baseline scenario set, the tailored lifecycle without housing wealth provides the highest welfare, which is, however, not the optimal strategy according to our model.

The sensitivity analysis showed that the optimality of the individualized lifecycles strongly depends on the economic scenarios, the investment opportunities of the lifecycle fund and on certain features of the individual profile. The optimal asset allocation is generally driven by the time-invariant Merton-solution, which is determined by the risk-return profile of the risky asset and the individual's risk aversion. In the baseline scenarios, the risky asset, which is a stock-only portfolio in our model, has a Sharpe ratio of only 17.5%. This makes the supposedly optimal, individualized strategy with housing, less attractive and suboptimal, due to its high exposure to equities. However, assuming better risk-return profile for the risky asset - in our case for stocks - makes this more aggressive individualized lifecycle optimal, as suggested by the mean-variance analysis too. The welfare gains relative to the Neutral default were as large as 6% in CEC for the representative individual and 13.05% for the employee with high stock-income correlation. Therefore, the added value and power of individualizing lifecycle investments is strongly dependent on the features of the chosen Return Fund, risky asset within the lifecycle portfolio.

Further, extremely low risk aversion and high stock-house correlations can also result in the optimality of the model-suggested lifecycle with housing wealth, even in the baseline scenarios. Our results confirm the importance of these two factors in the tailoring process of lifecycles, although both risk aversion and stock-house correlations for different regions for instance, are hard to estimate precisely.

Lastly, to answer the third research question, we conclude three individual factors that have substantial impact on the lifecycle asset allocation and therefore, on the pension outcome. These are: risk aversion, stock-income correlation and stock-house correlation. Risk aversion is the factor that drives the time-invariant Merton-solution, also within our explicit formula and has large tilting effect on the optimal portfolio choice. It is also key in determining welfare, in the CRRA utility function. The two correlation coefficients have their similar impacts on the hedging demand terms, correcting for the implicit equity exposures through labor income and housing wealth. They also determine the evolution of the three correlated random variables: returns on stocks, housing and labor income.

On the other hand, factors like career path and idiosyncratic income risk turned out to have ambiguous welfare enhancing effect when individual heterogeneity was considered. They are responsible for great variation in the labor income process, but have low or zero impact on the optimal asset allocation and thus, on retirement wealth. Especially idiosyncratic risk still seems to be hard and costly to capture and quantify. In terms of our model, where it is not included in the asset allocation decision, its impact on the pension income can only be approximated.

7.2 Discussion

Our results confirm the importance and welfare enhancing effect of individualizing lifecycles, although there is still room for further extensions. Firstly, the considered individual characteristics are not always clearly defined and some are hard to estimate precisely. An obvious extension of this thesis is, therefore, the deeper studying of these, such as risk aversion, idiosyncratic income risks, stock-income correlations per sectors or stock-house correlations per regions. Having better understanding and estimations of these can improve the quality of the analysis and contribute to the better description of individual heterogeneity.

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

Our model took advantage of several simplifications, both in the modeling approach and in the assumptions, which can be refined to make the model more realistic. Assuming constant risk-free interest rates was one of these. By choosing constant risk-free rate, we excluded interest rate risk from our model, while its efficiency has decreased too. The direct impact of the risk-free rate is rather hard to quantify, since it affects the discount rates, the conversion to the fixed annuity, the Sharpe ratios and the mortgages too. Its impact can be further discussed in sensitivity analyses and elaborated by using stochastic interest rate models.

Another obvious extension of our work is to quantify the costs of individualizing lifecycle investments, to carry out a cost-benefit analysis. The process to retrieve the individual-specific information is costly for both the pension fund and for the participants. These costs should be measured in certainty equivalent consumption in order to determine the net-of costs and break-even welfare gains, which would have high practical relevance too.

Lifecycle investing is a flexible instrument, with great room for further individualization for heterogeneous clients. Our research confirmed the welfare enhancing effect of tailoring lifecycles with respect to risk aversion, stock-income correlation and stock-house correlation. The results suggest that the exploration of further individual characteristics might yield additional benefits too. Besides the welfare implications of our research, new regulations on DC lifecycle investing also imply the introduction of tailored instruments and, thus, increase the practical use of our results and the relevance of the issue of individualizing lifecycles.

References

[1] Agnew, J. R. & Szykman, L. R. (2005): Asset Allocation and Information Overload: The Influence of Information Display, Asset Choice, and Investor Experience. *Journal of Behavioral Finance*, 6(2), 57-70.

