# Illiquid Wealth and the Timing of Retirement

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**Abstract**

Retirement saving is relatively illiquid. We explore whether this can account for the clustering of retirement decisions around the normal retirement age. We construct a series of retirement models featuring realistic financial market frictions and pension systems. We then estimate these models using Dutch micro data on income, wealth, and retirement choices. We use the estimated model to simulate various pension reforms and examine their impact on labor force participation. The model can account well for the observed delay in the average age of retirement in the Netherlands between 2000 and 2016. A general message from the analysis is that households' willingness to retire early is very sensitive to the liquidity of their retirement savings.

## 1 Introduction

In many developed economies, aging populations are straining public finances. This population aging reflects a mix of rising longevity, coupled with the post-war surge in fertility coupled with lower fertility in more recent decades. Perhaps the key margin along with governments have responded to the associated fiscal pressure has been by increasing the normal retirement age, which directly reduces pension expenditure and also potentially stimulates labor force participation at older ages. Assessing the positive and normative implications of such policy changes requires being able to predict how workers will adjust both labor supply and savings.

In this paper we build a life-cycle model to address these questions, and use it to interpret recent changes in older-age labor force participation in the Netherlands. Between 2006 and 2016 the median age of retirement in the Netherlands rose dramatically from 60 to 64. Over the same period, the age at which households became eligible to start collecting public pensions rose from 65 to 65 and 6 months.

Our model is in most respects a standard life-cycle model. We innovate on one margin, which is to recognize that a lot of retirement wealth is relatively illiquid prior to the normal retirement age. For example, in the US there is a tax of x percent on early withdrawals from 401(k) retirement plans. Our analysis starts with a simple continuous-time model in which retirement and savings decisions can be characterized analytically. Workers face no uncertainty, and can borrow and lending freely subject only to a constraint that accessing retirement saving prior to the normal retirement age is costly. The key choice is when to retire, which trades off the utility cost of working a little longer against the benefit of higher lifetime income and consumption. Workers are heterogeneous with respect to earnings and the disutility of work effort, which generates heterogeneity in the optimal retirement age.

We highlight two key model properties. The first is that the model with illiquid retirement wealth generates clustering in the timing of retirement at the normal retirement age. This is a striking feature of observed retirement behavior in many countries. Absent illiquid retirement wealth there is no such clustering. The second interesting model property is that it predicts a discrete step down in consumption at the age of actual retirement, for those workers who choose to retire early (followed by a step back up once they reach the normal retirement age). A decline in consumption at retirement age is another well-known feature of the data. Moreover this fact is a priori puzzling from the standpoint of standard consumption theory, given that life-cycle wealth is typically maximized around retirement age. In contrast, we show that reducing consumption is optimal when assets are relatively more illiquid prior to the normal retirement age.

How do model workers respond to − possibly pre-announced − changes in pension policy? Suppose, for example, that the pension replacement rate is reduced. We show that households who are optimally retiring either early or late will respond primarily by adjusting their planned date of retirement, while those who are optimally retiring exactly at the normal retirement age will instead adjust consumption. If the normal retirement age is increased, without changing expected lifetime pension income, early and late retirees will not respond much, but those retiring at exactly the normal age will delay retirement.

After describing our simple model we introduce a richer version of the model that is the focus of our quantitative analysis. This model features realistic age-dependent mortality risk, realistic lifecycle earnings profiles, and a pension system with a lump-sum component and a component indexed to lifetime earnings. In addition, the utility of cost of working is allowed to vary by age, since the slope of this cost around retirement ages plays a quantitatively important role in determining the sensitivity of the retirement age to changes in pension policy parameters.

We calibrate the joint distribution over model income and disutility of work to replicate the respective observed variances of lifetime earnings and retirement age in the Netherlands, and the correlation between income and retirement age. We set the proportional cost of selling assets prior to retirement to replicate the share of workers retiring exactly at the normal retirement age. We then feed into the model statutory changes in the normal retirement age and wealth losses reflecting asset price declines during the Great Recession.

The first question we address is whether the model can account for the average delay in retirement age observed over this period, as well as the changes

Figure 1: Average Retirement Age by Education Groups.

