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Should some be left behind in the race to increase the retirement age?

Evidence from a life-cycle model pension reform simulation for Sweden

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Abstract

Governments across the world are undertaking retirement age reforms to preserve fiscal sustainability in the face of population aging. However, research suggests that increasing the retirement age often has the unwanted side effect of increased disability insurance claiming, which can offset a big part of the savings realized due to lower spending on retirement benefits. In this thesis, I explore whether it would be optimal for retirement age increase reforms to only target individuals facing low health risk, to avoid triggering a large increase in disability insurance spending. I build a life-cycle labour supply model with an overlapping generations structure calibrated to the Swedish economy and simulate two retirement age increase reforms: a universal one (affecting everyone) and a selective one, where the retirement age is only increased for the low-risk group (college graduates). Comparing their outcomes, I find that the selective reform produces worse results than the universal one from the public finances perspective, if the increased retirement age remains below the age threshold at which individuals are transferred from disability insurance to retirement. However, if the retirement age is increased beyond that, the selective reform results in lower government spending on social benefits in the long run.

Keywords: Life cycle, retirement, pension reform, disability insurance

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1 Introduction

According to a recent OECD report, those retiring in the OECD countries in 2060 will, on average, be facing a 1.9 years higher normal retirement age compared to those retiring now (OECD, 2019), reflecting that retirement age reforms will be undertaken almost universally across the rich world. This is a logical outcome of the population aging phenomenon putting a strain on social security systems in most rich economies. With more and more receivers of old-age pensions and fewer social security tax payers, governments are obliged to reform their Pay-as-you-go (PAYG) pension systems to keep the social insurance funds solvent. Raising the statutory retirement age is one of the politically feasible reform types, making it a common reform choice among governments in rich countries. While retirement age reforms are not necessarily the most effective (Laun et al., 2019), the majority of commonly discussed alternatives, such as the gradual abolition (i.e., privatisation) of the public pension systems, the lowering of pension replacement rates or increasing the income tax rates for the working population would, in most cases, be very difficult politically (see, e.g., Cooley and Soares, 1999).

Modern pension systems are usually characterised by several retirement age thresholds, all of which might be altered as a part of retirement reform. The most important ones are the minimum retirement age[1], which denotes the earliest age at which a person can start drawing their old-age pension, and the so-called normal retirement age (NRA), usually denoting the age from which old-age pensions can be claimed without any downward adjustments for early claiming. In the Swedish public pension system, the concept of NRA is not that significant as no penalties are applied for starting to claim the old-age pension as soon as one becomes eligible. The Swedish equivalent of NRA is more important as an age at which individuals are transferred from other social programmes (such as disability insurance) to old-age retirement. This paper is focused on minimum retirement age increases, therefore, unless specified differently, the words "retirement age" will be used throughout to refer to this threshold in particular.

Reforms increasing the minimum retirement age shrink the size of the population entitled to pension benefits and are supposed to enlarge the body of social insurance tax payers, thus enhancing the financial sustainability of social insurance funds. They also appear justifiable in the context of increasing life expectancy, whereby even when allowed to retire later, newer generations spend the same (or a larger) share of their adult life in retirement as compared to the older generations. However, despite rising life expectancy, deteriorating health remains a constraint on how long a person can work. A high retirement age makes individuals who

[1] Also referred to as the "early access age to old-age retirement" or simply "early retirement age".

are in bad health before they are eligible to retire look for alternative retirement options, the most usual one being to claim disability insurance benefits for the years remaining until the age at which one is transferred from disability to retirement (this age does not always coincide with the minimum retirement age). Since Bound et al. (2010), disability insurance claiming has been an increasingly important feature in economics literature modeling retirement behaviour.

The side effect of increased flows into disability is a large drawback of retirement age increase policies. This consideration is particularly relevant for the Scandinavian countries, which have very generous disability insurance systems (Laun et al., 2019; Laun and Wallenius, 2015) and where disability benefit claiming is very widespread (Jönsson et al., 2012). In Sweden, disability insurance benefits received by people close to retirement can significantly exceed the pensions these people would receive were they allowed to retire earlier. According to the existing rules, an individual without university education retiring at the current minimum retirement age of 62 with an average lifetime annual salary of SEK 330 000 can expect a public old age pension of roughly SEK 115 000 per year. However, if the same person was granted access to disability insurance, their benefits would amount to roughly SEK 213 000 a year. It is thus costly for the government to further delay retirement for people who are likely to suffer negative health shocks throughout their lives.

With that in mind, the ideal policy for the government would be to identify the people who are the most likely to be in bad health as they age and to allow them to retire early, while raising the retirement age for everyone else. This concept is to different extents implemented in at least 18 OECD countries where the representatives of risky occupations are allowed to retire earlier than the common retirement age (Pestieau and Racionero, 2016). Such exceptions usually apply to the so-called 'hazardous' professions: miners, marine workers, teachers, armed and police forces (Zaidi and Whitehouse, 2009).

However, implementing a fully optimal selective retirement reform is never possible in real life. Government legislation setting the retirement age can only target groups of citizens based on observable characteristics, not on employees' individual attributes. Therefore, whichever characteristic the government picks for retirement age differentiation (e.g., sex, occupation or education level) will at best be a noisy signal of one's likelihood to be in bad health when older, not a perfect predictor. The stronger the signal is, the more efficient such a reform could be expected to be.

The aim of this paper is to simulate two retirement age increase reforms - a universal and a selective one - in a model economy calibrated to match Sweden's institutional features, employment and disability insurance claiming statistics. I construct a labour supply model with an overlapping generations structure and compare three different scenarios: in the first one, no reform is implemented; in the second one, the minimum retirement age is increased by 4 years (from 61 to 65) for everyone; in the third one the retirement age increases by the same amount, but only for individuals facing lower health risks. This is then repeated with a 6-year increase (from 61 to 67). Using data from the Survey of Health, Aging and Retirement in Europe (SHARE), I find that the attribute which has the most predictive power in determining ones' health while aging and is also observable for the social planner is whether a person has pursued tertiary (college) education. I choose it as the basis for the pension reform differentiation in the third scenario and explore the differences between the outcomes of the two reform types when it comes to disability claiming, employment rates, tax revenue, as well as combined spending on all social benefits.

Modeling the disability claiming procedure realistically and endogenously is essential for a simulated policy experiment such as this one to be informative. I use the information contained in SHARE microdata and combine it with aggregate disability insurance claiming patterns in the Swedish population to detect the most likely determinants of disability insurance claiming. This allows me to construct functions for probabilities of disability insurance applications being successful. Whether an individual leaves the labour force and starts claiming disability benefits when the application is successful is modeled as a part of the individuals' utility maximization decision.

It is not immediately obvious which reform (if either) would be more efficient at reducing the pressure on the government budget, defined as the share of government revenue spent on social benefits. The scale of the universal reform is larger, implying that it should result in a bigger drop in pension spending and a larger increase in employment (and thus in income tax revenue). However, it is also likely to heighten the disability claiming rates considerably. In a simulation calibrated to the United States (US) institutional setting, Li (2018) finds that 40% of the savings resulting from a universally increased normal retirement age is immediately offset by increased disability spending. The selective reform, where the retirement age is increased only for those with some college education, will not decrease the retirement rates as much, but - assuming that college education is a strong signal of better health in old-age - it should produce a much lower jump in disability claiming.

The simulations show that both types of 4 year retirement age increase reforms make public finances sounder relative to the benchmark scenario where no reform takes place: they both result in social insurance expenditure (i.e., pension and disability benefit spending combined) shrinking relative to the government tax revenue. The main driver of this result is the decreased spending on pensions immediately following the adoption of the reform. The expected side effect of increased disability claiming, on the other hand, is minimal with both reforms. As a result, the universal reform appears as a much more attractive option from the public budget balancing perspective as it impacts the short term pension spending by more and does not entail the hypothesised downside of soaring disability insurance spending. The only apparent drawback of both reforms is their ineffectiveness in the long run: because of the nature of the notional defined contribution pension system in Sweden, later retirement makes pension sizes increase considerably, which offsets the savings effect caused by a shrunk body of pension receivers over time.

The small jump in disability insurance claiming is not inconsistent with the previous literature (with a possible exception of Laun et al., 2019). As concluded by Bound et al. (2010), the increases in disability claiming mainly result from extending disability insurance to groups who previously did not have access to it. A 4-year increase in the Swedish early retirement age does not cause that to happen. The main reason for this is the overlap occurring in the age interval between 61 and 65 when an individual is allowed to claim disability benefits despite being eligible for retirement. Regardless of whether the minimum retirement age is 61 or 65, a person who has been working until, say, 63 and becomes eligible for disability at that age will be able to start claiming disability benefits with or without the reform (and continue to do so until transferred to retirement at 65). I find that implementing a retirement age increase of 6 years - and thus delaying the retirement age beyond the age of 65, at which one is currently transferred from disability to retirement, - changes the simulation results considerably (assuming that the disability insurance is logically extended to cover those aged 65 and 66 who are no longer able to retire). Both reform types trigger a significant jump in disability spending and while the universal reform remains more effective at reducing the pressure on the budget in the short term, once the effect of increased pension sizes starts kicking in, the selective reform entails a better longer-term result for the social security budget.

The results of this quantitative exercise suggest that under some specific conditions a selective retirement age increase might constitute a somewhat attractive alternative to an across-the-board reform and deserves further interest. Its direct applicability in the policy field is doubtful: legislation discriminating citizens based on education status would, in all likelihood, be controversial in a modern society. Nevertheless, the conclusions of the simulations could be applicable to different forms of retirement age differentiation that are more realistically implementable and correlate with education. Occupation type (e.g., blue-collar versus white-collar) or the industry in which one is employed could be a couple of examples of differentiation determinants corresponding to these criteria.

The paper is structured as follows: In Section 2, I briefly review the existing research on retirement age reforms, disability insurance and retirement age differentiation. In Section 3, I present some stylized facts about retirement, disability and the pension system in Sweden to further justify the relevance of this paper's research idea. In Sections 4 and 5, I present the economic model driving the results and thoroughly explain how it is calibrated. Section 6 presents the results of the quantitative pension reform simulations, whereas Section 7 summarizes the model's conclusions and discusses its limitations.

2 Related literature

Modeling retirement reforms, employment at old age and disability claiming

Conducting pension reform simulations using life-cycle labour supply models has a long tradition. Gustman and Steinmeier's (1985) paper is seen as the first modern heterogeneous agent study to simulate a retirement age reform (Li, 2018). The paper is focused on evaluating the changes in labour supply and retirement behaviour of US households which would be triggered by increasing the normal retirement age and adopting the other 1983 Social Security reform measures. The authors find that the reform would successfully increase the share of people in full-time employment among those aged 65 and older, and would incentivize later retirement. Gustman and Steinmeier (1985) was followed by other studies examining how retirement behaviour would change in response to hypothetical or real retirement reforms (e.g., Stock and Wise, 1988), with many of them concluding that delayed statutory retirement age does have a strong positive effect on employment rates among older age groups.

A big part of the retirement reform simulation literature has been influenced by the findings of the works focused on explaining the actually observed (rather than hypothetical) retirement behaviour, notably the peaks of the exit from the labour force occurring at certain ages in most rich economies. Rust and Phelan (1997) was one of the first studies to build a dynamic programming model which successfully replicated the retirement peaks at 62 and 65 observed in the US. One of the main conclusions of the authors was that replicating the retirement patterns observed in real life required very accurate modelling of "incentive schemes" created by the existing pension system, notably the "non-linearities" which it is characterised by. Replicating pre-reform retirement patterns through accurate calibration of pension system features has been an important aspect in many subsequent retirement reform simulations since (e.g., French, 2005; Laun and Wallenius, 2015) and is also attempted in this paper.

Accurate calibration of institutional features and preference parameters lead some of the subsequent studies to less optimistic conclusions about the effects of simulated retirement age increases. French (2005) study, one of such examples, does not find a simulated one-year increase in the minimum retirement age in the US to trigger any sizeable changes in the labour supply of older individuals. The main reason for this finding is that households willing to retire early tend to have enough savings to finance an additional year of retirement in French's model. Reducing the size of public old-age pensions is identified by the author as a more effective policy when it comes to incentivizing later retirement.

The inclusion of disability insurance (DI) into retirement simulation models is surprisingly recent. Bound et al. (2010) was the pioneering paper in this regard, constructing a life-cycle model where the "activity states" which the agents choose from in each period also include the option of applying for disability benefits. The authors of Bound et al. (2010) simulate a reform of the normal retirement age in the US, increasing it from 65 to 67, and find that it provokes a tangible jump in disability insurance applications. The effect is driven by the fact that the reform makes disability insurance available for individuals in the 65-67 age group, who did not have access to it prior to the reform. Another interesting trait of Bound et al. (2010) is their use of self-reported survey data on individual health, a feature also present in this paper.

Since Bound et al. (2010), including disability insurance claiming as an alternative way of exiting from the labour force has become quite common in the literature on retirement behaviour and employment at old-age.

Laun and Wallenius (2016) incorporate disability insurance into their analysis to explore the differences in retirement patterns across a set of OECD economies. They demonstrate that calibrating a life-cycle model to match the different institutional rules regulating disability insurance systems in different countries helps to explain a large share of differences in employment rates at old age across rich economies. Their paper also is an example of an effort to model DI as realistically as possible by representing it as an "imperfect screening" process (based on prior work by Low and Pistaferri, 2010).

Fiscal implications of retirement age reforms in the previous literature

Of particular interest to this paper are the previous analyses exploring the effect of retirement reforms from the fiscal stabilisation perspective. One such example is the Li (2018) paper analysing a hypothetical increase in the normal retirement age in the US. Li simulates the reform in two models: one without disability insurance in place and one with it, to disentangle the exact fiscal effects of DI. The author demonstrates that following a universal NRA increase in the model with DI in place, the rise in disability claiming offsets 40% of the savings that the Social Security budget realises thanks to a decrease in Old Age Insurance payments.

Laun et al. (2019) is also focused on fiscal sustainability analysis, mainly in the context of demographic change. The authors build a life-cycle model calibrated to Norway's institutional setting and simulate several policy reforms aimed at achieving revenue neutrality, including an increase in the early access age to old-age retirement. The retirement age increase reform (raising it from 62 to 67) is shown to be unsuccessful when it comes to achieving revenue neutrality as it triggers a large jump in disability spending through the channel of restricted access to retirement.