[2] Arts, J. (2015): DC Defaults & Heterogeneous Preferences. MSc Thesis. Tilburg University, Netspar.

[3] Arts, J., & Ponds, E. (2016). The Need for Flexible Take-ups of Home Equity and Pension Wealth in Retirement. Netspar Discussion Paper No. 01/2016-005. Tilburg, Netspar.

[4] Ascheberg, M., Kraft, H., Munk, C. & Weiss, F. (2013): The Joint Dynamics of Labor Income, Stock Prices and House Prices and the Implications for Household Decisions. Working Paper. Goethe University and Copenhagen Business School.

[5] Bagliano, F. C., Fugazza, C. & Nicodano, G.(2009): Pension Funds, Life-cycle Asset Allocation and Performance Evaluation. ....

[6] Bagliano, F. C., Fugazza, C. & Nicodano, G. (2014): Optimal Life-Cycle Portfolios for Heterogeneous Workers. *Review of Finance*, 18(6), 2283-2323.

[7] Benartzi, S., & Thaler, R. (2007): Heuristics and biases in retirement savings behavior. *Journal of Economic Perspectives*, 21(3), 81-104.

[8] Benzoni, L., Collin-Dufresne, P., & Goldstein, R. (2007): Portfolio choice over the life cycle when the stock and labor markets are co-integrated. *Journal of Finance*, 62 (5), 2123-2167.

[9] Bikker, J., Broeders, D., Hollanders, D. & Ponds, E. (2009): Pension funds' asset allocation and participant age: A test of the life-cycle model. DNB Working Paper No. 223. Amsterdam, DNB.

[10] Bodie, Z., Merton, R., & Samuelson, W. (1992): Labor supply flexibility and portfolio choice in a life cycle model. *Journal of Economic Dynamics and Control*, 16 (3), 427-449.

[11] Boelaars, I., Cox, R., Lever, M. & Mehlkopf, R. (2015): The allocation of financial risks during the life cycle in individual and collective DC pension contracts. Netspar Discussion Paper No. 12/2015-059. Tilburg, Netspar.

[12] Boeri, T., A. L. Bovenberg, B. Coeure & A. Roberts (2006): *Dealing with the New Giants: Rethinking the Role of Pension Funds.* Geneva Reports on the World Economy 8, CEPR and International Center for Monetary and Banking Studies (ICMB).

[13] Bovenberg, A. L. (2008a): Grey new world: Europe on the road to gerontocracy? *CESinfo Economic Studies*, 54 (1), 55-72.

[14] Bovenberg, A. L. (2008b): The life-course perspective and social policies: An overview of the issues. *CESinfo Economic Studies*, 54 (4), 593-641.

[15] Bovenberg, L., Koijen, R., Nijman, T. & Teulings, C. (2007): Savings and investing over the life cycle and the role of collective pension funds. *De Economist*, 155 (4), 347-415.

[16] Broeders, D. & Rijsbergen, D. (2010): A life cycle approach in the Dutch occupational pension system? *Rotman International Journal of Pension Management*, 3 (1), 52-59.

[17] Campbell, J., Cocco, J., Gomes, F. & Maenhout, P., (1999): Investing retirement wealth: A life-cycle model. Working Paper 7029, National Bureau of Economic Research.

[18] Campbell, J., & Viceira, L. (2002): *Strategic asset allocation: Portfolio choice for long-term investors.* Oxford, Oxford University Press.

[19] Choi, J.J., Laibson, D., Madrian, B. & Metrick, A. (2003): Optimal Defaults. *American Economic Review*, 93(2), 180-185.

[20] Cocco, J., Gomes, F. & Maenhout, P. (2005): Consumption and Portfolio Choice over the Life Cycle. *Review of Financial Studies*, 18 (2), 491-533.

[21] Commissie Parameters (2014): (Dutch) Advies Commissie Parameters.

[22] Davis, S. J. & Willen, P. (2000): Using Financial Assets to Hedge Labor Income Risks: Estimating the Benefits. Working Paper, University of Chicago and Princeton.

[23] EIOPA (2015): Report on investment options for occupational DC scheme members. EIOPA-BoS-15/016. Retrieved from European Insurance and Occupa-

tional Pensions Authority: https://eiopa.europa.eu/Pages/News/Final-report-on-investment-options.aspx

[24] Euwals, R., De Mooij, R. & Van Vuuren, D. (2009): Rethinking Retirement. CPB Special Publication No. 80. The Hague, CPB Netherlands Bureau for Economic Policy Analysis.

