CPB Netherlands Bureau for Economic Policy Analysis

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A crucial element of the model is that the disutility of working relative to leisure rises with age. The optimal sra then is reached at the point at which the disutility of working longer starts to outweigh the utility of the additional consumption that it enables. The model shows how this point changes in the course of time as a result of the rise in healthy life expectancy; the effects of the ageing population which dilutes per capita consumption; and increases in productivity.

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Abstract

This paper develops a stylized model that can serve as an instrument to assess how long term trends as demographic change and rising living standards affect the optimal future rise of the statutory retirement age (sra) in the Netherlands. As yet there is no such instrument. A crucial element of the model is that the disutility of working relative to leisure rises with age. The optimal sra then is reached at the point at which the disutility of working longer starts to outweigh the utility of the additional consumption that it enables. The model shows how this point changes in the course of time as a result of the rise in healthy life expectancy; the effects of the ageing population which dilutes per capita consumption; and increases in productivity. The first two of these trends lead to a higher optimal sra, respectively by lowering the disutility of working and by increasing the marginal utility of consumption. The third, productivity increases, tends to exert a downward pressure on the sra by lowering the marginal utility of consumption. This paper ignores other factors such as possible changes in the heterogeneity in society.

JEL code: H55, J11

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1. Introduction

The Dutch public pension system (AOW) is PAYG-financed and provides all residents of the Netherlands a flat-rate pension benefit at a level that is related to net minimum wage. Past incomes or contributions do not play a role and distinctions are only made on marital status and the past numbers of years of residence. On average it accounts for around half of total pension income, the other half being covered by the second pillar occupational pension which is funded and does depend on past incomes. The statutory retirement age (sra) for the public pension, or its eligibility age, has been 65 since 1957, the year in which it was introduced. As from 2013 it is raised in steps to the age of 67 in 2021 and as from that year will be linked to life expectancy at the age of 65. In all these years, there has never been a study that provides any kind of economic underpinning for this policy line: it has never been explored how the sra would optimally respond to changes in the demographic and economic environment. There appears to be no literature on this subject.This study aims to fill this gap. It assesses the optimal future increase in the sra as a response to these changes, the latter including the effects of the increase in healthy and total life expectancy, changes in birth rates and increases in productivity. Following current policies it is assumed that the eligibility age for the occupational pensions is linked to that of the sra.

In doing so, this paper builds on Bloom et al. (2014) and Heijdra and Romp (2009). These studies develop a methodology to optimize the retirement age for the average individual of different cohorts. Within cohorts they ignore any form of heterogeneity. An essential element of these papers is that the disutility of working relative to leisure rises with age and the ability and willingness to work declines. The optimal retirement age is then the age at which the disutility of working longer starts to exceed the benefits, or utilities, that it delivers due to the higher level of lifetime consumption that it enables. In Bloom et al. (2014) retirement income is fully financed by the individual's own private savings accumulated during working life: the public pension plays no role in this optimation. Heijdra and Romp (2009) do incorporate the public pension scheme by including social security wealth in the budget restriction of the individual and each cohort optimizes its retirement age subject to this restriction. The paper does not optimize the public pension scheme or the sra. These are exogenous.

This paper also imputes a rising disutility with age and ignores heterogeneity within cohorts. It however also deviates from these studies, mainly by its purpose to optimize the government's policy regarding the sra rather than determining the optimal retirement age of individuals: unlike the two papers, it takes the position of a welfare optimizing social planner. Herein lies its contribution. This means that the planner has to take account of the fact that the optimal sra differs between cohorts which implies that there is an inevitable conflict of interest between generations regarding the choice of the sra. This conflict of interest stems from the fact that the public part of the Dutch pension system is PAYG financed and contributions to the system therefore are not reflected in future pensions in an actuarially neutral way. This brings about transfers between generations and individuals, also when measured over the full remaining lifetimes of individuals, of which the size and sign depends on the sra. This will be further explained in section 3. The optimization in this paper is therefore not applied to individuals. This paper uses another measure: it searches for the sra that leads to the highest overall well-being by maximizing the aggregate utility in society. In other words: it searches for the sra at which the aggregate disutility of a further rise would start to outweigh the material benefits of the additional aggregate consumption that it enables. The analysis is carried out on an annual basis. The PAYG character of the public pension system entails that the determination of the optimal future rise of the sra has to take account of demographic trends such as the rise in the old age dependency ratio. In addition, our analysis will include two other ageing related developments: the rising aggregate costs of health and long term care and the decline in returns to capital which render lower benefits from second pillar pension savings. These trends reduce per capita consumption which in turn raises the utility of the additional consumption enabled by working longer and in this way affects the trade-off between the disutility of working longer and its benefits in terms of additional consumption. Including the effect of these trends forms a further contribution of this paper.

The purpose of this paper is mainly a methodological one. It develops an analytical framework to assess the optimal response of the sra to demographic changes and rising living standards. This framework is reflected into a stylized model that is also used to carry out simulations that may help to understand the workings of the system and make it possible to explore the main factors that determine the optimal response of the sra to demographic changes and growth, and how these factors interact. Other factors that may influence the sra, such as changes in the government's social security schemes and labour market institutions, are not included in this analysis. The impact of these variables and the actual retirement age are thus implicitly assumed to move up in line with the optimal sra.

The model does also not take account of how possible changes in the heterogeneity in society, such as that regarding healthy life expectancy, may affect preferences for the sra. It also does not explore whether its current level is optimal. This would require a study that examines whether the current uniform sra is aligned to preferences within society and appropriately reflects the heterogeneity regarding these preferences.

This paper may also serve as a basis for the discussion about the appropriate methodology for the determination of the sra in countries that feature a partly or fully PAYG-financed pension system. At present the policy debate lacks such a framework. Our intention is that this paper leads to a follow up that applies the methodology to an extended macro-economic model for the Netherlandsand that this paper also presents the effects of different paths of increases of the sra on the welfare of each of the cohorts. This may be relevant for policy makers as the intergenerational effects of the choice of the sra may be of interest to them as well.

As many countries now face decisions on how to adjust their pension systems in response to ageing, most of them having a PAYG-financed public pension system that is larger than in the Netherlands (European Comission, 2018), the methodology developed in this paper might certainly be valuable for other countries as well.

The simulations with the model, both for the past and the future, show that the outcomes are highly sensitive to the assumptions made. This applies especially to the utility valuation of increases in consumption. This valuation strongly influences the trade-off between consumption and leisure, as described above. This parameter value is also uncertain and the calculations are therefore carried out for a range of assumptions regarding this parameter value. Under the assumption that shows the best fit with the realized and projected developments in the period between 1957 and 2021 the optimal sra increase after 2021 turns out to be somewhat lower than in the current legislated policy line of linking it to life expectancy at 65. However, further research is required to substantiate this outcome.

2. Literature

There appears to be no literature of which the subject and basic methodology coincide with that of this paper: no paper determines the optimal future increase of the sra as a response to demographic developments and growth, and as well imputes a rising disutility of working with age. Bloom et al.

(2014) and Heijdra and Romp (2009), respectively BCM and HR hereafter, do include the rising disutility with age. And they also focus on the impact of demographic change and growth on the retirement age rather than exploring the optimality of its current level. But their analysis does not have the purpose of optimizing the government's policy regarding the sra. As mentioned above these studies optimize the individual's retirement age. They do this for different cohorts and take account of the differences in circumstances between the cohorts such as the differences in life expectancy and lifetime incomes. Another difference is that both studies do not assess the optimal future development of the sra, as this paper does. BCM explore whether the past decline of the retirement age can be explained by their model and HR's specification is of a more theoretical nature.

BCM optimize the retirement age for an average individual of a selection of cohorts who fully finance their retirement income by personal savings that are accrued during their working lives and transformed into an annuity. Their model does not include a social security system that raises taxes or provides a pension. There are no transfers between generations. The optimal retirement age is the age at which the disutility of working longer starts to exceed the benefits that it delivers in the form of the higher lifetime level of consumption. They also carry out an historical analysis for the U.S. that explains the decline in the retirement age during the last decades as a result from the fact that higher lifetime incomes have led to lower marginal utilities of consumption. This outweighed the impact of improved health and the resulting decline of the disutility of working.