In Haan and Prowse (2014), the fiscal effects of the disability insurance are not as strong as those found in Laun et al. (2019). Haan and Prowse (2014) perform a very similar retirement age increase simulation for Germany (instead of Norway) and are also interested in whether such a reform can achieve revenue neutrality. They find that a 3.76 years increase of the pension age thresholds would successfully offset the fiscal consequences of increased life expectancy expected over the next 40 years, even when accounting for the disability insurance as a route to early retirement.

Retirement reforms simulations in the Swedish setting

Such contradictions in similar simulations performed for different countries suggest that local institutional features, as well as pension and disability rules specific to a given country affect model conclusions considerably. However, a clear trend in the literature is that most papers focusing on simulating retirement reforms, their impact on retirement behaviour and employment rates at old age do not explore the diversity of institutional frameworks extensively, with most work being focused on the US. Attempts at conducting such simulations for Sweden have been very few.

Hviding and Mérette (1998) contains one of the first quantitative pension policy experiments calibrated to the characteristics of the Swedish economy. They construct an Auerbach and Kotlikoff (1987) type of Overlapping Generations (OLG) model and, among other reforms, simulate a 4-year retirement age increase. The paper evaluates the policy outcomes from the fiscal consolidation perspective and computes by how much wage-income tax rates would have to rise in the country to maintain a constant debt-to-GDP ratio in the context of population aging. It is shown that if a retirement age increase reform is implemented, the wage-income tax rate needs to rise by much less than in the baseline scenario of no reform, implying that higher retirement age has lasting fiscal benefits. However, the paper does not take into account disability insurance as a channel of exit from the labour force, which suggests that its conclusions about the effectiveness of the retirement age increase might be overly optimistic.

This thesis builds closely on Laun and Wallenius (2015), another paper analysing a pension reform in the Swedish institutional setting. The authors use a life-cycle model with endogenous disability claiming to examine Sweden's switch from a defined benefit to a notional defined contribution PAYG system which began in 1994 and will fully phase in by 2040. They find that the reform creates strong incentives for people to delay retirement and does not cause a big change in disability insurance claiming.

Could a case be made for a selective retirement age reform?

Overall, the previous literature has demonstrated that retirement age reforms do enhance the soundness of public finances and can allow governments to avoid the necessity to balance their budgets through more unpopular measures such as increased taxation (Haan and Prowse, 2014; Hviding and Mérette, 1998; Li, 2018). However, their effectiveness appears to decrease significantly when the disability insurance channel of exiting the labour force is accounted for (Laun et al., 2019; Li, 2018).

This paper attempts to answer the question that naturally follows: is it possible to design a retirement age reform which minimizes the disability insurance claiming effect while preserving the fiscal benefits of a reform? And could this be achieved with a retirement reform that affects only those who are least likely to become disability insurance claimers?

A clear finding in the disability insurance literature is that disability claiming is by no means random. Halpern and Hausman (1986) find (quite unsurprisingly) that being on disability insurance is more likely in case of certain medical conditions and with bad health in general. However, the literature indicates that other demographic characteristics can be good predictors of disability benefit claiming too: Autor and Duggan (2003) demonstrate the fact that disability claiming is much more widespread among low-skilled individuals, whereas Gallipoli and Turner (2009) show that even a person's marital status can affect their disability claiming behaviour.

Motivated by these findings, I simulate a selective retirement reform where the retirement age is increased only for the agents who have a lower average chance to be in bad health and become disabled eventually. I then compare its results to those produced by an across-the-board reform.

The idea of differentiated retirement reforms has been explored in previous works, but they were not clearly focused on fiscal implications of such reforms. Staubli and Zweimüller (2013) is perhaps the only notable exception. Their paper analyses the outcomes of a differentiated retirement age reform which actually took place in Austria in the early 2000s and estimate its fiscal results, concluding that the reform did improve the solvency of the social security budget and did not trigger a large increase in disability spending. However, neither the rationale of the analysed reform nor the method applied in Staubli and Zweimüller (2013) have anything in common with the analysis proposed here: the differentiation in the Austrian pension reform case was gender-based and aimed at decreasing the historical gap in early retirement ages applying to women and men; and the results of the reform are not analysed in a life-cycle model thus not allowing the authors to compare it to any counterfactual scenarios. A significant share of literature exploring the possibility of retirement age reform selectiveness is in fact focused on the welfare inequality aspect that health heterogeneity entails and looks at differentiated retirement ages as a remedy to that (e.g., Pestieau and Racionero, 2016; Vandenberghe, 2020). This paper, however, is very different in the sense that it addresses the question of efficiency of a differentiated reform from the public finances perspective.

The aim of this paper is to contribute to the wider literature on optimal retirement policy design from the public finances standpoint and to shed more light on the design choices along the retirement age differentiation dimension. While many other papers have explored the fiscal effects of various pension reform parameters (the size of the retirement age increases, the generosity of the benefits, etc.), the parameter of targeting only specific groups with a pension reform has not been widely explored before. It is also a contribution to the scarce body of literature analysing retirement behaviour in the Swedish institutional context, characterised by the notional defined contribution public pension system (which differs in many ways from the more often studied Social Security pension system in the US). To the best of my knowledge, no previous works have quantitatively simulated a retirement age increase reform for Sweden, while also incorporating the feature of disability insurance as an alternative way of retirement. Finally, this paper makes extensive use of Swedish microdata to inform the calibration of disability insurance application process and health processes. Whereas at least one of these features appeared in many previous papers, combining them allows me to make informed and realistic modeling choices regarding the disability insurance claiming phenomenon, the importance of which is recurrently emphasised in the retirement modeling literature.

3 Aging, retirement and disability insurance claiming in Sweden

Just like most other rich economies, Sweden is facing an aging population phenomenon. The share of population aged 65+ has been steadily increasing for the past few decades in

Sweden, rising from 11.8% in 1960 to 20.2% in 2019 (World Bank, 2021).

Sweden has been reforming its pension system to counter the effects that population aging has on public finances. Perhaps the most important pension reform in modern Swedish history was started in 1994, transforming the Swedish pension system from a defined benefit to a notional defined contribution program (Palmer et al., 2000). The first pensions from the new system were paid out in 2001 but the reform will not be fully phased in until 2040.

As a result of the reform, Sweden has stronger incentives for aging individuals to remain in employment than many other countries. In a notional defined contribution pension system, the size of retirement benefits depends not on the best, say, 15 years of one's career but on the value of the pension capital accumulated throughout one's lifetime. According to the current setup, 18.5% of Swedish employees' annual earnings up to 7.5 Base Income Amounts (BIA) (roughly SEK 500 000) are contributed to the pension capital, with 16% going into the income pension and the remaining 2.5% into the individual premium pension account. The contributions are uprated in accordance with the developments in economy-wide average earnings and the annuity is calculated by dividing the accumulated income pension capital by the remaining life expectancy at retirement. Even though this mechanism slightly resembles a fully-funded private pension plan, the system is still Pay-as-you-go, implying that contributions of the current young are used to finance the pensions of the current old.

With a notional defined contribution pension plan like this one in place, the workers are incentivised to stay in employment beyond the minimum retirement age, as longer employment naturally results in higher pension capital accumulation and thus bigger old-age state pensions (Laun and Wallenius, 2015).

Sweden is also rapidly increasing the minimum retirement age. In 2020, it increased from 61 to 62 and is scheduled to go up to 63 in 2023 and to 64 in 2026.

Reforms, together with improving health, have succeeded at considerably increasing the employment rates among older individuals. Whereas in 1995 the share of gainfully employed 60-64 year-olds was 46.6%, in 2019 this number reached 71.3% (SCB, 2021c). Among the OECD countries, Sweden has the second highest employment rate of 55-64 year-olds (OECD, 2021).

Even though senior citizens in Sweden tend to work for longer than their counterparts in most rich countries, disability claiming is also a prevalent practice among elderly Swedes. In January 2019, 14.8% of 60-64 year-olds were claiming disability insurance benefits in Sweden. Though the number appears very high, it is significantly lower than the peak disability incidence rate of 2008, when 28.7% of people in the same age group were claiming disability benefits (Försäkringskassan, 2021a). Historically, the Swedish Social Insurance Agency was also granting disability insurance benefits to older workers for pure labour market reasons (Jönsson et al., 2012; Laun and Wallenius, 2015), but this practice has not been applied lately, which, together with increased screening stringency, helped bring the numbers of disability insurance claimers down.

One of the reasons why disability insurance claiming is so prevalent in Sweden is the relative generosity of the disability benefit system. According to the current rules, the disability benefit is equal to 64.7% of the average income during the three years preceding disability, with a cap at SEK 230 976 (Försäkringskassan, 2021b). People can also accrue pension capital on their disability benefit income. Assuming that working carries an inherent cost to an individual, switching from employment to disability insurance as soon as eligible may present an attractive alternative: it can often result in a relatively small drop in income, which is compensated for by decreased labour disutility.

The analysis proposed in this paper appears particularly relevant at the current point in time: since 2020, the Swedish government has been undertaking a gradual retirement age reform which will considerably delay the age from which people are eligible to claim old-age pensions. The simulation results can thus be seen as a relevant indication of what the outcome of such a policy might be and whether a better outcome could have been achieved (at least in theory) if the undergoing pension reform was targeting only the individuals with low health risks.

4 The model

To analyze the implications of two different retirement age increase reforms (a universal and a selective one), I develop a life cycle labour supply model with an overlapping generations structure. Just like previous papers exploring the effects of pension reforms on individual level labour market decisions (French, 2005; Gustman and Steinmeier, 1985; Laun and Wallenius, 2015), I do not model the general equilibrium outcomes or the decisions of the firms in the economy. Given this simplification, the prices of production factors are not determined endogenously in the model, but rather taken as exogenous parameters calibrated to match real-life data. All quantities in the model are expressed in terms of one generic consumption good, the value of which can be interpreted as equivalent to SEK 1 in 2019.

4.1 Households

Household individuals in the model enter the economy at the age of 23 (the age by which education decisions are completed and entry into the labour force happens) and live until the age of 82 (average life expectancy in Sweden), after which they die with certainty. Each individual is thus active for 60 model periods corresponding to 60 years. Individuals are assumed to be heterogeneous with respect to how likely they are to suffer a negative health shock and in terms of productivity. Individuals' education decisions are not modelled. Each individual enters the economy without any assets and, knowing their life duration with certainty, uses up all of their savings before dying. Household agents are assumed not to have bequest motives.

In each period, every individual makes consumption, saving and labour supply decisions so as to maximize the utility for the remaining lifetime periods given the initial asset state, their health and whether they are eligible to claim pension or disability benefits. Preferences for the individual i are given by:

$$\sum_{a=1}^{60} \beta^{a-1} \left(ln(c_{a,i}) - d(h_{a,i}, a) l_{a,i} \right), \tag{1}$$

where a is the model age of the individual, $c_{a,i}$ denotes the consumption of the individual i at the age a, $h_{a,i}$ is the health of individual i at the age a, $l_{a,i}$ is the labour supply of individual i at the age a, and β is the parameter denoting the discount factor. I assume that the disutility derived from working, given by $d(h, a)$, is health dependent. The function $d(h, a)$ is assumed to be linear in health states (increasing with worsening health) and is allowed to differ for different age groups.

The individual maximizes their remaining lifetime utility under a sequence of budget constraints, imposing that in every period the sum of that period's consumption and the change in individual's capital stock cannot exceed the period's post-tax income:

$$(1 + \tau_c)c_{a,i} + (k_{a+1,i} - (1 + r)k_{a,i}) = (1 - \tau_{inc})Y_{a,i}. \tag{2}$$

In equation (2), τ_c and τ_{inc}[2] denote consumption and income tax rates respectively, $k_{a,i}$ denotes the asset holdings of individual i at the age a, r is the real interest rate on assets, and $Y_{a,i}$ is used to denote the income of the individual.

Within the framework of the model, income $Y_{a,i}$ can be either the labour market income ($Y_{a,i}^{wage}$), the public pension benefits ($Y_{a,i}^{pension\_benefit}$) or the disability insurance benefits ($Y_{a,i}^{disability\_benefit}$). For modelling purposes, I assume that during a given period an individ-

[2]Note that in practice τ_{inc} should be expressed as a function of $Y_{a,i}$ to reflect the progressive income tax schedule. Here the tax is assumed to be linear for simplicity. This choice is not too distortionary because the elevated income tax rate does not apply to any agents in the model as a result of chosen salary schedules (see the calibration section). However, some other relevant tax progressivity channels are disregarded here, one example being the earned income tax credit (EITC).

ual can only receive one of these income types (this assumption is further justified in the calibration section).

Labour income in the model is the product of the individual's labour supply and the market wage. Income derived from pension benefits and disability insurance benefits is calculated according to a formula mimicking institutional rules for determining the sizes of these benefits (see the calibration section).

Consistent with the literature acknowledging that individual labour supply usually has only two or three modes (see Diamond, 1980), the model allows for labour supply adjustments to happen in extensive margin only, meaning that individuals either supply one unit of labour in a period or do not work at all, $l_{a,i} \in \{0, 1\}$. This assumption could significantly affect the conclusions of the model if part time work was strongly prevalent among older people before transitioning into retirement. However, there seems to be no such trend in the data: Laun and Wallenius (2015) show that the incidence of part time work in Sweden is quite low (roughly 10%) and constant across ages in the 55-64 age group.

In any given period an individual can thus be in one of the four different activity states (in the sense of Bound et al., 2010): employed ($l_{a,i} = 1, Y_{a,i} = Y_{a,i}^{wage}$), voluntarily unemployed ($l_{a,i} = 0$, $Y_{a,i} = 0$), on disability insurance ($l_{a,i} = 0$, $Y_{a,i} = Y_{a,i}^{disability\_benefit}$) or retired with an old-age pension ($l_{a,i} = 0$, $Y_{a,i} = Y_{a,i}^{pension\_benefit}$). The decision to leave the labour force is assumed to be permanent, i.e., a person cannot go back to employment after having transitioned into disability insurance, retirement or voluntary unemployment.

The health of an individual can assume one of the 5 discrete states. These correspond to the 5 self-reported physical health states that participants can choose from in the SHARE survey: excellent, very good, good, fair and poor. An ordinal numerical relationship between these health states is established, whereby excellent health is denoted by value 1 and poor health by value 5 in one unit increments. All individuals are born into the economy with excellent health which then evolves according to the following law of motion:

$$h_{a+1,i} = h_{a,i} + \epsilon_{a,i}, \tag{3}$$

where $\epsilon_{a,i}$ denotes a random exogenous health shock which can assume only non-negative values (i.e., the health of an individual can only deteriorate). The probability with which the shock occurs depends on the individual's age and their health type (risky vs. non-risky).