[25] Flavin, M. & Yamashita, T. (2002): Owner-Occupied Housing and the Composition of the Household Portfolio. *American Economic Review*, 92(1), 345-362.

[26] Inkmann, J. & Shi, Z. (2014): Life-Cycle Patterns in the Design and Adoption of Default Funds in DC Pension Plans. Netspar Discussion Paper No. 10/2014-102. Netspar.

[27] Iyengar, S. S., Huberman, J. & Jiang, W. (2003): How Much Choice is Too Much? Contributions to 401(k) Retirement Plan. Pension Research Council Working Paper 2003-10.

[28] Iyengar, S. S. & Kamenica, E. (2010): Choice Proliferation, simplicity seeking, and asset allocation. *Journal of Public Economics*, 94(7-8), 530-539.

[29] Hanna, S. & Yao, R. (2005): The Effect of Gender and Marital Status on Financial Risk Tolerance. *Journal of Personal Finance*, 4(1), 66.

[30] Holzmann, R. & Hinz, R. (2005): Old-Age Income Support in the 21st Century - An International Perspective on Pension Systems and Reform. Washington, D.C., World Bank.

[31] Huberman, J., & Jiang, W. (2006): Offering versus Choice in 401(k) Plans: Equity Exposure and Number of Funds. *Journal of Finance*, 61(2), 763–801.

[32] Kahneman, D. (2012): *Thinking fast, thinking slow.* Now York, Farrar, Straus & Giroux.

[33] Kahneman, D. & Tversky, A. (1973): Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 5(2), 207-232.

[34] Kahneman, D. & Tversky, A. (1979): Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47(2), 263-292.

[35] Kraft, H. & Munk, C. (2011): Optimal Housing, Consumption and Investment Decisions over the Life-Cycle. *Management Science*, 57(6), 1025-1041.

[36] Kraft, H., Munk, C. & Wagner, S. (2015): Housing Habits and Their Implications for Life-Cycle Consumption and Investment. SAFE Working Paper Series No. 85. Frankfurt, Research Center SAFE - Sustainable Architecture for Finance in Europe, Goethe University.

[37] LCP Netherlands (2016): (Dutch) Lifecycle Pensioen 2016. Utrecht, Lane Clark & Peacock Netherlands B.V.

[38] Lizieri, C., Satchell, S. & Wongwachara, W. (2012): Unsmoothing Real Estate Returns: A Regime-Switching Approach. *Real Estate Economics*, 40(4), 775-807.

[39] Love, D. A. (2009): The Effects of Marital Status and Children on Savings and Portfolio Choice. The Society of Financial Studies. Oxford, Oxford University Press.

[40] Mercer (2015): *Melbourne Mercer Global Pension Index*. Melbourne, Australian Centre for Financial Studies. www.globalpensionindex.com

[41] Merton, R. (1969): Lifetime portfolio selection under uncertainty: The continuous-time case. *Review of Economics and Statistics*, 51 (3), 247-257.

[42] Merton, R. (1971): Optimum consumption and portfolio rules in a continuous-time model. *Journal of Economic Theory*, 3 (4), 373-413.

[43] Morin, R. & Suarez, F. (1983): Risk aversion revisited. *Journal of Finance*, 38 (4), 1201-1216.

[44] Munk, C. (2016): A Mean-Variance Benchmark for Household Portfolios over the Life Cycle. Working Paper. Copenhagen Business School.

[45] NEST (2012): Member Research Brief: Research to support the investment strategy. National Employment Savings Trust Corporation, London. NC 012 MRR 03/12

[46] NBIM (2015): The Diversification Potential of Real Estate. Discussion Note. Norges Bank Investment Management.

[47] OECD (2015): "Gross pension replacement rates" and "Old-age income poverty", in *Pensions at a Glance 2015: OECD and G20 indicators*, OECD Publishing, Paris.

[48] Poterba, J. M., Rauh, J., Venti, S. F. & Wise, D. A. (2006): Lifecycle Asset Allocation Strategies and the Distribution of 401(k) Retirement Wealth. NBER Working Paper No. w11974. National Bureau of Economic Research.

[49] Rouwendal, J. (2009): Housing wealth and household portfolios in an aging society. *De Economist*, 157, 1-48.

[50] Ruhmann, S. & Woolston, C. (2011): US Private Core Real Estate Investing. NEPC.

[51] Sablik, T. (2014): Investing over the Life Cycle: One Size Doesn't Fit All. Richmond Fed Economic Brief EB14-10. Federal Reserve Bank of Richmond.