HR also determine the optimal retirement age of individuals of separate cohorts. This is done in the form of theoretical expressions. In contrast to BCM, their optimization does include a government that raises taxes and provides a pension.

Other studies that deal with the optimal sra do not include a rising disutility with age in their analysis. Hansen and Lonstrup (2009) use a general equilibrium model for Denmark and analyze how the sra affects the lifetime welfare of individuals through its effects on savings, the capital intensity of the economy and returns to capital. In their analysis, the benefits of working longer become smaller the higher the sra. The higher sra leads to low required levels of saving to finance the retirement period and though this channel lowers the capital intensity in the economy and wages as a result. The optimal sra is then reached at the age that the overall material benefit that it brings starts to become smaller than the, non-age dependent, disutility of work. In a small open economy as the Netherlands, this mechanism appears to be of minor importance as is therefore ignored in this paper. Galama et al. (2013) include the health status of the population in a very different way which leads to rather counterintuitive results. In their analysis improved health decreases, rather than increases, the retirement age mainly because it generates higher earnings before retirement and in this way creates a wealth effect that reduces the need to work longer. They ignore any possible effect of health on the disutility of work, which is a key element in the framework of this paper.

Mao et al. (2014) use a stylized life cycle model and focus on the rise of consumption opportunities in the course of life that result from increasing wages and wealth. At higher ages this leads to a point where the additional utility of consumption becomes smaller than that of leisure. Kalemni-Oczan and Weil (2002) focus on the fact that the chance to reach a high age has increased substantially over the last decades. This has raised the incentive to save which in turn has reduced the retirement age.

Forman and Chen (2008) analyze the optimal retirement age from the three perspectives, individuals, the government and companies. They deal with many aspects of this issue but do so in a qualitative way and do not develop a methodology or model that makes it possible to derive the optimal sra.

Kalwij et al. (2016) compare the participation and mortality rates of elderly workers in 2010 to those in 1981. They point out that there has been a substantial drop in mortality among these age groups, indicating a strongly improved health condition, which has not resulted in accordingly higher participation rates. At the (higher) age at which the mortality rate was equal to that in 1981, participation in 2010 was lower than in 1981. They conclude that there is room for an increase in participation among these age groups.

3. Analytical framework

This paper follows BCM and HR by specifying a felicity function that is strongly separable in goods and leisure and subtracts the disutility from work from the utility from consumption. The approach however differs from that followed by these studies by adopting the position of a welfare optimizing social planner that aims to find the optimal retirement age within the context of the existing institutions. It therefore has to take account of the fact that part of the pension system is PAYG-financed. As these systems are inherently redistributional between generations the optimization exercise will not only have to take account of the effects on the cohort directly affected by the sra but also those on the rest of the population. PAYG-financed systems inevitably feature a conflict of interest between generations. This entails that there is no clear-cut optimal sra that suits everybody: for cohorts just before retirement the optimal sra is lower than for the cohorts that are already retired and the young as these can benefit from the financial room created by a high sra. Policy makers thus have to base their decision on a mixed picture. This paper therefore deviates from BCM and HR by not calculating the optimal retirement age for selected cohorts, measured over their full lifetimes, but by searching for the sra that delivers the highest aggregate utility across the whole population on an annual basis. It does this by employing a social welfare function. In a simplified form, this involves the maximization of the following expression with respect to the retirement age:

$$U_t = \sum_{age=0}^{le_t} pop_t^{age_t} u(c_t) - \sum_{age=0}^{ra_t} pop_t^{age_t} dis_t^{age_t} \tag{1}$$

In this equation the first term captures the aggregate utility from consumption in year t, $pop_t^{age_t}$ representing the vector containing the population of each age, le_t life expectancy and $u(c_t)$ average per capita utility from consumption. The latter rises if the retirement age becomes higher because aggregate income increases and enables a higher consumption across all age groups as contribution rates for the public and occupational pension schemes can decline. Imputing the average consumption, and thus ignoring the heterogeneity within the population, appears to be a justifiable simplification as this exercise explores the optimal increase of the sra over decades of time in a stylized way and for this purpose this variable may be an acceptable representation of the long term development of the standard of material well-being in society. A second reason why average consumption may be a justifiable simplification is that deviations from the average of individuals with higher and lower incomes may in part cancel out.

The second term represents the aggregate disutility from work across the population. The size of the disutility per person, represented by the vector $dis_t^{age_t}$, is assumed to rise with age as the willingness to work and productivity falls. This equation is elaborated on hereafter. In line with BCM and HR the optimization in this paper searches for the retirement age at which the disutility of the work effort (the second term) starts to outweigh the utility of the additional current and future consumption that it enables (first term). U_t then reaches its maximum level.

This rest of this section first discusses the modelling of both the disutility from work and the utility that it delivers in the form of the consumption enabled by it. Then it will discuss the way the optimal sra is derived by a combination of the two elements.

The disutility of working

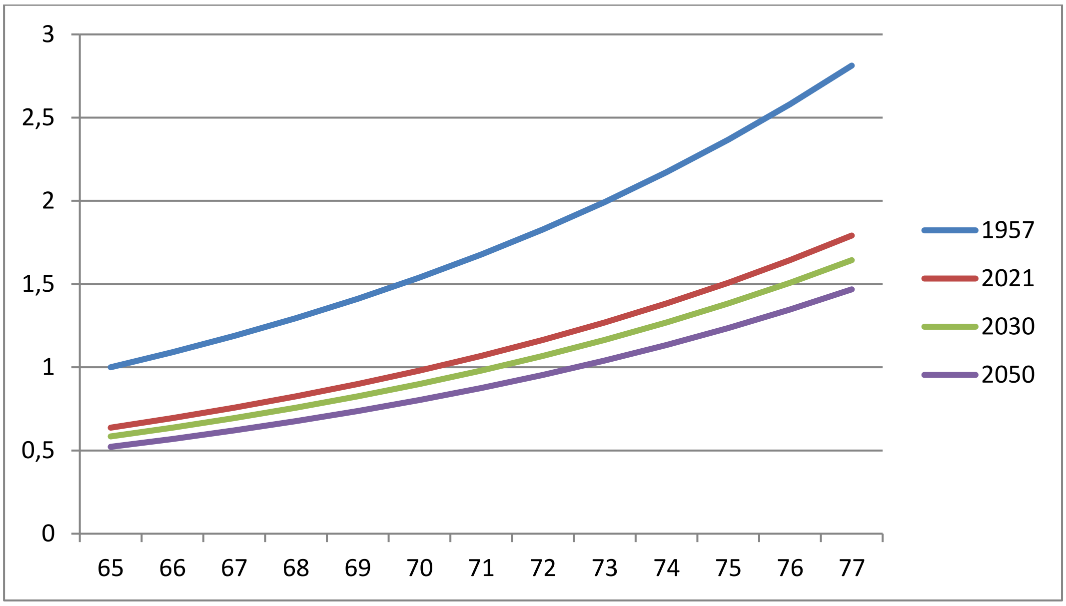
BCM and HR proportionally link the disutility of labour in any year to the rate of mortality. This means that disutility at the relevant ages rises with age at a rate that, if applied to the Netherlands, would be around 10 percent per year of age increase. They also take account of the fact that disutility at any specific age will decline as time progresses, due to health improvements. This is imputed in their model by making the assumption that the age of onset of disability rises in line with life expectancy at the age of 65.[1] This paper also incorporates these concepts. However, the way they are modeled differs somewhat. The rise with age in any year is not captured by the rise in mortality rates but by the rise in the rate of disability levels as measured in Dillingh et al. (2018). Disability levels probably provide a more direct link with the decline in working ability and disutility of labour and may therefore be a better indicator. This certainly applies to the ages around the sra at which mortality rates in the Netherlands are only around 1 percent and a large part of mortality may result from causes that are not related to working ability or disutility. Dillingh et al. find disability rates that increase by 9 percent per year in the relevant range which is close to the 10 percent at which mortality rates rise.