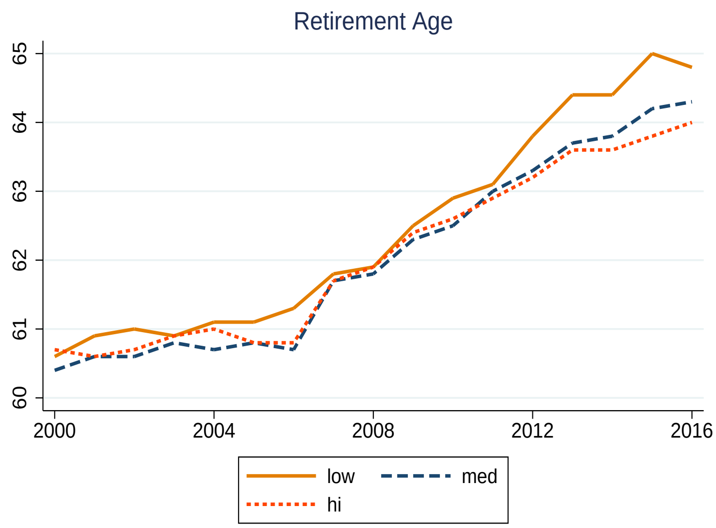


Figure 1 shows the average retirement age of Dutch individuals between 2000 and 2016. The retirement age has been relatively constant until 2006, after which it started to increase rapidly.

in retirement patterns by income and wealth. We then use the model to forecast future labor force participation rates, to evaluate the welfare implications of the Dutch reforms, and to decompose the relative roles of the reforms versus asset price declines in accounting for observed changes in retirement patterns.

## 2 Data

Over the last decade, the labor force participation rate of older-age individuals has increased dramatically in the Netherlands. From 2006 to 2016, the average retirement age has increased from 60 to 64 as shown in Figure 1. The increase in the labor force participation rate of older-age males is driven by strong increases in the labor force participation rate between the ages 59 and 65, while female labor force participation has increased at all ages from 55 and 65. This is shown in Figure 2.

What factors could drive such a dramatic increase in the older-age labor force participation rate? To understand whether the rise in labor force participation will persist, and to understand how it is driven by changes in retirement policy it is important to study the drivers of the observed increase in the older-age labor force participation rate.

In this section, we consider a number of potential explanations for the observed rise in the labor force participation rate. In particular, we explore losses

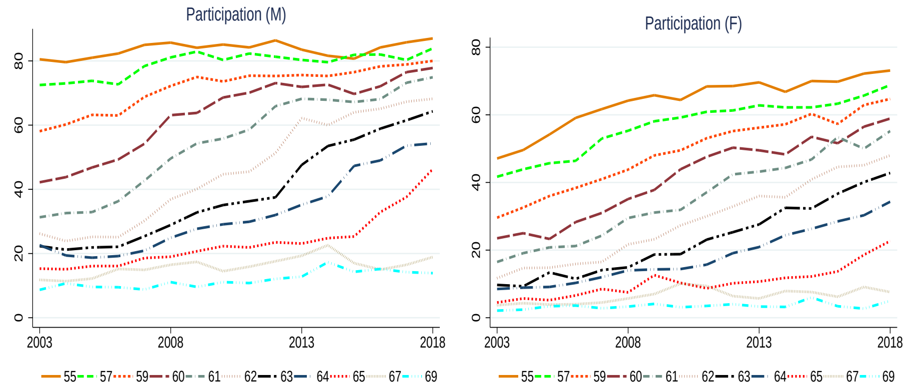


Figure 2 documents the labor force participation between 2003 and 2018 for men and women between the ages of 55 and 69. The left-hand panel shows the participation rates for men, the right-hand panel shows the participation rates for women.

Figure 2: Older-Age Labor Force Participation

in both financial and housing wealth in the Great Recession, increased mortality, and changes in retirement policy. In the next section, we introduce a life-cycle model incorporating these factors that we will use to quantify their importance in explaining the observed increase in the labor force participation rate.

When retired, households can finance consumption using private wealth or their pension income. When faced with adverse shocks to their private savings or their pension income, households can compensate by increasing their labor supply, or by reducing their consumption. To the extent that households adjust through labor supply, we expect expect households to delay retirement in response to adverse wealth shocks and changes to pension income. Over the last decade Dutch households have experienced both adverse wealths and changes in their pension income.