[52] Samuelson, P. (1969): Lifetime portfolio selection by dynamic stochastic programming. *Review of Economics and Statistics*, 51 (3), 239-246.

[53] Scatigna, M., Szemere, R. & Tsatsaronis, K. (2014): Residential property price statistics across the globe. BIS Quarterly Review, September 2014. 61-76.

[54] Sinai, T. & Souleles, N. (2005): Owner occupied housing as a hedge against rent risk. *Quarterly Journal of Economics*, 120(2), 763-789.

[55] Sinn, H.W. (2000): Why a Funded Pension System is Useful and Why it is not Useful. International Tax and Public Finance, 7(4), 389–410.

[56] Sundén, A. E. & Surette, B. J. (1998): Gender Differences in the Allocation of Assets in Retirement Savings Plans. *American Economic Review*, 88(2), 207-211.

[57] Thaler, R. H. & Sunstein, C. R. (2003): Libertarian Paternalism. *American Economic Review*, 93(2), 175-179.

[58] Van De Grift, M. (2016): (Dutch) PPI na vijf jaar volwassen. *FD Pensioen Pro*, Nr. 9., 8-11. Retrieved from: http://pensioenpro.fd.nl

[59] Van Ewijk, C., Bonenkamp, J., Lever, M. & Mehlkopf, R. (2014a): (Dutch) Pensioen in discussie; risicodeling moeilijker/keuze binnen grenzen. *Netspar Brief 1*.

[60] Van Ewijk, C., Bonenkamp, J., Lever, M. & Mehlkopf, R. (2014b): (Dutch) Pensioen in discussie; risicodeling moeilijker/keuze binnen grenzen, Achterdocument. *Netspar Brief 1*.

[61] Van Hemert, O., De Jong, F. & Driessen, J. (2008): Hedging House Price Risk: Portfolio Choice with Housing Futures. Netspar Discussion Paper No. 2007-022. Tilburg University, University of Amsterdam and NYU Stern.

Appendix A1

- $SB_{i,t+1}$ expressed in terms of $SB_{i,t}$ for $t = 0$ follows as:

$$SB_{i,0} = -\left(\sum_{s=1}^{30} \frac{I}{(1+r_f)^s}\right) = -\left(\frac{I}{(1+r_f)} + \frac{I}{(1+r_f)^2} + ... + \frac{I}{(1+r_f)^{30}}\right)$$

$$SB_{i,1} = -\left(\sum_{s=1}^{29} \frac{I}{(1+r_f)^s}\right) = -\left(\frac{I}{(1+r_f)} + \frac{I}{(1+r_f)^2} + ... + \frac{I}{(1+r_f)^{29}}\right),$$

which is equivalent to:

$$SB_{i,0} \cdot (1+r_f) = -\left(I + \frac{I}{(1+r_f)} + \frac{I}{(1+r_f)^2} + ... + \frac{I}{(1+r_f)^{29}}\right)$$

$$SB_{i,1} = SB_{i,0} \cdot (1+r_f) + I$$

- $L_{i,t+1}$ expressed in terms of L_{it} for $t = 0$ follows as:

$$L_0 = \frac{c_1 \cdot (Y_{i,1} - FR_1)}{(1+r_f)} + \frac{c_2 \cdot (Y_{i,2} - FR_2)}{(1+r_f)^2} + ... + \frac{c_{30} \cdot (Y_{i,30} - FR_{30})}{(1+r_f)^{30}}$$

$$L_0 \cdot (1+r_f) = c_1 \cdot (Y_{i,1} - FR_1) + \frac{c_2 \cdot (Y_{i,2} - FR_2)}{(1+r_f)} + \frac{c_3 \cdot (Y_{i,3} - FR_3)}{(1+r_f)^2} + ... + \frac{Y_{30}}{(1+r_f)^{29}}$$

$$L_1 = L_0 \cdot (1+r_f) - c_1 \cdot (Y_{i,1} - FR_1) = \frac{c_2 \cdot (Y_{i,2} - FR_2)}{(1+r_f)} + \frac{c_3 \cdot (Y_{i,3} - FR_3)}{(1+r_f)^2} + ... + \frac{Y_{30}}{(1+r_f)^{29}}$$

Appendix A2

- The mean-variance utility maximization problem, in terms of the returns over next-period wealth:

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

$$= \frac{F_{i,t}}{W_{i,t}} \alpha_{S,t+1}(\mu_S - r_f) - \frac{\gamma}{2}\left[\left(\frac{F_{i,t}}{W_{i,t}}\right)^2 \alpha_{S,t+1}^2 \sigma_S^2 + 2\frac{F_{i,t}L_{i,t}}{W_{i,t}^2} \alpha_{S,t+1} \sigma_{S,Y} + 2\frac{F_{i,t}H_{i,t}}{W_{i,t}^2} \alpha_{S,t+1} \sigma_{S,H}\right]$$

- F.O.C. with respect to $\alpha_{S,t+1}$:

$$\frac{\partial U}{\partial \alpha_S} = \frac{F_{i,t}}{W_{i,t}} \cdot (\mu_S - r_f) - \gamma \cdot \left[\left(\frac{F_{i,t}}{W_{i,t}}\right)^2 \cdot \alpha_{S,t+1} \cdot \sigma_S^2 + \frac{F_{i,t}L_{i,t}}{W_{i,t}^2} \cdot \sigma_{S,Y} + \frac{F_{i,t}H_{i,t}}{W_{i,t}^2} \cdot \sigma_{S,H}\right] = 0$$

$$\frac{\mu_S - r_f}{\gamma} = \frac{F_{i,t}}{W_{i,t}} \cdot \alpha_{S,t+1} \cdot \sigma_S^2 + \frac{L_{i,t}}{W_{i,t}} \cdot \sigma_{S,Y} + \frac{H_{i,t}}{W_{i,t}} \cdot \sigma_{S,H}$$

$$\alpha_{S,t+1} = \frac{\mu_S - r_f}{\gamma \sigma_S^2} \cdot \frac{W_{i,t}}{F_{i,t}} - \left(\frac{L_{i,t}}{W_{i,t}} \cdot \sigma_{S,Y} + \frac{H_{i,t}}{W_{i,t}} \cdot \sigma_{S,H} \right) \cdot \frac{W_{i,t}}{F_{i,t}} \cdot \frac{1}{\sigma_S^2}$$

- The optimal share of the risky asset within the lifecycle portfolio:

$$\alpha_{S,t+1} = \frac{\mu_S - r_f}{\gamma \sigma_S^2} \cdot \left(1 + \frac{L_{i,t} + H_{i,t}}{F_{i,t}} \right) - \frac{L_{i,t}}{F_{i,t}} \frac{\sigma_{S,Y}}{\sigma_S^2} - \frac{H_{i,t}}{F_{i,t}} \frac{\sigma_{S,H}}{\sigma_S^2}$$

Appendix A3

The unsmoothing technique used for house price and wage returns is the base model described by Lizieri et al. (2010), to derive unsmoothed returns with the true level of volatility. Smoothed returns in both cases are assumed to be explained by the following AR(1) model:

$$r_t^S = \alpha + a \cdot r_{t-1}^S,$$

where α is the constant and $a \in (0; 1)$ is the smoothing parameter estimated from the regression. The true unsmoothed returns are derived from the smoothed ones as:

$$r_t^U = \frac{1}{1-a}(r_t^S - a \cdot r_{t-1}^S)$$

Appendix B

	Stock-income correlation			Individual income risk		
	$\rho_{SY}=0$	$\rho_{SY}=0.2$	$\rho_{SY}=0.4$	$\sigma_\varepsilon=3\%$	$\sigma_\varepsilon=5\%$	$\sigma_\varepsilon=7\%$
Mean	105 841	105 927	105 986	102 429	103 313	102 432
Median	98 621	99 001	99 304	97 537	96 244	92 856
Volatility	41 958	42 421	42 707	33 731	40 993	50 762
Volatility/Mean	39.64%	40.05%	40.38%	32.93%	39.68%	49.56%
97.5^{th} perc.	205 676	206 090	206 380	184 536	200 902	236 446
95^{th} perc.	183 261	185 232	184 087	162 877	178 941	197 723
5^{th} perc.	52 973	52 516	52 043	56 117	51 635	41 124
2.5^{th} perc.	46 363	46 157	45 954	51 140	45 260	36 957

Table B1: Distribution of final-year labor for different stock-income correlation and different idiosyncratic risk profiles, in €.