When making labour supply and saving decisions, claiming retirement benefits or deciding whether to apply for disability benefits, the agents in the model consider all the possible employment scenarios given their current health state and rationally compare the expected utilities resulting from each scenario.

However, I assume that the agents do not take into consideration the health shocks that they might face in the future, i.e., they always expect that in the next period their health will be identical to this period's health.[3] As a result, agents do not accumulate precautionary savings and are not getting ready for unexpected health shocks. This assumption in some sense undermines agent rationality, but remains quite appealing. Firstly, according to many previous works, it appears to be a realistic reflection of how real-life agents make saving decisions. Many of the pre-2008 empirical studies find precautionary savings to be an "unimportant part" of consumer behaviour (see, for instance, Dynan, 1993). Analyses on precautionary savings related to health shocks also do not find that agents increase savings when facing increased health risks (Yilmazer and Scharff, 2014). Later studies find that precautionary saving motives are strong when it comes to income uncertainty and possible spells of unemployment (e.g., Krueger et al., 2016), but such motives are not relevant in this model setup. Secondly, it allows keeping the agent optimization problem deterministic and less complex mathematically by reducing the number of possible future states that an agent needs to consider the value function for.

Many papers in the retirement modeling literature (e.g., Laun et al., 2019; Laun and Wallenius, 2015) impose a borrowing constraint to prevent individuals from not working when young, which they would otherwise see as appealing due to the hump-shaped nature of the labour earnings schedule (see the calibration section). Here such an assumption is not needed because the choice to leave employment is assumed to be permanent - by not working in the first periods the agents would lose the right to work for the rest of their lifetimes, which is never optimal, as it would result in zero lifetime consumption.

Following Laun and Wallenius (2015), I populate each model generation with a large number of agents. Here, each generation is represented by 1000 individuals at a time (i.e., there are always 1000 twenty-three-year-olds, 1000 twenty-four-year-olds, etc. in the economy); 60000 individuals are alive at all times. This number is large enough for random variable draws to approach their true distributions but does not impose computational hurdles. For the calculations of the aggregates, savings, incomes, consumption, tax payments, and social benefits received by these cohorts are scaled by their real sizes in a given period.

4.2 Government

The government in the model collects income, social security and consumption taxes and uses this tax income to finance disability insurance benefits and pensions. The remaining

[3] I also make an assumption that they do not consider the option of being on disability before they are actually eligible.

government revenue is assumed to be "thrown away", in the sense that it is not redistributed to the agents in any form (an identical assumption is made in Laun and Wallenius, 2016). Realistically, this could be interpreted as government financing defence, culture, and other social programmes which are not considered as substitutes to the consumption good and which provide agents with separable utility, not affecting the marginal utility of private consumption.

No assumptions about the government's borrowing constraints are made because in neither of the simulations does the government expenditure on disability insurance and pension benefits ever exceed the tax revenue (the social benefit spending fluctuates between 20% and 30% of the government revenue in most periods). The following inequality holds in every period:

$$\sum_i \tau_{inc} Y_{a,i} + \sum_i c_{a,i}\tau_c + \sum_i \tau_{ss} Y_{a,i}^{wage} l_{a,i} > \sum_i Y_{a,i}^{pension\_benefit} + \sum_i Y_{a,i}^{disability\_benefit}, \tag{4}$$

where τ_{ss} is the social security tax rate[4] and other variables are defined above. The government never runs a deficit; instead, it decreases its spending unrelated to social benefits when the benefit claiming increases.

4.3 Solving the model

Because the general equilibrium is not modeled, only the household maximization problem needs to be solved for each household agent in every period. Every household agent is trying to maximize their discounted lifetime utility,

$$max \sum_{a=1}^{60} \beta^{a-1} \left(ln(c_{a,i}) - d(h_{a,i}, a) l_{a,i} \right), \tag{5}$$

s.t.

$$(1+\tau_c)c_{a,i} + (k_{a+1,i} - (1+r)k_{a,i}) = (1-\tau_{inc})Y_{a,i}. \tag{6}$$

In order to achieve this, at every age a, the agent considers the state $S_{a,i}$ they are in, and chooses controls $C_{a,i}$ which will determine what state $S_{a+1,i}$ the agent will be in during the

[4]Note that the social security tax is only levied on labour market income and is paid by the employer, which is the reason why it does not appear in the household budget constraint.

next period.[5] Therefore, in every age period the household agent is maximizing the value function:

$$V(S_{a,i}) = \max_{\{C_{a,i}\}} \{ln(c_{a,i}) - d(h_{a,i}, a_i)l_{a,i} + \beta V(S_{a+1,i})\} \tag{7}$$

The components of agent i's state at age a, $S_{a,i}$ are:

1. Assets in the current period
2. Employment status (when the agent stopped working, if ever)
3. Disability status (when the agent started claiming disability benefits, if ever)
4. Health
5. Eligibility for disability insurance (eligible or not)

The components of agent i's controls vector at age a, $C_{a,i}$ are:

1. Assets in the next period (i.e., how much to save)
2. Whether to work in this period (if worked in the previous period)
3. Whether to start claiming disability benefits in this period (if eligible and not claiming them yet)

Note that the consumption choice is not a part of the controls, as consumption can be computed from the budget constraint once the savings choice is made and the income is known. Similarly, when to start claiming retirement benefits is not a control, given the assumption that old-age pension claiming starts automatically as soon as the agent retires (component 2.), or as soon as they are eligible (see Section 5.2).

A standard way to solve such a problem would be via a dynamic programming algorithm, as in Rust and Phelan (1997), French (2005), Bound et al. (2010), Laun and Wallenius (2015) and other similar papers. Given that the problem is finite (i.e., the agent dies with certainty at model age 61), it is possible to compute the value functions for all possible states at age 60 and then solve the problem using backward induction. This approach would allow to find a set of optimal decision rules for every possible state $S_{a,i}$.

[5] The state $S_{a+1,i}$ will also depend on the random realizations of health shocks and disability application outcomes, but given the assumptions made about agent expectations in Section 4.1, agents do not take this into consideration.

However, the dimensionality of the problem makes such a solution extremely heavy computationally. It would entail finding the optimal controls choice for every possible combination of state components, which become very numerous once considering every different employment and disability claiming history, health state, and every possible position on a reasonably fine asset grid - an issue known as the Bellman's curse of dimensionality (Bellman, 1957). Depending on the asset grid choice, the number of state combinations in such problems can reach a six-digit number (see, e.g., Hubbard et al., 1995).

Given the computational constraints, I choose an alternative solution method. Instead of computing the decision rules for every possible state $S_{a,i}$, I consider the actual state of each agent in the model and compute the optimal controls on a case-by-case basis. To implement this, I build an algorithm where the agent i of age a considers every possible activity schedule for the remaining lifetime periods. Then the optimal asset allocation path is found through backward shooting for each one of the schedules and associated utilities are computed. This period's activity status from the utility maximizing schedule (working, not working or moving onto disability insurance) is recorded as components 2. and 3. of the controls vector $C_{a,i}$. The $k_{a+1,i}$ resulting from the optimal asset allocation path for the utility maximizing schedule is recorded as component 1. of $C_{a,i}$.

In Appendix A, I derive an equation expressing the optimal asset holdings in a given period ($k_{a,i}$) as a function of asset holdings in the two upcoming periods ($k_{a+1,i}$ and $k_{a+2,i}$) and the income in the current and the upcoming period ($Y_{a,i}$ and $Y_{a+1,i}$), which is used to find the optimal asset allocation path through backward shooting. Knowing that $k_{61,i} = 0$ (agents use up all of their assets before dying), I provide a guess for $k_{60,i}$ and compute the asset allocation path for all the other ages going backwards. If the resulting asset allocation for the first period $k_{1,i}$ is not zero, the assumption that the agents enter the economy with no assets is violated. In that case, the guess for the last period is updated and the backward computations are redone until the $k_{1,i} = 0$. Starting from the second period, agents already have some asset holdings which they have brought in from the previous period. When the backward shooting algorithm is used to solve for their asset allocation path, the left boundary condition is no longer that $k_{1,i} = 0$ but that the implied asset holdings for the current period would match the actual asset holdings.

The method discussed above has several flaws compared to dynamic programming. First of all, the backward shooting would not work if the maximization problem was stochastic (Feng et al., 2014). This is prevented here by assuming that agents do not take into consideration the future health shocks and potential disability eligibility while maximizing, which allows me to keep the problem deterministic. Also, this solution method is less scalable, meaning that its computational intensity increases proportionally with how many different agents the problem is solved for. However, it also has some advantages. Perhaps the main one is that the agents can choose exactly how much to save, as opposed to sticking to the closest point on a discretized capital grid (Feng et al., 2014).

4.4 Running the simulations in MATLAB

I make the assumption that the economy is in a stationary state in 1970 where all the individuals are working if they are under 61 and retired afterwards. All the generations have the same optimal asset allocation path. I then let the model update fully until 2019, with individuals making endogenous labour supply, disability and pension claiming, consumption and saving decisions. Note that the model is in partial equilibrium in every period, but a stationary state is never reached again.

In each period, an individual first faces a potential health shock and then evaluates every possible future activity schedule available to them given their age, health and institutional features. Next, they compare the expected utilities from each one of the possible activity state schedules and the income schedules associated with them. They choose the activity status associated with the schedule providing the highest expected remaining life-time utility: they either remain employed, stop working (with or without an old-age pension, depending on the age) or start claiming disability insurance (if eligible). If the agent is in one of the activity states outside of active employment (voluntarily unemployed, retired or on disability insurance), they only make an asset allocation choice and remain in the same activity state (unless they are transferred from disability insurance into retirement). Given the labour supply choice, the agents solve for the optimal asset allocation and consumption path. After all individuals' choices are computed, the aggregate outcomes (such as aggregate disability spending, tax revenue, etc.) scaled by the actual sizes of each generation are recorded and the next period starts (with a new cohort of individuals being born).

The MATLAB code used to implement this algorithm is structured as a series of nested loops. The outer *for* loop captures the model periods (years), and the inner *for* loop loops over each one of the 60000 individuals alive in the model. Within it, another loop rolls over every possible activity schedule available to an individual. This loop also nests the *while* loop solving the asset allocation problem for each individual associated with each activity schedule variant using backward shooting. Once the expected lifetime utilities from each schedule are compared, the income, asset allocation and consumption schedules associated with the decision providing the highest utility are recorded in respective aggregate matrices.

In 2020 either nothing happens or one of the two reforms is implemented (without being anticipated by the agents):

1) Early retirement age is increased from 61[6] to 65 (or to 67) for everyone;

2) Early retirement age is increased from 61 to 65 (or to 67) for the individuals of the non-risky health type, i.e. the group with college education.

I follow a standard assumption in life-cycle modeling that the reform is not anticipated by the agents, i.e., when making decisions, they expect that the rules of the current period will be "maintained indefinitely" (Haan and Prowse, 2014).

Individuals who are already retired despite being younger than the new retirement age remain in retirement but new retirees are only able to retire after they reach the new retirement age. In real life the transition is more likely to be gradual, but in the setting of the simulation such a choice allows for the reform results to materialize quicker without changing the ultimate conclusion.

Then the model is run for 31 more periods, until 2050. The same seed is set for the benchmark no-reform scenario, as well as for reforms 1) and 2) to ensure that the differences in outcomes are not caused by different random draws of health shocks or disability application outcomes.

Simulation outcomes are presented in the Results section.

5 Calibration and parametrisation

The model is calibrated to match the relevant characteristics of the Swedish economy, its institutional features, demographic situation and health distributions of different groups. For aggregate calibration targets and institutional setup I use 2019 as the reference year. 2020 is chosen as the year in which the reforms get implemented as it coincides with the year when Sweden in effect started increasing the minimum retirement age.

5.1 Health calibration and risky versus non-risky health types

An important aspect of the calibration process is related to constructing the risky and non-risky health types and assigning those types to individuals in the model in a realistic way. Consistently with the previous literature analysing retirement behaviour (e.g., Bound et al., 2010; Coile and Gruber, 2007), I turn to micro level data for this purpose.

In this paper, I use the microdata from the Survey of Health, Ageing and Retirement in Europe (SHARE). The SHARE data set contains information on each surveyed individual's demographics, employment and family situation, income, education, as well as a self-reported

[6] 61 was the early retirement age in Sweden until the end of 2019. The retirement age reform timing is assumed to coincide with the year when the Swedish government actually started increasing the minimum retirement age, i.e., 2020. For this reason, 61 is used as the base minimum reitrement age.

health measure. The respondents evaluate their health as corresponding to one of the five categories: excellent, very good, good, fair and poor.

I use the data from survey respondents in Sweden and restrict my focus to respondents aged 45-74. The majority of respondents in the data set belong to this age group, and such a choice seems to be relevant given that the people in this age interval are the most likely to be affected by retirement reforms.[7]

The resulting data set contains 15784 individual survey responses, collected between 2004 and 2017. Some individuals were interviewed in more than one survey wave and represent more than one observation. This is not regarded as a drawback because tracking the characteristics (say, health) of the same individual across different ages is as much insightful as looking at different individuals of different age.

An essential exercise here is to determine which characteristics (that would be observable to a government undertaking a pension reform) could serve as predictors of whether an individual is a risky or a non-risky type health-wise, i.e., are they more or less likely to suffer from negative health shocks. I run several statistical models including logit, quadratic discriminant analysis, and a classification tree using the cross-validation approach to determine which observable predictors have the most explanatory power when it comes to classifying individuals into the good health group (excellent, very good or good health) and the bad health group (fair and poor health). Most models, however, have close to zero sensitivity at predicting one's belonging to the bad health group (e.g., the fitted classification tree model appears one-modal, classifying all the individuals into the more often occurring good health group). I then proceed with a simpler approach of regressing one's health (quantified to a 1-5 scale) on observable characteristics and comparing the coefficient sizes reflecting the differences in means.[8] The largest significant difference in means is observed along the dimension of the variable capturing individual's education on the ISCED-97 scale. The difference is the most considerable comparing the means of the individuals with ISCED-97 Level 5 and Level 6 education (some tertiary education) versus Level 1-4 education (no college education).

As can be seen in Figure 1, the health distribution of the non-college group is considerably more skewed to the right (i.e. towards poor health). It is also a consistent trend that the fraction of individuals in the two worst health states is approximately 1.5 higher in the non-college group in every 5-year age bracket. In the light of these findings, I choose the college versus non-college split as the basis of retirement age differentiation in the simulated selective reform.