The shift of the disutility curve to the right through time in this paper represents the development of healthy life expectancy (hle) as projected by the RIVM and Statistics Netherlands. These projections indicate that the measures of hle that appear to be most relevant for working ability roughly move up in line with total life expectancy.[2] This paper makes the same assumption and imputes increases of 5.2 years between 1957(the year the public pension scheme was introduced) and 2021 and further increases of 1.0 and 3.3 years for respectively the periods 2021-2030 and 2021-2050. Figure 1 shows the shape of the disutility curves for 1957, 2021, 2030 and 2050.

[1] These projections are carried out by Statistics Netherlands. The projections for 2030 and 2050 are published at https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84345NED/table?ts=1545379578392. The figure for 2012 is published at https://www.cbs.nl/nl-nl/maatwerk/2017/27/geslachtsneutrale-levensverwachting-op-65e-verjaardag.

[2] This finding does not apply to all measures of healthy life expectancy. Life expectancy without chronical diseases turned out to show no improvement (Fontijn and Deeg (2016)) or even a decline (Van Duin and Stoeldraaier (2014)) in the last decades. However, as pointed out in Dillingh et al. this indicator shows a relatively weak relationship with employment and is therefore considered a weak indicator of working ability.

Figure 1 Imputed shape of disutility curves for 1957, 2021, 2030 and 2050



Equation 2 captures the two mechanisms described above. The variable α takes account of the rise with age and equals 9 percent per year of age increase. The impact of health improvements in the course of time is included by a shift of the disutility curve that is equal to the increase of healthy life expectancy (hle).

$$dis_t^{age_t} = de^{\alpha\left(age_t - (hle_t - hle_0)\right)} \tag{2}$$

The level of d in BCM is determined by a calibration exercise. In their exercise it is assumed that the retirement age for a certain reference cohort, which is the cohort born in 1900, is optimal. The value for d is then subsequently derived by assuming that for the average individual of this cohort the disutility of labour at the retirement age equals the marginal lifetime utility of consumption made possible by the work effort. This level of d is also applied in the optimization exercises for the later cohorts. The analysis in this paper similarly keeps the value for d constant. As is shown hereafter and in appendix 1, its level however does not play a role as this paper only analyzes the optimal increase of the sra as a response to future demographic and economic developments. To this end, only changes in d would affect the outcome. It does not explore whether its current level is optimal. This would require a study that examines whether the current uniform sra is aligned to preferences within society and appropriately reflects the heterogeneity regarding these preferences.

The utility of consumption

This paper follows BCM by employing the following functional form for utility from per capita consumption[3]:

[3] The variable k in this equation is an arbitrary positive constant that ensures that utility is always positive. It plays no role in the maximization of utility and is only added because a negative utility from consumption may be difficult to interpret.

$$u(c_t) = k + \frac{c_t^{1-\beta}}{1-\beta} \text{ if } \beta \neq 1 \text{ and } u(c_t) = k + \ln(c_t) \text{ if } \beta = 1 \tag{3}$$

In this stylized model, the long term development of per capita consumption is computed by the following equation:

$$c_t = (\frac{ra_t}{pop_t^{tot}} pf_t - cc_t)e^{gt} \tag{4}$$

The variable c_t represents the average per capita consumption made possible by the work effort in year t. It is the relevant concept for the trade-off with the disutility that the work effort brings about. This includes both current consumption and the present value of future consumption that is created by the pension premiums in t to the pension fund.[4] Accordingly it excludes current consumption made possible by pension premiums in the past. It ignores savings outside the pension fund as these play only a small role in financing the private consumption of pensioners in the Netherlands. The population in the model is also simplified. People below working age are ignored and the analysis therefore starts at the age of 20. Above that age there are pop_t^{tot} persons. This variable is exogenous. In the working ages, which spans ra_t (retirement age) years, there is one person at each age who earns one unit of labour income.[5] There are $pop_t^{tot} - ra_t$ retired individuals. This number deviates from $(le_t - ra_t)$ which captures the average number of years in retirement. The variable w_t is introduced to account for the size of the retired cohorts relative to that in the working ages. Changes in w_t largely reflect changes in (past) birth rates. The demographic variables are exogenous and chosen in such a way that they roughly represent the age structure of the population in the Netherlands.The change in the share of workers in the total population (excluding those below the age of 20), capturing how much earned income is spread out across the population, is denoted by changes in the ratio $\frac{ra_t}{pop_t^{age_t}}$. Many other countries face similar changes in this ratio.This can be decomposed into the change in the age structure, which is reflected by changes in the denominator $pop_t^{age_t}$, and the compensating increase in the retirement age, which is reflected by increases in ra_t.

The imputed concept of consumption also takes account of two other detrimental factors that are both related to the ageing of the population. The first allows for the fact that the worldwide ageing of the population may lead to a surplus of capital relative to labour and declining returns to capital as a result, which in turn lead to lower future benefits from pension premiums paid to pension funds. This effect is captured by the variable pf. It measures, in a simplified way, how much the declining returns reduce consumption opportunities created in t either through lower future pensions or higher pension premiums. In this paper this is done by the latter: we impute the increase of pension premiums that is required to keep future pensions unaffected. This leads to future values for the pf that are lower than 1. Its derivation is elaborated in appendix 2. We assume that the return on capital equals 3 percent in real terms in 2021, reflecting the situation in the world before the effects of ageing

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[4] It assumed that the discount rate equals the pension funds'rate of return.

[5] At these ages, we thus ignore mortality and differences in income between age groups.

set in, and declines to 2.5 percent in the later years. On average second pillar pension income makes up around half of total pension income, the other half consisting of the public PAYG financed part. As this large share of second pillar pension income is rather specific for the Netherlands this factor may be less relevant for other countries. However, in many other countries lower pension incomes may be compensated by private savings and lower returns on capital may reduce consumption through a higher need for these savings.

The second detrimental factor is that ageing will lead to increases in the expenditure on health care and long term care. This factor also plays a larger role in the Netherlands than in most other countries as its publicly financed long term care system is relatively large,.Older people need more health treatments and have to reside more often in nursing homes. As far as the increases, measured as a share of income, are the result of ageing alone and not of improvements in the quality of these services, these increases constitute additional outlays that intend to compensate for or mitigate the decline in health conditions. This does not mean that these outlays are wasteful. They simply reflect that a higher level of expenditure is needed 'to keep people going' and, assuming that people do not derive utilities from health treatments or residing in a nursing home, they do not lead to a higher standard of living or level of welfare. This notion is reflected by subtracting the variable cc_t in the expression for consumption.[6] The substraction ensures that the variable only has this negative 'setback' effect of worsening health conditions on c and that the additional production generated by increases in the retirement age ra fully lands in c and does not differentiate between health services and other forms of consumption.

Finally, long term productivity growth is captured by multiplying the expression by e^{gt}. In the long run this term has a dominant effect on c_t. In BCM this variable turns out to be the main driver of past developments in the retirement age.

An important decision to be made involves the choice for the value of β. This parameter variable determines the utility valuation of increases in consumption and therewith the size of the income effect in the trade-off between consumption and leisure. BCM impute a value of 2 in their analysis of the past development of the sra. However, section 4 of this paper will show that this may be on the high side for the Netherlands. Moreover, the appropriate value of it for the future may be lower due to several factors. One of these may be that leisure time has become more abundant in the course of decades and the sra has accordingly fallen far short of the increase in life expectancy.

Derivation of the optimal increase of the statutory retirement age

The optimization of the sra consists of the optimization of the increase of the average retirement age ra: this variable is directly related to the work effort and therewith to the trade off between consumption and the disutility of work relative to leisure. The increase in the sra is assumed to be equal to that of the ra. The impact of other factors on the transition from working life to life in full retirement is thus assumed to remain constant. Accordingly, it is assumed that consumption generated from other sources such as incomes from other social security arrangements and private savings follow the increase of the sra and that their roles in the transition from working life to retirement

[6] In contrast, expenditure increases that improve quality should be included as these do improve the welfare situation of the population.

remain unchanged[7]. In a stylized model that solely focusses on the impact of demographic developments and growth these simplifying assumptions may be justified as it is unlikely that these factors would significantly affect the optimal difference between the ra and sra. Their levels may obviously differ.

