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Paying too fast and too slow -
Heterogeneous Life Expectancy and the Swedish Public Pension System

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Abstract: In many pension systems, pension benefits are calculated based on the life expectancy in the population. However, in recent years the gap in life expectancy and mortality across socioeconomic groups has been growing in Sweden and the OECD. As such, research has indicated that pension systems that are meant to be progressive may end up being regressive due to a redistribution from short-lived, low socioeconomic status groups, to long-lived, high socioeconomic status groups. In countries, such as Sweden, where an NDC scheme is part of the pension system this redistribution occurs implicitly through a homogeneous annuity divisor. In this thesis we explore the impact of how a policy shift to a heterogeneous annuity divisor would impact agent behaviour and the ex ante fairness of the system. We employ a dynamic model where we separately model and analyze three life cycles calibrated based on different levels of educational attainment in Sweden to research the impact of the policy shift. We find that the policy produces no shift in workforce participation or benefit claiming for the beneficiary of the reform (low socioeconomic agent) but a larger fraction of contributions are received as benefits. The middle agent is hardly affected by the reform and the behaviour outcome for the agent with high socioeconomic status is in part dependent on the model setup.

Keywords: Pension Policy, Life Expectancy, NDC systems, Life Cycle

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1. Introduction

A majority of the Swedish population worries that they will, or already receive a pension that is too low to live on (Katalys, 2021). Additionally, the pension system and the level of benefits are frequent topics for debate in Sweden and were key issues during the forming of government in fall 2021. At the same time, Sweden, alongside many of the OECD-countries, is facing an aging population where fewer individuals of working age are supporting a growing fraction of retirees (Amaglobeli et al. 2020). In response to this change, Sweden alongside other European countries are increasing the minimum retirement age as well as the targeted retirement age in an attempt to balance pension system finances. However, altering the retirement age to limit the number of pension beneficiaries in an attempt to urge people to work for a longer period of their lives is only one of many potential interventions. Sweden, Italy, Norway and a few other European countries, have a notional defined contribution (NDC) pension scheme as part of their pension systems (OECD, 2019). In such a scheme, one accumulates pension balance through pension contributions which is recorded on a notional account. Upon retirement the pension balance is divided by a factor to determine pension benefits. In Sweden, this factor is called an annuity divisor (Chłoń-Domińczak et al., 2012), reflecting life expectancy at retirement and a premature interest. The annuity divisor is homogeneous for all individuals of the same cohort, regardless of gender or socioeconomic status. At the same time, the gap in life expectancy and mortality between different socioeconomic groups has been growing in Sweden and the OECD(OECD, 2016). During 2006 and 2019 the life expectancy gap for 30-year-olds in Sweden between people with post-secondary education and compulsory education grew by 1.6 years, from 4.4 to 6.0 years (Public Health Agency of Sweden, 2020).

Research has shown that pension systems that are designed to be progressive often end up being regressive due to high education, high income individuals living longer than low education, low income individuals and the long-lived individuals then receiving pension benefits beyond the average life expectancy (Ayuso et al., 2016; Sanchez-Romero & Prskawetz, 2017). In Sweden, heterogeneous mortality rates have been shown to account for 26 percent of the differences in pension benefits between educational groups for men in the 1925 cohort (Shi & Kolk, 2021). This indicates that there could exist ex ante inequalities in pension systems where people with less education and lower socioeconomic status receive a relatively small(er) portion of their entitled pension because of shorter life expectancy. The redistributions from short-lived to long-lived occur by design in NDC schemes where pension benefits are calculated based on life expectancy in the population. The reason being that the life expectancy of the long-lived groups then exceeds the life expectancy used to determine their benefits. In Sweden, the guarantee pension mitigates some of the redistributive effect of the homogeneous annuity divisor as indicated by the results in Carlsson and Mikula (2016). However, the guarantee pension is received by individuals that for whatever reason have had low or no income throughout life (Swedish Pensions Agency, 2020a). Arguably, the guarantee pension is not meant to make up for the fact that some individuals' pension balance is paid out to them in a too slow (or too fast) manner due to the heterogeneity in life expectancy in Sweden.

One policy option which could account for the growing differences in life expectancy between socioeconomic groups and mitigate potential ex ante inequalities in an NDC system would be to impose a policy altering the annuity divisor to consider the heterogeneous life expectancies between groups. In Sweden, such a change could furthermore be argued to be more in line with the 1994 pension reform in which the system was changed to be more representative of an individual's lifetime income. Currently, short-lived groups with relatively low wages and short life span (i.e. low socioeconomic status) could, in contrast to the principles of the system, be argued to be losing out on a part of their entitled pension income since they have a shorter life expectancy than the one used to determine the annuity divisor.

Hence, the purpose of this thesis is to study the impact of a policy implementing a heterogeneous annuity divisor based on socioeconomic life expectancy by employing a dynamic model where three life cycles are modelled and analyzed one at a time. The thesis will consider the policy's impact on lifetime utility, benefit-to-contribution ratios and agents' choices for retirement and savings in a model reflecting the Swedish NDC system and Swedish demographic data (e.g. wages and life expectancy). Socioeconomic groups will be proxied using different levels of educational attainment. The choice of using educational attainment as the foundation for agent heterogeneity is explained in greater detail in section 4.1, but in brief, education should not be seen as the perfect indicator but rather as a proxy to capture socioeconomic differences in general. The goal of evaluating a policy with a heterogeneous annuity divisor in this thesis is not to present in detail how policy should be structured, but could be helpful to policymakers in improving or altering the design of pension systems to address life expectancy and longevity differences. Our contribution hence lies in studying the implications of implementing a heterogeneous annuity divisor in an NDC system.

The use of a dynamic model is necessary simply because, to our knowledge, there has been no actual policy reform targeting heterogeneous life expectancies in a public pension system, and while one can measure the differences that occur due to a homogeneous annuity divisor, such research has already been conducted (see Carlsson and Mikula (2016)). In addition, questions relating to retirement policy have a close connection to savings decisions and labor supply throughout life as choices made in the past will impact the optimal retirement decision. Hence, in order to fully grasp the implications of the proposed policy, a life cycle model is deemed most suitable. Given that the model is a partial equilibrium model only considering individual decisions given wages, longevity, etc., the thesis has limited ability to address how the financing of the system will be impacted. However, the results can provide some indications on financing given that retirement age and benefits-to-contribution for the short-lived and long-lived individuals can be observed.

The results showed that a heterogeneous annuity divisor reform likely would have a negligible impact on lifetime utility. Meanwhile, the consumption equivalent indicated that the low socioeconomic status agent would require 0.37 percent more consumption per period to remain under the homogeneous annuity divisor scenario. In contrast, the high socioeconomic status agent would accept a consumption loss of up to 0.56 percent per period in order to remain. The results further suggest that the agent with low and middle socioeconomic status would not change their working decision under the policy scenario - something that suggests that the policy would be compatible with planned and recent increases of the retirement age. However, the results for the agent with high socioeconomic status are not as clear due to the gap between workforce exit and benefit claiming in the calibrated model (the gap likely being an artefact of the employed model). Nevertheless, these results suggest a later workforce exit and earlier benefit claiming while the sensitivity analysis suggests no change from the calibrated scenario to the policy scenario. Furthermore, the estimated benefit-to-contribution ratios provide some indications of the fairness of the income-based public pensions. The current homogeneous annuity implicitly redistributes from short-lived to long-lived and, in extension, from groups of low socioeconomic status to groups of high socioeconomic status. As such, the analyzed policy reform is a policy tool that could be used, at least in theory, to address potential ex ante unfairness in NDC pension schemes.

The structure of the thesis is as follows: Section 2 discusses related literature. Section 3 provides a broad overview of NDC systems as well as the Swedish public pension system but with a particular focus on its NDC component. Section 4 introduces the life cycle model employed and discusses some of the most crucial choices made in that regard, while section 5 then continues by presenting how the life cycles have been calibrated. Section 6 presents the policy scenario and the estimated results from it, and section 7 presents some sensitivity analyses based on points of concern discussed in earlier sections. Finally, the thesis is brought to an end in section 8 with a discussion on the findings, limitations, as well as a brief discussion on potential directions for future research.

2. Related Literature

2.1. Pension Systems and the Notion of Fairness

A pension system, depending on its design, can serve many different purposes at once. In Shi and Kolk (2021), the authors discuss the different functions of pension systems and state that there are two types of systems in general - “Bismarckian” and “Beveridgean”. The former is centered around redistributing from young to old as well as reducing the income variance regardless of the future length of an individual’s life. The latter is instead oriented towards mitigating poverty amongst the elderly, particularly through the redistribution of wealth between young and old which ultimately steers away from connecting pension contributions with pension benefits. Many systems also include mechanisms that redistribute from high income to low income individuals (Shi & Kolk, 2021). However, as Shi and Kolk (2021) point out, due to the growing heterogeneity in life expectancy, the impact of the redistributive effect of these two systems is shifting, and ensuring fairness across and within cohorts is becoming increasingly difficult.

Queisser and Whitehouse (2006) elaborate on the notion of fairness in pension systems and discuss the concepts of “actuarial fairness” and “actuarial neutrality”, concepts commonly brought up in work on pension systems. “Actuarial fairness” is essentially an outcome where the present values of lifetime contributions and benefits are equal. Assessing actuarial fairness requires that the lifetime contributions and benefits are discounted since these occur at different points in time and at different stages of an individual’s life. When calculating the present value of lifetime contributions the challenge lies in deciding which interest rate to apply (Queisser & Whitehouse, 2006) as this will directly affect whether or not a pension system is deemed to be actuarial fair or not. Queisser and Whitehouse (2006) discuss three potential interest rates that could be used: the market rate of return on investments, the riskless interest rates, and the fiscally sustainable returns. The authors argue that the riskless interest rate is a suitable point of reference when it comes to pay-as-you-go pension systems. An important implication of “actuarial fairness” is that under an actuarial fair outcome, there is no redistribution between individuals (Queisser & Whitehouse, 2006). The concept of “actuarial neutrality”, differs from “actuarial fairness” and necessitates that “pension wealth for retiring a year later is the same as pension wealth when retiring today plus whatever pension is accrued during the additional year of work” (Queisser & Whitehouse, 2006, p.13). This means that the concept relates to the implications of remaining longer in the workforce (Queisser & Whitehouse, 2006). In relation to these concepts a relevant thing to point out, which is brought up by Queisser and Whitehouse (2006), is that “it is very difficult to design pension systems around these actuarial concepts alone” (Queisser & Whitehouse, 2006, p.4). Some parts of a pension system are by default neither actuarially neutral nor fair, this applies to for instance mechanisms that aim at protecting individuals from poverty during their retirement (Queisser & Whitehouse, 2006). Hence, a perfectly actuarially fair system might not be desired by a society.

In addition, “actuarial neutrality” and “actuarial fairness” are concepts that only make sense from an ex ante perspective (Queisser & Whitehouse, 2006) meaning that expected outcomes (ex ante) are considered, rather than actual outcomes (ex post). For actuarial fairness and neutrality this implies that a system should be fair in advance but might be unfair when considering ex post outcomes, simply because one individual, by chance, had a longer lifespan than another individual. While it might seem unfair that some individuals will die prematurely while others won’t (ex post differences in longevity), one can argue that a pension system is fair from an ex ante perspective as long as the differences are completely random (i.e. all individuals were expected to live as long and in expectation reap the same pension benefits).

However, one could argue that pension systems that do not consider life expectancy differences when deciding retirement age, annuity divisors and pension benefits are in fact ex ante unfair, as research indicates that there exist differences in life expectancy between socioeconomic groups. The reason being that as a result of life expectancy differences, some groups in expectation get less pension benefits in relation to their contributions than others.

Baurin (2020) discusses the differences between ex ante and ex post notions of fairness and directs critique towards the ex ante perspective when differentiating retirement ages between socioeconomic groups by providing an example of an egalitarian social planner. Essentially, once an egalitarian social planner takes one step towards adjusting ex ante differences (e.g. adjusting retirement age based on parental income) there is in theory no stopping point until all ex ante differences have been accounted for and the results end up being (in a deterministic world) adjusted for the ex post outcome (i.e. the longevity) (Baurin, 2020). For a pension system wanting to consider ex ante differences, the convergence of the ex ante and ex post would imply perfectly individualized retirement ages and annuity divisors. Baurin (2020) estimates the effect of attempting to account for longevity and life expectancy through differentiated retirement ages and finds that the effects of such a policy are limited, and thus suggests that other policies and further research on the topic should be considered. While presenting a critique towards the ex ante approach, Baurin (2020) states that there is an inability (or lack of data) to perfectly estimate an individual's longevity. Based on this, one can argue that the ex ante and ex post convergence in a deterministic world does not invalidate attempts to consider ex ante notions of unfairness when it comes to pension systems in reality. In addition, there might exist a societal wish to consider ex ante differences across groups or individuals.

2.2. Mortality and Life Expectancy by Socioeconomic Status

For the sake of keeping terminology straight it is deemed appropriate to present a definition of average remaining life expectancy (commonly used interchangeably with life expectancy). Statistics Sweden (2021d) describes life expectancy as "an index that described [*sic*] mortality in all ages for a [certain] year or a specific period". As emphasized by Statistics Sweden (2021e) it is not identical to the average lifespan for a specific cohort. Since mortality may change over time the life expectancy at birth for a certain cohort does not have to be the same as the average lifespan of the cohort once everyone in the cohort has passed (Statistics Sweden, 2021e).

In an attempt to structure the discussion of causal effects on mortality, Hayward et al. (2015) propose a framework based on a vast empirical overview. As displayed in the framework by Hayward et al. (2015), early life factors can act as potential confounding factors for adult mechanisms affecting mortality during adulthood, and at least in part by affecting educational attainment. In turn, the relationship between educational attainment and adult mortality is described as education being an instrument that enables attainment of skills, knowledge and networks that mitigate negative adult mechanisms on mortality. However, educational attainment is not the only social factor that has been found to be associated with mortality and life expectancy. In a report from 2016, Statistics Sweden analyzed differences in life expectancy and mortality in Sweden by looking at different subsets of the population based on different social factors. The report finds statistically significant differences in mortality for social factors such as marital status, income, housing, number of children, country of birth group as well as education. For instance, in 2010-2013 the life expectancy at age 30 for women in different disposable income quartiles ranged from 52.0 years for the first quartile to 56.3 years for the last quartile. The corresponding range for men was 46.0 to 53.9 years (Statistics Sweden, 2016b).

When Statistics Sweden (2016b) analyzed the mortality risks in 2010-2014 for groups with different educational attainment, they found that the present variations in mortality between the groups decreased when other social factors also were considered together with education. The single social factor that was found to affect the mortality differences the most between groups with different educational attainment was income. Nevertheless, the differences between the groups still remained which, as brought up in the report, indicates that education has implications for differences in mortality in and of itself (Statistics Sweden, 2016b).

During 1986-2014 the differences in life expectancy at 30 years of age for groups with different levels of educational attainment in Sweden increased (Statistics Sweden, 2016b). The increasing gap between groups with different educational attainment in Sweden was further confirmed by the Public Health Agency of Sweden (2020) who looked at similar data for the years 2006-2019 and found that the gap in life expectancy at age 30 between different groups of education had grown from 4.4 to 6.0 years during the studied time period (Public Health Agency of Sweden, 2020).