[7] Such a choice is also conditioned by the specifics of the data set. Because the SHARE project surveys are focused on individuals aged 50 or older, younger respondents are not numerous in the resulting data set. Whereas 45-50 year-olds are still present, very few observations of individuals younger than 45 are found.

[8] For this purpose the health variable is treated as continuous.

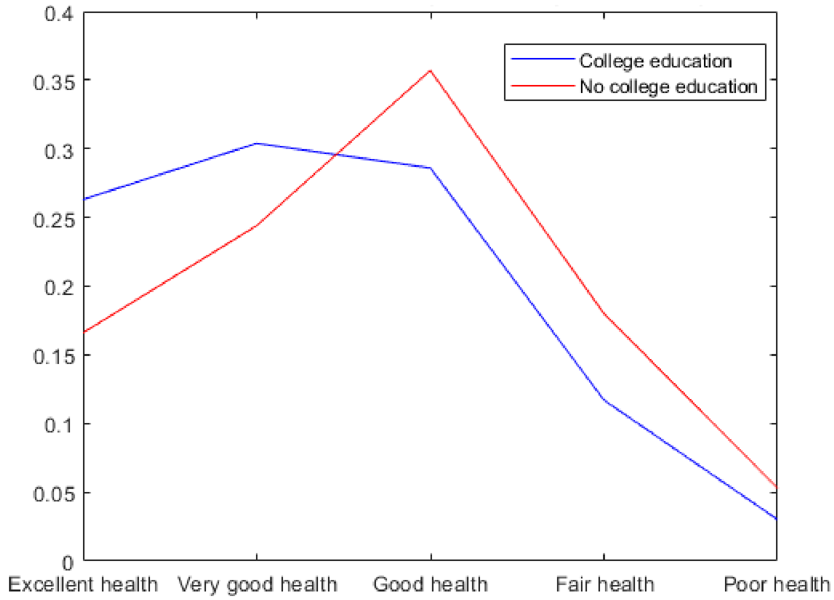

Figure 1: Health state distributions of 45-74 year olds in SHARE data by education type

In the SHARE data set, roughy one third of surveyed individuals have college education and two thirds do not in the 45-74 age group. I use the same proportion in the model and assume that each newly born agent has the respective probabilities to belong to one of the two types.

The choice of education level as the pension age differentiating factor is, perhaps, not ideal. Even though it serves as an adequate predictor of health status, it is a little unlikely that the government would actually choose this attribute to enable some groups in the society to retire earlier than others. With a richer microdata set, it would be preferable to define risky and non-risky groups based on occupation or employment industry, however, SHARE data does not contain variables with such information. The education type split here should thus be interpreted as a proxy for other characteristics, mostly occupational, which could serve as a realistic basis for retirement age increase differentiation. For example, education level is assumed to correlate strongly with whether one is a blue-collar or a white-collar worker. Having different retirement rules for blue-collar and white-collar workers is not only realistic but is already a feature of the occupational pension schemes in Sweden (Palmer et al., 2000), implying that further differentiation along this dimension would not be unimaginable.

I calibrate the health shock probabilities for the two education types and for the different age groups so as to match the share of individuals in "fair" and "poor" health (the two worst health states) among survey respondents aged between 45 and 74. The calibrated health shock parameters are presented in Table 1 and the accuracy of the calibrated model

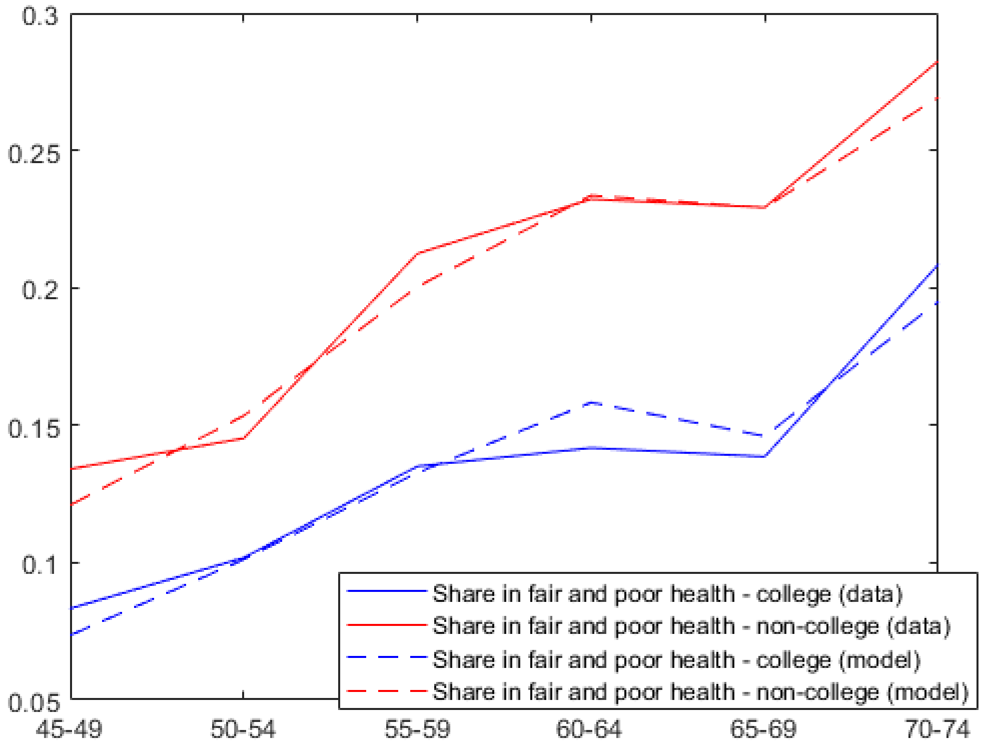

Figure 2: Shares in "fair" and "poor" health by age group: calibration results

outcomes is compared to the data in Figure 2. The self-reported health data in the SHARE dataset has several inconsistencies which make it difficult to match. Perhaps the most unexpected irregularity is that the share of people in "fair" and "poor" health states is lower among 65-69 year olds than it is among 60-64 year olds. A health process which assumes persistent health shocks will not perfectly replicate this. Also, trying to match this data as closely as possible requires imposing that at some age intervals individuals face a zero health shock probability, which is highly unrealistic. There are several reasons why self-reported health data might have such unexpected patterns: it might be that people evaluate their health not in absolute terms but relative to others in their age group or that some individuals start feeling more healthy once they retire and suffer much less discomfort from their health problems than they used to when working. Nevertheless, this being the best source of health data available to me, I choose to match its patterns as closely as possible.

5.2 Pension system

The pension system in the model is calibrated to match the features of the current pension system in Sweden (even for the periods preceding its adoption). Agents in the model accu-

Parameter	Value (college)	Value (non-college)	Explanation
ϵ	1	1	health change following a health shock
$p^{\epsilon}_{under45}$	0.04	0.055	probability of a health shock for those under 45
p^{ϵ}_{45-49}	0.04	0.025	probability of a health shock when aged 45-49
p^{ϵ}_{50-54}	0.03	0.025	probability of a health shock when aged 50-54
p^{ϵ}_{55-59}	0.015	0.04	probability of a health shock when aged 55-59
p^{ϵ}_{60-64}	0.0	0.0	probability of a health shock when aged 60-64
p^{ϵ}_{65-69}	0.0	0.025	probability of a health shock when aged 65-69
p^{ϵ}_{70plus}	0.10	0.08	probability of a health shock when aged 70+

Table 1: Health calibration parameters

mulate pension capital equal to 18.5% of the period's income not exceeding 7.5 Base Income Amounts (the 2019 Base Income Amount size of roughly SEK 66 800 is used throughout) every period. They can start claiming the benefits starting from the age of 61 (model age 39), as was the case in Sweden until the retirement age increase in 2020. Their pension capital is then divided by the expected number of remaining lifetime periods and paid out in equal parts until the end of their lives. In the model, I abstract away from the distinction between the income pension and the premium pension, assuming that all the pension capital goes into the distribution system. The pension benefits are thus computed according to the formula below:

$$Y^{pension\_benefit}_{a,i} = \frac{\sum_{a=1}^{a_{ret}-1} 0.185 * \min(Y_{a,i}, 7.5BIA)}{82 - a_{ret} + 1}, \tag{8}$$

where a_{ret} denotes the age at which the individual starts claiming retirement benefits. I assume that if an individual retires being older than the minimum retirement age, a_{ret} coincides with the age of departure from the labour force (i.e., the individual starts claiming old-age pension benefits immediately after they stop working). If an individual retires before being eligible for either disability benefits or old-age pension benefits, they live without any income until they reach the minimum retirement age, at which point they start claiming the old-age pension immediately ($a_{ret} = 61$). Finally, if an individual is claiming disability insurance, they continue to do so until the age $a_{ret} = 65$, at which point they are automatically transferred from disability to retirement with old-age pension benefits.

Some of these assumptions could be seen as contestable. Agents could, in principle, start claiming pension benefits while they are still working. Such a practice, however, is not very prevalent and would mainly concern heavy discounters, which are absent in the model by construction. It is demonstrated by Coile et al. (2002) that under some assumptions individuals could also be better off delaying pension claiming (i.e., not starting to draw their pension immediately after leaving employment) but in this model setting there are no incentives to behave so, which makes me abstract away from this option.

Occupational pensions are an important part of the Swedish pension system, with approximately 90% of Swedes covered by occupational pension schemes (Laun and Wallenius, 2015). However, the complexity and variety of these schemes make it practically impossible to model them with accuracy. For the sake of simplicity, occupational pensions are not included in the model. Note that restricting the focus to public pensions only is a common choice in retirement literature. For instance, Rust and Phelan (1997) entirely exclude individuals with non-public pension plans from their analysis. It is a common finding that the Social Security pensions (i.e., public pensions) affect people's retirement behaviour more than any other pension types (Diamond and Hausman, 1984). Omitting non-public pensions can be problematic when the incentives they create are strongly at odds with those created by public pension rules, notably if non-public pension plans encourage early retirement, as analysed in Stock and Wise (1990). However, that is not the case in the Swedish setup where the normal age for occupational pension claiming (65) exceeds the minimum retirement age.

5.3 Disability insurance system

The disability insurance is also modeled so as to mimic the current Swedish disability benefit system. In accordance with the rules for disability benefit claiming in Sweden, the benefit size is equal to 64.7% of the average annual income during the last 3 years before becoming disabled and is capped at SEK 230 976 (Försäkringskassan, 2021b). The size of the disability benefits is computed according to the formula below:

$$Y_{a,i}^{disability\_benefit} = \min\left(0.647 * \frac{Y_{a_{dis}-3,i} + Y_{a_{dis}-2,i} + Y_{a_{dis}-1,i}}{3}, 230976\right), \tag{9}$$

where a_{dis} denotes the age at which the individual starts claiming disability benefits. Benefit claimers are transferred from disability to retirement at the age of 65 (model age 43) and are not allowed to be employed while on disability insurance.

The big dilemma when modelling disability insurance is how to capture all the complex decisions that result in an individual receiving access to disability benefits. An ideal model would need to accurately capture (1) the factors that make a person apply for disability benefits and (2) the factors based on which the public authorities decide whether an individual's application is successful. In this paper, every individual can start claiming disability benefits with a certain probability which is a function of one's health and demographic variables. This probability can be seen as an implicit combination of the individuals' likelihood to apply and the likelihood that the public authorities will approve the application. Individuals thus "apply" for disability insurance in every period (in most cases, with zero success probability) until the application is successful or until they retire and disability insurance is no longer relevant. If an individual is granted the access to disability insurance, they calculate if claiming disability benefits is utility enhancing compared to continuing employment and move from employment to disability if that is the case.

To see which variables should go into determining with what probability an individual has access to disability insurance, I estimate a linear probability model using the SHARE data. The binary indicator of whether a person is on disability insurance is regressed on age, dummy variables for the different health states and education type (a very similar procedure for estimating the probability of being eligible for DI, only with different indpendent variables, is used in Haan and Prowse, 2014).[9] The details of the estimation can be found in Appendix B. The only variables which appear to meaningfully increase the probability of being on disability insurance are the dummies capturing "fair" and "poor" health states. This is consistent with the findings in previous research (e.g., Haan and Prowse, 2014; Halpern and Hausman, 1986) where the effects of health conditions or health scores are found to be by far the most important variables in predicting disability insurance claiming. Even though the microdata does not present evidence for that, I also include the age variable into the probability function. Given that the share of people in the data who are in bad health does not increase dramatically with age, it would not be possible to match the aggregate increase in disability claiming close to retirement without allowing for the probability of gaining access to disability insurance to grow the older one is. Surprisingly, I do not find that the education level impacts the likelihood of being on disability. Even though some previous literature emphasises the difference in disability claiming patterns between more and less qualified employees (Autor and Duggan, 2003), the education variable has a negligible and nonsignificant coefficient in the estimated linear probability model, once health is controlled for. Thus, it is not assumed to impact the probability of gaining access to disability insurance on it own.

Even though the decision about which variables should affect the the likelihood of gaining access to disability benefits is based on the patterns observed in microdata, the shape of the probability functions is constructed so as to match the aggregate incidence of disability claiming among different age groups in 2019. The disability insurance claiming data is retrieved from the Swedish Social Insurance Agency Statistics Database (Försäkringskassan, 2021a).

[9]Note that this regression analysis does not have a purpose to provide causal estimates. I am only interested in finding which variables that are accounted for in this paper's labour supply model correlate with being on disability.

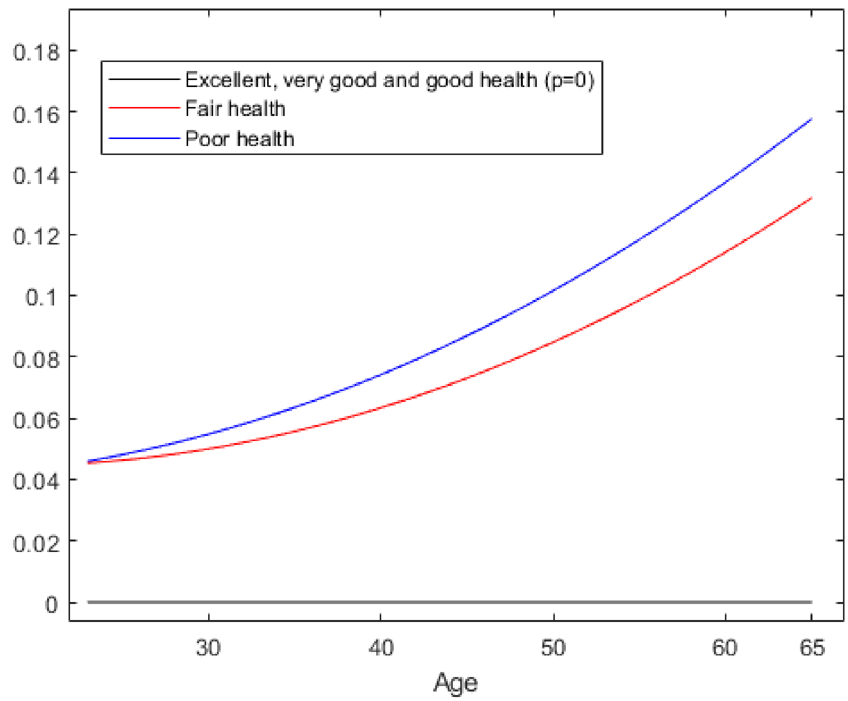

Figure 3: Probability of gaining access to disability insurance by health state

Figure 3 graphically represents the probability an individual has to gain access to disability insurance in the model, based on age and health.