**Great Recession**. Over the course of the Great Recession, Dutch households on average lost a quarter of their private wealth as is shown in the left-hand panel of Figure 3. Between 2008 and 2013 households lost on average about 50 thousand euros. This loss is equivalent to the mean after-tax household income, and about 1.5 times median after-tax household income.

A large share of the wealth losses were concentrated on homeowners. On average, Dutch house prices declined from their peak in 2008, at 285 thousand euros, to about 215 thousand euros in 2013 as is shown in right-hand side panel of Figure 3. The average house price decline, however, masks significant geographic variation.

Interestingly, and useful for the identification of the effect of housing wealth-effect on labor supply, we see significant regional variation in this decline of

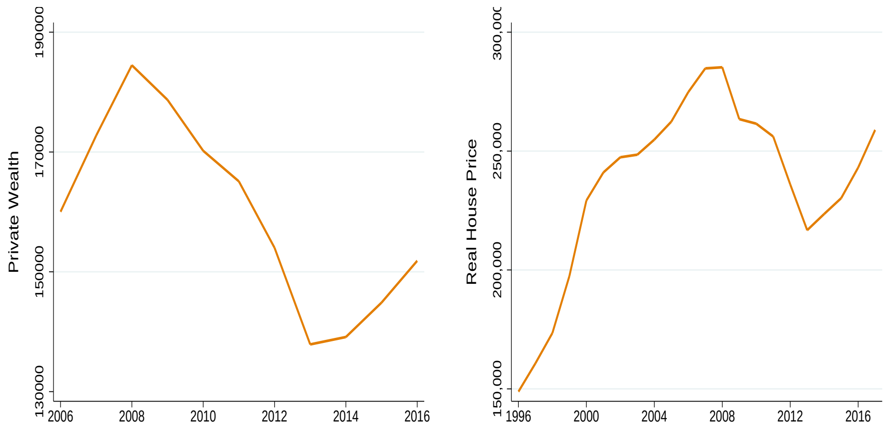


Figure 3 documents the changes in private wealth and real house prices over the course of the Great Recessions. Private wealth decreased by roughly 50 thousand euros (left-hand panel); real house prices declined on average by 70 thousand euros.

Figure 3: Private and Housing Wealth in the Great Recession

house prices, and in their recovery from 2013. To illustrate this variation, we plot the changes in house prices relative to their pre-crisis peak for the three most-populated regions in Figure 4. The regions Noord-Brabant, Noord-Holland and Zuid-Holland capture about half of the country's population. Zuid-Holland has seen a smaller decline and a slow recovery, Noord-Holland experienced a sharp decline and a fast recovery, while Noord-Brabant experienced an equally sharp decline and a slow recovery.

**Retirement Policy**. Over the past two decades, the Dutch pension system has gone through two major reforms. First, the tax-favored status of early retirement programs was abolished in 2005. Second, the normal retirement age has been increased since 2013.

In 2005, the government abolished the favored status of early retirement programs. Starting January 2006, contributions towards early retirement were no longer tax-deductible. Prior to 2006, contributions towards early retirement programs were tax-deductible, while the pension income in early retirement was taxed. After 2006, the contributions are not tax-deductible, while the pension income in early retirement is exempted from taxes.

The normal retirement age used to be 65, but has been gradually increasing since 2013. In Table 1, we show the normal retirement age for every individual born before October 30 1956. It is still possible to opt for early retirement, but this must be financed independently as your public pension is not issued until you reach the normal retirement age. Similarly, individuals can work past the normal retirement age which increases their benefits and allowance.

We provide more detail about the Dutch pension system in Appendix A.

Figure 4: Regional Variation in House Prices by Education Groups.