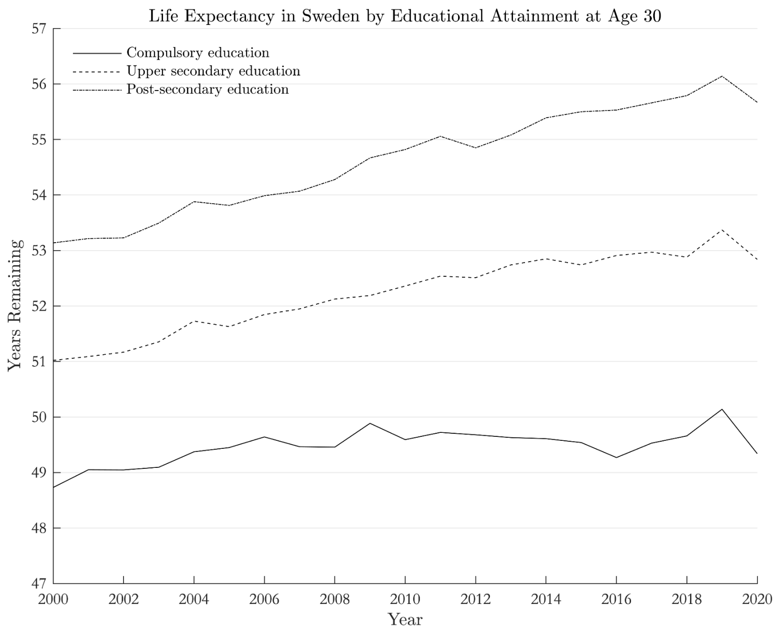

Figure 1: Life expectancy in Sweden by educational attainment at age 30 in the years 2000-2020. Data has been accessed from Statistics Sweden (2021c) and includes only people born in Sweden.

Meanwhile, the educational attainment in Sweden has increased during the last decades which has potential consequences for mortality differences within and between groups and accordingly might impact the relevance of this thesis. For instance, between 2005 and 2016 the number of individuals with only compulsory education in ages 20-64 fell from 841,000 to 586,000 (Statistics Sweden, 2018). The trend of increased educational attainment is discussed by Statistics Sweden (2016b) who writes that the fraction of individuals in ages 30-37 with only compulsory education has remained rather stable during the 15 years preceding the report. Hence, this thesis is not studying a negligible subset of the population but rather an existing difference between citizens which, at least in part, is manifested through educational attainment.

The socioeconomic trends in life expectancy and mortality are not unique to Sweden. In an OECD report Whitehouse and Zaidi (2008) surveyed over 50 reports on socio-economic differences in mortality across a multitude of countries, time periods and socioeconomic measures. They found evidence for the existence of socioeconomic differences in mortality and that these gaps seemed to be growing over time (Whitehouse & Zaidi, 2008). The second part of Whitehouse and Zaidi (2008) then considered not only the growing differences in socioeconomic mortality, but more specifically the impact of these growing differences on various pension systems in the OECD. The authors found that the pensions for black men in the U.S with less than higher secondary education are 20 percent less valuable than to the average American, due to lower life expectancy. Similarly, pensions in Europe were also deemed less valuable for individuals with low educational attainment than individuals with high educational attainment as a result of varying life expectancy across groups (Whitehouse & Zaidi, 2008). Similar trends with regards to the growing gap in life expectancy are found in a more recent OECD paper as well (OECD, 2016). Accordingly, the growing heterogeneity in life expectancy will impact the distribution of pension benefits between educational, and socioeconomic groups.

2.3. Life Expectancy, Heterogeneity and Pension Systems

There is evidently a close connection between life expectancy, socioeconomic status and pension systems, both in how the systems function but also with regards to their outcomes. Accordingly, a lot of research has been dedicated to this relationship. For instance, Sanchez-Romero and Prskawetz (2017) use a general equilibrium model to study how increasing life expectancy differences leads to a more regressive pension system in the U.S.. They find that despite the progressiveness of the U.S pension system with respect to the connection between pension benefits and lifetime income, the system is in fact not redistributing from high skilled (long-lived) to low skilled (short-lived) individuals, due to the high skilled (long-lived) receiving their pension benefits for a longer period of time.

Shi and Kolk (2021) reach similar conclusions when looking at differences in mortality rates to calculate losses in pension benefits for different socioeconomic groups in Sweden. They use five decades of Swedish taxation records to study how lifetime pension income is structured across different socioeconomic groups and study differences with regards to gender, education, and preretirement labor earnings. With regards to the lifetime pension differences Shi and Kolk (2021) find that men with post-secondary education have a lifetime pension of more than twice that of men with only primary education. For men born in the 1925 cohort, mortality differences between the two educational groups account for 26 percent (822 KSEK) of the total lifetime pension income difference. The remaining difference is explained by lifetime income differences and redistributional effects. For women, the differences in lifetime pension income between educational groups are smaller, partially due to the smaller socioeconomic differences in mortality and earnings for women, as well as the mortality differences due to educational attainment being smaller for women than for men (Shi & Kolk, 2021). Shi and Kolk (2021) are studying a similar phenomenon as this thesis, however, as the authors note, they are evaluating the entire system and no particular subcomponent in particular as well as only considering historical outcomes. Meanwhile, we analyze a policy targeting a subcomponent of the pension system, based on these well-documented mortality differences, and in turn consider the effect of such a policy. Interestingly, the Swedish Pensions Agency have performed a similar exercise as Shi and Kolk (2021) but instead looked at income quintiles and heterogeneous life expectancies in order to calculate the effect of the homogeneous annuity divisor. Their results are similar to Shi and Kolk (2021) with regards to the redistributive mortality effects but they argue that the guarantee pension mitigates the homogeneous annuity divisor effect of short-lived (low income) individuals losing out on benefits (Carlsson & Mikula, 2016). However, the guarantee pension is received by those that for whatever reason had low income throughout life (Swedish Pensions Agency, 2020a). The guarantee pension is arguably not meant to make up for the fact that some individual's pension balance is paid out to them in a too slow (or too fast) manner due to the heterogeneity of life expectancy in Sweden.

Another paper that considers the potential impact of life expectancy and mortality differences between groups is Ayuso et al. (2016). The authors discuss the various redistributive components of pension systems and consider how the heterogeneity in life expectancy affects the redistributive motives. Ayuso et al. (2016) then goes on to suggest a multitude of different interventions to address the current regressivity of the system. Among the interventions they suggest are a differential in pension contribution and retirement age for different socioeconomic groups, indexing benefits to cohort-specific life expectancy but more notably they do discuss the potential of linking the annuity calculation [divisor] to substandard mortality for different groups. This suggestion is built upon by Sanchez-Romero et al. (2020) who calculate the impact of different progressive pension systems. In Sanchez-Romero et al. (2020), they calibrate a life cycle model to U.S data and find that, out of their five fictional pension systems, the systems that calculate pension benefits based on life tables for each income quintile achieve the highest welfare for the three lowest quintile groups while the others actually redistribute wealth from the lower quintiles to the upper ones (Sanchez-Romero et al. 2020).

While this thesis also considers an annuity divisor effect, it differs in several aspects compared to Sanchez-Romero et al. (2020). Firstly, they calibrate their model to the U.S social security system and then create, amongst other systems, two fictional NDC systems one of which has a heterogeneous conversion factor (in essence an annuity divisor) based on income. In this thesis, we analyze the life cycles of different groups in a framework with a pension system that builds upon a non-fictional pension system currently used in Sweden. Meaning we are able to more accurately shape our pension system to a real-life example (e.g. real contribution rates and maximum pension-credited contributions) as well as calibrate the model to an economy where such a system actually exists. Secondly, the context of this thesis is different as we are considering the Swedish public pension system. While the results in Sanchez-Romero et al. (2020) give indications on the regressivity of pension systems in general, this thesis adds value by analyzing how a shift to one component of an existing pension system impacts the fairness as well as the decisions of Swedish citizens.

Boado-Penas et al. (2020) also look at annuity divisors and try to pin down the redistribution for different socioeconomic groups that stems from the annuity divisor being gender-neutral. The authors consider different subsets of the population based on gender and educational attainment. The measurement applied to evaluate the redistribution is the present value ratio of expected lifetime pension benefits to contributions (Boado-Penas et al. 2020). This ratio is an expression of the actuarial fairness of the system, the concept discussed by Queisser and Whitehouse (2006). By the calculations of Boado-Penas et al. (2020), based on Swedish data and NDC system, the present value ratio for men with a gender-neutral annuity divisor is 0.9495. Meanwhile, for women it is 1.0640. For both genders there is an education gradient to the ratio and for women all groups have a ratio greater than 1. A ratio greater than 1 implies that the group receives a net transfer. These ratios are based on the authors' calculations when including the inheritance gain in the Swedish pension system from the pension calculations. Furthermore, they are calculated under a set of assumptions concerning, among other things, lifetime labor market participation and retirement age. When not considering the inheritance gain, the estimated ratio for men is 0.9080 and 1.0175 for women (Boado-Penas et al., 2020).

Halvorsen and Pedersen (2019) study gender equality in the Norwegian NDC pension system and, amongst other things, consider the redistributive effects of annuity divisors. As pointed out by the authors, a NDC system is meant to create "a closer and more transparent link between lifetime earnings and lifetime contributions on the one hand and (expected) pension benefits on the other" (Halvorsen & Pedersen, 2019, p.133). One implication of this connection is that if women have lower wages and a larger tendency to work part-time, then there is a likelihood for a pension gender gap. However, there are several mechanisms in place that reduce the connection between wages and pension benefits in the Norwegian system. The authors group these mechanisms into three categories, one of which is referred to as "latent redistributive mechanisms" which relates to life expectancy differences and the annuity divisor. As the annuity divisor is gender-neutral but there exist differences in life expectancy between men and women, an implicit redistribution occurs (Halvorsen & Pedersen, 2019). Halvorsen and Pedersen (2019) apply a microsimulation model and look at the 1963 cohort. They start with a baseline case in which they simulate a made-up pension system without any redistributive mechanisms. In the baseline case the annuity divisor is tied to gender life expectancy and the pension rights are proportional to lifetime income. By the authors estimations, such a system would yield a gender gap of 43 percent in average yearly pension benefits during retirement. In a subsequent step, the authors alter the annuity divisor to one that is gender-neutral. When doing so, the estimated gap is decreased to 31 percent. Once an array of redistributional mechanisms (such as child credits and guarantee pension) are taken into account, they estimate the gender gap to 7 percent with the gender-neutral annuity divisor being the mechanism with the largest contribution to narrowing the gap. When considering the sum of pensions instead of average pensions the gender gap is estimated to be 1 percent. Furthermore, the authors find relatively high inequality among individuals of the same gender when considering the sum of pensions. This is something they attribute to the correlation of life expectancy with lifetime income and pension rights (Halvorsen & Pedersen, 2019).

Ultimately, there are many studies looking at heterogeneity in life expectancy and its effect on pension systems. Increasing the retirement age in response to growing life expectancies and to balance finances is amongst the planned and recent policy changes in Sweden and the OECD (Swedish Pensions Agency 2021c; OECD, 2019). However, due to heterogeneity (in for instance health) amongst agents increasing the retirement age has been shown to have contradictory effects on fiscal outcomes due to increases in disability benefit claiming (Laun et al., 2019). Meaning that other policy alternatives should be considered. While Baurin (2020) argues that heterogeneous policies targeting groups might have limited effect due to heterogeneity within groups, it is evident that homogeneous policies also lack effect and might have unexpected regressive outcomes. To the best of our knowledge no paper has employed a life cycle model in a country where a NDC system is actually used to study the impact on agent choice and lifetime utility when considering a policy shift towards a heterogeneous annuity divisor with respect to socioeconomic status. Sanchez-Romero et al. (2020) as well as Halvorsen and Pedersen (2019) considers heterogeneous annuity divisors in an NDC system, but the former does so by creating five fictional systems calibrated to the U.S economy, hence lacking a connection to an economy using an NDC system, and further only consider income quintiles. The latter does not consider behaviour responses. Hence, the contribution of this thesis is thus to consider the impact of a heterogeneous annuity divisor, in a system where a homogeneous annuity divisor is currently used, to understand how agent's life cycle choices and utility is affected.

2.4. Learnings from Model Building and Pension Studies

Questions that relate to retirement are closely connected to an individual's decisions for savings, consumption, and labor supply throughout life. The choices that are made today in terms of savings, consumption, and labor supply affect the choices that will be feasible in the future. In the same way, the decisions made while young will affect the decisions that will be feasible and optimal during old age and ultimately affect retirement decisions. Hence, there is an interrelatedness of the decisions made throughout life. Someone that decides to work and save a lot when young will, all else equal, be able to consume more or afford to spend less time working in the future compared to someone that worked less early in life. However, such a set of choices would naturally imply giving up welfare when young in favour of welfare when old. This means that individuals are facing a trade-off between today and tomorrow when making decisions. Because of these dynamics, and the research question focusing on a shift in pension policy, this thesis employs a dynamic model. The model is solved and analyzed numerically using MATLAB. The reasons for using numerical methods to solve and analyze dynamic models are discussed and motivated in textbooks such as Auerbach and Kotlikoff (1987), Miranda and Fackler (2002), and Adda and Cooper (2003). The common line of reasoning relates to the limitations in obtaining analytical solutions in many dynamic models. However, as pointed out by Miranda and Fackler (2002), increased computational speed is one thing, among others, that have enabled economists to use numerical methods to analyze these types of models.

There are many papers that use numerical methods in order to investigate different questions relating to retirement and retirement decisions. Two papers that have done so in a Swedish context are Karlstrom et al. (2004) as well as Laun and Wallenius (2015). These papers provide an important backdrop to this thesis in order to better understand how different model choices influence the possibility of capturing the central aspects of a pension system and the key choices faced by individuals in relation to it. In addition, Laun and Wallenius (2015) provides inspiration as to how one can think about heterogeneity amongst agents. Karlstrom et al. (2004) employ a dynamic programming model in which they estimate retirement decisions based on longitudinal individual data on male blue-collar workers born in the period 1927-1940. In the model used, individuals obtain utility from consumption and leisure. They estimate two versions of their model. In one version they let the parameter that dictates the utility from leisure vary with age and in the other version they let it be fixed. The inclusion of age-dependent leisure is motivated by producing a better fit, at the cost of possible over-parameterization, the former also rests on the assumption of work becoming more tedious at an old age. The employed model has five different state variables. They are age, wage earnings, average pension points, retirement age, as well as civil status. Disability insurance is not included in the model which according to the authors is due to the model becoming easier to specify and estimate with no disability insurance. After calibrating their model, the authors run simulations under a hypothetical reform scenario in which there is a postponement of three years for the age in which individuals are eligible to public pensions compared to the actual eligible age (Karlstrom et al., 2004). Similarly, a hypothetical reform is analyzed in this thesis as well.

In a more recent paper, Laun and Wallenius (2015) estimate how labor supply in old age was affected by the Swedish pension reform from 1994. To do so, a life cycle model is employed and is calibrated using longitudinal individual data to the pension system that preceded the reform. In the model, agents are heterogeneous in terms of their skills (Laun & Wallenius, 2015). Allowing agents to be heterogeneous enables an analysis of a potential heterogeneous impact of the reform. In their model, Laun and Wallenius (2015) let agents obtain utility from consumption and health, as well as disutility from working. The magnitude of the disutility from working depends on health status. Besides the possibility of applying for disability insurance, the model incorporates the agents' choices for consumption, investment in capital, a binary labor supply choice, and if the agent is to apply for pension benefits. After having calibrated the model, the pension reform is analyzed by incorporating the changes from the pension reform (Laun & Wallenius, 2015).