The idea to model disability insurance applications as an "imperfect screening" process with some non-100% probability that the application will be successful even in bad health is mimicking the modeling choices in Haan and Prowse (2014), Laun and Wallenius (2016) and Li (2018). I model this procedure almost identically to them, with a minor difference that I do not allow for "mistakenly" granting access to disability benefits for individuals who are not in bad health.

Figure 4 presents the disability incidence rates among the different age groups in 2019 as simulated by the model and allows the reader to compare them against the aggregate Social Insurance Agency data.[10] The model slightly overshoots the disability incidence numbers for those younger than 60 but fits the data relatively well overall.

Leaving the labour force and transitioning to benefit claiming is absorbing: if an individual has started claiming disability or pension benefits, they are no longer able to go back to employment.

[10]The model used in this paper is not able to explain why some individuals never work throughout their lifetimes. The share of the disability insurance claimers is scaled to account for that.

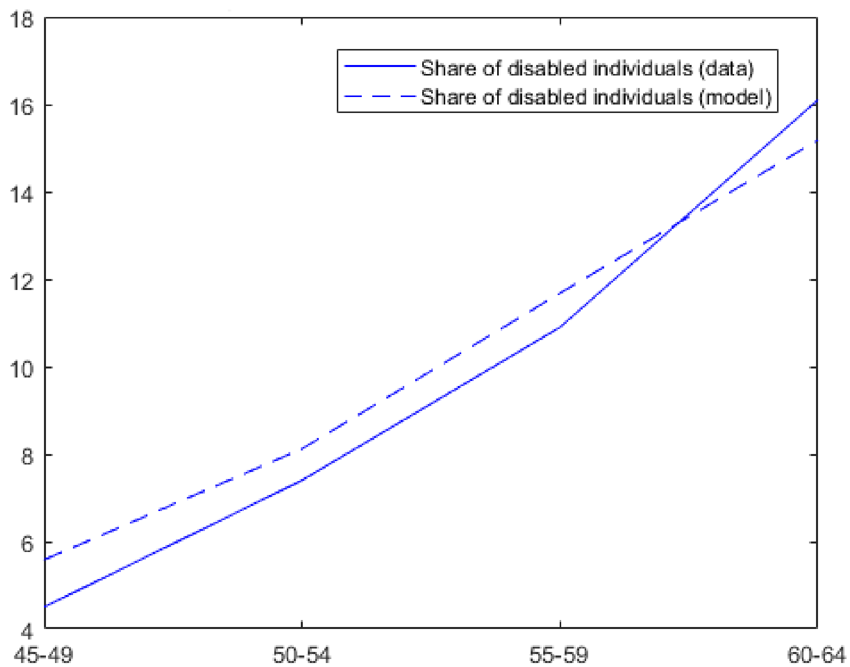

Figure 4: Disability insurance claiming incidence in 2019 by age group (in %): data vs. model

5.4 Demographic, income, tax and preference variables

Statistics Sweden (SCB) data is used to calibrate the demographic variables such as real sizes of each generation in the model. As a starting point, the vector of generation sizes is taken from the Swedish population pyramid in 1970 and the recorded (or forecasted) number of births is added to the vector in every new period (with a delay of 23 years).

Labour incomes for both the college and the non-college types are computed using the SCB monthly salary statistics by level of education in 2019 (SCB, 2021a). The statistics contain average monthly salaries for each one of the ISCED-97 education levels as well as the number of salary earners within each education level. I use these statistics to compute the weighted average of yearly salaries in the non-college and college type groups. They are SEK 330 000 and SEK 422 000 (or 4.94 and 6.31 Base Income Amounts for 2019), respectively.

Consistently with the tradition in Economics literature analysing earnings profiles (e.g., Hall and Mishkin, 1982), I make an assumption that agents' salary schedules are hump-shaped: they start at a lower than average salary level when they enter the economy and reach the earnings peak in their fifties; then the labour income starts slowly decreasing. I construct the hump-shaped labour income schedules for employed individuals so as to match

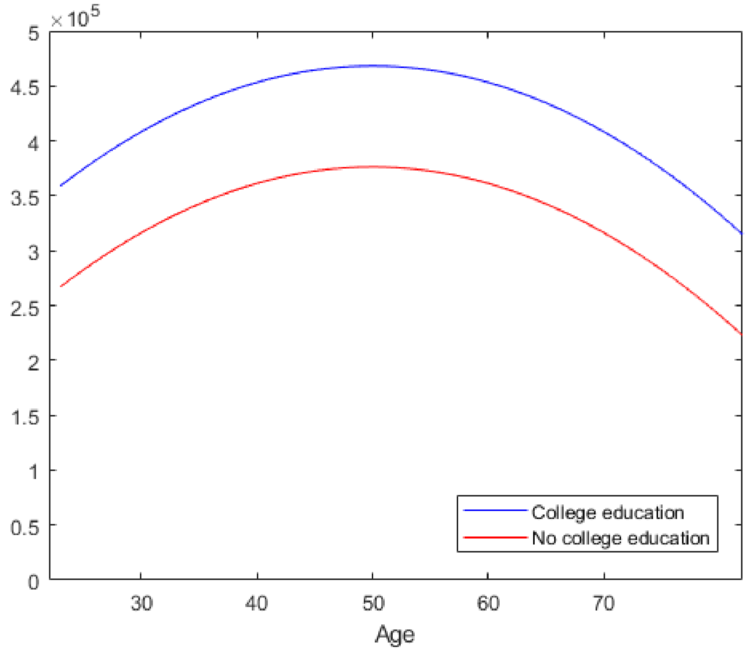

Figure 5: Life-cycle earnings schedules by education type

the income averages mentioned above throughout an agent's working life and to mimic the curvature of the "hump" used in Laun and Wallenius (2015). The resulting salary schedules are presented in Figure 5.

Every generation in the model faces the same salary schedules, and no increases in salary averages happen throughout an individual's lifetime. This is inconsistent with the general tendency for salaries to rise across years as a result of economic growth. However, such a simplification is acceptable when it comes to analysing a pension system with a Balance Index rule in place, ensuring that pension entitlements change to reflect the changes in average income (Swedish Ministry of Health and Social Affairs, 2016). The reasoning in this quantitative exercise can be interpreted as based on Base Income Amounts and not currency units.

The income tax (τ_{inc}) is set to 31% (the elevated progressive rate does not apply to any of the individuals in the model given the decisions about the salary structure) and the consumption tax (τ_c) is set to 25%, the size of the Value Added Tax for most goods and services in Sweden. The social security tax, which does not appear in the household budget constraint as it is paid by the employer, is set to 31.42% and is levied from the gross income of employed individuals.

Just like in Laun and Wallenius (2015), the interest rate is set to $r = 3\%$, and the discounting parameter β is conventionally set to $1/(1 + r) = 0.97$, to have the discount rate and the interest rate offset each other in consumption smoothing. The utility function is set to be logarithmic, following the convention in similar papers (French, 2005; Laun et al., 2019; Laun and Wallenius, 2015).

5.5 Calibrating disutility from working

Parameters determining disutility from working are calibrated to match the share of people who are employed at the age 50-74. The real employment rates for matching are obtained from SCB Labour statistics based on administrative sources (SCB, 2021c).

Parameter	Value	Explanation
d_1	0.45	disutility from working in excellent health
d_2	0.90	disutility from working in very good health
d_3	1.35	disutility from working in good health
d_4	1.80	disutility from working in fair health
d_5	2.25	disutility from working in poor health
d_{65-69}	2	The factor by which the disutility from working is multiplied for the agents in age group 65-69

Table 2: Disutility from work parameters

The model used in this paper is not able to explain why some individuals (approximately 8% of the population) never work throughout their lifetimes. Because their situation is impossible to model in this framework, the shares of the employed and the disability insurance claimers are scaled in such a way that for the 45-49 group these two groups would make up 100% of the population (a similar approach is used Laun and Wallenius, 2015).

The numeric values of disutility parameters appear in Table 2. In the model, agents incur the disutility only if they are working full time in a given period, and are not affected by it if they are on disability, retired or voluntarily unemployed. Disutility from working is assumed to increase linearly as the health worsens, irrespective of age. The sole exception is the age gap between 65 and 69 in which the disutility from working needs to be doubled for all health states, so as to match the big drop in employment occurring at that age. Whereas here this is achieved through an age dependent parameter, in real life this "doubling" of working disutility for those 65 to 69 years old should be interpreted as a result of multiple factors not accounted for in this model. Perhaps the most important among such factors is the consideration that during the 65-69 age interval individuals can start claiming full occupational pension benefits (starting from 65) and lose their legal right to retain employment (at the age of 68).

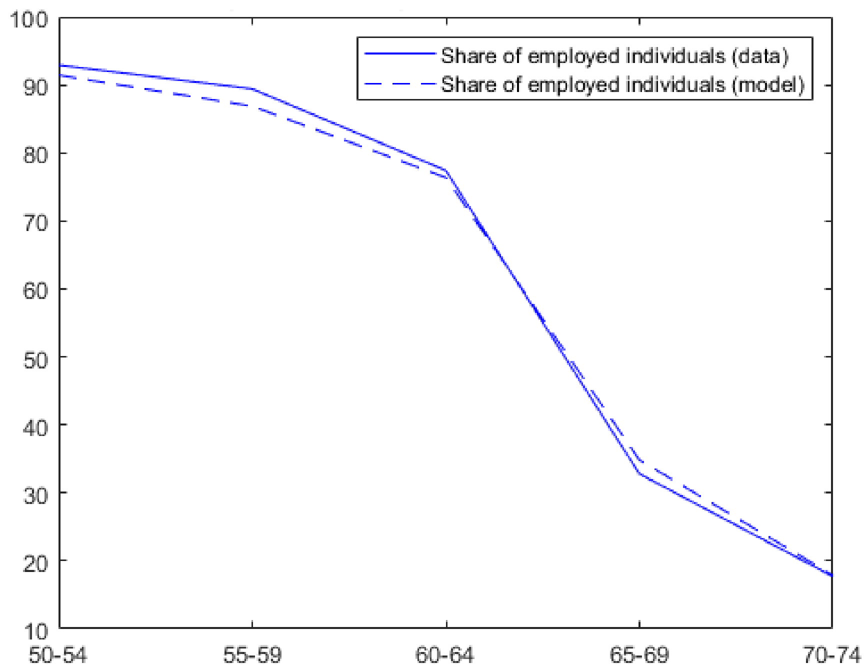

Figure 6: Employment rates in 2019 by age group (in %): data vs. model

Figure 6 presents the employment rates for 2019 simulated by the model and compares them against the SCB Labour Statistics data (SCB, 2021c). The model matches real employment rates quite accurately for every age group.

6 Results

This section presents the results of two separately run simulation rounds. In the first round, the two variants of a retirement age reform are examined in the context of a 4 year minimum retirement age increase; in the second round the increase is 6 years.

6.1 Increasing the retirement age from 61 to 65

I first simulate a universal and a selective retirement age reform (affecting the college group only) where minimum retirement age is increased from 61 to 65.

The first look at the results of the simulation suggests that the effects of the reforms are relatively negligible in scale compared to the effects of demographic change across years. Nevertheless, some interesting patterns emerge.

Both of the reforms produce the expected effect. They decrease the share of people retired with old-age pensions among 60-64 year olds (-2.3 percentage points for the selective reforms and -8.24 percentage points for the universal reform by 2050) and cause a slight increase in employment within this group (+1.34 percentage points for the selective reform and +4.4 percentage points for the universal reform by 2050). Figures 7 and 8 represent this graphically. The selective reform delays the average age of exit from the labour force by 0.08 years, and the universal reform delays it by 0.31 years. As expected, the effect of the universal reform is stronger. This is due to two reasons: firstly, the universal reform simply affects more agents than the selective one; secondly, the selective reform is targeted at the agents who tend to retire quite late even without the reform (only 36% of agents in the college group leave the labour force before 65 in the no-reform scenario), implying that their behaviour is not very responsive to the retirement age increase.

Note that many people in the 60-64 age group who are no longer old-age pension recipients if either of the reforms is implemented do not choose to stay in employment: they still retire early, just without an old-age pension in the first years of retirement. This is in line with the findings in French (2005), where a simulated minimum retirement age increase does not boost employment by much, as most households willing to retire early have enough savings to finance additional time in retirement.

The universal reform also results in a higher long-run jump in disability insurance claiming as demonstrated in Figure 9. However, the increases in disability claiming following the two reforms do not seem as considerable as was expected: the universal reform triggers a jump of 0.78 percentage points in the affected 60-64 age group, whereas for the selective reform the jump is almost unnoticeable at 0.22 percentage points, relative to the no-reform counterfactual. This is similar to the findings in Staubli and Zweimüller (2013), where the early retirement age increase for Austria is also found not to trigger a significant jump in disability claiming.

The triggered increase in spending on disability benefits remains very marginal for both the universal and the differentiated reform (see Figure 10). In 2050, the simulated disability insurance spending is only 0.5% higher in the selective reform case and 1.5% higher in the universal reform case, relative to the no-reform benchmark.