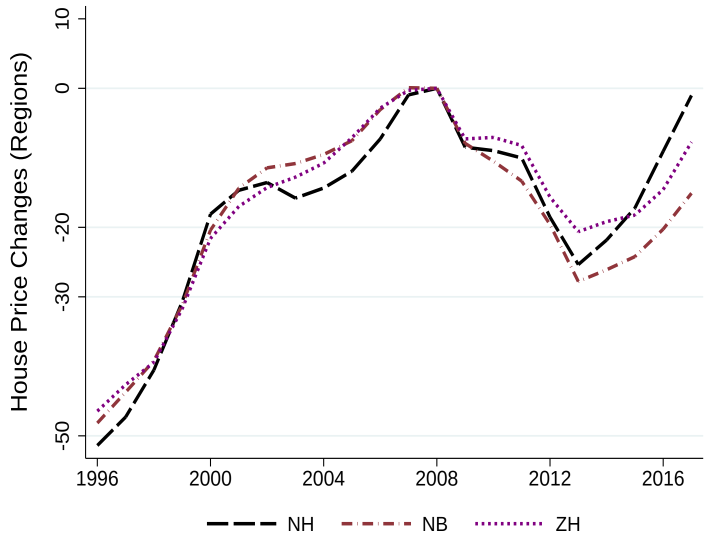


Figure 4 shows the regional variation in house price changes between 1996 and 2016 relative to their pre-crisis peak in 2008. The lines are for the three most populated regions of the Netherlands: Noord-Holland (NH), Noord-Brabant (NB) and Zuid-Holland (ZH).

**Increased Life Expectancy**. Increased life expectancy is another potential force towards delaying retirement. To finance the desired consumption levels for more retirement periods, households may have to work longer. To explore the quantitative potential of this mortality channel, we examine empirical survival probabilities. In particular, we document the survival probabilities conditional on being alive at age 25 for the cohorts 1946-1950, 1951-1955 and 1956-1960 in Figure 5. These are cohorts that have retired in the last decades and are expected to retire in the near future.

The left panel of Figure 5 shows that survival probabilities for men have hardly changed across the three cohorts. To illustrate, the probability of reaching age 60 was 79.1% for the cohort of men born between 1946 and 1950 and 79.6% for the cohort born between 1956 and 1960. Similarly, the probability of reaching age 85 was 19,0% and has increased to 20.1%.

The survival probabilities for women, however, have improved significantly for the same cohorts as is shown in the right-hand panel of Figure 5. Women born into the 1946-1950 cohorts expected to reach age 60 with a probability of 86.0%, while women born between 1956 and 1960 had a 87.1% probability. For reaching age 85, the respective probabilities are 21.7% and 26.6%.

Table 1: Normal Retirement Age for Dutch Individuals by Date-of-Birth

| Minimum Birth Date | Maximum Birth Date | Year for AOW | Age AOW |
|---|---|---|---|
| | Dec 31, 1947 | 2012 | 65 |
| Jan 1, 1948 | Nov 30, 1948 | 2013 | 65 + 1/12 |
| Dec 1, 1948 | Oct 31, 1949 | 2014 | 65 + 2/12 |
| Nov 1, 1949 | Sep 30, 1950 | 2015 | 65 + 3/12 |
| Oct 1, 1950 | Jun 30, 1951 | 2016 | 65 + 6/12 |
| Jul 1, 1951 | Mar 31, 1952 | 2017 | 65 + 9/12 |
| Apr 1, 1952 | Dec 31, 1952 | 2018 | 66 |
| Jan 1, 1953 | Aug 31, 1953 | 2019 | 66 + 4/12 |
| Sep 1, 1953 | Apr 30, 1954 | 2020 | 66 + 8/12 |
| May 1, 1955 | Dec 31, 1954 | 2021 | 67 |
| Jan 1, 1955 | Sep 30, 1955 | 2022 | 67 + 3/12 |
| Oct 1, 1955 | Sep 30, 1956 | 2023 | 67 + 3/12 |

Table 1 shows the normal retirement age for individuals born prior to October 1, 1956. For individuals born after October 1, 1956 the lower bound on the normal retirement is 67 years and 3 months. Further adjustments in the normal retirement age will be related to adjustments in life expectancy from 2022 onwards.

Figure 5: Survival Probability

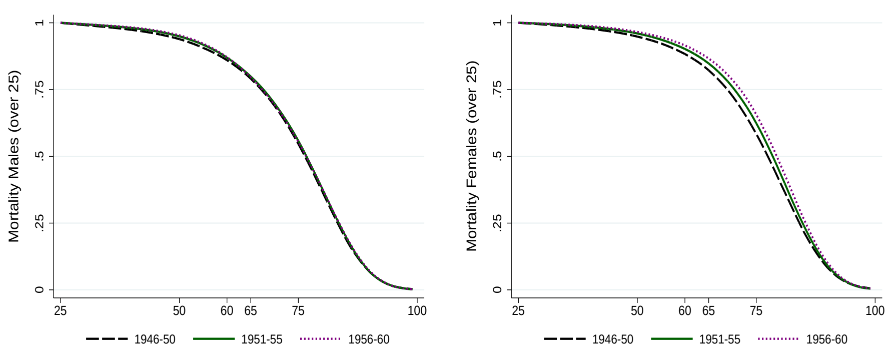


Figure 5 plots the survival probabilities for men and women for the cohorts 1946-50, 1951-55 and 1956-60 conditional on reaching age 25. Survival probabilities for men (left panel) show little improvement, while survival probabilities of women have improved. Women born into the 1946-1950 cohorts expected to reach age 60 with a probability of 86.0%, while women born into between 1956 and 1960 had a 87.1% probability to reach 60.