3. Key Aspects of the Swedish Public Pension System

This section will provide an overview of NDC systems and explain some of the core aspects of the Swedish public pension system. The description in this section will put emphasis on the public pension since this is the part of the pension system of main focus in this thesis. Nevertheless, the occupational pension also impacts an individual's financial condition in old age. The disparity in occupational pensions, due to the amount of unique employee agreements and collective agreements, makes the occupational pension out of scope and too complicated to incorporate in this thesis. There also exist a few components of basic social benefits within the Swedish public pension system. The main ones are guarantee pension, housing supplements and financial support for the elderly. The housing supplement is dependent on an individual's housing costs, and the financial support for the elderly is targeted at individuals who become residents in Sweden late in life and have no or little foreign pension (Swedish Pensions Agency, 2020b). As such, these are out of scope for this thesis. The guarantee pension impacts the heterogeneous outcomes of the annuity divisor as indicated by Carlsson and Mikula (2016). However, the guarantee pension is arguably not meant to make up for the fact that some individual's pension balance is paid out to them in a too slow (or too fast) manner due to the heterogeneity of life expectancy in Sweden. The guarantee pension is also funded by the government and is as such a redistribution across (from young to old) rather than within generations. Hence, we focus on the "pure" impact that a heterogeneous annuity divisor would imply for the heterogeneous life expectancies without the incorporation of the guarantee pension. One additional feature of the Swedish Pension system is the inheritance gain, which inherently redistributes from short-lived to long-lived individuals. However, as this thesis intends to study the effect of heterogeneous life expectancies manifested through the homogeneous annuity divisor, rather than mortality effects in general, we do not consider inheritance gain.

3.1. NDC Pension Schemes and the Swedish NDC

The Swedish public pension system mainly consists of a notional (non-financial) defined contribution (NDC) scheme with a minor part being a financial defined contribution (FDC) system. In an overview, Palmer (2006) describes NDC schemes as defined contribution, pay-as-you-go pension schemes in which a fixed contribution rate decides the contributions that are paid into the system by an individual. The contributions are recorded on an individual's account but are unfunded. The accounts are in that sense notional. In contrast, in a FDC scheme the contributions made to the system are invested on financial markets. Accordingly, an aspect that separates the two types of schemes is the return rate that is obtained on the accounts. In a FDC scheme, financial market return rates are obtained. In a NDC scheme the equivalent is an internal rate of return. This rate is decided based on determinants of economic development (Palmer, 2006). The pension benefits received are life annuities. Upon retirement, the annuities are decided based on the balance of an individual's account and the life expectancy of the cohort (Chłoń-Domińczak et al., 2012). NDC schemes provide a connection between benefits and contributions due to the benefits being based on the contributions. However, it is possible that the benefits in an NDC scheme might not give adequate protection during old age for an individual (due to the aforementioned connection) and that the scheme therefore necessitates that some form of basic protection is in place in addition to it. The formula of the NDC scheme does not in and of itself feature any redistribution (Palmer, 2006). However, the application of average life expectancy does imply redistribution between for instance men and women. A tool that can be used to implement distributions is to provide rights that are not based on earnings, i.e. noncontributory rights (Chłoń-Domińczak et al., 2012).

An NDC system was introduced as the new national public pension system in Sweden in 1999[1] through a major pension system reform. The reform was in part in response to the growing pension expenses (estimated to equate to roughly 13 percent of Sweden's GDP in 1993) and the growing number of retirees in relation to the working population (Pensionsarbetsgruppen, 1994). Hence, as explained by Pensionsarbetsgruppen (1994) the purpose of the reform was to create incentives to remain in the workforce for a longer period, as well as to tackle the growing financing issues of the then current system. A key difference between the new (NDC) system and the old (pre-reform) system is how income is linked to pension benefits. The current system is centred around the "lifetime income principle" where contributions are made throughout an entire (work) life and all contributions result in pension benefits, whereas the old system can be expressed, in a slightly simplified way, to have based its benefits on an individual's average earnings out of the 15 years with highest earnings (Pensionsarbetsgruppen, 1994). While an individual would have had to work for at least 30 years to receive full benefits in the old system, the basis for the benefit calculation is notably different between the systems. There are transition policies in place for cohorts affected by both systems (1938-1953), but the cohorts born in 1954 and onwards are fully dependent on the new system (Swedish Pensions Agency, 2021f).

3.2. Income Pension and Premium Pension

In an overview of the Swedish pension system, Pensionsmyndigheten (Swedish Pensions Agency, 2021a) uses a pyramid to symbolize the different components of the system and is illustrated in Figure 2.

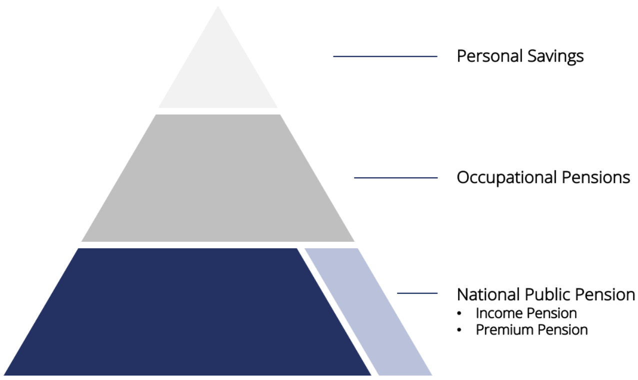

Figure 2: Author's illustration based on the Swedish Pensions Agency's pension pyramid.

The national income-based public pension system is constituted by the income pension and the premium pension. In 2019, the benefits from the public pension system could be claimed from an age of 61, which was subsequently changed to 62 in 2020 (Swedish Pensions Agency, 2021c). The benefits are funded through contributions made by individuals, employers, and in some instances by the government (Swedish Pensions Agency, 2021e) as in the case of the aforementioned noncontributory rights. An employed individual pays 7 percent of their pre-tax wage as contributions. Likewise, contributions of 7 percent are paid on any received social or unemployment insurance benefits. Meanwhile, the individual's employer also pays pension contributions corresponding to 10.21 percent of the employee's wage (in the case of self-employment there are corresponding contributions) (Swedish Pensions Agency, 2021e). There is a built-in cap on how much of the total contributions that are added to an individual's accounts (i.e. the pension credit). This cap is reached when an individual has an income of 8.07 income base amounts

[1] The reform was accepted by the Swedish Parliament in 1994 and implemented in 1999.

(equal to 519,708 SEK in 2019[2]). Employers still pay contributions when an employee's income is above 8.07 income base amounts; Yet, the amount that exceeds the cap does not yield anything to an individual's account. Similarly, there is a lower limit to when an individual earns credits to his or her individual accounts. This happens when an individual earns 42.3 percent of a price-related base amount or more in a year. When the individual reaches the lower limit, they start earning credits on their entire income (up to the cap) (Swedish Pensions Agency, 2020c).

The majority of the contributions in the Swedish system, 86.5 percent (Chłoń-Domińczak et al., 2012), are allocated to the income pension which constitutes the NDC component of the national public pension system. Because of the large proportion of contributions designated to it (and in turn the proportion of benefits received from it), the income pension could be argued to constitute the cornerstone of the public pension. An individual's account within the income pension (i.e. its pension balance) grows not only with contributions but also through a predetermined internal rate of return. The applicable indexation is in principle decided by an income index (essentially the growth in average wage), but under certain circumstances a balance index is used instead (Swedish Pensions Agency, 2020c; Swedish Pensions Agency, 2021b). A motif for indexing according to the growth in wages was to keep the ratio of average wages and benefits constant (at least in principle). Meanwhile, the balance index functions as a balancing mechanism to insure against the risk of a shrinking workforce (Chłoń-Domińczak et al., 2012) and is activated whenever the liabilities of the system exceed its assets. To decide the monthly benefits received from the income pension, the balance on an individual's account at retirement is divided by the annuity divisor (Swedish Pensions Agency, 2021e) (explained in further detail in section 3.3 and 4.4).

The remaining 13.5 percent of the contributions are allocated to the premium pension which constitutes the FDC component of the national public pension. In principle the contributions are invested in funds by the individual's choice, and if no active choice has been made they are invested in a default alternative (Swedish Pensions Agency, 2021e; AP7, n.d.). Hence, one evident aspect that differentiates the premium pension from the income pension is the possibility for individuals to allocate their premium pension themselves. Consequently, the two differ with respect to the return rates. The indexation of the income pension, as previously mentioned, is directly linked to the Swedish economy. The premium pension then functions as a complement to the income pension by diversifying the risks through exposure to global capital markets (AP7, n.d). The annuity divisor for the premium pension is slightly different from the one used for the income pension and is instead of life expectancy built on forecasted life expectancy using mortality rates (Swedish Pensions Agency, 2021e). While different from the income pension annuity divisor, the same heterogeneity in life expectancy forecasts (or mortality rates) are likely to be present. While slightly different, we abstract from the difference in annuity factors in the model (for further discussion, see end of section 4.3).

3.3. Annuity Divisor

When calculating the pension benefits received from the income pension an individual's account balance (i.e. the pension balance of the income pension) is divided by an annuity divisor. The latter resembles the life expectancy at the time of retirement for an individual's cohort. Furthermore, the annuity divisor also depends on an interest rate of 1.6 percent (Swedish Pensions Agency, 2021e; Chłoń-Domińczak et al.,

[2] One income base amount equalled 64,400 SEK in 2019 (Swedish Tax Agency, n.d.).

2012). The interest rate relates to the earlier discussed income index. As explained in Chłoń-Domińczak et al. (2012), the interest rate is the expected growth in real wages and it hence displays expectations of real growth in the long term (Chłoń-Domińczak et al., 2012). One implication of incorporating the interest rate when deciding the annuity divisor is that the annuity divisor becomes lower than the life expectancy. In addition, the annuity divisor also includes an adjustment for those individuals in the cohort that will pass away during the ongoing year, events that are assumed to be evenly distributed throughout the year. The annuity divisor for the income pension, as presented by Swedish Pensions Agency (2021e) is given by:

$$D_i = \frac{1}{12L_i}\sum_{k=i}^{r}\sum_{X=0}^{11}(L_k + (L_{k+1} - L_k)\frac{X}{12})(1.016)^{-(k-i)}(1.016)^{\frac{-X}{12}}, \quad i = 61, 62, ..., r$$ [3]

where

$D_i = annuity\ divisor\ for\ age\ group\ i$

$k - i = number\ of\ years\ of\ retirement\ (k = i,\ i + 1,\ i + 2,\ etc.)$

$X = number\ of\ months\ (0, 1, ..., 11)$

$L_i = number\ of\ survivors\ in\ age\ group\ i\ per\ 100,000\ born.$

The life expectancy data (survivors per 100,000 born) used in the annuity divisor calculation is based on five-year averages. If an individual starts claiming pension benefits at age 65 or later, this five-year period reflects the years prior to the year the individual turned 65. However, if the pension benefit claiming occurs before age 65, the individual receives a preliminary annuity divisor and the five-year average instead reflects the five-year period prior to the early retirement age (62 in 2021 and 61 in 2019). In the latter case, the annuity divisor is recalculated once the person turns 65 to accurately reflect the cohort's life expectancy at retirement. Consequently, this results in a recalculation of the income pension (Swedish Pensions Agency, 2021e). The annuity divisors are determined for each cohort and are shared by everyone in the cohort regardless of gender and socioeconomic status. The annuity divisor and its implementation in the model is discussed in further detail in section 4.

[3] Note that i starts at 61. This resembles the earlier rules where someone could claim benefits already at an age of 61 which has been changed lately. For the rules applied in 2021 i should start at 62.

4. The Model

4.1. Model Overview and Proxying Socioeconomic Groups

To answer the research question we employ a life cycle model to analyze three different life cycles based on three socioeconomic groups (denoted by SES where SES 1 implies low socioeconomic status, SES 2 middle socioeconomic status, and SES 3 implies high socioeconomic status). The socioeconomic groups are calibrated based on three levels of educational attainment. The educational attainment is exogenous to the agents. The groups are heterogeneous in terms of life cycle wages and how many periods they live. An agent's life cycle starts at age 25, and the terminal period of an agent's life is deterministic, denoted by T^{SES}.

The research question aims to study the impact of a heterogeneous annuity divisor in the presence of life expectancy differences between socioeconomic groups. While there are multiple socioeconomic factors which characterize different groups and between which life expectancy differences have been observed (as discussed in section 2.2), this thesis will use educational attainment. The motivation for exogenous education as the socioeconomic decider is as follows.

With regards to the choice of not having endogenous education in the model one should consider the purpose of this thesis. The purpose of this thesis is to study the impact of a policy addressing the heterogeneous life expectancies present in Sweden. By not allowing individuals to alter their status we want to capture the persistence of such groups in society, regardless of pension policy. As such, this thesis aims to understand if and how they alter their retirement age, savings decisions, how their lifetime utility is affected, and how their benefits-to-contributions ratio changes under a policy aimed at targeting said socioeconomic differences in life expectancy. Rather than studying how people might alter their education (or some other SES indicator) under a SES-dependent policy.

Accordingly, the idea is not to suggest a policy for implementation, but rather to research the impact of a socioeconomically adjusted annuity divisor. Hence, the choice of indicator is not to be seen as the one true decider of SES or the ideal basis for policy in practice, but rather the aim is to use an indicator that captures socioeconomic status, differences in life expectancy and is determined rather early in life in order to assign individuals at the start of the modelled life cycles (as opposed to a policy where individuals alter their status throughout life). It is important to note that in reality individuals can alter their educational attainment and that adjusting pension policy to depend on education is likely to affect the choice of education to some extent. However, even in Sweden, where post-secondary education is subsidized (and free), educational attainment is still highly correlated with the educational attainment of one's parents. Only 25 percent of individuals with parents lacking high school education have finished post-secondary education, compared to 80 percent of individuals with two parents having finished post-secondary education (Statistics Sweden, 2016a). Accordingly, while individuals have the ability to alter their educational attainment, it is still seemingly dependent on other socioeconomic factors such as parents' background, meaning that for the purpose of this thesis it can function as a proxy for general socioeconomic status and should be understood as such. Ultimately, while there is an argument to be made in favor of using education instead of other SES-indicators one should not view the choice of education to be the only relevant socioeconomic factor but rather as a proxy for an individual's socioeconomic status in general.

4.2. Agent Problem

The agent's lifetime utility is the sum of discounted utility from all periods, t, of an agent's life. In a given period, utility is obtained from consumption, c_t, and from leisure, α^{SES}, where the utility from leisure is obtained through the choice of labor supply, l_t. The parameter for utility from leisure, α^{SES}, varies across groups which enables calibrating the workforce exits to differ between groups (in order to be able to mimic real-life patterns of the groups). The parameter is not dependent on age and while such a design could be useful in fitting the life cycles to data in the calibration, we abstract away from this. This choice is not of utmost importance given that the model is still able to replicate workforce exit patterns observed in the data. The reason to incorporate utility from leisure in the utility function is to endogenize the decision to exit the workforce instead of having an exogenous retirement age (in case it would change under the policy scenario). Utility from consumption has a natural log-form assuming the agent has diminishing returns to consumption in a period. This is included simply to mimic a reality in which a unit of consumption at low levels (e.g. the first dinner for the evening) should give more utility than at higher consumption levels (e.g. the third dinner for the evening). Labor supply either takes a value of 0 or 1. While it is possible for agents to work part-time in reality, we abstract from this possibility to reduce the complexity of contribution calculations.

$$\sum_{t=1}^{T^{SES}} \beta^{t-1} u(c_t, l_t)$$

$$\text{where } u(c_t, l_t) = ln(c_t) + \alpha^{SES} ln(1 - l_t)$$

The agents are constrained in their choices in several ways which is captured by the budget constraint that an agent faces. The budget constraint depends on whether the agent is still in the workforce or has started claiming benefits. When agents are still in the workforce and decide to work they earn a wage, w_t^{SES}, that is dependent on SES and age. Pension contributions, τ, are paid on wage earnings. Agents are constrained by their asset holding, a_t, the interest earned, r, on these, and the assets that are brought to the next age, a_{t+1}. Agents are constrained both when they are in the workforce and when they are claiming benefits. The budget constraint for an agent in the workforce can hence be written as follows:

$$c_t + a_{t+1} = (1 + r)a_t + (1 - \tau)w_t^{SES} l_t$$

It is assumed that agents have no assets in the beginning of the life cycle and that they have no assets at the end of it. Agents are further borrowing constrained, meaning that assets will be at least 0 in all periods. This choice follows from the reasoning made by Laun and Wallenius (2015), namely that this can be a way to make agents work at a young age despite lower wages. Hence, the following constraints apply to all agents:

$$a_1 = a_{T^{SES}+1} = 0$$
$$a_t \geq 0$$

Furthermore, the decision to claim benefits is assumed to be an absorbing state and being mutually exclusive with labor supply. In other words, once the agent has started claiming benefits the agent will claim benefits for all future periods and cannot supply labor. While it is possible to work and claim benefits in real-life, we abstract away from this possibility for simplicity. This assumption implies that the budget constraint will be different when claiming pension benefits compared to when the agent is in the workforce. For a benefit claimer (retired agent) the budget constraint can be written as follows:

$$c_t + a_{t+1} = (1 + r)a_t + PB(RetAge)$$

Where PB is the pension benefit and is given by:

$$PB(RetAge) = \frac{\sum_{i=25}^{RetAge-1} \min\{\tau w_i l_i, Cap\}}{AD_{RetAge}}$$

$$Cap = 8.07 \times income\ base\ amount \times \tau$$

The pension benefit is modeled solely as a function of the age at which benefits are first claimed, $RetAge$. AD_{RetAge} denotes the annuity divisor and Cap reflects the cap on how much of the contributions that are added to an individual's pension balance in a year, as discussed in section 3.2.[4]

All in all, this means that there are four state variables in the model: age (t), current assets (a_t), benefit claiming (ret), and age when benefit claiming starts ($RetAge$). Choice variables of the model are consumption (c_t) and labor supply (l_t). However, when solving the model numerically, we let the agent choose the assets in the next age (a_{t+1}) and then back out the consumption based on the choice made.