The modelling of the optimal increase of the sra imputes these assumptions. As explained above, the optimal sra follows the increase of the ra. The exercise starts with the optimization of the ra in year t.

Equation (5) is the social welfare function that has to be optimized in year t with respect to ra_t.

$$U_t = pop_t^{tot}\left[k + \frac{\left((\frac{ra_t}{pop_t^{tot}} pf_t - cc_t) e^{gt} \right)^{1-\beta}}{1-\beta}\right] - \sum_{age_t=0}^{ra_t} pop_t^{age_t} d e^{\alpha\left(age_t - (hle_t - hle_0)\right)} \quad (5)$$

The first term of the r.h.s. represents the aggregate utility from consumption in year t. It multiplies the total size of the population pop_t^{tot} with the utility derived from average per capita consumption. The expression for c_t is substituted into the utility function. The second term represents the disutility from the labour effort. It adds up the disutilities at all ages up to the retirement age ra_t. Both terms increase if ra_t rises and the optimal value for it is reached when the increase in the second starts to become larger than that of the first. Appendix 1 shows how the optimal increase of the ra_t, and therewith the optimal increase of the sra_t, is derived. This leads to the following expression for the optimal increase of the sra in year t relative to base year 0:

$$sra_t - sra_0 = (hle_t - hle_0) - \frac{\beta}{\alpha}\left[\frac{(\frac{ra_t}{pop_t} pf_t - cc_t)}{(\frac{ra_0}{pop_0} pf_0 - cc_0)} - 1\right] + \frac{1}{\alpha}(\frac{pf_t}{pf_0} - 1) + \frac{1-\beta}{\alpha} gt \quad (6)$$

The solution of this equation has to be determined numerically as the ra_t also forms part of the right hand side. The interpretation of it is straightforward and very intuïtive. The first term shows that the optimal sra rises in line with the increase of hle. The second term captures the three income effects of ageing; the larger spreading of income across the population as the share of people in the working ages declines relative to the total population; the fact that the lower returns of pension funds lead to higher pension premiums and a lower aggregate level of consumption; and the increase of the costs of health and long term care which lead to lower living standards. These three effects result in a lower level of consumption c_t. Each percentage point decrease of it raises its marginal utility by β percent which, given the assumption that the disutility of work increases by α percent per year, leads to a $\frac{\beta}{\alpha}$ years higher level of the ra_t at which the equality between the marginal utility from consumption and

[7] Moreover, as mentioned in the introduction, the optimization does not correct any possible misalignment of the current sra to preferences in society.

the disutility of working longer is restored and thus a new optimal level is reached. By assumption, this translates into an equal change of the sra.

The third term captures the fact that, apart from its income effect, the lower pension fund's returns on capital also have a negative substitution effect that leads to a lower optimal sra: an additional unit of work effort now has a smaller positive effect on lifetime income and consumption. For each percent that this is the case the optimal ra_t, and thus optimal sra_t, declines by $\frac{1}{\alpha}$ years because it takes α percent per year of decline in disutility for this to be matched by a decline in disutility . The last term captures the effect of productivity growth. It includes both the income and the substitution effect. The variable d in equation 5 disappears in (6): this variable, as long as it remains constant, does not affect changes in the optimal sra. It only affects its level (see appendix 1).

The calculations implicitly respect the government's budget restriction: the specification of equation (6) implies that increases in income translate into equal increases in consumption and that the government's budget balance is not affected. Eventual lower (higher) government expenditure on pensions, resulting from a rise (fall) in the sra, is thus neutralized by a correspondingly fall (rise) in taxation.

4. Other aspects in the choice of the statutory retirement age

Policy makers might attach weight to other criteria than only that of achieving a maximum aggregate utility. They might for instance find it necessary to consider the distributional effects as well, both between generations as between income levels. This paper does not elaborate on this aspect. Our current intention is that a follow up paper addresses the intergenerational issue: it will also present results on how different future paths of the sra affect the net lifetime utility levels of generations and in this way present the conflict of interest between generations which is inevitably related to the choice of the sra. This is illustrated in appendix 3.

The redistributional effects between income levels will not be addressed in the intended follow up paper. The choice of the sra does have redistributional effects as the Dutch first pillar pension is of a flat rate nature and financed by income dependent taxation. This entails a lifetime redistribution from high to low incomes that becomes larger the more money has to be raised by taxation and thus the lower the sra (Bonenkamp et al, 2013).[8] This effect on redistribution could interfere with the choice of the optimal sra. This is also the case if compensating tax measures would be implemented as these would in turn affect the progressivity of the tax system and the distortions it creates.

Heterogeneity regarding the disutility of work at the relevant ages is also ignored in this paper. However, it should be noted that heterogeneity has also been considered in the determination of the current level of the sra and that this aspect therefore only affects its optimal future increase if future demographic change affects the various groups in diverging ways. For instance if the increase in the healthy life expectancy of the low educated lags behind that of the average. Moreover, it would also require that policy makers attribute a higher weight to one of these groups. If so, this could be reflected in the variable d. Including heterogeneity in the model would provide a more comprehensive insight into the effects of changes in the sra, especially because the effects on the group with high

[8] This redistributional effect is mitigated by the second pillar system, which features a redistribution in the opposite direction. This effect however is far smaller.

levels of disutility, generally considered to be individuals with the lower incomes, attract a lot of attention in the current policy debate. This might be left for a future extension of the model.

Another aspect is the role of tax wedge. This is not included in the model. A higher sra makes it possible to lower the tax rate, thereby lowering the excess burden and loss of utility that is related to taxation. Including this in the framework would thus lead to a higher optimal level of the sra. This element could be taken on board in an extension of the model.

This paper focusses on the impact of demographic change and rising living standards on the optimal future increase of the sra. It does not explore whether its current level is optimal. This would require a study that explores whether the current preferences for leisure, in this model captured by variable d in equation (6), is appropriately reflected into the current level of the sra. It also requires that employability of employees as well as the behaviour of employers regarding employability of elderly workers shifts in line with the sra (Lazear,1979) .

5. Analyzing the developments in the period between 1957 and 2021

Between 1957, the year the current public pension arrangement was introduced, and 2012 the sra has remained at the age of 65. Between 2012 and 2021 it is raised, in legislated steps, to 67 and after 2021 it is linked to life expectancy at 65. Figure 2 shows the time path of the sra and life expectancy at 65 for the period between 1957 and 2050, as currently projected. During this period enormous changes have taken place, and are expected to take place in future, in the factors determining the optimal sra as presented in the analytical framework developed in the previous section. This involves significant increases in (healthy) life expectancy; rises in the old age dependency ratio; and spectacular increases in living standards. This section explores how the developments in the period 1957-2021, the period before the linkage to life expectancy, fit in the model developed in the previous section: we address the question whether the policy line in this period can be justified on the basis of welfare optimization as specified by the model.