# 3 Environment

We consider an overlapping generations economy. Time is continuous. There is no aggregate risk, and uncertain longevity is the only source of idiosyncratic risk. Individuals make two decisions: a standard consumption savings choice, and a decision about when to retire. They are heterogeneous with respect to labor earnings, preferences for work and the timing of consumption, and expected longevity. These are all potentially important sources of heterogeneity in the timing of retirement. We will study transitions to unanticipated shocks to the economy. Our primary focus will be on shocks to details of the pension system. We will also consider shocks to wealth, to the equilibrium interest rate, and to expected longevity.

## 3.1 Demography

People are born at age $a = 0$ and live to maximum possible age $A$. When they enter the economy individuals draw a type $x$ which determines their expected earnings profile, preferences, and expected longevity.

Let $S(a; x)$ denote the probability of surviving from age 0 to age $a$ conditional on an individual being of type $x$.

## 3.2 Preferences

Individuals derive utility from consumption $c$ and disutility from labor supply $l$. The choice set for $l$ is restricted to $l \in \{0, 1\}$. Retirement is also irreversible, so agents effectively choose a retirement age $a_R$. The period utility function at age $a$ is

$$u(c, l; x, a) = \frac{c^{1-\gamma}}{1-\gamma} - \varphi(a; x)l \ .$$

where the utility cost of working $\varphi(a; x)$ potentially varies with both age and type. An individual's pure discount rate $\rho(x)$ is age-invariant but potentially type-specific.

Thus, expected lifetime utility is

$$U(x) = \int_0^A S(a; x) \exp(-\rho(x)a) \left( \frac{c(a)^{1-\gamma}}{1-\gamma} - \varphi(a; x)l(a) \right) da$$

where $c(a)$ and $l(a)$ should be interpreted as consumption and hours conditional on being alive.

## 3.3 Income and Credit

Conditional on working, labor income at age $a$ for type $x$ is $y(a; x)$. Labor income is taxed at a proportional rate $\tau$. Individuals can save at a constant interest rate $r$. They can borrow up to an age-varying limit $\underline{b}(a)$, where $\underline{b}(A) = 0$.

There is a normal retirement age $A_N$. We will generally impose $\underline{b}(a) = 0$ for $a \geq A_N$.

In addition to borrowing constraints, there is a second asset market friction, which is that selling illiquid assets is potentially costly. In particular, there is a liquidation cost $\chi(a)$ per unit of assets sold. This cost is designed to capture taxes and transaction costs associated with running down retirement saving, such as early withdrawal penalties from tapping 401(k) style retirement accounts, or costs associated with downsizing housing.

There are no private annuity markets allowing agents to insure against the risk of leaving unintended bequests. If $\underline{b}(a) < 0$ individuals can potentially die with debts.

## 3.4 Pension System

When individuals live beyond the normal retirement age, they collect a fixed pension from $A_N$ until death. The size of the pension depends on the retirement age $a_R$ and on the value of lifetime earnings up to the normal retirement age,

$$Y(a_R; x) = \int_0^{a_R} e^{r(A_N - a)} y(a; x) da$$

In our baseline model the pension will take the form

$$p(a_R, x) = p_0(a_R) + p_1(a_R) Y(a_R; x)$$

where $p_0(a_R)$ defines a lump-sum pension component, and $p_1(a_R)$ captures the sensitivity of pensions to accumulated lifetime earnings (and thus lifetime tax payments). Both these coefficients potentially vary with $a_R$ to reflect the idea that pensions typically rise with retirement age, although not necessarily in an actuarially fair way.