4.3. Incorporating Components of the Swedish Pension System

To follow the logic of the NDC system, the pension benefits upon claiming benefits should in principle be calculated based on two things: 1) the annuity divisor (the denominator), and 2) the pension balance (the numerator). The annuity divisor depends, among other things discussed in section 3, on the life expectancy after retirement. Since this is of main interest to this thesis, it is central that the age at which benefits are claimed is a component in determining the pension benefits in the model as well. When it comes to the pension balance, it should naturally be a function of the years of work and thereby the contributions made through-out life. However, a simplification has been made to the model in this regard.

The simplification in the calculation of the pension benefits is that the numerator is solely an approximation of pension balance. Instead of keeping track of the actual pension balance based on the actual contributions made by the agent, it is calculated as if an agent would work all periods from age 25 (at the start of the life cycle) until benefits are claimed. This simplifies things as we do not have to keep track of the pension balance which would imply that we would need an additional state variable. Given that an agent starts in the workforce and provides labor for all periods until benefits are claimed, the pension balance in our simplification symbolizes the actual contributions. However, if an agent would stop working, but not claim benefits for one or more periods, and then start claiming benefits, the benefits per period would be higher than if the claiming had started directly after retirement as the

[4] The cap in the model differs slightly (≈+87 SEK) from the maximum pension credit in 2019 of 89,355 reported in the annual report of the Swedish Pensions Agency. The small discrepancy stems from roundings when calculating the cap based on 8.07 income base amounts and 17.21% contribution rate instead of 7.5 income base amounts and 18.5% contribution rate.

benefits are calculated based on the claiming age. What we then risk losing out on with this simplification is a more precise connection between an individual's contributions and benefits. This is a potential flaw in the model that needs to be noted.

One issue with having pension benefits as a state (which is one of the considered alternatives) is that it would imply either using a very large number of different states for the pension balance, or use fewer grid points leading to a rather blunt approximation and possible disjoint between pension balance growth between two periods, and the actual contribution during that period. Late into the thesis work, we came up with a solution which in brief was to introduce a state for workforce exit. However, due to limited time and the complexity of including one more dimension this was not included in the final model.

Furthermore, the public pension system contains a large array of components and thereby also a multitude of different rules. As such, abstractions are necessary when modeling the pension system, and in addition, not all components are relevant and/or crucial to the purpose of the thesis. Some have already been discussed in this section, whereas the implications for the annuity divisor will be explained in detail below. For instance, we do not include the indexation of contributions (as this depends on wage growth). In addition, for simplicity we assign the entire pension contribution to the NDC part of the income-based pension. While the income pension and premium pension differ in terms of their return rates in reality, we thus abstract from this possibility as well as model the annuity divisor to follow that of the income pension.

4.4. Calculating the Annuity Divisor in the Model

The nature of the model has certain implications for the calculation of the annuity divisor. Section 3.3 presented an overview of the annuity divisor for the income pension which in essence is a measure of life expectancy, adjusted by an interest rate to account for future growth as well as an assumption that part of the cohort passes away in the ongoing year. In our model, we have no wage or economic growth (as we do not consider time) and longevity is deterministic. Furthermore, for simplicity and in order to approximate the discrete periods in the model, it is assumed that the number of people alive per 100,000 lives the entire year in comparison to the assumption of evenly distributed deaths throughout the year used by the Swedish Pensions Agency[5]. As such, the annuity divisor calculation in the model becomes simplified in comparison to the equation presented in section 3.3 (for a step-by-step explanation as well as a stylized image of how it has been calculated in the thesis see Appendix D and E). Both the homogeneous and heterogeneous annuity divisor in the model is hence given by:

$$\frac{\sum_{k=n}^{\infty} L_k}{L_k} \quad where\ n = \ the\ retirement\ age\ chosen\ by\ the\ agent$$

L_k is the number of survivors in age group i per 100,000 born. The Swedish Pensions Agency provides an excel model for a step-by-step calculation of the annuity divisor based on the equation in section 3.3. This model has been used to certify that the calculations in MATLAB using the equation above have matched those of the Swedish Pensions Agency Excel model (adjusted for the abstractions of deterministic, discrete time and zero interest rate)[6].

[5] In comparison, when Statistics Sweden calculates average remaining life expectancy, they also consider the fact that people pass away between birthdays. For a further description of a more granular approach to calculate average remaining life expectancy, see Statistics Sweden (2013).

[6] The Excel-file is available through the Swedish Pensions Agency (2021g).

Another aspect of the annuity divisor is the fact that early retirees receive a preliminary annuity divisor which is then adjusted once the individual reaches 65 years old (the target retirement age). The preliminary divisor is dependent on the annuity divisor of the cohort that is at the target retirement age once the early retiree reaches the minimum retirement age. In real-life, the preliminary and definitive annuity divisors are likely to differ slightly due to differences in life expectancy between cohorts, however, in our model the preliminary and definitive annuity divisors are identical.

4.5. Solving the Model

The logic of the method for solving the model generally follows a solution algorithm presented in "Applied Computational Economics and Finance" by Miranda and Fackler (2002). The solution algorithm is designed for dynamic models with discrete time and states with finite horizons which is presented in chapter 7 of the aforementioned textbook. We have decided to set up the model of the thesis with discrete states which means that the states an agent can be in are restricted to a specified number of grid points. The structure of the type of model of interest is as follows: agents observe the state of the economy in each period, perform an action, and in doing so they obtain a reward. The reward is dependent on the state as well as the action (Miranda & Fackler, 2002). A quote by Miranda and Fackler (2002) provides further insight into the optimization problem faced by an agent:

> The agent seeks a sequence of policies $\{x_t^*\}$ that prescribes the action $x_t = x_t^*(s_t)$ that should be taken in any given state and period so as to maximize the present value of current and expected future rewards over a time horizon T, discounted at a per-period factor δ. (Miranda & Fackler, 2002, pp.155-156)

To solve the model a dynamic programming approach is employed. Dynamic programming stems from the principle of optimality. This principle can be formalized by the Bellman equation (Miranda & Fackler, 2002). The Bellman equation as presented in Miranda and Fackler (2002) where s denotes the state and x denotes the action:

$$V_t(s) = \max_{x \in X(s)} \left\{ f(s,x) + \delta \sum_{s' \in S} P(s' | s,x) V_{t+1}(s') \right\},\ s \in S,\ t = 1, 2, 3, ..., T$$

The Bellman equation is utilized to find the optimal value functions as well as the optimal policy functions using backward recursion. However, in this thesis there is no stochastic component in comparison to the equation above. Since this thesis aims to investigate the behaviour of individuals over a predetermined lifetime, the problem has a finite horizon. Due to the finite horizon and by defining the value function for the period following the last, i.e. V_{T+1}, one can solve for the optimal value function for all the different states in the preceding period, i.e. $V_T(s)$. Once this period has been solved for, one can move back another period and repeat this procedure to solve for $V_{T-1}(s)$. This can then be done recursively until the first period is reached. The model in this thesis is deterministic. This means that for a given state and action, the next state is known.

Following Miranda and Fackler (2002), to find optimal value and policy functions we begin with initialization. Model parameters such as the discount rate, β, pension contribution rate, τ, interest rate, r, and the terminal period, T , are initialized. We then construct the grids for the state variables as well as the control variables. Next, we initialize the utility obtained from all the controls in all of the different states. Following Miranda and Fackler (2002), the reward (in our case utility) is set to negative infinity whenever the control is infeasible. In our case this happens whenever:

(1) the choice of assets in the next period exceeds an agent's means (and thereby result in negative consumption),
(2) an agent is claiming benefits and working (since we don't allow these at the same time),
(3) an agent is retired and the benefit claiming age is above the age of the agent, or
(4) the claiming age is below one's age if one is still in the workforce

Furthermore, the value function in $T + 1$ is set to 0.

Once the initialization is complete, the next step is the backward recursion. With the value function being defined in $T + 1$, the optimal value function and optimal policy function is solved in T for all the different states. This is repeated until the first period has been reached, i.e. when $t = 1$. The backward recursion algorithm is structured as three layers of loops. The outer layer of the loops is the age. The middle layer of the loops consists of loops over the other state variables (asset grid, retirement, and benefit claiming age). Finally, the inner layer of the loops consists of loops over the controls (i.e. assets in the next period and labor supply).

When solving for the optimal value functions there is a difference in solving it for an agent that has started claiming benefits and for an agent that is still in the workforce. Since we assume benefit claiming is an absorbing state, this means that an agent that claims benefit in t will also be doing so in $t + 1$. This means that the value function in $t + 1$ for an individual that claims benefits in t is a value function in which the individual still claims benefits. However, if an agent is in the workforce, the value function in the next period is the maximum of the value function from being in the workforce in the next period and the value function from claiming benefits in the next period. The value function of being in the workforce thereby incorporates benefit claiming likely occurring at some point in time. The logic used here is an adaptation of one presented in Iskhakov et al. (2017) for a life cycle consumption-savings model with a binary retirement decision that is absorbing.

Below is a sketch of the applied backward recursion algorithm:

Stylized Backward Recursion Algorithm.

for $t = T, T - 1, ..., 1$ **do**
  for All state combinations of a_t, ret, and $RetAge$ **do**
    for All choice combinations of a_{t+1} and l_t **do**
      if $ret = 0$ **then**
        $v_t(a_t, 0, RetAge) = u(a_{t+1}, l_t) + \beta \times max\{v_{t+1}(a_{t+1}, ret = 0, RetAge), v_{t+1}(a_{t+1}, ret = 1, RetAge)\}$
      else if $ret = 1$ **then**
        $v_t(a_t, 1, RetAge) = u(a_{t+1}, l_t) + \beta \times v_{t+1}(a_{t+1}, ret = 1, RetAge)$
      end if
    end for
    Find optimal value and policy function in each state.
    $v_t(a_t, 0, RetAge) = \max_{a_{t+1}, l_t} \{u(a_{t+1}, l_t) + \beta \times v_{t+1}(a_{t+1}, ret \in \{0, 1\}, RetAge)\}$
    $v_t(a_t, 1, RetAge) = \max_{a_{t+1}, l_t} \{u(a_{t+1}, l_t) + \beta \times v_{t+1}(a_{t+1}, ret = 1, RetAge)\}$
  end for
end for

Once the optimal value and policy functions have been solved we perform what Miranda and Fackler (2002) describes as dynamic-path analysis for each SES independently. Essentially, this means that, given a state in which an agent starts, one follows the path that develops over time. This can be done for all possible states where there is an optimal policy that results in a transition to some other state in the next age. The agent starts in a state with 0 assets, at age 25, and is assumed to be in the workforce. Given the state in period 1, the optimal benefit claiming age is solved for. If the value function of claiming benefits at the suggested age is greater than the value function of starting to claim benefit at the agent's current age, the agent will remain in the workforce and follow the prescribed optimal policy of this state. The optimal policy gives the next state as the transition is deterministic. This procedure is then repeated until a period is reached where the value function of claiming benefits (i.e. start claiming benefits at the agent's current age) is greater than the value function of remaining in the workforce until the suggested benefit claiming age. Once the agent has started claiming benefits, the optimal policy will always prescribe claiming benefits in the states that follows since, as previously touched upon, the value function of claiming benefits prescribes benefit claiming for all future periods.

5. Calibration and Data

The three life cycles are calibrated to 2019. Meaning that, when applicable, the features of pensions as well as the demographic data (e.g. wages and life expectancy) are meant to reflect the different socioeconomic groups and the NDC system in Sweden at that time. As the available data is not longitudinal individual data, the calibration will reflect 2019 and not be based on any specific cohort. 2019 is chosen partially to avoid effects on life expectancy stemming from Covid-19, as well as to limit the number of people who are still in the workforce and affected by transitory policies stemming from the 1994 reform (people born after 1953 are unaffected) (Swedish Pensions Agency, 2020c). Important to mention once more is that the minimum retirement age was increased in 2020 (from 61 to 62). There have also been a few minor pension policy additions (such as the income pension complement implemented in September 2021 (Swedish Pensions Agency, 2021d)). While the exclusion of these changes does not directly affect the studied mechanism in this thesis, one should bear the altered age targets in mind when considering the results with regards to retirement ages. The calibration is gender-neutral, meaning that parameters (where applicable) reflect their respective level of educational attainment averaged over men and women. This is likely to have implications on the results of the model, as the life expectancy effect differs for men and for women indicated by Carlsson and Mikula (2016). However, in an attempt to display the general implications of the homogeneous annuity divisor we calibrate the model to the gender-neutral averages instead of doing gender-specific analysis. While differences between men and women in terms of life expectancies as well as intergender differences are relevant, this is not the core focus of this thesis.

5.1. General Calibrations

The interest rate is set to 3 percent and the discount factor to $\beta = \frac{1}{1+r}$ following the targeted interest rate and assumed discount factor in Laun and Wallenius (2015), leading to β being roughly equal to 0.9709. By setting the discount factor to $\frac{1}{1+r}$ consumption is smoothened over the life cycle. With regards to the level of the discount factor, it can be noted that it is also in the proximity of the discount factor used by Karlstrom et al. (2004) of 0.97.

With regards to the pension system, the earliest retirement age is set to 61 (or period 37). As previously mentioned, agents pay taxes or contributions on their wages of 17.21 percent. In reality, the employee only pays 7 percent and the employer pays 10.21 percent of the employee's wage in contributions, however, in our model we simplify the contributions and add them directly to the wage of the individual. We also combine the income pension and the premium pension. As brought up in section 3, the income pension constitutes the majority of the income-based public pension and for simplicity we model the pensions as if the premium pension was identical to or essentially a part of the income pension and thereby follow the same rules. In addition, this also allows the magnitude of the pension benefits in the model to be more in line with what individuals receive from the Swedish pension system in reality (compared to leaving it out entirely).

Table 1: Parameters shared by all SES groups.