Figure 2 Statutory retirement age and life expectancy at 65 in 1957-2050

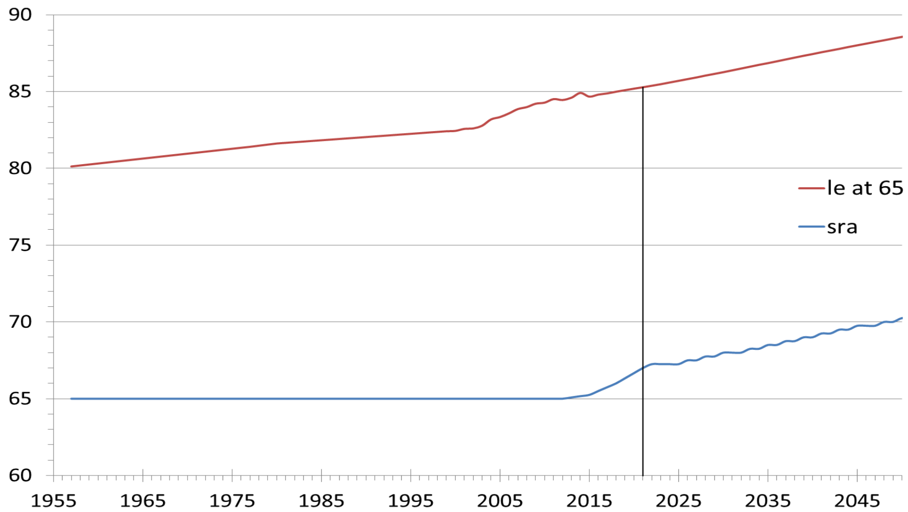

Table 1 summarizes the developments[9] that impact on the optimal sra. It shows that life expectancy at 65, or the number of years that pensioners were expected to benefit from the public pension, increased from 15.1 to 19.5 years, or by 4.4 years[10] in the period up to 2012. In the period up to 2021 it is projected to have increased to 20.3 years, or by 5.2 years. Based on Van Duin and Stoeldraaijer (2014) we will impute the same increase for healthy life expectancy.[11] Table 2 also shows that the old age dependency ratio rose by more than 13 percentage points between 1957 and 2012, and for the period 1957 till 2021 it is projected to have risen by more than 20 percentage points. Per capita consumption[12] and productivity per hour worked respectively increased by 128 percent and 195 percent in 1957-2012 and is currently projected to have increased by 143 and 217 percent in 1957-2021. The difference between the latter two (variable 6) is imputed in the second term of equation 6. In line with the model it is mainly assumed to be due to the combined effect of the increase in the old age dependency ratio, the rise in the costs of health and long term care and lower returns of pension funds that necessitated higher pension premiums. Together, these factors turn out to have lowered per capita consumption by around 23 percent in 2012 and, according to the latest projection, 24 percent in 2021. Somewhat arbitrarily we will assume that pension fund returns declined by 1 percentage point since 1957, from 4 to 3 percent, implying a 3 percent decline in the pf -variable (third term of (6)). The annual average productivity growth of 1.82 percent , which is implied by the full period productivity increase of 217 percent, is imputed in the variable g of the last term of equation 6.

Table 1 Developments of key variables between 1957 and 2021

	1957	2012	2021
1. Life expectancy at 65 (in years)	15.1	19.5	20.3
2. Increase of (healthy) life expectancy	-	4.4	5.2
3. Old age dep. ratio (65+/20-64)	15.9	29.2	36.2
4. Consumption per capita (1957=100)	100	228	243
5. Labour productivity per hour (1957=100)	100	295	317
6. Non-productivity effects on consumption (4/5)	100	77	76
7. Effect of decline in pension fund returns	100	97	97

As the outcomes are highly dependent on the value of β, which is uncertain, we carry out the calculations for a range of values of this variable, including the value at which the observed policy would have been optimal. The outcomes are presented in Table 2. The results show that, within the

[9] The data of the first two variables are derived from Statistics Netherlands and can be handed over on request. The data for the last three variables are based on Statline, https://opendata.cbs.nl/#/CBS/nl/dataset/7343nr/table?ts=1542635566464 and own calculations.

[10] These are not the actual or cohort life expectancies but the period life expectancies as published by Statistics Netherlands. The latter concept, which does not take account of future declines in mortality rates, is more in line with the analytical framework developed above as the optimization here is on an annual basis and, moreover, the legislated sra increase is also based on period life expectancies. The cohort life expectancies are around two years higher than the period life expectancies but both show similar increases in the course of time and the outcomes of the analysis are therefore only slightly affected. Another reason is that Statistics Netherlands does not project mortality rates beyond 2060 which implies that the cohort life expectancies of the cohorts born after 1960 or so cannot be measured properly. This argument is relevant in the next section in which we assess the optimal future increase in the sra.

[11] This study explores how the increase of two measures of healthy life expectancy compare to that of total life expectancy. The analysis starts in 1983 and shows that as from that year the increase of both measures roughly matched that of total life expectancy. We will assume that the same has occurred before 1983. The study also projects that this will be the case for the years up to 2030.

[12] This variable is defined as total private consumption divided by the 20+ part of the population, reflecting the part of the population in which incomes are earned.

chosen range, the optimal increase of the sra ranges from an increase of 7.9 years if $\beta = 1$ to a decrease of 2.2 years if $\beta = 2$ with the obvious conclusions regarding the optimality of the actual policy followed in this period.[13] In the case that $\beta = 1.6$ the actual policy of raising the sra by 2 years would be optimal. It leads to an increase in the expected number of years in retirement of 3.2 years (row 6), from 15.1 to 18.3 years (row 7), which can be fully attributed to the rise in life expectancy. The other factors, especially the increase in productivity, on balance exerted a downward pressure. If $\beta > 1.6$ the optimal number of years in retirement would have been further extended, and the sra accordingly lowered, because the income effects related to the increases in the standards of living would become larger, reflecting a lower valuation of these increases. In the extreme case that $\beta = 2$ the increase of years in retirement would be extended by 7.2 years to 22.3 years. If the age of 65 reflected the political preferences of the population in 1957 this implies that the optimal sra in 2021 would be 63.0 years (row 8). In the case that $\beta < 1.6$ the opposite holds: the sra in 2021 should then be higher than 67 and the number of years in retirement lower than they are now projected to be. In the extreme case that $\beta = 1$ the optimal sra would even be 72.9 years which implies that the length of the retirement period is reduced by 2.7 years.

The decomposition in rows 2 till 5 reveals that the differences in outcome are primarily driven by the impact of the 217 percent productivity increase in this period (row 5). The larger β becomes, the more the lower utility valuation of the rise in the standard of living gains weight. The income effect that results from the consumption diluting effects of the non-productivity factors (row 3) only partially offsets this effect at higher values for β.

It might be argued that the two year rise of the sra in the period from 1957 up to 2021 can be interpreted as a form of revealed preference. In this view this outcome could be seen as a reflection of the existing preferences for additional consumption relative to leisure at the relevant ages: it shows how society actually experienced the relative importance of these variables. The years up to 2021 are included in this period because the two year rise of the sra in the years 2012 to 2021, after a long period with no change, at a rate that is roughly twice that of the increase in life expectancy, could be interpreted as a consciously taken long overdue catch-up adjustment of the sra to its optimal level that corrects for past inertia. This revealed preference view would entail that preferences for additional consumption are best reflected by a value for β that equals 1.6.

Table 2 Optimal increases of sra and years in retirement in 1957-2021 for various values of β

Value for β	1.0	1.4	1.6	1.8	2.0
1. Optimal increase of sra	7.9	3.9	2.0	0.0	-2.0
Due to:					
2. Increase of (healthy) life expectancy	5.2	5.2	5.2	5.2	5.2
3. Income effects of non-productivity factors	3.0	4.2	4.8	5.4	6.0
4. Decline in pension fund returns (subst. effect)	-0.3	-0.3	-0.3	-0.3	-0.3
5. Productivity increase (subst. and inc. effect)	0	-5.1	-7.7	-10.3	-12.8
6. Optimal increase of retirement period	-2.7	1.3	3.2	5.2	7.2
7. Optimal length of retirement period	12.4	16.4	18.3	20.3	22.3
8. Optimal sra in 2021	72.9	68.9	67.0	65.0	63.0

[13] As the model is almost linear the outcomes for values of β outside the chosen range can be approximated by extrapolation.

6. Simulations for the period after 2021

The simulation exercise for the future consists of finding the solution for ra_t in equation (6). We will use 2021 as our base year and impute the actual sra of that year, 67, as its starting level. The exercise is carried out for 2030 and 2050. Table 3 presents the assumptions imputed in the model. Life expectancies at the age of 65 increase from 20.3 years in 2021 to eventually 23.5 in 2050. Following Van Duin and Stoeldraaijer (2014) and RIVM[14] we impute the same increases in healthy life expectancy. The imputed values for w_t, cc_t are respectively based on demographic projections of Statistics Netherlands and projections of the CPB model Gamma and those for pf_t on the formula developed in appendix 2. In line with the CPB long term projections in the Ageing studies (e.g. Smid et al., 2014) we impute a value for g of 1.5 percent.