Simulated spending on old-age pensions drops following both reforms, as expected. 5 years after the selective reform, government spending on pensions is 0.4% lower and 5 years after the universal reform it is 1.2% lower than in the counterfactual case of no reform. An interesting observation, however, is that the effect on pension spending appears to be only temporary and fades away approximately 15 years after the reform. This is a logical result in the context of a notional defined contribution pension system. Immediately after the reform is implemented, the number of eligible old-age pension recipients decreases whereas

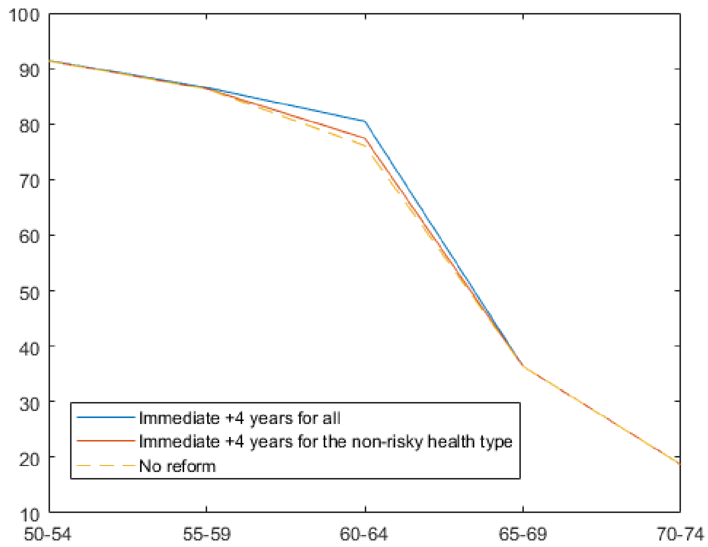

Figure 7: Simulated employment rates in 2050 by age group (in %)

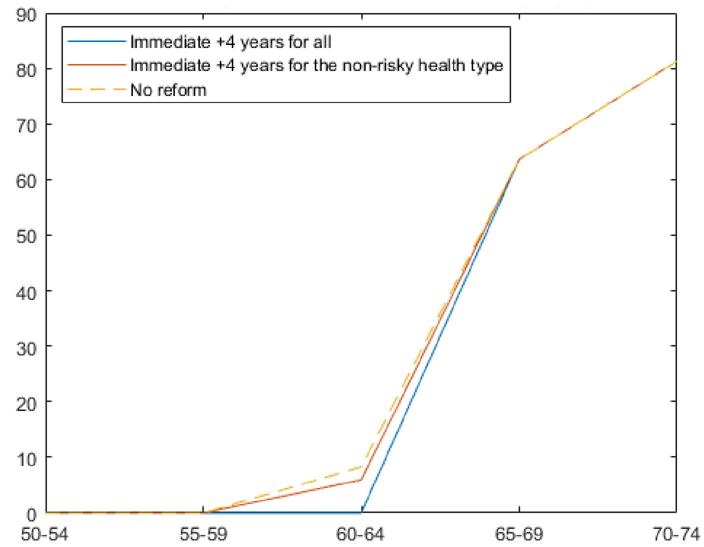

Figure 8: Simulated share of old-age pension claimers in 2050 by age group (in %)

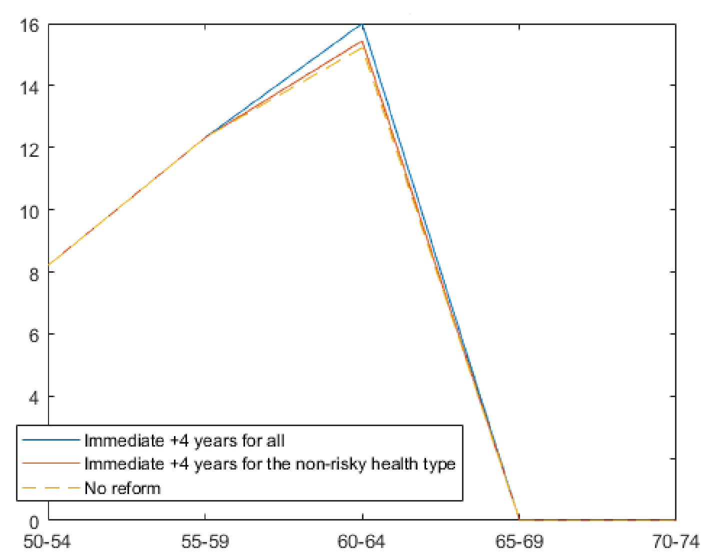

Figure 9: Simulated disability incidence rates in 2050 by age group (in %)

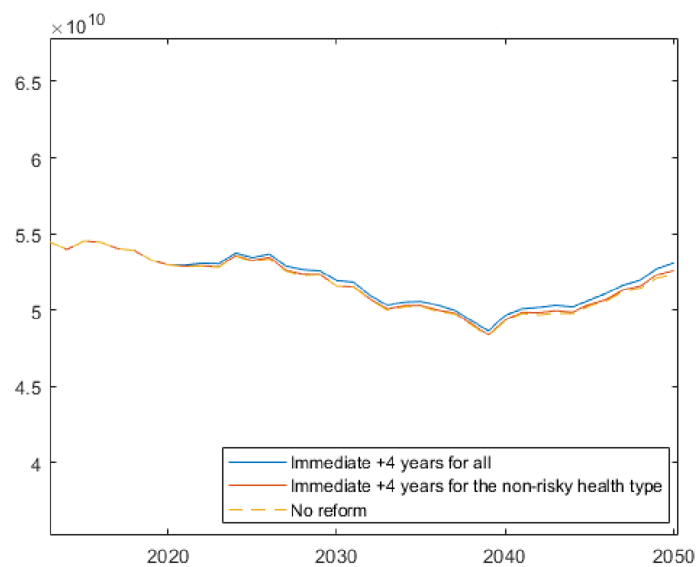

Figure 10: Simulated annual spending on disability benefits

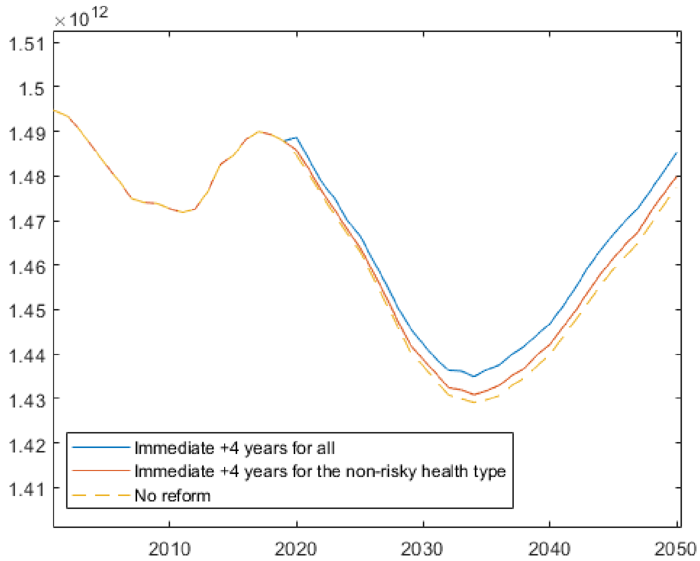

Figure 11: Simulated annual tax revenue (consumption, income and social security taxes collected)

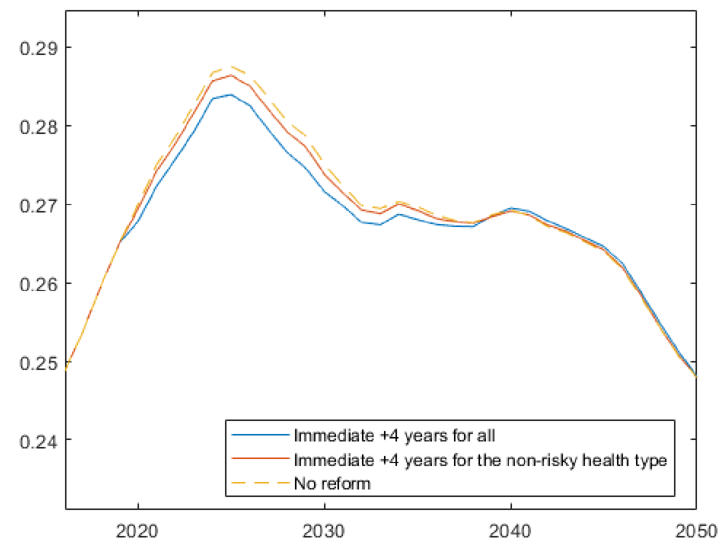

Figure 12: Share of government tax revenue spent on disability benefits and pensions (simulated)

the pensions of those retired do not change, causing the aggregate pension spending to drop. However, in the longer term the sizes of average pensions increase as a consequence of individuals working for longer, accumulating more pension capital and spending fewer years in retirement. Indeed, the average simulated pension size in 2050 is 0.8% higher in the selective reform scenario and 3.2% higher in the universal reform scenario, relative to the no-reform benchmark. Thus, the effect of the shrinkage of the body of pension recipients is offset by the fact that these recipients are entitled to higher pensions in the long run.

The government collects slightly more revenues from income, social security and consumption taxes if one of the reforms is implemented (see Figure 11). In 2050, the simulated tax revenue is 0.14 % and 0.5% higher in selective and universal reform scenarios respectively, relative to the no-reform benchmark. This effect is explained by the fact that when forced to work for longer people have higher lifetime incomes: later transition into retirement implies that people earn labour income - which is higher than old-age pensions - for longer, and the pensions themselves increase due to more pension capital being accumulated. As a result, people can also afford more consumption. The effect is again slightly stronger with the universal reform. The increase in tax revenue and decreased pension spending is sufficient to outweigh the additional expenditure related to slightly increased disability spending.

As the main measure of reform effectiveness at contributing to the sustainability of public finances, I look at the share of public revenues spent on social benefits, i.e., old-age pensions and disability benefits combined (a very similar approach is adopted in Laun and Wallenius, 2015). The evolution of this metric over time is demonstrated in Figure 12. Immediately following either of the two reforms, the share of spending on pensions and disability benefits as a percentage of tax revenue decreases. In policy terms, this means that both of the two reforms positively contribute to the solvency of social insurance funds.

Unlike hypothesised, the differentiated retirement age increase reform is associated with worse results for the social insurance budget than the universal reform. For both reforms, the main factor triggering the decrease in share of spending on social benefits in the government budget is the decrease in old-age pension payments. Because the scale of the universal reform is bigger (it affects the pension claiming of both college and non-college individuals), its effects on total social spending are also stronger.

Another clear take-away from this quantitative exercise is that a retirement age reform will only succeed at improving the financial soundness of the public social insurance system in the short term. As seen in Figure 12, the effect of both reforms starts fading away around 2035 when average pensions increase by enough to compensate for the fact that there are fewer pension receivers in the economy. While the modeled reforms are rather abstract and do not capture all the complexity that a real life pension reform would entail, the simulations do seem to signal that with Sweden's new choice of a notional defined contribution pension system, the fiscal effects of retirement age increase reforms are likely to fade with time.

An important phenomenon revealed by the simulations is that under the existing rules for pension and disability claiming in Sweden, the increase of the retirement age from 61 to 65 does not increase disability benefit claiming by much. Some support for this finding can also be found in the Swedish Social Insurance Agency data, which indicates that no change at all occurred in the trend of disability insurance claiming around January 2020 when the retirement age was actually increased (albeit by one year only) in Sweden (Försäkringskassan, 2021a). This suggests that the barely visible increase in the DI claiming in the model is not a result of unrealistic assumptions only.

Such an outcome makes the selective retirement reform practically unappealing: it has the inherent drawback of reducing old-age pension claiming by less and its potential upside of not triggering a big increase in disability spending (relative to the universal reform) is not relevant here because the disability benefit claiming does not go up considerably in the case of the universal reform either.

To understand why the incidence of disability benefit claiming in the model does not change by much following the reforms, consider the two scenarios illustrated in Figure 13.

In Scenario 1, an individual becomes eligible for disability benefit claiming at the age of 61, 62, 63 or 64 (i.e. their disability insurance application is successful) and would not

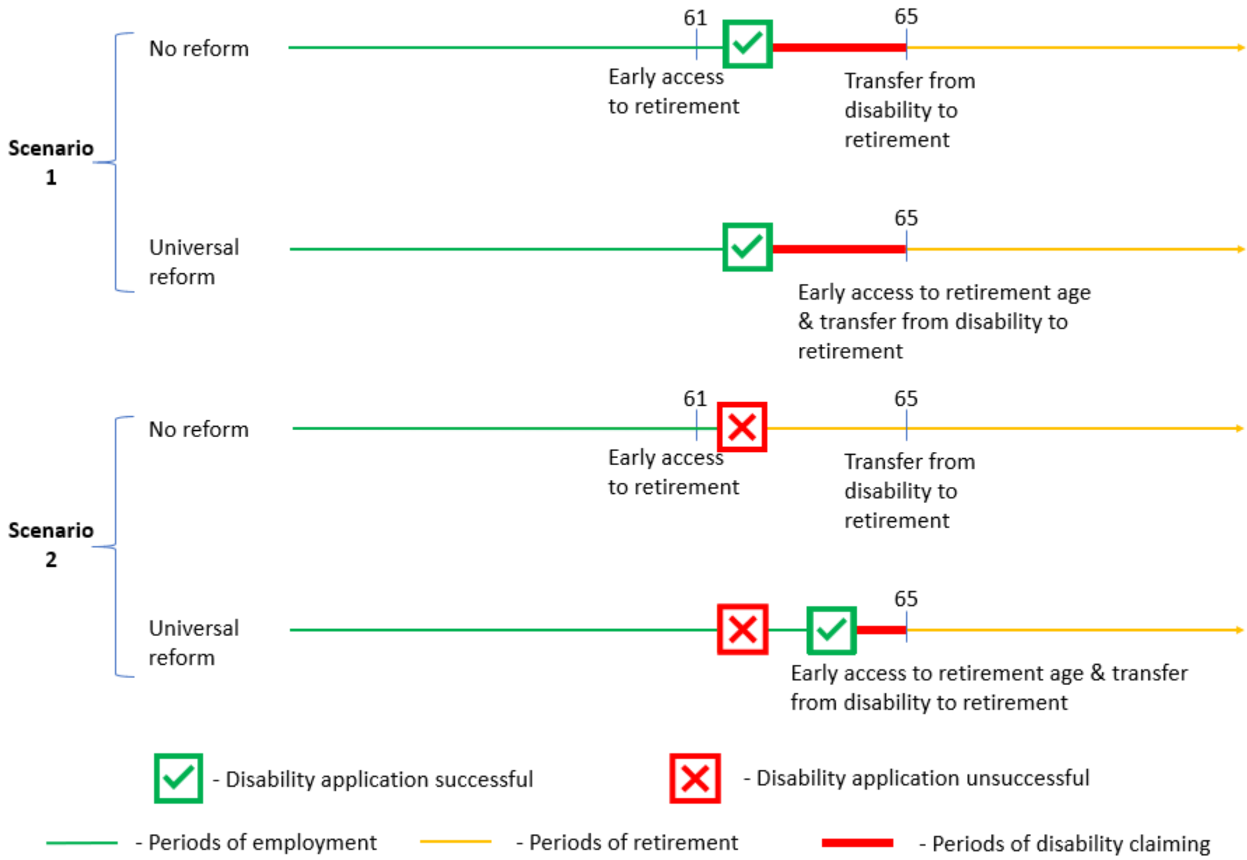

Figure 13: Exploring disability claiming patterns

find it utility enhancing to retire earlier than that. If the universal reform is implemented, such a person will claim disability benefits from that moment until the age of 65 when they will be transferred to retirement. However, even if no retirement reform is implemented, the outcome for such an individual is the same. If they work until, say, 62 and become eligible for disability at that age, they can still claim disability benefits until 65 according to the current legislation, despite the fact that they could already retire with an old-age pension at that age. Therefore, the reform does not increase the disability claiming among individuals who become eligible for retirement between 61 and 65 (or before) and who would not prefer to retire before their disability application is successful.