	Stock-income correlation			Individual income risk		
	$\rho_{SY}=0$	$\rho_{SY}=0.2$	$\rho_{SY}=0.4$	$\sigma_\varepsilon=3\%$	$\sigma_\varepsilon=5\%$	$\sigma_\varepsilon=7\%$
	Before tailoring					
Mean	1 014 862	1 014 433	1 015 406	1 007 009	1 014 862	1 007 509
Volatility	403 321	411 598	421 756	386 655	403 321	420 268
Volatility/Mean	39.74%	40.57%	41.54%	38.40%	39.74%	41.71%
	After tailoring					
Mean	1 014 862	1 003 896	993 258	1 045 295	1 014 862	979 995
Volatility	403 321	398 738	394 682	433 082	403 321	393 498
Volatility/Mean	39.74%	39.72%	39.74%	41.43%	39.74%	40.15%

Table B2: Distribution of retirement wealth (in €) for different stock-income correlation and different idiosyncratic risk profiles, before and after tailoring lifecycles.

	1.	2.	3.	4.	5.	6.	7.	8.
CEC in €	52 275	52 741	50 856	52 257	52 651	52 302	52 126	51 667

CEC outcomes for the individualized and default lifecycles, for the profile with zero idiosyncratic labor income risk. 1. With Housing; 2. Without Housing; 3. Offensive; 4. Neutral; 5. Defensive; 6. 100-age%; 7. 40%-60%; 8. Merton-solution

Table B3: Welfare analysis for the individual with no idiosyncratic labor income risk.

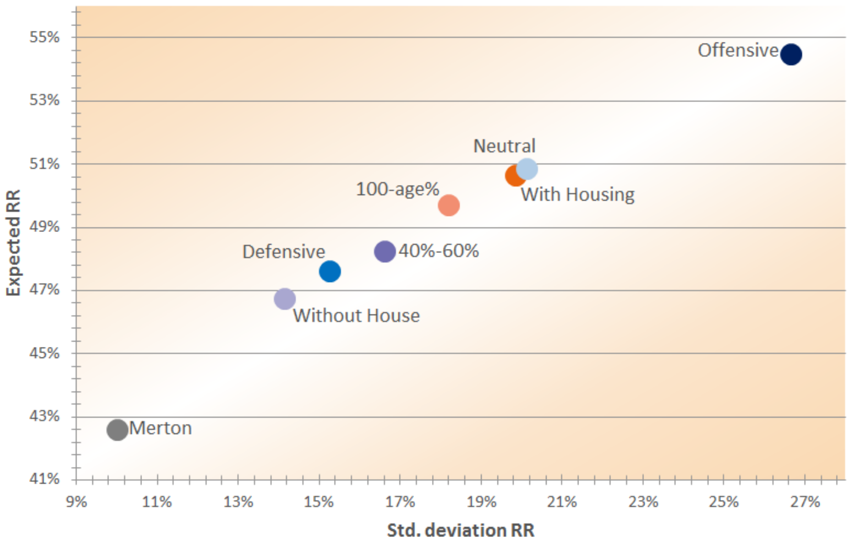


Figure A. Benchmark profile

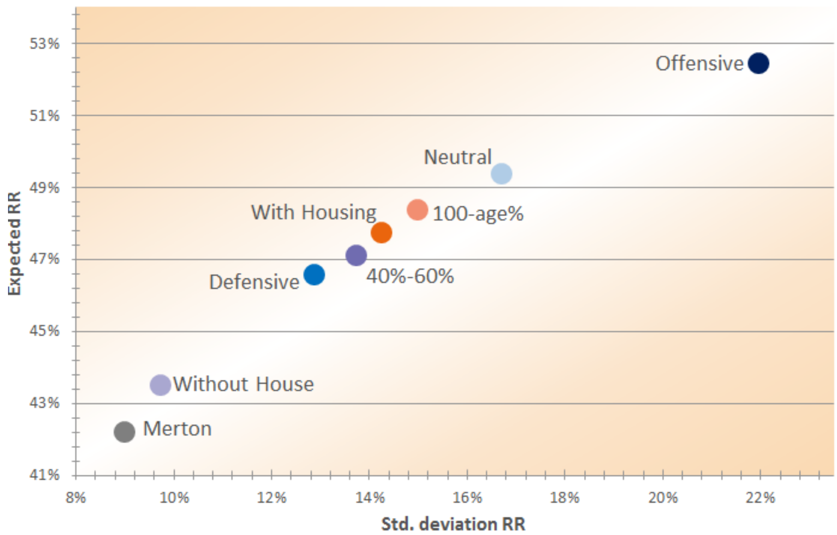


Figure B. Finance sector profile

Figure B1: Standard mean-variance graph for lifecycle investment strategies.

The figure plots the expected replacement ratio of each lifecycle strategy against its volatility for the benchmark and the Finance sector profiles. The strategies clearly follow the higher risk-higher return principle.