Table 3 Assumptions and parameter values imputed in simulation exercises

	2021	2030	2050
Inputs:			
ra_t (as from age 20)	45		
le_t (life expectancy at 65)	20.3	21.3	23.5
w_t	0.83	0.95	1.00
pf_t	1	0.986	0.987
cc_t	0.10	0.115	0.135
α	0.09	0.09	0.09
r_t	0.03	0.025	0.025

The previous section showed that the outcomes are very sensitive to the imputed value of β. As the appropriate value for it is uncertain as well, the calculations are carried out for the full range between 1.0 and 2.0. Table 4 presents the outcomes. The first row presents the optimal level of the sra, row 2 its optimal increase and rows 3 till 10 provide a decomposition of the increase. It shows that under the assumption that $\beta =$ 1.6, the value for which the policy between 1957 and 2021 would be optimal, the optimal sra increases by 1.2 and 2.5 years in 2030 and 2050 respectively. These increases are primarily driven by the increased number of years that people are expected to live in good health (row 3, representing the first term of equation 6). The combined income effects of the three ageing related non-productivity factors (row 4), represented by the second term of (6), adds to this rise. They capture the fact that per capita consumption is lowered and working longer therefore becomes more attractive. This term consists of the increase in the old age dependency ratio (row 5), which is partly compensated by the income generating effect of the increase in the retirement age (row 6), declining pension returns and the higher pension premiums that result from that (row 7), and higher costs of cure and care (row 8). The other two terms of equation (6) exert a downward pressure on the sra. This effect is small for the substitution effect of the lower pension fund returns but is large over these long time spans for the combined income and substitution effects of the productivity growth if β is larger than 1.

[14] The projections of Van Duin and Stoeldraaijer (2014) range up to 2030. Those of the RIVM up to 2040 (https://www.vtv2018.nl/Levensverwachting).

In the case that $\beta < 1.6$ the downward pressure of the productivity increase becomes smaller and the optimal sra higher. The opposite holds if $\beta > 1.6$. The outcomes would be lower if the two rather Dutch specific factors would be excluded from this analysis. This is indicated by the fact that rows 7,8 and 9, which capture these effects, on balance have a positive effect. Applying this exercise on other countries might therefore generate lower optimal increases of the sra.

Table 5 compares these outcomes for the optimal sra with the increase in life expectancy at 65 and the increases of the sra under the current policy. The middle columns show that if $\beta = 1.6$, the optimal sra increases by 1.2 years in 2030 and 2.5 years in 2050. This implies that the optimal length of the retirement period in these years (row 3) respectively show a decrease of 0.2 years and an increase of 0.8 years. Rows 4 and 5 compare the outcomes with the sra increase under the current policy and show that the optimal increase is 0.2 years higher than is currently legislated in 2030 but 0.8 years lower in 2050 (2.5 versus 3.3 years). This non-linearity results from the fact that the upward impact of the ageing related non-productivity factors occurs earlier in time than the downward effect of the increase in productivity. If $\beta < 1.6$ the optimal sra becomes higher which leads to lower length of the optimal retirement period. The opposite holds if $\beta > 1.6$.

Table 4 Optimal increase of statutory retirement age as from 2021

	$\beta = 1$		$\beta = 1.4$		$\beta = 1.6$		$\beta = 2.0$	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
1. Optimal sra	68.6	71.1	68.3	70.0	68.2	69.5	68.1	68.6
2. Optimal increase of sra	1.6	4.1	1.3	3.0	1.2	2.5	1.1	1.6
Of which as a result of:								
3. Increase in (healthy) life expectancy at 65	1.0	3.3	1.0	3.3	1.0	3.3	1.0	3.3
4. Income effects of non-productivity factors:	0.7	1.0	1.0	1.8	1.3	2.3	1.7	3.3
Of which due to:								
5. Changing age structure	0.7	1.3	1.1	1.8	1.1	2.0	1.4	2.6
6. Compensating increase in retirement age	-0.4	-1.1	-0.5	-1.1	-0.5	-1.0	-0.6	-0.8
7. Decline of pension fund returns (inc. effect)	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4
8. Higher costs of cure and care	0.3	0.6	0.4	0.9	0.4	1.0	0.5	1.2
9. Decline of pension fund returns (subst. effect)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
10. Productivity increase (subst. and inc. effect)	0.0	0.0	-0.6	-1.9	-0.9	-2.9	-1.5	-4.8

Table 5 Comparison with increases in life expectancy and sra under current policy after 2021

	$\beta = 1$		$\beta = 1.4$		$\beta = 1.6$		$\beta = 2$	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
1. Optimal increase of sra	1.6	4.1	1.3	3.0	1.2	2.5	1.1	1.6
2. Increase in life expectancy at 65	1.0	3.3	1.0	3.3	1.0	3.3	1.0	3.3
3. Optimal increase of retirement period (2-1)	-0.6	-0.8	-0.3	0.3	-0.2	0.8	-0.1	1.7
4. Sra increase under current policy	1.0	3.3	1.0	3.3	1.0	3.3	1.0	3.3
5. Difference with current policy (1-4)	0.6	0.8	0.3	-0.3	0.2	-0.8	0.1	-1.7

Table 6 presents the outcomes of a sensitivity analysis. It explores how the outcomes change if we impute a number of alternative assumptions. Row 2 shows the outcomes if healthy life expectancy, or the willingness and ability to work, does not show the same increase as total life expectancy, as is assumed in the baseline, but increases at a 25 percent lower pace. The outcomes for 2030 then turn out to be around 0.2 years lower than in the baseline and those for 2050 around 0.6 years lower. These effects are smaller than the decline in healthy life expectancy because the compensating income effects become larger.

The assumption regarding the capital returns (row 3) turns out not to have a large impact. In part, this results from the fact that this also leads to a substitution effect that mitigates the income effect.

Row 4 shows the result if it is assumed that outlays on health and long term care are alternatively seen as normal consumption goods and impact on the trade-off between consumption and leisure in the same way.[15] This would lead to somewhat lower sra's: around 0.5 years in 2030 and 0.9 years in 2050. This is due to the fact that in this view the rise in these outlays does not add to the consumption diluting non-productivity factors, captured by the second term of equation (6), and as a result the upward income effect becomes smaller than in the baseline.

Raising the α **,** the rate at which age increases the disutility of working, from 9 to 12 percent per year has a small effect on the optimal sra (row 5). It is slightly lower if β =1 because the upward effect of the consumption diluting factors on the sra become smaller: it requires a smaller rise of the sra for the marginal disutility of working longer to rise in line with the marginal utility of consumption. If $\beta > 1$ the opposite effect of the productivity increase (the last term of (6)) becomes effective of which the size increases with β and the length of the period considered. In the case that $\beta = 2$ and in the last year of our time horizon, 2050, the higher value for α raises the sra by 0.3 years. Finally, a lower growth rate leads to a larger increase in the sra if $\beta > 1$ (row 6). Under these circumstances the income effect of growth, which dampens the rise of the sra, becomes smaller as living standards grow at a lower pace.

[15] In this exercise variable cc_t is excluded from equation 4,5 and 6.

Table 6 Sensitivity analysis: optimal increase of sra after 2021 under alternative assumptions

	$\beta = 1$		$\beta = 1.4$		$\beta = 1.6$		$\beta = 2$	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
1. Baseline assumptions	1.6	4.1	1.3	3.0	1.2	2.5	1.1	1.6
Alternative assumptions:								
2. increase hle 25 percent smaller	1.4	3.5	1.1	2.4	1.0	1.9	0.9	1.1
3. no decline of capital returns	1.6	4.1	1.3	2.9	1.2	2.4	0.9	1.4
4. no impact hc and ltc	1.3	3.6	1.0	2.2	0.8	1.6	0.6	0.6
5. α **=0.12 (instead of 0.09)**	1.5	3.9	1.3	3.0	1.2	2.6	1.0	1.9
6. 0.5 percent lower g	1.6	4.1	1.5	3.4	1.4	3.1	1.4	2.6

7. Conclusion

This paper develops a stylized model that assesses how long-term trends as demographic change and rising living standards affect the optimal statutory retirement age (sra). A core element of the analysis is that improving health conditions, related to higher life expectancies, exert an upward pressure on the age at which the disutility of working longer starts to outweigh its benefits in the form of additional income and consumption, raising the optimal sra. Rising living standards however on balance tend to mitigate this rise by decreasing the marginal utility of consumption.