	Value
Interest rate, r	3%
Discount factor, β	0.9709
Contribution rate, τ	17.21%

5.2. Socioeconomic Calibrations

The proxy used for SES is the level of educational attainment. Hence, the groups are calibrated using data for 1) compulsory education, 2) upper secondary education, and 3) post-secondary education. There are differences in employment rates for the different groups. People with higher education are employed to a larger extent than people with less education (Statistics Sweden, 2018). In the model however, with labor supply being binary and the life cycles being based on representative agents of the three groups, the labor supply is calibrated so that each agent of the three groups work full time from the first period until they exit the workforce. Hence, when setting the parameter that determines the utility from leisure, α^{SES}, the aim is to match the workforce exit for each SES with the workforce exit of the corresponding educational group. The data points for workforce exits have been retrieved from the Swedish Pensions Agency through the report "Medelpensioneringsålder och utträdesålder 2011" by Karlsson and Olsson (2012). Since age is discrete with one year intervals in the model, α^{SES} is calibrated so that the workforce exit in the model matches the full year in integers of the observed workforce exit in the data. In other words, if the workforce exit in the data is 61,7 years, α^{SES} is calibrated so that the agent works up until the period the agent turns 62. We then assume, and aim to calibrate a scenario in which benefits are claimed right after the workforce exit. In the calibrated model, we are able to match the workforce exit for all three groups, however the SES 3 delays benefit claiming (for further discussion see section 4.3, 6 and 8). In general, workforce exit has been on an upward trend during the last decades (see Figure 3) and has risen from 63.3 years in 2009 to 64.0 years in 2019. The data used in the calibration is likely displaying earlier workforce exits than during the year of interest (2019), although possibly mitigated by the upward rounding of workforce exit. However, without being able to access more recent data for workforce exits by educational attainment, α^{SES} has been calibrated based on the available data since we cannot tell if and to what extent this trend might have differed between groups.

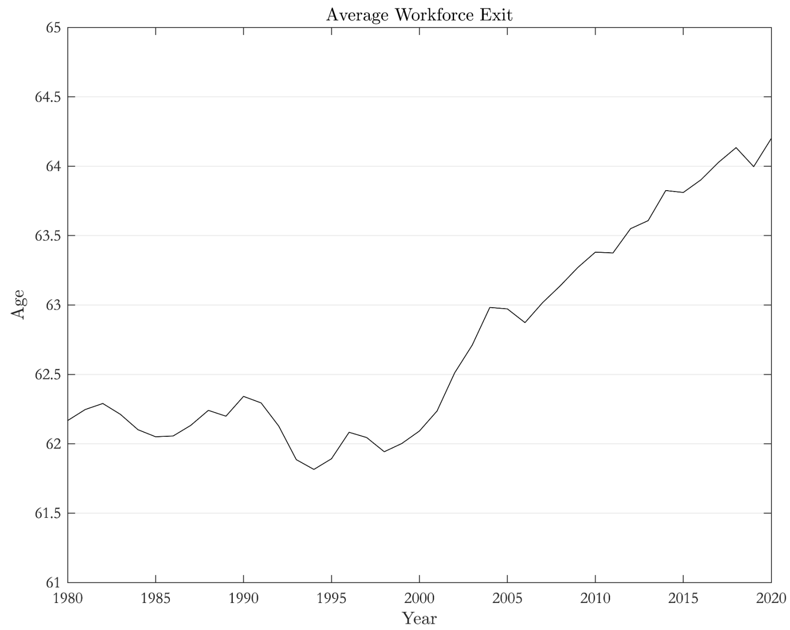

Figure 3: Average age of workforce exit in the years 1980-2020. Authors' rendering. The data has been accessed from the Swedish Pensions Agency through the report "Pensionsåldrar och arbetslivets längd" by Granseth et al. (2021).

To calculate the life expectancies and the annuity divisor for the different groups, five-year life tables for the period 2015-2019 have been used. The data has been retrieved from Statistics Sweden (2021a) and reflects only the part of the Swedish population that is born in Sweden (due to data availability). The observations retrieved is the number of people alive per 100,000 aged 30 for ages 30 to 95+. The life cycles start at age 25 but the data used in the calibration starts at age 30. Hence, when calculating the life expectancies at age 25 we extend the vector of observations so that it starts at age 25 and for the appended ages 25-29 the number of people alive is set to 100,000. This should naturally cause an increase in life expectancies because this would correspond to there being no mortality in these ages.

When determining the last period an agent lives, one could perceive the deterministic life expectancy as 1) An agent enters the economy at 25 years old, looks at the life expectancy in that period, takes that as determined, and acts thereafter - this will lead to the annuity divisors overestimating the agent's lifespan as the divisors are calculated later on (at retirement), but reflect the knowledge of that agent at that time or 2) An agent enters the economy at age 25, however, instead considers the life expectancy differences at the minimum retirement age and the deterministic life span is set based on that. Divisors will also be overestimated in this scenario, as they are continuously updated until the agent retires, however, by less than option 1. Both perceptions have limitations in their reasoning and effects, and will have some impact on the magnitude of the benefit-to-contribution ratios, as well as alter asset accumulation. However, the goal is mainly to consider how agent choices differ between the two policy alternatives, hence this choice, and potential implications, become less important. We determined lifespan using the former perspective. The annuity divisor is also calculated using data from life tables and reflects life expectancy at the retirement age rather than the deterministic lifespan imposed in the model. This implies that the annuity divisor will not perfectly match the periods an individual lives, even under the heterogeneous policy. While the aim of this thesis is to suggest a heterogeneous annuity divisor that better matches the individual's life expectancy, one can think of this imperfection as an attempt to mimic the real-life impact on pension benefits of the homogeneous versus heterogeneous annuity divisor.

To calibrate the wage (or productivity) over an agent's life cycle, one approach is to use wage data and estimate a polynomial (there are different variations of this approach (for one example see Almerud (2021)). Estimating life cycle wages using polynomials requires a few steps, and in this thesis the following steps have been taken. First, data of the total earned income by education for people registered in the national population register during the whole year was accessed. The data has been retrieved from Statistics Sweden (2021f), and it is binned by income and age with various bin sizes. The lowest income bin is a total earned income of 0 SEK and the bin with the largest income is +1,000 KSEK. For incomes above 0 SEK up to 400 KSEK the bins are equally sized with intervals of 20 KSEK. Above 400 KSEK the bins are either in intervals of 100 or 200 KSEK until the last bin of +1,000 KSEK. The age bins used are the age intervals 20-29, 30-39, 40-49, 50-59, 60-64, 65-69, and 70-75. Secondly, for all bins the median of the total earned income as well as the number of people in the bin has been accessed. The two lowest income bins have been excluded, meaning that the lowest bin is a total earned income of 20-39 KSEK. The reason for doing so is that the lower bound of this bin approximately corresponds to the minimum income for pension credit eligibility (42.3 percent of a price-related base amount[7] (Swedish Pensions Agency, 2021e)). For each age bin, the weighted average of the median total earned income has been calculated. Since this is an average for each age bin, these averages are identical within a bin and are assigned to all ages of the bin. Lastly, with having estimated total earned income for all ages from 20 to 75 (by level of education), we estimate the life cycle wages by using a second-degree polynomial. Finally, the wage vectors are subset based on the calculated life expectancies of the different groups. This results in the estimated life cycle wages seen in Figure 4. It is observed from Figure 4 that the estimated life cycle wages for SES 3 display more curvature with wage increases being larger in the earlier parts of life compared to other groups.

[7] With a price-related base amount in 2019 of 46,500 SEK this equals 19,670 SEK (Swedish Pensions Agency, 2020c).

Figure 4: Estimated life cycle wages for all SES groups. Author's calculations using data accessed from Statistics Sweden (2021f). For further description on calculations, see the preceding section of the text.

The total earned income consists of both employment income (*"inkomst av tjänst"*) and business income (*"inkomst av näringsverksamhet"*). Meanwhile, capital income is not included. The former type of income includes pensions and taxable benefits from the social security systems (Statistics Sweden, 2021b). The measure could be argued to not be ideal for resembling wages earned from labor in the model. One source of concern relates to business incomes and taxable benefits being included when estimating the life cycle wages, potentially causing an overestimation of the wages (and thereby contributions) in the model. As a result, we benchmark pension benefits (as they are wage dependent) with real data in section 5.3. However, one could also argue that earned income is an appropriate measure since it incorporates business income which necessitates labor like any employment and will impact consumption and savings decisions in reality. Also, as mentioned in section 3.2, contributions are paid on received social or unemployment insurance benefits, as well as in the case of self-employment (i.e. business income).

When calibrating the model, the number of grid points for assets is set to 295. The maximum asset an individual can hold is set to different levels for the groups (see Table 2). There are several reasons for how the asset grid is set up. Savings and consumption are continuous decisions but are modelled as discrete and since a grid with finer increments yields a better approximation of a continuous decision, we therefore want to maximize the number of grid points (while keeping the size of the grid intervals suitable to the group). However, there are computational limitations. The more grid points the longer it takes to solve the model. This means that there is an apparent trade-off when deciding the number of grid points. In an attempt to balance this trade-off, we set the number of grid points to 295 (a level at which the computation time is deemed reasonable and grid points are reasonably fine given wage levels). Meanwhile, the ability to save is different for the groups due to different wages. In the interest of not letting SES 3 (individuals with high socioeconomic status) dictate the size of the grid points, at the expense of less fine grid points for SES 1 and SES 2, we let the grids differ between the groups by altering the maximum asset level. Another aspect considered when deciding the grids, is that we wanted to ensure that the maximum grid point is not reached or gets close to being reached. If an agent reaches the maximum grid point, they are unable to save further hence leading to a behaviour which could possibly be suboptimal. The same thing might occur when an agent is close to reaching the maximum grid point as the unconstrained optimal behaviour could be to save an amount leading to a state above the maximum asset grid point. Consequently, during the calibration the maximum asset is set to a level corresponding to approximately 1.5 times the maximum level held by the agent. The combination of grid points and maximum level of assets on the grid implies that SES 1 can save in increments of roughly 8.84 KSEK yearly, SES 2 in increments of 11.56 KSEK, and that SES 3 can save in increments of around 15.31 KSEK.

Table 2: Information on the asset grids for the different SES groups. The asset ratio is given by $\frac{Maximum\ Asset\ level}{Asset\ Accumulated}$ and the targeted ratio is 1.5. The maximum asset level is the highest theoretical asset level an individual can reach in the model. Maximum Asset Level and Assets Accumulated are reported in KSEK.

	Maximum Asset Level	Assets Accumulated	Asset Ratio
SES 1	2600	1724.5	1.51
SES 2	3400	2266.7	1.50
SES 3	4500	2969.4	1.52

5.3. Calibrated Life Cycles

Table 3 reports parameters applied that are specific for the different SES.

Table 3: Parameters, parameter values and potential targets used. [1)] The target of workforce exits reported are the ones reported by Karlsson and Olsson (2012); However, the actual targets are rounded. For further description, see discussion in 5.2. [2)] less than 3 years of secondary education/3 years secondary education. [3] Less than 3 years post-secondary education/3 years or more post-secondary education.

Parameter	Target	Value
Utility parameter for leisure	Workforce exit age [1]	
$\alpha^{SES\,1}$	61,7	1.15
$\alpha^{SES\,2}$	62,5/62,9 [2]	1.07
$\alpha^{SES\,3}$	63,2/63,5 [3]	1.14
Terminal period		
$T^{SES\,1}$		55 (age 79)
$T^{SES\,2}$		58 (age 82)
$T^{SES\,3}$		61 (age 85)

In Figure 5-7 the life cycles for SES 1-3 under the homogeneous annuity divisor are displayed. First of all, we are able to match the workforce exits in the life cycles with the used data. However, SES 3 delays the benefit claiming which results in a gap in which neither a wage nor a benefit is received. As can be observed from Figure 7, this results in a relatively substantial dissaving at this time. For SES 1 and SES 2, the dissaving starts when benefits are claimed which happens right after the last period of work. As indicated by the after-contribution wage, and the fact that labor supply is either 1 or 0, agents supply one unit of labor for all periods until the period they stop earning a wage.

Given that $\beta = \frac{1}{(1+r)}$, consumption is smoothened by construction. However, since there is a borrowing constraint in the model agents consume less at a young age when the wages are low and exhaust it entirely for consumption. This happens up until a point where the agents can start to save and still maintain a relatively constant level of consumption. The spiky shape of the savings and consumption stems from the discretization of assets. In each period an agent chooses which asset grid point to be at in the next period. Consequently, the savings decision is limited to certain points which creates its stair-like shape. As consumption is backed out from the choice of asset grid point (as well as the labor supply choice), this spills over to the consumption.

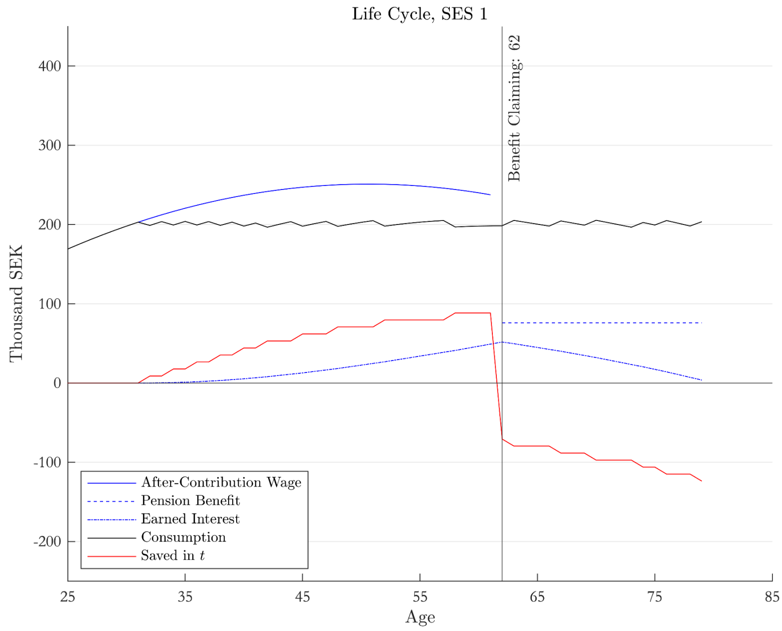

Figure 5: Estimated life cycles for SES 1. In any period where the after-contribution wage is displayed labor is supplied in that period. Likewise, whenever the pension benefit is displayed it means that benefits are being claimed.

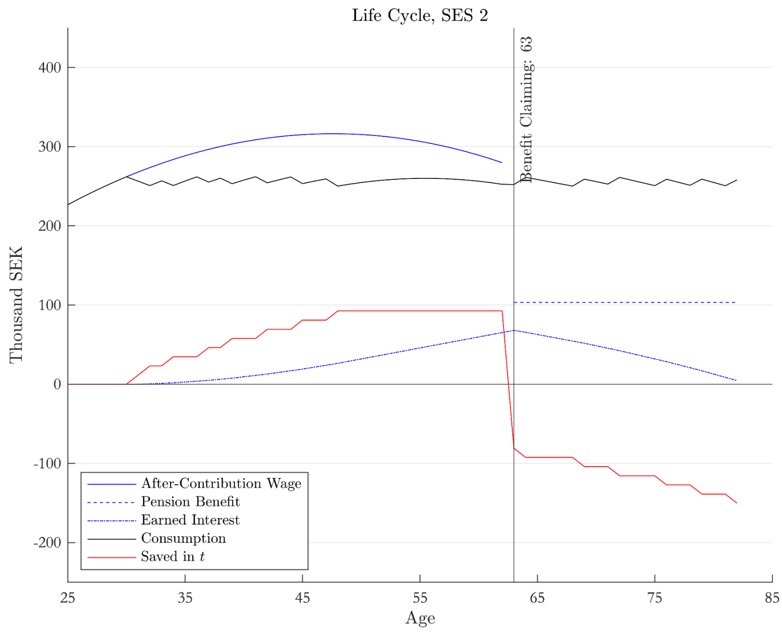

Figure 6: Estimated life cycles for SES 2. In any period where the after-contribution wage is displayed labor is supplied in that period. Likewise, whenever the pension benefit is displayed it means that benefits are being claimed.