The group of agents within which the disability claiming increases after the reform are the ones considered in Scenario 2. Here, an individual's disability insurance application is unsuccessful at the age of, say, 62. Assume that in the no-reform scenario, such an individual would decide to retire after not being granted access to disability benefits, because the disutility from working in their health state would outweigh the utility derived from additional income. After the reform, such an agent will not be able to retire with an old-age pension following an unsuccessful application (even though they would prefer to). They will then continue working and applying until the age of 65 and if in one of the periods their application is successful, the person will start claiming disability benefits (which would not have happened without the reform, as the individual would already be in retirement).

The only change in disability claiming following the reforms in the simulation will thus be caused by individuals in Scenario 2. However, such individuals appear to be less numerous in the model than those to whom Scenario 1 applies. As a consequence, the disability claiming with or without the reforms will differ only marginally.

This mechanism is a result of the overlap between the age interval when an individual can be in retirement (61 to 82) and the age interval when they are able to claim disability benefits (23 to 65), which exists in the pre-reform state of the world. Due to this overlap, by increasing the minimum retirement age to 65 the disability insurance is not extended to any groups that did not use to have access to it before. I hypothesise that if the retirement age was pushed beyond the right boundary of this overlap (i.e., beyond 65), the disability claiming patterns would be impacted much more significantly.[11]

6.2 Increasing the retirement age from 61 to 67

To test the mechanism outlined in the paragraphs above, I perform the same simulations as the ones discussed previously, but this time with the minimum retirement age being increased from 61 to 67 (and not 65) either universally or for the college group only. This automatically extends the age until which disability insurance can be claimed from 65 to 67 for the affected group(s).

Some of the results remain comparable to those generated in the first simulation. Both reforms slightly increase the employment rates observed in 2050 (+1.36 percentage points in the 60-64 group for the selective reform and +4.52 percentage points for the universal reform) as well as annual tax revenues (+0.3% for the selective reform and +0.7% for the universal reform by 2050). The average age at which household agents leave the labour force also increases slightly when the reform is phased in (by 0.15 years with the selective reform and by 0.58 years with the universal reform). Even though the 6-year reform delays the minimum retirement age by 50% more than the 4-year reform, its effects on employment or tax collection are not proportionally higher. The reason for this is that a large share of

[11]Note that the above reasoning slightly contradicts the conclusions in Laun et al. (2019), where a similar retirement reform is simulated for Norway and the retirement age is also not increased beyond the age until which it is possible to claim disability benefits. Regardless of that, the authors still find a retirement age increase to trigger a sizeable jump in disability insurance claiming. Most likely, this contradiction comes from the institutional differences in the Swedish and Norwegian social security systems.

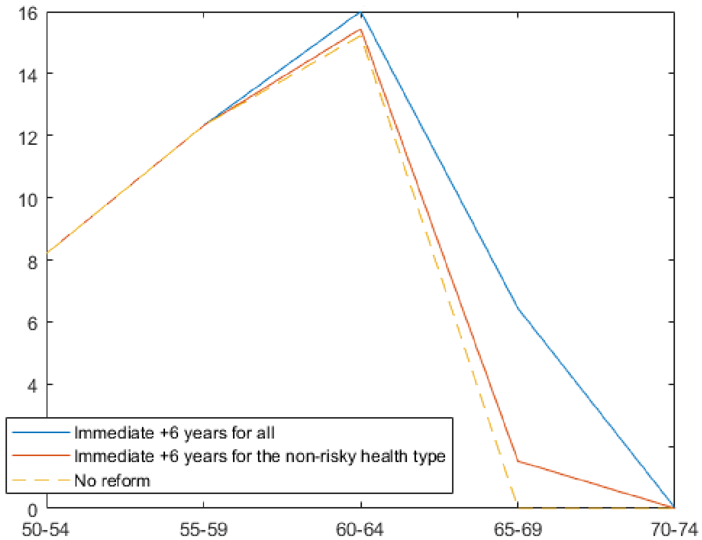

Figure 14: Simulated disability incidence rates in 2050 by age group (in %)

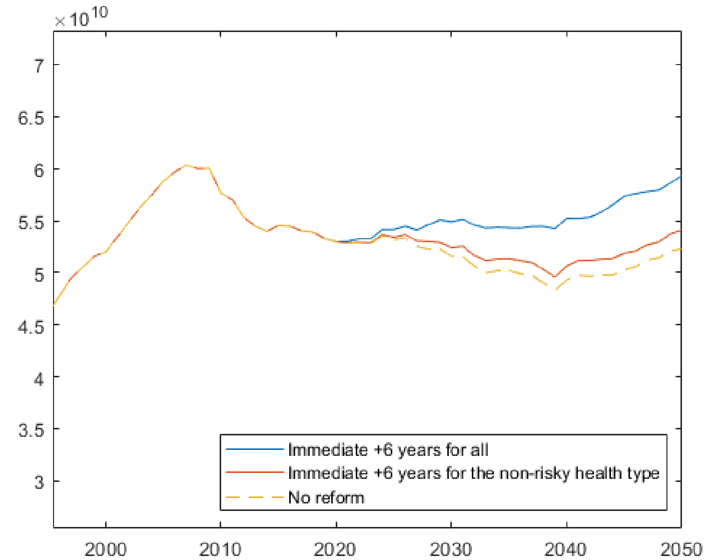

Figure 15: Simulated annual spending on disability benefits

individuals simply retire before becoming eligible for old-age pensions following this drastic increase in retirement age.

Some results, however, differ significantly from those obtained in the simulation of a four year retirement age increase reform. Pushing the minimum retirement age beyond the age until which agents are originally allowed to claim disability benefits increases the disability claiming rates (Figure 14) with both reforms, but especially if the universal reform is implemented. This outcome is consistent with Bound et al. (2010), who identify that an increase in disability claiming mainly results from increased availability of disability insurance. In the US setting, this happens if the Normal Retirement Age is increased and those who previously were able to claim full pensions are no longer able to do so, which allows them to move to disability insurance instead (a situation explored in, e.g., Li, 2018). Here the mechanism is similar: disability insurance becomes a newly available retirement option for those aged 65-66, as they are no longer able to start claiming retirement benefits at that age.

Model conclusions also differ slightly when it comes to comparing the share of government spending going to financing social benefits. In the short run, both reforms reduce the share of government revenue spent on social benefits by more, if the retirement age is delayed by 6 years rather than 4. Five years after the reform implementation, the decrease is approximately 0.4 and 0.15 percentage points larger for the universal and the selective reforms respectively. However, with the 6-year increase the changes in disability benefit

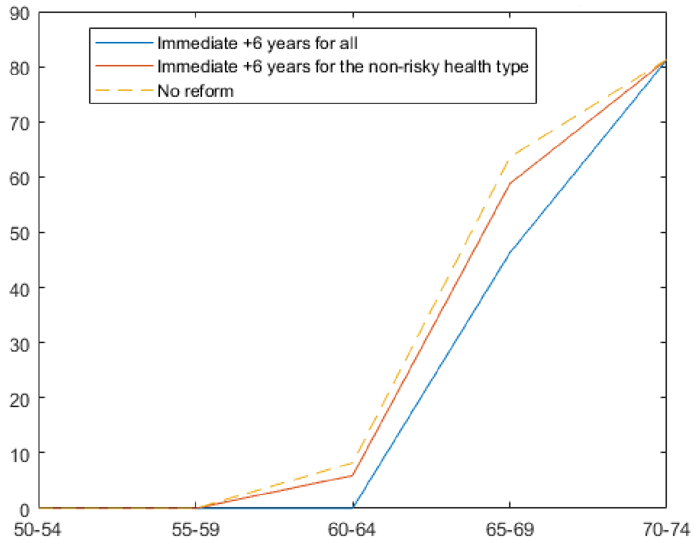

Figure 16: Simulated share of old-age pension claimers in 2050 by age group (in %)

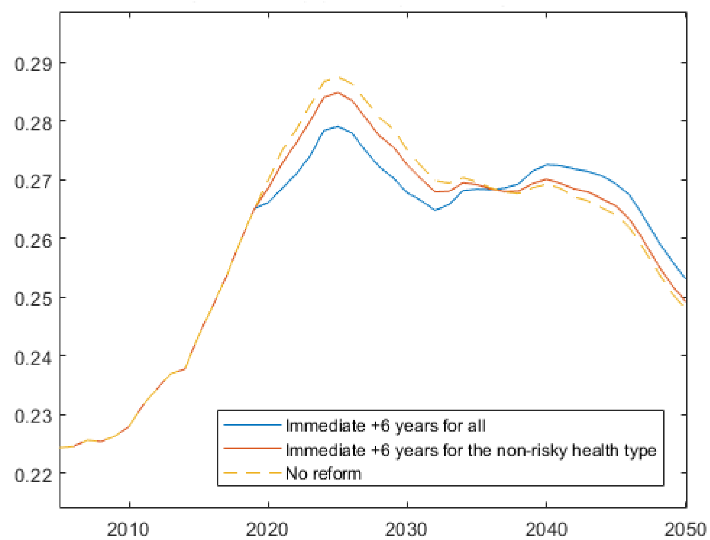

Figure 17: Share of government tax revenue spent on disability benefits and pensions (simulated)

spending are also considerable, with selective and universal reforms now triggering 3.5% and 13.5% higher disability insurance spending in 2050 respectively, compared to the no-reform scenario (Figure 15). The increase in pension sizes in the long run is also more sizeable: after raising the retirement age by 6 years, the average size of old-age pensions in 2050 is 2.5% higher if the reform is selective and almost 10% higher if the reform is universal (relative to the no-reform benchmark).

As shown in Figure 17, the universal retirement age reform still remains more efficient than the selective one at decreasing the social benefit burden in the short term (approximately the first fifteen years following the reform). This, again, is a result of a considerably shrunk body of old-age pension claimers (Figure 16). However, the longer term outcome of the universal reform is worse than that of the no-reform benchmark or the selective reform alternative. About 15 years after the reform implementation, the benefits of decreased pension spending start fading away for both the universal and the selective reform due to higher re-adjusted pension sizes (in fact, the pension spending in the reform scenarios even becomes higher than in the no-reform scenario by 2038[12]). At the same time, the burden of considerably increased disability spending persists, making both reforms less appealing than the benchmark of no reform in the long run. Though this applies to both reform types, it

[12]This is a result of unequal cohort sizes in the 61+ age group. If the model is run assuming that every generation is of equal size, the pension spending simply converges back to the no-reform levels but does not exceed them.

is clear that the long run outcome of the across-the-board reform is inferior to that of the reform targeting the non-risky individuals only (i.e., the college group). By 2050, the spending on disability and pension benefits as a share of government revenue is approximately 0.3 percentage points higher after the universal reform, relative to the selective reform. This result is in part a consequence of the fact that now the differentiated reform creates much less persistent excess disability spending than the universal one, as hypothesised from the beginning.

6.3 Sensitivity analysis

In this section I explore how robust the findings are to changes in certain model and calibration features. While many of the parameter values (e.g., disutility from work parameters) or model assumptions cannot be altered without failing to match the calibration targets or to preserve consistency with previous literature, some more contestable ones are examined here.

One of the modeling choices that might considerably affect the model conclusions is related to how the access to disability insurance is gained. In the main part of the paper DI applications are modeled as random draws with some success probability depending on health and age. As an alternative, I also try out a simpler approach used in Laun and Wallenius (2015), whereby anyone in the two worst health states ("fair" and "poor") is automatically granted access to disability insurance. In order to still match the aggregate disability claiming patterns, this approach requires recalibrating the health shock probabilities which results in the incidence of "fair" and "poor" health predicted by the model no longer matching the incidence observed in microdata. However, I still replicate the ratio of college and non-college individuals in the two worst health states for each age group.

The simulation results obtained using this approach are almost identical. The conclusions regarding the efficiency of the two reform types at reducing the share of tax revenue spent on social benefits still hold and the shapes of curves in Figures 12 and 17 remain very similar.

As the next sensitivity check, I modify the assumption regarding the reform implementation timing. In the main part of the paper, it is assumed that the full pensionable age increase takes effect immediately (i.e., everybody not yet retired faces the new retirement age already in the first year of the reform). As an alternative, I run the simulations where the increases in retirement age are spread out over 4 (or 6) years and implemented in one year increments. In other words, the minimum retirement age becomes 62 in 2020, 63 in 2021, etc.

This setup changes the transition dynamics slightly, making the outcomes of the three scenarios (no-reform, selective reform and universal reform) diverge less quickly. In Figures 12 and 17, the three curves remain closer to each other for the first 3 to 5 periods than in the mainline simulations. A few periods later the curve shapes become almost identical to the ones presented above and the conclusions of the previous subsections still hold.

Lastly, I modify the assumption made about the shares of risky and non-risky (i.e., college and non-college) individuals in the model. Imposing that one third of the individuals in the model should have college education appears justifiable as that corresponds to the percentage of such individuals in the SHARE dataset. However, most of the respondents in SHARE survey belong to the 50+ age group, in which tertiary education is less prevalent than it is among younger generations. I rerun the simulations assuming a higher share of college types in the model to account for the changes in educational attainment patterns in Sweden. According to Statistcs Sweden, roughly 42% of Sweden's inhabitants aged between 25 and 74 had some tertiary education in 2018 - I use this number as an alternative parameter to check the sensitivity of the results (SCB, 2021b).