The main purpose of the paper is methodological: it may serve as a basis for the discussion about how to determine the optimal rise of the sra in the coming decades. At present, no such instrument exists. Simulations with the model also help to gain insight into the effects of the main factors at work and how they interact. Our intention is that a follow up paper will carry out the analysis with a macro-economic model that incorporates the elements described above and applies more realistic inputs.

The paper also carries out simulations, both for the past and the future. These show that the optimal increases of the sra depend on the assumptions made, in particular that regarding the utility valuation of increases in consumption. The simulations show that if the utility valuation is chosen with which the past policy would be optimal, the current legislated future time path of increases in the sra seems somewhat on the high side. However, more research is required to be able to arrive at more definitive conclusions. This particularly applies to the future value of this utility valuation. This might be considered a priority. Another element that could be put under scrutiny is the model itself.

The analysis on the optimal future time path for the sra may also benefit from a number of extensions to the model. One would be the addition of the intergenerational effects of increases of the sra. These too may be of interest to policy makers. We intend to cover this issue in the follow up to this paper. Another one would be the incorporation into the model of the effects of the sra on the level of taxation and the distortions related to this. Finally, the introduction of the heterogeneity between high and low income groups, especially regarding the disutility of working at higher ages, could enrich the insight into the effects of the choice for the sra on these different groups.

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Appendix 1

The purpose of the exercise is find the ra_t that maximizes equation (A.1.1), or equation (5) in the main text:

$$U_t = pop_t^{tot}\left[k + \frac{\left((\frac{ra_t}{pop_t^{tot}} pf_t - cc_t)e^{gt}\right)^{1-\beta}}{1-\beta}\right] - \sum_{age_t=0}^{ra_t} pop_t^{age_t} de^{\alpha(age_t-(hle_t-hle_0))} \quad \text{(A.1.1)}$$

This can be rearranged as follows:

$$U_t = pop_t^{tot}k + pop_t\left[\frac{\left((\frac{ra_t}{pop_t^{tot}} pf_t - cc_t)e^{gt}\right)^{1-\beta}}{1-\beta}\right] - \sum_{age_t=0}^{ra_t} pop_t^{age_t} de^{\alpha(age_t-(hle_t-hle_0))} \quad \text{(A.1.2)}$$

Maximizing U_t wrt ra_t leads to:

$$\frac{dU_t}{dra_t} = \frac{1-\beta}{1-\beta} pop_t^{tot}[(\frac{ra_t}{pop_t^{tot}} pf_t - cc_t)e^{gt}]^{-\beta} \frac{pf_t}{pop_t^{tot}} e^{gt} - pop_t^{ra_t} de^{\alpha(age_t-(hle_t-hle_0))} = 0$$

and after further elaboration and considering that $pop_t^{ra_t}$ is set at 1 to:

$$[(\frac{ra_t}{pop_t} pf_t - cc_t)e^{gt}]^{-\beta} pf_t e^{gt} = de^{\alpha(age_t-(hle_t-hle_0))} \quad \text{(A.1.3)}$$

The lhs denotes the total marginal utilty across the population of raising ra_t, and extending the length of working careers, by one year. It has a negative slope. The rhs denotes the disutility of raising ra_t by one year and has a positive slope. This disutility is borne by the worker at the age of ra_t and we will substitute this variable for age_t. The optimum ra_t is reached at the point where both are equal.

Taking the logarithms of (A.1.3) leads to:

$$-\beta \ln(\frac{ra_t}{pop_t} pf_t - cc_t) - \beta gt + \ln pf_t + gt = \ln d + \alpha(ra_t - (hle_t - hle_0)) \quad \text{(A.1.4)}$$

The corresponding equation for the base year is:

$$-\beta \ln(\frac{ra_0}{pop_0} pf_0 - cc_0) - 0 + \ln pf_0 + 0 = \ln d + \alpha(ra_0 - (hle_0 - hle_0)) \quad \text{(A.1.5)}$$

Subtracting (A.1.5) from (A.1.4) and some further elaboration leads to:

$$-\beta\left[\left(\frac{(\frac{ra_t}{pop_t}pf_t - cc_t)}{(\frac{ra_0}{pop_0}pf_0 - cc_0)} - 1\right)\right] + \left(\frac{pf_t}{pf_0} - 1\right) + (1-\beta)gt = \alpha\left[(ra_t - ra_0) - (hle_t - hle_0)\right] \qquad \text{(A.1.6)}$$

The l.h.s denotes how the aggregate marginal utility of consumption that results from increasing the retirement age ra_t, changes through time. The r.h.s denotes how the aggregate marginal disutility of increasing it changes. The expressions on both sides depend on the level of ra_t which entails that the equation has to be solved numerically. Solving the equation means finding the level of ra_t at which a further increase of it would not deliver additional net benefits and thus an optimal level is found: at that level the marginal disutility of a further rise would equal the marginal material benefit from it.

After some simplification and imputing our assumption that the change in the sra_t is equal to that of the ra_t, this leads to the following expression for the optimal increase of the sra_t:

$$sra_t - sra_0 = (hle_t - hle_0) - \frac{\beta}{\alpha}\left(\frac{(\frac{ra_t}{pop_t}pf_t - cc_t)}{(\frac{ra_0}{pop_0}pf_0 - cc_0)} - 1\right) + \frac{1}{\alpha}\left(\frac{pf_t}{pf_0} - 1\right) + \frac{1-\beta}{\alpha}gt \qquad \text{(A.1.7)}$$

The optimal increase of the optimal sra derived in A.1.7 assumes that the variable d remains unchanged in the course of time: disutility depends only on age and healthy life expectancy. This reflects the focus of this paper on the impact of demographic variables. However, d might change as a result of several other factors. One example is a shift in revealed political preferences that puts a higher (lower) weight on individuals with a relatively high (low) level of disutility. This would lead to a higher (lower) level of d and to lower (higher) optimal sra's. Other examples are changes in labour market policies or working conditions. Such changes might also lead to a change in d. Such policies could be included in the analytical framework by making d time dependent. This would lead to the following expression:

$$sra_t - sra_0 = (hle_t - hle_0) - \frac{1}{\alpha}(d_t - d_0) - \frac{\beta}{\alpha}\left(\frac{(\frac{ra_t}{pop_t}pf_t - cc_t)}{(\frac{ra_0}{pop_0}pf_0 - cc_0)} - 1\right) + \frac{1}{\alpha}\left(\frac{pf_t}{pf_0} - 1\right) + \frac{1-\beta}{\alpha}gt$$

(A.1.8)

However, as this paper focusses on the effects of demographic change alone and thus ignores changes in d it uses equation (A.1.7) in its assessment of the optimal sra.

Appendix 2 The reduction of consumption due to the decline of returns to capital

The impact of the lower returns to capital on lifetime consumption in this paper is captured by modelling how this works out in an institutional setting in which pension funds play an dominant role in providing pension income such as in the Netherlands. Second pillar pension income roughly covers half of pension incomes, the other half mainly being the flat rate PAYG-financed public pension.

In this paper, the reduction of consumption due to the decline of returns on capital is measured as the increase in the pension premium that is required to keep pensions unaffected. We compare a world with the 'new' low returns r_t to that with the 'old' high returns r_0. For both situations, we calculate the pension premiums under the simplified assumption that at retirement (ra), each cohort's accumulated value of pension premiums paid to the pension fund including its returns (l.h.s of equation (A.2.1)), equals the present value of its future pensions (r.h.s of A.2.1). We ignore any possible lifetime intergenerational tranfers within the second pillar pension system and, in line with Dutch institutions, impute a constant pension premium pp_t across all working ages.