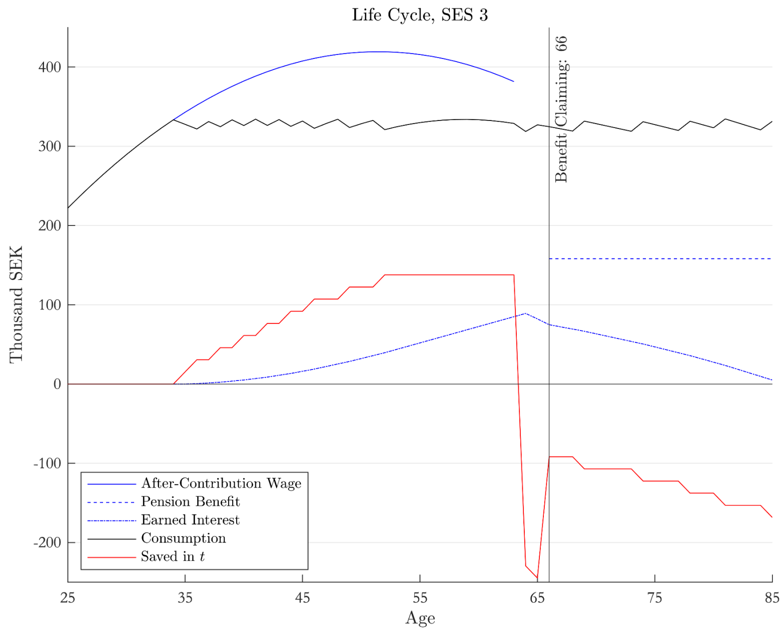

Figure 7: Estimated life cycles for SES 3. In any period where the after-contribution wage is displayed labor is supplied in that period. Likewise, whenever the pension benefit is displayed it means that benefits are being claimed.

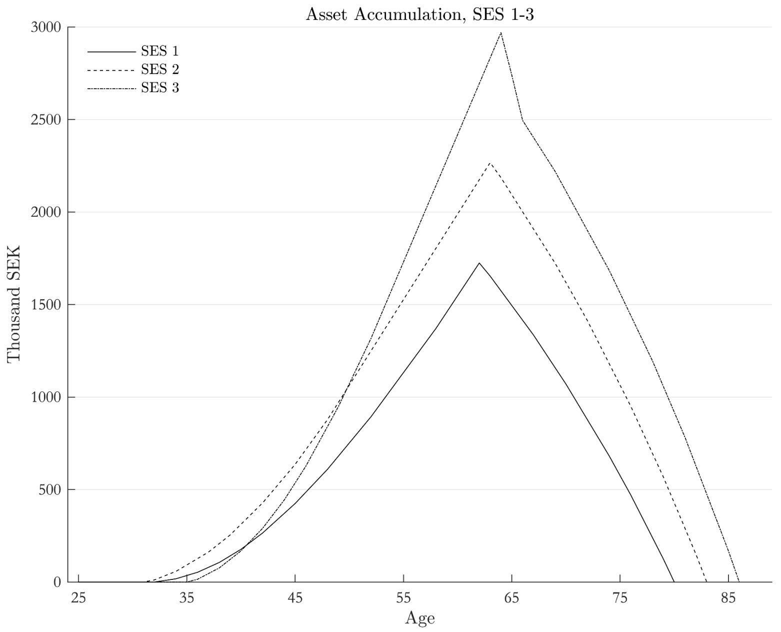

Figure 8: Asset accumulation for SES 1-3 in the calibrated scenario.

To benchmark the benefits of the model to the income pension and premium pension we look at data accessed from the Swedish Pensions Agency (n.d.). The data is for December 2019 and shows the first quartile, the median, and the third quartile of the income pension and premium pension for people aged 61-64 that receive public pension. When comparing the annual pension benefits in the calibrated life cycle with data on the magnitude of pension benefits in the Swedish system today, the pensions in the calibrated life cycle are lower than those received by retirees in the system today which is at least in part a result of the exclusion of the interest adjustment in the annuity divisor calculation.

Table 4: Estimated pension benefits in the calibrated model as a function of benefit claiming age. Pension benefits are reported in KSEK.

	Age 61	Age 62	Age 63	Age 64	Age 65	Age 66
SES 1	71.23	76.01	81.11	86.54	92.35	98.58
SES 2	90.96	96.90	103.21	109.93	117.09	124.76
SES 3	113.78	121.55	129.81	138.61	148.00	158.05

Table 5: Data on monthly income pension and premium pension in KSEK by quartile for people aged 61-64 has been accessed from the Swedish Pensions Agency (n.d.). The data reflects December 2019. Within parentheses the monthly benefits have been converted to its annual counterpart which together with roundings and the reported sums are authors' calculations.

	Age 61-64		
	First quartile	Median	Third quartile
Income Pension	7.83 (93.91)	10.25 (123.02)	12.48 (149.81)
Premium Pension	.77 (9.28)	1.10 (13.29)	1.47 (17.60)
Sum	8.60 (103.19)	11.36 (136.27)	13.95 (167.41)

6. Results

6.1. Description of the Policy Analysis

With the purpose of this thesis being to consider the impact of heterogeneous annuity divisors, the annuity divisor in the model is now shifted from a homogeneous and general annuity divisor to three heterogeneous annuity divisors. These are calculated the same way as the homogeneous annuity divisor has been calculated, but they reflect the life expectancies of the different groups (i.e. each SES now has its own annuity divisor based on life expectancy data for their SES). The three calibrated life cycles under the homogeneous policy described in section 5 are rerun but with the heterogeneous policy implemented (i.e. under the fictional policy). Since the annuity divisor is changed under the policy scenario, the pension benefit changes and thereby the consumption and utility from different state and choice combinations change. The set of feasible choices are likely affected as well. This means that the backward recursion and the deterministic simulation are repeated for all of the three SES groups. Once this is done the outcomes under the policy scenario can be compared to the outcomes of the calibrated life cycles presented in section 5. The key indicators that are analyzed in the model are 1) the benefit claiming age, 2) how long an agent works, 3) the discounted lifetime utility, 4) the maximum level of assets, 5) the average level of assets, 6) the aggregate contributions made, 7) the aggregate benefits received, and 8) the benefit-to-contribution ratio. In addition, we will also consider the consumption equivalent, which measures the per-period increase (decrease) in consumption required for agents to be indifferent between the two policy scenarios (for further detail on the consumption equivalent see for instance Attanasio et al. 2005)

Figure 9 shows the calculated homogeneous and heterogeneous annuity divisors.

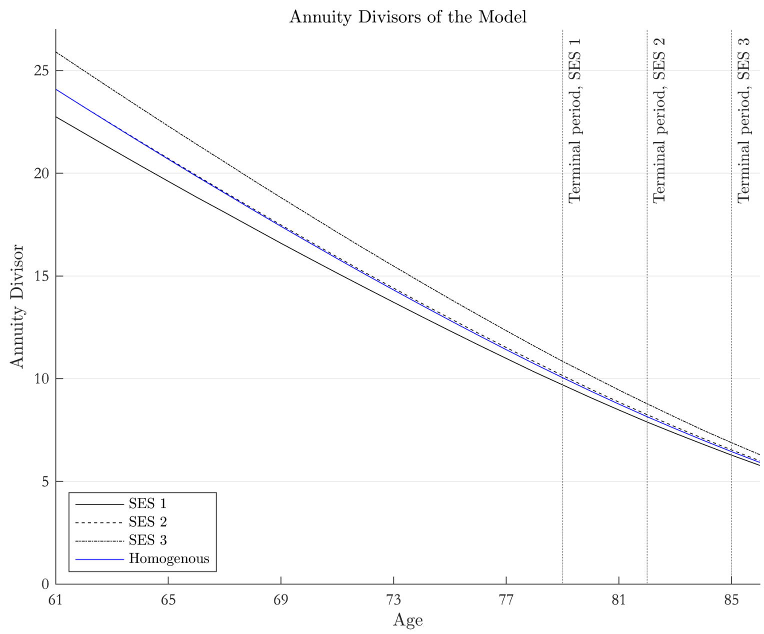

Figure 9: Annuity divisors of the model. Authors' calculations using data accessed from Statistics Sweden. For further details on the calculations, see section 4.4 and 5.2.

The homogeneous annuity divisor at 61 (earliest possible retirement age) is 24.09 and the heterogeneous annuity divisor for SES 1 and SES 3 is 22.75 (-1.34) and 25.91 (+1.82) respectively (see Appendix C for calculated annuity divisors). As expected, the heterogeneous annuity divisor for SES 3 is higher than the homogeneous divisor, and the heterogeneous divisor for SES 1 is lower than the homogeneous divisor. SES 2 follows the homogeneous annuity divisor very closely indicating that this policy would only have a minor impact on their pension benefits. As age increases, the annuity divisors converge. The convergence, while interesting, is not of large importance to this thesis as agents retire earlier in life, when the discrepancy is larger between the homogeneous and heterogeneous annuity divisors, and annuity divisors become "fixed" upon retirement. The change in the annuity divisors above lead to the following changes in pension benefits (expressed in age at benefit claiming):

Table 6: Estimated pension benefits in the calibrated scenario (Homogeneous) and in the policy scenario (Heterogeneous) as a function of benefit claiming age as well as the difference from the calibrated model. Figures are reported in KSEK.

	Age 61	Age 62	Age 63	Age 64	Age 65	Age 66
SES 1 (Homogeneous)	71.23	76.01	81.11	86.54	92.35	98.58
SES 1 (Heterogeneous)	75.43	80.40	85.72	91.39	97.42	103.88
Difference	4.20	4.38	4.62	4.85	5.06	5.30
SES 2 (Homogeneous)	90.96	96.90	103.21	109.93	117.09	124.76
SES 2 (Heterogeneous)	90.97	96.89	103.15	109.81	116.88	124.48
Difference	0.01	-0.01	-0.07	-0.12	-0.21	-0.28
SES 3 (Homogeneous)	113.78	121.55	129.81	138.61	148.00	158.05
SES 3 (Heterogeneous)	105.80	112.95	120.55	128.64	137.30	146.51
Difference	-7.98	-8.60	-9.26	-9.97	-10.70	-11.54

6.2. Results from the Policy Analysis

First off, the policy shift produces the expected effect where pension benefits, all else equal, increase for SES 1, remain almost unchanged for SES 2, and decrease for SES 3. The behaviour with regards to the number of periods worked for SES 1 and SES 2 remain unchanged. While we are presenting the outcomes for all groups Table 7, it is important to remember that we are analysing the six different life cycles (three calibrated life cycles and three policy outcomes) one at a time. The utility gain for SES 1 is smaller than the loss for SES 3, this is likely a result of the difference between the homogeneous annuity divisor and the corresponding heterogeneous annuity divisor being smaller for SES 1 than for SES 3. This means that the benefit gain for SES 1 will be smaller than the benefit loss for SES 3 per period. The consumption equivalent calculation displays similar results as SES 1 would require a smaller gain (compared to the accepted loss for SES 3) to be indifferent between the homogeneous and heterogeneous annuity divisor.

Table 7: Estimates under the homogeneous and heterogeneous scenarios as well as differences between the two scenarios. Estimates are presented for all SES groups. For Maximum assets, Mean assets, Pension benefits, Aggregate contributions and Aggregate benefits are all expressed in KSEK. The ratio in the last column is the benefit-to-contribution ratio. 1) Corresponding age at which benefit claiming starts is displayed in parentheses. 2) Corresponding last age worked is displayed in parentheses.

	Benefit claiming period[1]	Number of worked periods[2]	Lifetime utility	Maximum assets accumulated	Mean assets	Pension benefit	Aggregate contributions	Aggregate benefits	B/C Ratio
SES 1, Homogeneous	38 (62)	37 (61)	151.19	1724.49	650.47	76.01	1765.47	1368.26	0.78
SES 1, Heterogeneous	38 (62)	37 (61)	151.30	1662.59	631.52	80.40	1765.47	1447.18	0.82
Difference	0	0	0.10	-61.90	-18.95	4.38	0.00	78.92	0.04
SES 2, Homogeneous	39 (63)	38 (62)	161.20	2266.67	917.72	103.21	2308.77	2064.28	0.89
SES 2, Heterogeneous	39 (63)	38 (62)	161.20	2266.67	917.72	103.15	2308.77	2062.90	0.89
Difference	0	0	0.00	0.00	0.00	-0.07	0.00	-1.38	0.00
SES 3, Homogeneous	42 (66)	39 (63)	170.50	2969.39	1082.04	158.05	2982.99	3161.02	1.06
SES 3, Heterogeneous	41 (65)	40 (64)	170.34	3015.31	1138.82	137.30	3060.91	2883.25	0.94
Difference	-1	1	-0.16	45.92	56.78	-20.75	77.92	-277.77	-0.12

For SES 1 the estimated increase in public pension benefits each period under the heterogeneous policy is 4.38 KSEK (a 5.8 percent increase). As the claiming age remains constant, the entire change stems from the change in the annuity divisor, from 23.23 to 21.96 (a 5.5 percent decrease). Over the duration of the benefit claiming in the model, the yearly gain of 4.38 KSEK translates into 78.92 KSEK more in total benefits and while the magnitude of the change is not of first order importance (given the limitations of the model and the data employed) it is essential in order to understand the unchanged labor supply and claiming age. If the agent would leave the workforce and claim benefits one period earlier, all else equal, the agent would gain one period of benefits and utility from leisure at the cost of losing one period of wage. The received benefits would be lower as they depend on claiming age (both through an increase in the annuity divisor and one less period of contributions, as they are dependent on claiming age). Consequently, the life cycle income would decrease as one period of wage is already evidently higher than the benefits as seen in Figures 5-7. With the policy in place, benefits are increased for this group. However, as the workforce and benefit claiming decisions do not change, the hypothetical benefit gain from leaving the workforce one period earlier is still not large enough to offset the loss in wages and lower benefits.

As contributions paid by the agent are constant across the two scenarios, the estimated benefit-to-contributions ratio in the model increases by 0.04 units from 0.78 to 0.82. This means that SES 1 receives a higher proportion of their contributions as benefits under the heterogeneous policy scenario.

A ratio of 1 would imply a scenario in which received benefits equal total contributions. However, as discussed in section 5.2, even the heterogeneous annuity divisor is not equivalent to the deterministic life span. This means that the ratio is sensitive to what the deterministic life span is set to in the model. Nevertheless, with the life span being constant across the policy scenarios, the relative change of the benefits-to-contribution ratio would be unaffected with altered life spans (holding contributions fixed) and the results are thereby perceived to be indicative for the fairness implications of the evaluated policy. Furthermore, SES 1 reduces its asset holding under the policy scenario which is in line with expectations as the foresighted higher benefit in old age under the policy scenario reduces the need for saving when young in order to smooth consumption, all else equal. The estimated change in the discounted utility is 0.10 units. When considering the consumption equivalent, the agent would require 0.37 percent more consumption per period in the calibrated model to be indifferent between the homogeneous and heterogeneous annuity divisor. This equates to a consumption of 41.05 KSEK over the course of the agent's lifespan, which is smaller than the benefit increase stemming from the policy shift.

For SES 2, the estimated effects of the heterogeneous policy are minimal since in the model, the homogeneous annuity divisor and the heterogeneous annuity divisor for SES 2 are almost inseparable as displayed in Figure 9. The annual public pension benefit decreases by 0.07 KSEK in the policy scenario, which causes the aggregate benefits to decrease by 1.38 KSEK. Rounded to two decimals, there is no legible effect to the benefit-to-contributions ratio or utility; however, there is a small shift of 0.0006 units and 0.0013 units respectively. Expectedly, this does not lead to any change in either labor supply or asset holding. However, this result can be interpreted as this group already having an annuity divisor that lies close to one that would be "adjusted" to their socioeconomic group.