This change affects the simulation results more considerably. With a higher percentage of college educated individuals, the overall productivity in the economy increases, which, for instance, drives up the tax revenue collected (with or without the reforms). Perhaps the most important change regarding the model conclusions is that the effects of the selective reform become slightly more sizeable. The 6-year pensionable age increase for the college group only now delays the average retirement age in the economy by 0.18 years (compared to 0.15 years in the main results); the employment rate in the 60-64 age group is increased by 1.5 percentage points (compared to 1.36 percentage points in the main results). The increase in disability spending triggered by the selective reform is also slightly larger: +3.7% relative to the no-reform benchmark in 2050 (compared to +3.5% in the main results). When it comes to analysing the spending on pensions and disability as percentage of government revenue, the effects of the selective reform are slightly more similar to those of the universal reform. During the first 15 years after implementation, the selective reform reduces the share of tax revenue going to financing social benefits by more than in the mainline simulations where a lower rate of individuals with tertiary education was assumed. However, in the longer run, the spending associated with the selective reform is slightly higher too (due to higher disability spending and more strongly increased average pension sizes). The curve shapes in Figures 12 and 17 remain very similar, with the only change being that the curve representing the selective reform outcomes shifts slightly closer to the universal reform's outcome curve.

7 Conclusion and limitations

The aim of this paper was to explore whether increasing the retirement age only for the employee groups facing lower health risks could be a remedy to the flaw of retirement age increase reforms often discussed in the retirement literature: namely that the fiscal gains of such reforms tend to be lessened considerably through the channel of increased disability insurance spending (Laun et al., 2019; Li, 2018). A few interesting conclusions emerge from simulating otherwise identical universal and selective retirement age increase reforms in a model calibrated to the Swedish institutional setting:

- In the Swedish institutional setting, increasing the minimum retirement age does not trigger a considerable jump in disability insurance spending as long as the minimal retirement age remains below (or coincides with) the age until which people are allowed to claim disability benefits, regardless of whether the increase is targeted or universal. A differentiated retirement reform, aimed at the less risky group only, has virtually no advantages in such a case, and contributes to the sustainability of public finances less than a comparable universal reform.

- Increasing the retirement age beyond the original age until which disability benefits can be claimed (and thus extending the availability of disability insurance until the new minimum retirement age) does provoke a sizeable jump in disability benefit claiming. If the retirement age increase is oriented at the non-risky group only, the jump in disability benefit claiming is much smaller. However, in the short run, the universal retirement age increase still remains more appealing because it decreases the spending on old-age pensions by considerably more than the spending on disability benefits is caused to increase.

- In the longer run (15+ years), the spending on old-age pensions starts converging back to no-reform levels and even exceeding them - regardless of which reform type was implemented - as a result of increased pension sizes for employees who now work for longer and claim their retirement benefits later. The disability spending, however, remains more elevated persistently. As a result of these two mechanisms, the selective retirement age increase becomes more appealing in the longer run, as it produces lower spending on social benefits as a percentage of government revenue than the universal retirement age increase, if no further reforms are implemented.

In light of these findings, the argument that can be made in favour of increasing the retirement age selectively is at best a weak one, at least in the Swedish context. Such an approach only seems attractive for a relatively extreme pensionable age increase and only in the longer run. The minor long run superiority of the selective reform is due to the nature of the notional defined contribution pension system, whereby delaying pension claiming automatically results in increased pension sizes, thus not allowing the government to realize long run economies in pension payments. With a more discretionary pension size setting system, this advantage of the selective retirement age increase might not be relevant at all. Nevertheless, this quantitative exercise illustrates that under certain specific conditions a selective retirement increase can be a fiscally attractive policy and should deserve further attention.

Another more general takeaway from the simulations seems to be that the Swedish government can safely keep increasing the minimum retirement age (as it is doing currently) without triggering an unwanted jump in disability insurance claiming, as long as the minimum retirement age does not exceed the threshold at which disability insurance claimers are currently transferred to retirement. Any increases beyond that, however, will most probably require an accompanying disability insurance reform, to make them fiscally beneficial.

The analysis presented in this thesis has several limitations which could be addressed in future research. The decision to define the high-risk group whom the selective retirement reform would not affect as those without college education might appear as quite arbitrary and unrealistic to the reader. While this choice appeared the most optimal given the microdata that was available to me, similar future research should try to rely on data which allows to identify narrower groups of people most likely to be in bad health while aging (e.g., members of certain occupational groups or employees within certain industries). Simulating a retirement reform where such groups are excluded would be both more realistic (retirement age differentiation in most countries is implemented on occupation basis) and would potentially allow for the reform selectiveness to be based on a better predictor of bad health than education is (e.g., health differences between aging miners and lawyers might be much more considerable than between college and non-college educated people on average), which might shift the results more in favour of the selective reform. A big drawback of the selective reform in my simulations is that it simply leaves the retirement age unaltered for a very large share of the population, thus resulting in lower savings on retirement benefits in the short run. Ideally, a selective reform could identify only a few per cent of the employees that should be left unaffected (those with the very highest health risks) while everyone else would face an increased retirement age. With such accurate targeting, the selective reform could perhaps closely compete with the universal one even in the short run.

Another advantage of having data linking agents' earnings and health profiles with occupations is that it would also enable one to include occupational pensions into the model framework somewhat accurately.

A valuable exercise for the future would be to repeat this quantitative exercise using the dynamic programming framework to solve the agent optimization, thus allowing the agents to form rational expectations about future health shocks. The main outcome of such a modification would be a slight change in household savings behaviour, whereby households would accumulate precautionary savings. With more assets accumulated throughout their lifetimes, such households might prove to be less responsive to retirement age changes than predicted in this model.

One more considerable omission in my analysis is the choice not to model the general equilibrium effects of the simulated pension reforms. Whereas such a choice is defensible for a small open economy like Sweden and is common in related literature, allowing for adjustments in other markets (notably the capital market) might add more nuance to the findings. In their sensitivity checks, Laun and Wallenius (2015) demonstrate that including the general equilibrium effects does have a slight influence on predicted post-reform retirement behaviour.

Finally, exploring the welfare and fairness aspects of a selective retirement age reform would be an interesting research avenue. By restricting the focus to fiscal efficiency, this paper does not touch upon the argument advanced in several other papers (e.g., Hasselhorn, 2020; Pestieau and Racionero, 2016; Vandenberghe, 2020) that differentiated retirement ages are needed in order to mitigate the welfare inequalities emerging due to different occupational hazards that heterogeneous individuals face. Encouraging later retirement universally can be particularly welfare-diminishing to lower-education individuals with worse health and shorter life expectancy, which is not taken into consideration here when comparing different reform types, but could be a potentially strong argument in favour of retirement age reform selectiveness.

8 Appendix A

In this appendix I derive the expression for $k_{a,i}$ in terms of $k_{a+1,i}$, $k_{a+2,i}$, $Y_{a,i}$, $Y_{a+1,i}$ and pre-set parameters used in the backward shooting algorithm to find the optimal asset allocation paths for model agents.

The agent consumption maximization problem once the labour supply decisions are made is given by:

$$\max_{k_{a+1,i}} \sum_{a=1}^{60} \beta^{a-1} u(c_{a,i}), \tag{10}$$

where $u(c_{a,i})$ denotes the separable part of the utility function dependent on consumption, subject to the constraint:

$$(1+\tau_c)c_{a,i} = (1+r)k_{a,i} + (1-\tau_{inc})Y_{a,i} - k_{a+1,i}. \tag{11}$$

The maximization problem can be rewritten in terms of the value function giving us the Bellman equation:

$$v_{a,i}(k_{a,i}) = \max_{c_{a,i}} u(c_{a,i}) + \beta v_{a+1,i}(k_{a+1,i}) \tag{12}$$

The first order condition for the problem is:

$$u'(c_{a,i}) - \beta v'_{a+1,i}(k_{a+1,i}) = 0 \tag{13}$$

Taking the derivative of the utility function with respect to consumption is straightforward but the value function is unknown (and so is its derivative). Nevertheless, we can take the derivative of the value function by applying the envelope theorem, the conditions for which our problem satisfies (see McCandless, 2008). The envelope condition allows to express $v'_{a+1,i}$ as:

$$v'_{a+1,i} = (1+r)u'(c_{a+1,i}) \tag{14}$$

Combining equations (13) and (14), we obtain the Euler equation for the maximization problem:

$$u'(c_{a,i}) = \beta(1+r)u'(c_{a+1,i}) \tag{15}$$

Plugging in the logarithmic utility function and taking the derivatives with respect to $c_{a,i}$ and $c_{a+1,i}$, equation (15) becomes:

$$\frac{1}{c_{a,i}} = \beta(1+r)\frac{1}{c_{a+1,i}} \tag{16}$$

Plugging in the expression for $c_{a,i}$ and $c_{a+1,i}$ from the budget constraint gives:

$$\begin{gathered}\left(\frac{(1+\tau_c)}{(1+r)k_{a,i}+(1-\tau_{inc})Y_{a,i}-k_{a+1,i}}\right) = \\ \beta(1+r)\left(\frac{(1+\tau_c)}{(1+r)k_{a+1,i}+(1-\tau_{inc})Y_{a+1,i}-k_{a+2,i}}\right)\end{gathered} \tag{17}$$

Rearranging gives an expression for $k_{a,i}$:

$$k_{a,i} = \frac{(1+r)k_{a+1,i} + (1-\tau_{inc})Y_{a+1,i} - k_{a+2,i}}{\beta(1+r)^2} - \frac{(1-\tau_{inc})Y_{a,i} - k_{a+1,i}}{(1+r)} \tag{18}$$

Equation (18) can then be rewritten as:

$$k_{a,i} = \gamma_1 k_{a+1,i} + \gamma_2 k_{a+2,i} + \gamma_3 Y_{a,i} + \gamma_4 Y_{a+1,i}, \tag{19}$$

where

$$\gamma_1 = \frac{1}{\beta(1+r)} + \frac{1}{1+r} \tag{20}$$

$$\gamma_2 = -\frac{1}{\beta(1+r)^2} \tag{21}$$

$$\gamma_3 = -\frac{1-\tau_{inc}}{1+r} \tag{22}$$

$$\gamma_4 = \frac{1-\tau_{inc}}{\beta(1+r)^2} \tag{23}$$

Equation (19) combined with the boundary conditions ($k_{1,i} = k_{61,i} = 0$) can then be used within the backward shooting algorithm to determine the optimal asset allocation path of a household.

9 Appendix B

This appendix outlines the steps of the regression analysis used to determine which variables present within the labour supply model constructed in this paper are the most important predictors of being on disability.

The data used for the analysis comes from the SHARE microdata set. Only observations of individuals surveyed in Sweden and younger than 65 are used. The age limit is imposed because all people on disability are transferred to retirement at the age of 65. The resulting dataset contains 8,081 observations.

The variables used in the regression analysis are presented in Table 3. The criterion for variable selection is straightforward: every characteristic present in the model along which the individuals are heterogeneous is included.

Variable	Explanation
disabled	A dummy variable capturing whether a person reported their employment situation as “permanently sick or disabled”.
college	A dummy variable capturing whether a person’s education level is higher than 4 on the ISCED 1997 scale, i.e., whether they have some tertiary education.
verygoodhealth	A dummy variable equal to 1 if the respondent reported being in a very good health state.
goodhealth	A dummy variable equal to 1 if the respondent reported being in a good health state.
fairhealth	A dummy variable equal to 1 if the respondent reported being in a fair health state.
badhealth	A dummy variable equal to 1 if the respondent reported being in a bad health state.
age	A continuous variable capturing the age of the respondent in years at the time of the survey.

Table 3: Variables in the regression

The following Linear Probability Model (LPM) is estimated in Specification 1:

$$disabled = \beta_0 + \beta_1 college + \beta_2 verygoodhealth + \beta_3 goodhealth + \beta_4 fairhealth + \beta_5 badhealth + \beta_6 age \quad (24)$$

As an alternative, I also estimate an LPM specification where the *age* variable is discretized and three dummy variables for age are included instead: *age50to54*, *age55to59*, *age60to64* (Specification 2). This specification would be more appropriate if the probability of being on disability did not rise linearly with age but jumped at a certain threshold.

Regression results are presented in Table (4).

The first takeaway from the results in Specification 1 is that irrespective of age, someone in an excellent (base health group not included in the regression) or a very good health state seems to have a close to zero probability to be disabled on average. This can be inferred

Table 4: Predictors of disability

	(1) Specification 1	(2) Specification 2
college	-0.0067	-0.0066
	(0.0048)	(0.0048)
verygoodhealth	0.0042	0.0041
	(0.0062)	(0.0062)
goodhealth	0.0258***	0.0257***
	(0.0061)	(0.0061)
fairhealth	0.1116***	0.1115***
	(0.0074)	(0.0074)
poorhealth	0.2582***	0.2583***
	(0.0109)	(0.0109)
Age at interview (in years)	0.0003	
	(0.0005)	
age50to54		0.0044
		(0.0147)
age55to59		0.0003
		(0.0142)
age60to64		0.0077
		(0.0141)
Constant	-0.0104	0.0039
	(0.0284)	(0.0143)
R-squared	0.0921	0.0923
Number of observations	8081	8081

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dependent variable: *disabled*

from the insignificant and very small coefficients on *age*, *verygoodhealth* and a negative as well as insignificant constant. Discretizing the age variable in Specification 2 does not change anything - when controlling for health, all the age dummy variables are close to zero and insignificant.

The coefficient on *college* is also both very close to zero in size and insignificant, demonstrating that it is not an important predictor of whether a person is on disability or not, when health is accounted for.

It appears that the only significant predictors of being disabled with non-zero probability are *goodhealth*, *fairhealth* and *poorhealth*. The coefficients on these health state dummies are positive, and both statistically and economically significant.

In the light of these results, I impose that the probability of gaining access to disability insurance should be a function of health but should not be affected by the education level.

I also impose that the probability of gaining access to disability insurance is zero for people in excellent, very good and good health. This decision is slightly inconsistent with the data: the regression results suggest that people in "good" health state do have a small chance of being on disability. However, keeping this probability positive would be problematic in the model. Firstly, correctly replicating the share of people in "good" health is not one of the calibration targets in this paper, which could lead to incorrect conclusions if the people in good health were allowed to get disabled. Secondly, the notion of people being on disability insurance in good health seems wrong conceptually: such an occurrence should be extremely rare with a screening system in place.

The regression results also suggest that age is irrelevant when it comes to predicting disability claiming. However, allowing age to influence the probability of gaining access to disability insurance is necessary in order to match the rise in disability claiming among older people observed in the aggregate data, which cannot be explained by deteriorating health.

The calibrated probability schedules taking into account these findings appear in Figure 3.

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