Under the new situation this can be modelled as follows:

$$\sum_{k=0}^{ra_t-1} pp_t\left(\frac{1+r_t}{1+g}\right)^{ra_t-k} = \sum_{n=1}^{le_t-ra_t} pens_t\left(\frac{1+g}{1+r_t}\right)^{n-1} \qquad \text{(A.2.1)}$$

This can be worked out to:

$$pp_t\left[\frac{\left(\frac{(1+r_t)}{(1+g)}\right)^{ra_t} - \frac{(1+r_t)}{(1+g)}}{\frac{(r_t-g)}{(1+r_t)}}\right] = pens_t\,\frac{1+r_t}{r_t-g}\left[1-\left(\frac{1+g}{1+r_t}\right)^{le_t-ra_t}\right] \qquad \text{(A.2.2)}$$

Further elaboration leads to the following expression for pension premiums:

$$pp_t = pens_t\,\frac{1-\left(\frac{(1+g)}{(1+r_t)}\right)^{le_t-ra_t}}{\left(\frac{(1+r_t)}{(1+g)}\right)^{ra_t} - \left(\frac{(1+r_t)}{(1+g)}\right)} \qquad \text{(A.2.3)}$$

Equation A.2.3 shows that pension premiums essentially depend on the (aspired) level of the pensions $pens_t$, the span of the retirement period $le_t - ra_t$, the span of the working age period ra_t and the differential of returns to capital r relative to the growth rate g. In our simulations we impute a value for $pens_t$ of 0.3. As, on average, the first pillar pension is equal in size the total average replacement rate amounts to 0.6.

Under the 'old' situation, with r_0 as the return on capital, the expression becomes:

$$pp_{t,r_0} = pens_t \frac{1-\left(\frac{(1+g)}{(1+r_0)}\right)^{le_t - ra_t}}{\left(\frac{(1+r_0)}{(1+g)}\right)^{ra_t} - \left(\frac{(1+r_0)}{(1+g)}\right)} \tag{A.2.4}$$

The change in the required pension premium equals the difference between both expressions and lands in the pf_t -variable as follows:

$$pf_t = 1 - pp_t + pp_{t,r_0} \tag{A.2.5}$$

Appendix 3 Intergenerational effects of an increase of the statutory retirement age

The effects in the year of increase

The intergenerational effects of an increase of the sra can be illustrated by a simple model that takes account of the effects of this measure on net incomes and disutility at different ages. In this illustration, unlike in the main text, the simplifying assumption is made that also the levels of the sra and ra are equal. Here, ra and sra denote the values for these variables before the age increase. We impute that an increase of both variables by one year leads to an additional labour income of 1 at the age of sra + 1 and a loss of public pension income at that age which is equal to p. The disutility of the work effort at that age is valued at du. The lower public expenditure of p enables a tax decrease which in this model is imputed in the form of an equal tax reduction for all citizens. The population consists of 1 person at each age and life expectancy is le which implies that the total population is equal to pop. If the sra and ra are increased by one year this entails that all citizens benefit from a tax reduction of p/pop. The effect on aggregate welfare adds up to 1- du. Table A.3.1 sums up these effects.

The highest aggregate net welfare is achieved if the level of the sra is such that the net effect of an sra increase on aggregate welfare is 0 and thus if du = 1. If du would be smaller than 1 the disutility of working longer would fall short of its material benefits and a higher sra would lead to a higher aggregate welfare. The opposite is the case if du is larger than 1.

Table A.3.1 Effects on welfare at different ages in year of increase of sra

Age	
1) all ages up to sra	p/pop
2) sra + 1	1- p + p/pop - du
3) all ages above sra + 1	p/pop
4) aggregate effect (whole population)	1 - du

The intergenerational effects over the remaining lifetimes

If r and g respectively denote the discount rate and the annual growth rate of all variables, the present value of the intergenerational effects of the increase of the sra (and ra) over the remaining lifetimes of the currently living and yet unborn cohorts can be expressed by the following expressions:

For the cohorts above the age of sra + 1:

$$\Delta U_{t-by} = \sum_{n=0}^{le-(t-by)} (\frac{p}{pop})(\frac{1+g}{1+r})^{le-(t-by)-n} \qquad (A.3.1)$$

For the living cohorts under and at the age of sra + 1 and the yet unborn cohorts:

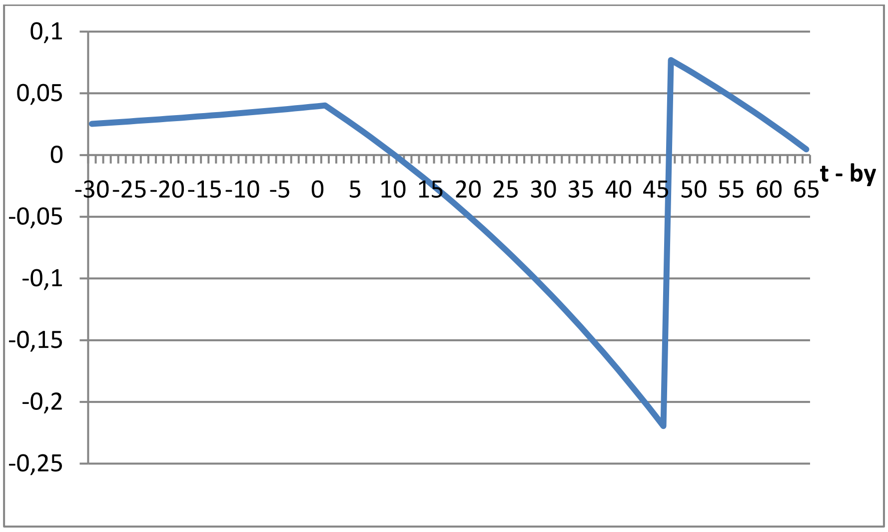
$$\Delta U_{t-by} = (1-p-du)(\frac{1+g}{1+r})^{sra+1-(t-by)} + \sum_{n=0}^{le-(t-by)} (\frac{p}{pop})(\frac{1+g}{1+r})^{le-(t-by)-n} \qquad (A.3.2)$$

In these expressions t and by respectively refer to the year of the increase of the sra and the birth year of the cohort, implying that, in case of the currently living cohorts, t – by denotes the age of the cohort in the year of the sra increase. In the case of the yet unborn cohorts t - by is negative and it represents the number of years that the sra is increased before the cohorts' birth.

Figure A.3.1 presents these effects if the sra is raised in year t under the assumptions that du equals 1, p equals 0.3, le and pop 65 years and the sra 45 years. The discount rate r and productivity growth rate g are respectively equal to 3 and 1.5 per cent. It shows that there is a clear conflict of interest between the cohorts. Cohorts above the age of the sra increase, in this stylized model at age 46, obviously benefit as they only have years with lower taxation ahead of them. The older the cohort the smaller this benefit becomes as a result of the declining life expectancy. The most disadvantaged cohorts are the ones just under the age at which the sra increase takes place. Below this age the net benefit becomes less negative the younger the cohort becomes because these cohorts increasingly benefit from the tax cut and the loss of pension income lies farther away and becomes less important in present value terms. At the age of ten the net benefit even becomes positive: the present value of the future tax cuts then outweighs the loss of pension income at age of the sra increase.

For the yet unborn cohorts, the cohorts for which t – by < 0, the present value slowly declines the more their birth year is higher than the year of the sra increase. This decline results from the fact that these benefits lie further ahead in the future and are therefore discounted at an increasingly higher rate. As a share of lifetime incomes however the benefit remains constant as these incomes are also discounted at the increasingly higher rate.

Figure A.3.1 Net lifetime benefit from an increase of the sra for different cohorts



The equivalence of aggregating present values of annual and cohort utilities

This paper uses the highest aggregate utility in each year as the criterion to determine the optimal future path for the sra increase with. As stated in the main text and illustrated above, an exercise that would base this choice on the effects on separate cohorts cannot lead to an unequivocal optimal outcome due to the inevitable conflict of interest between the cohorts. It would require that the policy maker would attribute weights to the interests of each of the cohorts. One possibility would then be to weigh all effects equally entailing that all future net benefits from the measure are attributed equal weights in present value terms irrespective of how these benefits are distributed across the cohorts. This would boil down to determining which future path of sra increases delivers the highest present value of future net benefits and this would result in the same outcome as the one followed in this paper as both exercises involve the maximization of future aggregate welfare, irrespective of its distribution.