When interpreting the results for SES 3 one must consider the aspect brought up earlier in section 4.3 with regards to the simplification of the model where benefits are determined based on the claiming age and not periods worked. As there is a gap between workforce exit and benefit claiming in the calibrated life cycle for SES 3, the benefit is disjointed from the workforce exit. Meanwhile, under the policy scenario the workforce exit is postponed by one period and the benefit claiming starts one period earlier compared to the calibrated model which causes no such gap to occur. With the simplification in how pension benefits are determined in the model, the fact that the agent works one more period under the policy scenario is not taken into account when determining the pension benefit, only their earlier claiming is. Hence, the decrease in benefits under the heterogeneous policy (-20.75 KSEK per period) is not only due to the heterogeneous annuity divisor shifting the benefit calculation but also because benefits are claimed earlier which affects also the contributions. Parts of the effects on the benefits, and consequently the benefits-to-contribution ratio is an artefact of the model. Thus, the only gain from working is the additional wage. Nevertheless, the results still provide intuition and indications of how agents respond to the policy scenario.

In the calibrated model, SES 3 starts claiming benefits at an age of 66. The homogeneous annuity divisor when claiming benefits at 66 is equal to 19.85, in comparison to 21.41 (+1.56 or +7.9%) if the agent would claim benefits at 66 under the heterogeneous policy scenario. This would cause, all else equal, a noticeable downward shift in the pension benefits under the policy scenario. Since the agent strives towards smoothening consumption, and pension income in old age (all else equal) decreases under the policy, the optimal course of action to offset the loss in benefits is for the agent to combine an altered asset holding with a shift in behaviour with regards to workforce exit and benefit claiming. Under the heterogeneous policy model, SES 3 holds more assets on average than in the calibrated scenario as a result of saving until an older age and working an additional period. In fact, in the calibrated model, the agent displays a behaviour of large dissavings prior to benefit claiming to finance the gap between workforce exit and benefit claiming, a behaviour which is not present in the policy scenario. The increased savings under the heterogeneous policy is hence a result of lower benefits making the agent continue to save in the periods prior to benefit claiming, by postponing their workforce exit relative to the baseline, in order to smooth and uphold consumption when old. If the agent still would like to maintain the gap seen in the calibrated case, the agent would have to give up even more consumption at a young age to accumulate more assets. This is suboptimal as this choice is not made, which in turn is interpreted as the reason for why benefits are claimed instantly after leaving the workforce (i.e. in order to not cause large dissaving and to smooth consumption).

The utility for SES 3 decreases by 0.16 units (-0.09 percent) in the policy scenario from the estimated 170.50 units in the calibrated life cycle. The consumption equivalent calculation indicates that the agent would lose up to 0.56 percent consumption per period in the calibrated model in order to remain in the system with the homogeneous annuity divisor. Hence, while the agent is able to almost perfectly offset the impact of the reform in terms of utility and the consumption equivalency indicates a consumption loss which, in relative terms, is larger than the utility loss. With regards to the benefit-to-contribution indicator the discrepancy following from the model simplification in benefit calculation causes the ratio to be less informative than for the other groups. For this reason, the analysis of SES 3 is complemented in the sensitivity analysis in which the life cycle is calibrated so that the workforce exit is immediately followed by benefit claiming. However, the policy shift does cause the ratio to drop by .12, which is in line with the large reduction in pension benefits stemming from an annuity divisor which is now closer corresponding to the group's life expectancy. Notably, the ratio drops below 1, which implies that SES 3 no longer get their entire contribution back as benefits later on. Still, the magnitude of the ratios is sensitive to the deterministic life span.

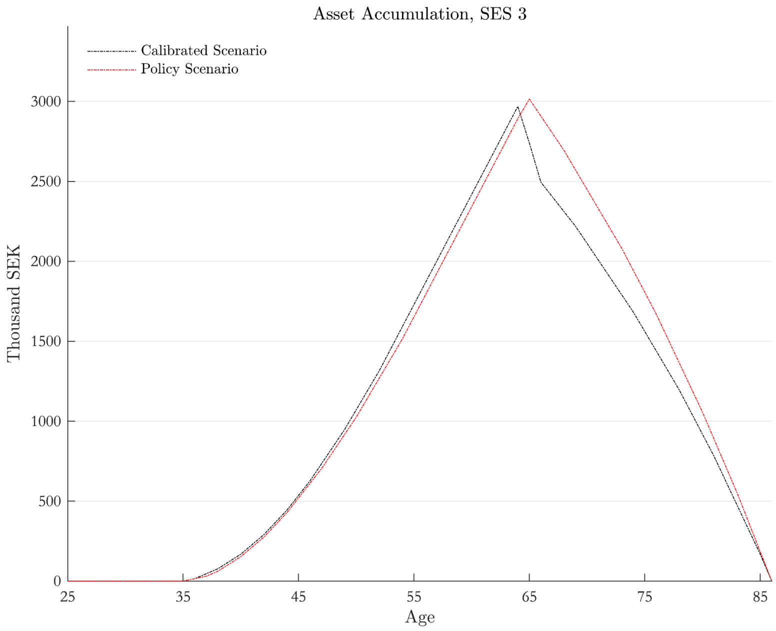

Figure 10: Asset accumulation for SES 3 in the calibrated scenario and in the policy scenario.

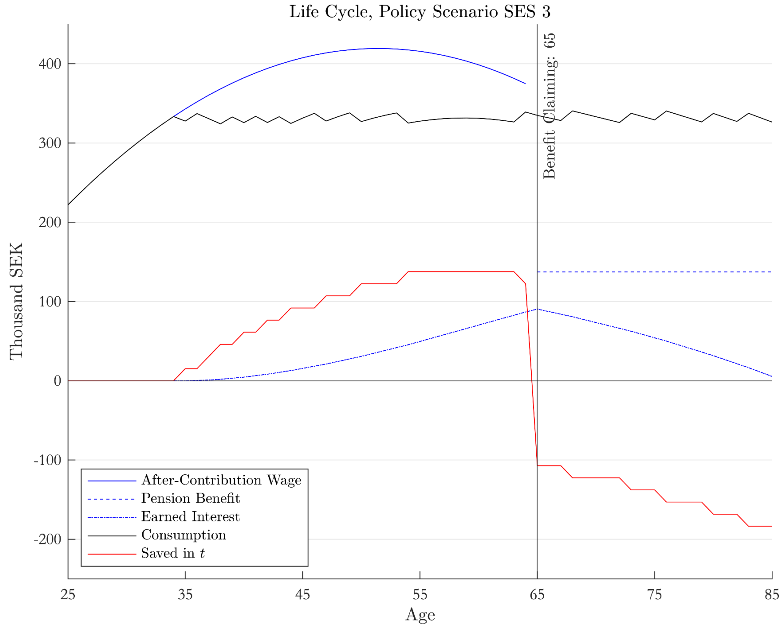

Figure 11: Estimated life cycles for SES 3 in the policy scenario.

7. Sensitivity Analysis

In order to study the robustness of the results in the previous section we consider their sensitivity to some of the parameter values. While there are many parameters to alter in the model, some cannot be altered without directly affecting the calibration of the model, e.g. α is set to match workforce exits. As such, simply altering a multitude of parameters provides limited information as to the robustness or sensitivity of the calibrated model, if there is not a clear purpose in doing so. This section will hence focus on a couple of critical choices in the model in order to provide insight into how these either affect the results, or how robust the results are to such purposeful change.

Firstly, a shift in the number of grid points for assets is considered to examine how sensitive the results are to the discretization. As discussed in section 5.2, the grid points create a discrete approximation of a continuous savings decision, hence it is important to consider the impact of less refined grid points in order to understand how increasing grid points (and thereby a better approximation of the continuous choice) affects the results. Accordingly, we ran the life cycles again under the two scenarios but altered the grid points in two steps, first from 295 to 245, and then from 295 to 195, and then looked at the same indicators as in 6.1 (these are found in Appendix A). When changing the number of grid points, no changes in neither the working nor benefit claiming decisions are observed. Consequently, there is no effect relating to the pension benefits or pension contributions. However, there are changes to the assets held. This is expected and happens by construction when changing the sizes of the grids. The most important finding from increasing the grid points from 195 to 295 as well as from 245 to 295 is probably that the utility increases with the number, yet marginally, of grid points under both policies for all of the 3 agents. The interpretation of this finding is that when the approximation of the continuous choice is improved it enables choices of savings and consumption closer to what would have been optimal in a continuous setting. However, the utility changes are small and the differences are larger going from 195 to 245 grid points than they are going from 245 to 295. All in all, utility differences are small and appear to be diminishing with the number of grid points.

Secondly, as SES 3 delays benefit claiming in the calibration presented in section 6.2, and due to the benefit calculation depending on benefit claiming age (as discussed in 4.3), SES 3 was calibrated to work up until the benefit claiming[8] (estimates are reported in Appendix B). This means SES 3 is calibrated to exit the workforce at age 65 instead of at age 63 as in section 6. This was achieved by changing $\alpha^{SES\,3}$ from 1.14 to 1.07. With the model simplification (benefits decided by claiming age), calibrating the workforce exit to match benefit claiming is deemed to create a scenario that better represents the connection between benefits and contributions of an actual NDC. As a result, this exercise provides a better indication of the benefits-to-contribution ratio in the baseline case (which is where a gap is displayed). This is estimated to be 1.01 in the sensitivity analysis model, in contrast to 1.06 in section 6. This implies that under both calibrations, SES 3 obtains benefits that exceed contributions under the baseline policy scenario. This is expected and in line with the findings of Boado-Penas et al. (2020) that people with a high degree of educational attainment benefit from the gender-neutral annuity divisor. Moreover, an important difference in this calibration from the baseline is that there is no behaviour change with regards to the number of periods worked or benefit claiming age across policies, as opposed to the analysis conducted in section 6. This analysis then suggests no change in workforce exit and benefit claiming

[8] As we have utility from leisure we can calibrate the age at which agents stop working, but the benefit claiming age can not be directly calibrated.

(similar to what was observed for SES 1 and 2 in section 6) despite a decrease of 7.30% in periodic benefits. Namely, that while the heterogeneous annuity divisor shifts the benefits downwards the shift is not large enough to cause a shift in workforce exit and benefit claiming behaviour.

8. Conclusion and Limitations

8.1. Conclusion

The purpose and ambition of this thesis was to study the impact of a heterogeneous annuity divisor on individuals in an NDC system in an attempt to account for the heterogeneity in life expectancy across socioeconomic groups. In a NDC system with a homogeneous annuity divisor, the system redistributes from short-lived to long-lived by design. As such, this thesis sought out to investigate what would happen if the system would account for differences in life expectancy between socioeconomic groups, and arguably be less ex ante unfair. From the analysis of three different life cycles proxying socioeconomic status using different levels of educational attainment which follow simplified pension rules representing the Swedish income-based public pension, we find the following:

SES 1 receives an increase to their estimated pension benefit (+4.40 KSEK annually) as the annuity divisor falls from 23.23 to 21.96 (-1.27) at the group's benefit claiming age under the heterogeneous policy scenario. In comparison, a recent policy reform (the income pension complement) in Sweden increased pensions for low income individuals by 0 to 7.20 KSEK annually (Swedish Pensions Agency, 2021d). Accordingly, while the heterogeneous annuity divisor has a negligible utility effect on SES 1, the estimated effect in monetary value is in the proximity of policy reforms recently undertaken by the government. Which indicates that the estimated monetary effect of the heterogeneous annuity divisor for groups with low educational attainment within the framework is perhaps not negligible and thus not irrelevant from a political or real world standpoint. As the workforce participation nor benefit claiming decision is altered by SES 1, the results indicate that the policy would potentially not incentivise a reduction in retirement age. This finding is notably relevant given that reforms increasing the target retirement age are underway and any policy that risks counteracting these reforms is likely incompatible with current efforts. In response to the increase in pension benefits for this group, less assets are accumulated when young. Furthermore, the benefit-to-contribution increases by .04 (from .78 to .82). While the size of the ratio(s) is dependent on the deterministic life span, the relative change of the ratio shift is indicative of how the ratio would be affected by such a policy. While simplified, and not a perfect approximation of actuarial fairness (as discussed by Queisser and Whitehouse (2006)), one can think of the shift in ratios as a proxy for the actuarial fairness effects of the reform. As such, the ratio shift is also an indication of fairness in the system.

The change in pension benefits for SES 2 is negligible under the heterogeneous policy scenario. This naturally stems from the calculated heterogeneous annuity divisor being very similar to the calculated homogeneous model annuity divisor. As such, the indicators show small or no differences across the two policies. While this group experiences little change to their pension benefits, it is important to consider the discussion of Baurin (2020). While heterogeneity in longevity within groups is relevant across all socioeconomic groups, it is particularly important to remember that heterogeneity is likely present within SES 2 as well. As such, there likely exist individuals within this group that would be unaffected by the heterogeneous policy as well as individuals that would either gain or lose benefits from a policy shift.

SES 3 experiences a noticeable decrease to their estimated pension benefit (-20.75 KSEK per period) under the heterogeneous policy scenario. However, a large part of the reduction stems from a reduced claiming age which impacts benefits both indirectly through the annuity divisor as well as directly since the model calculates contributions (and thus benefits) based on claiming age rather than workforce exit.

Notably, the group, despite the large reduction in pension benefits, sees almost no change to their lifetime utility, indicating that they can almost perfectly offset the policy reform in the model with regards to utility. However, the consumption equivalent indicates a larger relative consumption loss than the utility loss. Under the heterogeneous policy scenario SES 3 stays in the workforce for one additional period while also claiming benefits one period earlier causing the gap between workforce exit and benefit claiming in the calibrated model to disappear. As argued above, reforms causing retirement to occur earlier in life are likely incompatible with current efforts to raise the retirement age. However, while the group claims benefits earlier under the heterogeneous policy than in the calibrated model, they do extend their workforce participation by one period. Under the policy scenario, it is no longer optimal to exhibit the heavy dissaving seen in the calibrated scenario and as such claiming is shifted forward. It is important to mention that the disjoint between contributions and workforce participation could at least in part be the cause of this shift in behaviour and as such an artifact of the model. In contrast, in the sensitivity analysis when the baseline for SES 3 is calibrated to not display a gap between workforce exit and benefit claiming, no change in the behaviour of agents with regards to workforce participation and claiming is displayed under the policy scenario. While the magnitude of the benefit-to-contribution ratio is highly dependent on the deterministic life span of the model, the ratio both under the baseline and sensitivity analysis are above 1 meaning that SES 3 receives more in benefits than they pay in contributions. For the baseline calibration, one must bear the benefit calculation flaw in mind, meaning that the ratio shift stemming from the policy shift is less informative for SES 3 than for SES 1 and 2.

Ultimately, while the results showed that a heterogeneous annuity divisor reform likely would have a negligible impact on lifetime utility, the consumption equivalent indicated that the agent requires (accepts) a larger consumption gain (loss), in relative terms, than the estimated utility shift, albeit still a relatively small change. Nevertheless, the estimated magnitude of the effect on pension benefits for the policy's beneficiaries is deemed to be of sizable monetary value as it is somewhat in the proximity of the recently implemented income pension complement. The results further provided indications of under which scenarios it was (not) optimal for agents to shift their workforce and retirement claiming decisions and thus provided intuition regarding retirement incentives. For the agent with a high level of education the results are not as clear as for the other groups due to the gap between workforce exit and benefit claiming (likely an artefact of the employed model). Furthermore, the estimated benefit-to-contribution ratios provide some indications of the fairness of the income-based public pensions. As discussed throughout the thesis and brought up in much of the related literature in section 2, the current homogeneous annuity implicitly redistributes from short-lived to long-lived and, in extension, from groups of low socioeconomic status to groups of high socioeconomic status. As such, the analyzed policy reform is a policy tool that could be used, at least in theory, to address potential ex ante unfairness in NDC pension schemes stemming from heterogeneous life expectancies.

8.2. Limitations and Future Research

There are some limitations that need to be addressed due to their impact on the estimated results and conclusions drawn from the thesis. First of all, the pension benefit calculation and incorporation in the life cycles include multiple simplifications and assumptions which affect the estimates of the analysis. The perhaps most critical one has been brought up and discussed throughout, namely the simplification of benefits being a function of the age of benefit claiming. This introduces the risk of a disconnection between contributions and benefits which in such a case limits, to some extent, the ability to analyze the behaviour throughout the life cycle and indication of fairness of the pension received. This is what was seen and discussed for SES 3 in section 6 and was therefore complemented in the sensitivity analysis. Furthermore, the pension system contains a large array of components and a multitude of different rules and while deemed reasonable to focus on the income-based pensions and abstract from some of the complexity of the system, the abstractions will have an impact on the results. For instance, even though the emphasis lies on the income-based public pension, incorporating occupational pensions would likely impact the estimated results when it comes to agent behaviour (such as the effect on savings) since the estimated change in benefits under the policy would constitute a smaller fraction of the total benefits. Furthermore, the annuity divisor applied in the model is a simplification. The magnitudes of the shifts in the annuity divisors therefore deviates from what would have been the case if they would have been calculated the same way as in reality. However, the aim is to analyze the outline of the effects of heterogeneous annuity divisors rather than pinning it down to its decimal point.

Moreover, data constraints are also affecting the precision of the estimated results. When calibrating the life cycles of the three representative agents, aggregate data is used rather than longitudinal individual data. This means that they are calibrated to a "snapshot" of the situation in 2019 with regards to wages and life expectancies. The life expectancy of a 25 year old today, might not match the mortality outcomes of, for instance, current 50 year olds. Likewise, the current 50 year old likely faced different wages when they were young compared to the current 25 year olds. An alternative approach would be to use data for one or more cohorts which would enable a more accurate calibration of the life cycles and thereby to potentially obtain more precise estimates. Due to data access limitations this was not possible within the scope for this thesis. However, we do not expect that the intuition of the results would change markedly as the data used in this thesis is expected to exhibit similar patterns and relationships as cohort data. More precisely, even if longitudinal individual data for a certain cohort would be applied, we still expect that the workforce exit gradient and life expectancy gradient for different levels of education would still be present, and that the life cycle wage would exhibit similar shapes and differences. In addition, as we consider the impact of a shift in the annuity divisor, and the annuity divisor in the model is calculated using the same aggregated data as used in reality, the core aspect of this thesis can be argued to be using appropriate data.

Bearing these limitations in mind, there are several possible lines of future research in order to gain further knowledge of what the potential impact would be of addressing the pension effects of heterogeneous life expectancies through heterogeneous annuity divisors. For one, by building on the model presented in this thesis and incorporating not only a correction to the benefit calculation (where benefits are directly linked to contributions) but also including stochastic components to mortality and income, one could address the limitations with the current model as well as provide increased richness to agent behaviour. The agent behaviour in this thesis has been analyzed in a deterministic setting. However, questions relating to life expectancy and making decisions today based on expectations of the future naturally involve a whole lot of uncertainties which could be further addressed by introducing a stochastic environment. Furthermore, by incorporating within-group heterogeneity one could integrate the discussion of Baurin (2020), namely that pension policies (such as the retirement age) differentiated by socioeconomic groups still fail to account for within-group differences in longevity. Hence, this is something that would have to be considered for a fuller picture of the impact of heterogeneous annuity divisors and could be considered in a more sophisticated model framework. One could also use a general equilibrium model in order to further understand the fiscal implications of the suggested policy and other outcomes not only related to agent behaviour. Another exercise that could provide valuable insight as to how to address the heterogeneity in life expectancy would be to consider the impact of a different policy shift than the one suggested in this thesis. For instance, one could imagine a less direct policy where contributions as a percentage of wages are constant but progressive. While not directly targeting life expectancies this would have an impact on benefit-to-contribution ratios.

Lastly, addressing the impact of life expectancy heterogeneity in pensions is not necessarily straightforward. Firstly, there exists heterogeneity within different socioeconomic groups meaning broad policies targeting groups might not perfectly address these heterogeneities. In this thesis level of educational attainment has been used as a determinant for socioeconomic group, but one could argue that in reality this would be a rather blunt way of deciding policy as naturally people may differ a lot in other aspects (e.g. health and income) for which differences in life expectancy and longevity can also be observed. Secondly, related to the discussion by Baurin (2020) on how far an egalitarian social planner would have to go to account for life expectancy differences, one might question how far a policy maker can go in the pursuit of ensuring an actuarial fair system (in which present value of benefits match contributions). Apart from the issue of getting legislative approval for shifting the annuity divisor, there are clearly some ethical concerns in trying to perfectly estimate individual (heterogeneous) annuity divisors. For instance, would such a policy require individuals to declare all their good and bad habits, medical history and so forth, in order for a pension agency to generate individualised annuity divisors? If so, ethical concerns might heavily outweigh the gains of actuarial fairness. This thesis sought to study the impact of a policy targeting the annuity divisor to address pension effects of life expectancy differences between different socioeconomic groups. As such, the ethical or practical considerations were not addressed in this thesis. Instead, this thesis could serve as inspiration for future policy analysis and design when thinking about mechanisms in the pension system and efforts could be made to more directly address the ethical and practical considerations mentioned above.

9. Appendix

Appendix A.1: Estimated results with 195 grid points for assets.

	Benefit claiming period	Number of worked periods	Lifetime utility	Maximum assets accumulated	Mean assets	Pension benefit	Aggregate contributions	Aggregate benefits	Ratio
SES 1, Homogeneous	38 (62)	37 (61)	151.189	1715.46	656.22	76.01	1765.47	1368.26	0.78
SES 1, Heterogeneous	38 (62)	37 (61)	151.293	1661.86	626.07	80.40	1765.47	1447.18	0.82
Difference	0	0	0.104	-53.61	-30.15	4.38	0.00	78.92	0.04
SES 2, Homogeneous	39 (63)	38 (62)	161.194	2243.30	911.93	103.21	2308.77	2064.28	0.89
SES 2, Heterogeneous	39 (63)	38 (62)	161.193	2260.82	918.17	103.15	2308.77	2062.90	0.89
Difference	0	0	-0.001	17.53	6.24	-0.07	0.00	-1.38	0.00
SES 3, Homogeneous	42 (66)	39 (63)	170.498	2992.27	1087.96	158.05	2982.99	3161.02	1.06
SES 3, Heterogeneous	41 (65)	40 (64)	170.337	3015.46	1123.50	137.30	3060.91	2883.25	0.94
Difference	-1	1	-0.161	23.20	35.54	-20.75	77.92	-277.77	-0.12

Appendix A.2: Estimated results with 245 grid points for assets.

	Benefit claiming period	Number of worked periods	Lifetime utility	Maximum assets accumulated	Mean assets	Pension benefit	Aggregate contributions	Aggregate benefits	Ratio
SES 1, Homogeneous	38 (62)	37 (61)	151.191	1726.23	651.71	76.01	1765.47	1368.26	0.78
SES 1, Heterogeneous	38 (62)	37 (61)	151.294	1672.95	628.12	80.40	1765.47	1447.18	0.82
Difference	0	0	0.103	-53.28	-23.59	4.38	0.00	78.92	0.04
SES 2, Homogeneous	39 (63)	38 (62)	161.196	2299.18	926.52	103.21	2308.77	2064.28	0.89
SES 2, Heterogeneous	39 (63)	38 (62)	161.195	2299.18	926.52	103.15	2308.77	2062.90	0.89
Difference	0	0	-0.001	0.00	0.00	-0.07	0.00	-1.38	0.00
SES 3, Homogeneous	42 (66)	39 (63)	170.499	3043.03	1100.91	158.05	2982.99	3161.02	1.06
SES 3, Heterogeneous	41 (65)	40 (64)	170.339	2969.26	1128.27	137.30	3060.91	2883.25	0.94
Difference	-1	1	-0.161	-73.77	27.37	-20.75	77.92	-277.77	-0.12

Appendix B: Sensitivity analysis for SES 3 with recalibrated workforce exit.

	Benefit claiming period	Number of worked periods	Lifetime utility	Maximum assets accumulated	Mean assets	Pension benefit	Aggregate contributions	Aggregate benefits	Ratio
SES 3, Homogeneous	42 (66)	41 (65)	170.164	2709.18	1004.53	158.05	3137.30	3161.02	1.01
SES 3, Heterogeneous	42 (66)	41 (65)	170.008	2831.63	1061.55	146.51	3137.30	2930.18	0.93
Difference	0	0	-0.155	122.45	57.03	-11.54	0.00	-230.83	-0.07

Appendix C: Model annuity divisors under the two policies.

	Age 61	Age 62	Age 63	Age 64	Age 65	Age 66
SES 1, Homogeneous	24.09	23.23	22.37	21.52	20.68	19.85
SES 1, Heterogeneous	22.75	21.96	21.16	20.38	19.61	18.84
Difference	-1.34	-1.27	-1.20	-1.14	-1.08	-1.01
SES 2, Homogeneous	24.09	23.23	22.37	21.52	20.68	19.85
SES 2, Heterogeneous	24.09	23.23	22.38	21.55	20.72	19.89
Difference	0.00	0.00	0.01	0.02	0.04	0.04
SES 3, Homogeneous	24.09	23.23	22.37	21.52	20.68	19.85
SES 3, Heterogeneous	25.91	24.99	24.09	23.19	22.29	21.41
Difference	1.82	1.77	1.72	1.67	1.61	1.56

Appendix D: Annuity divisor derivation.

While meant to be an indication of life expectancy for a specific cohort at retirement adjusted by an advance interest rate, the annuity divisor formula can be seen as a calculation of the total number of future annuity payouts due (adjusted by the advance interest rate) (Swedish Pensions Agency, 2015). The sum of total annuity payouts is then divided by the number of individuals in the relevant cohort and divided by 12 to reach the number of payouts in years for each individual.

The annuity divisor equation can be written as:

$$D_n = \frac{1}{12L_n}\left[\left(\sum_{k=n}^{\infty} \frac{L_k}{(1+r)^{(k-n)}} \bullet \sum_{X=0}^{11} \frac{1}{(1+r)^{\frac{x}{12}}}\right) + \left(\sum_{k=n}^{\infty} \frac{\frac{L_{k+1}-L_k}{12}}{(1+r)^{(k-n)}} \bullet \sum_{X=0}^{11} \frac{X}{(1+r)^{\frac{x}{12}}}\right)\right] \quad \text{Equation 1.}$$

Where the second of the inner parentheses adjusts for the fact that some of the calculated payouts in the subsequent year will not be paid out due to the fact that some individuals in the cohort will pass away before these initial payouts will have to be paid out, events that are assumed to occur evenly distributed over the subsequent year (Pensionsmyndigheten, 2015). With further rewriting, and the defining the following parameters the annuity calculation becomes:

$$A = \sum_{X=0}^{11} (1 + r)^{-x/12}$$

$$B = \sum_{X=0}^{11} x(1 + r)^{-x/12}$$

$$S_1 = \sum_{k=n}^{\infty} (1 + r)^{-(k-n)} L_k$$

$$S_2 = \sum_{k=n+1}^{\infty} (1 + r)^{-(k-n-1)} L_k,$$

$$S = \frac{S_2}{(1+r)}$$

$$D_n = \frac{1}{12L_n}[(A - B/12)(L_n + S) + (1 + r)(B/12) \bullet S] = \frac{A-B/12}{12} + \frac{A+r*B/12}{12} \bullet \frac{S}{L_n}$$

However, for simplicity and in order to approximate the discrete periods in the model, it is assumed that the number of people alive per 100,000 lives the entire year in comparison to the assumption of evenly distributed deaths throughout the year used by the Swedish Pensions Agency. Hence, we can disregard the second inner parentheses in equation 1. This gives the following equation:

$$D_n = \frac{1}{12L_n}\left(\sum_{k=n}^{\infty} \frac{L_k}{(1+r)^{(k-n)}} \bullet \sum_{X=0}^{11} \frac{1}{(1+r)^{\frac{x}{12}}}\right)$$

The internal rate of return in the Swedish pension system is in part dependant on assumed economic growth and assuming no economic growth, $r = 0$, we can rewrite the equation accordingly:

$$D_n = \frac{1}{12L_n}\left(\sum_{k=n}^{\infty} \frac{L_k}{(1+0)^{(k-n)}} \bullet \sum_{X=0}^{11} \frac{1}{(1+0)^{\frac{x}{12}}}\right) = \frac{1}{12L_n}\left(\sum_{k=n}^{\infty} \frac{L_k}{(1)^{(k-n)}} \bullet \sum_{X=0}^{11} \frac{1}{(1)^{\frac{x}{12}}}\right) = \sum_{X=0}^{11} \frac{1}{(1)^{\frac{x}{12}}} \bullet \frac{1}{12L_n} \bullet \sum_{k=n}^{\infty} \frac{L_k}{(1)^{(k-n)}} =$$

$$12 \bullet \frac{1}{12L_n} \bullet \sum_{k=n}^{\infty} \frac{L_k}{(1)^{(k-n)}} = \frac{S_1}{L_n} \text{ where } S_1 = \sum_{k=n}^{\infty} (1 + 0)^{-(k-n)} L_k = \sum_{k=n}^{\infty} L_k, \text{ due to } r = 0.$$

The two different annuity divisor calculations then become:

$\frac{S_1}{L_n}$ for the one used in our model, and

$\frac{A-B/12}{12} + \frac{A+r\bullet B/12}{12} \bullet \frac{1}{(1+r)} \bullet \frac{S_2}{L_n}$ for the one used by the Swedish Pensions Agency.

Disregarding the first term and the factors in front of $\frac{S_2}{L_n}$ the difference simply becomes inclusion and exclusion of L_n (individuals alive in the current period) in the summation of S_1 and S_2. Hence, when comparing these two equations from the perspective of calculating the sum of future annuity payouts and dividing by individuals alive in period k, the equation used in real-life can be understood to calculate the total future annuity payouts in period $k + 1$, and then adjusting the number of payouts upward by the two factors in front of $\frac{S_2}{L_n}$ in the equation above, in order to factor in the payouts that occur prior to the evenly distributed deaths throughout the year. In contrast, the equation used in the model calculates the total future annuities immediately due to the assumption of no deaths within a given year[9]. The remaining difference between the two equations stem from the assumption of r being equal to 0 in the model.

[9] The same reasoning explains the difference between the annuity divisor in the model (i.e. proxy for life expectancy at retirement) and the life expectancy tables Statistics Sweden calculate using the same data since they do a similar reduction in years lived by assuming some deaths occur throughout the year

Appendix E: Stylized image of how the annuity divisors and life expectancy are calculated in the thesis.

	A	B	C
1	**Out of 100 000 persons aged 30, number of persons still living**	**Intermediate step**	**Annuity divisor**
2	= A7	=SUM(A2:$A$50)	=B2/A2
3	= A7	=SUM(A3:$A$50)	=B3/A3
4	= A7	=SUM(A4:$A$50)	=B4/A4
5	= A7	=SUM(A5:$A$50)	=B5/A5
6	= A7	=SUM(A6:$A$50)	=B6/A6
7	100000	=SUM(A7:$A$50)	=B7/A7
8	99796	=SUM(A8:$A$50)	=B8/A8
9	99567	=SUM(A9:$A$50)	=B9/A9
10	99284	=SUM(A10:$A$50)	=B10/A10
11	99085	=SUM(A11:$A$50)	=B11/A11
	...	...	...

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