## 3.5 Budget Constraints

Let $b(a)$ denote household wealth at age $a$ and let $s(a)$ denote active saving at age $a$:

$$s(a) \equiv \mathbb{I}_{\{a < a_R\}} y(a; x)(1 - \tau) + \mathbb{I}_{\{a \geq a_R \text{ and } a \geq A_N\}} p(a_R; x) - c(a)$$

The law of motion for wealth is

$$\dot{b}(a) = \begin{cases} s(a) + rb(a) & \text{if } s(a) \geq 0 \\ \frac{s(a)}{1 - \chi(a)} + rb(a) & \text{if } s(a) < 0 \end{cases}$$

Note that if active saving is positive, the law of motion is standard. When active saving is negative – illiquid assets are being sold – then the rate of asset decumulation is effectively accelerated.

Households face a lifetime budget constraint

$$\int_0^A \exp(-ra)\frac{s(a)}{\mathbb{I}_{\{s(a)\geq 0\}}(1-\chi(a))}da \geq 0$$

and a sequence of credit constraints of the form $b(a) \geq \underline{b}(a)$ for all $a$, where

$$b(a) = \int_0^a \exp(rz)\frac{s(z)}{\mathbb{I}_{\{s(z)\geq 0\}}(1-\chi(z))}dz.$$

Note that since there are no private annuity markets, survival probabilities do not enter the household budget constraints.

The household problem is to maximize expected lifetime utility by choosing sequences $c(a)$, $s(a)$, $b(a)$ and a retirement age $a_R$, subject to the budget and borrowing constraints described above.

# 4 Analytic Example 1

To develop intuition about how pension system parameters drive retirement choices, we now consider a special version of the model which delivers closed-form characterizations for optimal consumption and savings decisions, and the optimal age of retirement. In particular, assume that risk aversion $\gamma$ is equal to one, so utility is logarithmic in consumption. In addition, assume there is no mortality risk prior to maximum age $A(x)$, i.e., $S(a;x) = 1$ for all $a \leq A(x)$.

Individuals' discount rate and the interest rate are both zero: $\rho = r = 0$. Liquidation costs apply only prior to the normal retirement age: $\chi(a) = \chi$ for $a < A_N$ and $\chi(a) = 0$ for $a \geq A_N$. Earnings and the disutility of work are age-invariant:

$$\begin{aligned} y(a;x) &= y(x) \\ \varphi(a;x) &= \varphi(x) \end{aligned}$$

The pension received post retirement is given by

$$p(a_R;x) = \begin{cases} 0 & \text{if } a_R < A_N \\ \frac{A-A_N}{A-a_R}\left[p_0 + p_1 y(x) a_R\right] & \text{if } a_R \geq A_N \end{cases}$$

Lifetime utility is given by

$$U = \int_0^A \log(c(a))da - a_R\varphi(x)$$

and the lifetime budget constraint is

$$\int_0^A \frac{\mathbb{I}_{\{a<a_R\}}y(x)(1-\tau) + \mathbb{I}_{\{a\geq a_R \text{ and } a\geq A_N\}}p(a_R;x) - c(a)}{\mathbb{I}_{\{s(a)\geq 0\}}(1-\chi(a))}da \geq 0$$

In addition, we require $\underline{b}(a) = 0$ for $a \geq A_N$.

Assuming the pension system is not too generous and/or that borrowing constraints are sufficiently loose, individuals in this economy are never borrowing constrained.

If households choose $a_R \geq A_N$, they will accumulate private savings during the working phase of life, and decumulate private savings in retirement. Given that all asset decumulation will occur after the normal retirement age, they will never incur any liquidation costs. Thus, given $\rho = r = 0$, they will choose perfectly flat life-cycle consumption satisfying

$$c(a) = \frac{1}{A}\Big[a_R y(x)(1-\tau) + (A - a_R)p(a_R;x)\Big] \,.$$

However, if individuals choose to retire before the normal retirement age, there will be an interval of time $a \in (a_R, A_N)$ during which they receive no labor income and no pension income. Consumption during this period must be financed via asset sales, which will incur liquidation costs. The first order condition for optimal consumption indicates that

$$\begin{array}{ll} \frac{1}{c(a)} = \mu & \text{for } a \leq a_R \text{ and } a \geq A_N \\ \frac{1-\chi}{c(a)} = \mu & \text{for } a \in (a_R, A_N) \end{array}$$

where $\mu$ is the multiplier on the lifetime resource constraint. The logic is that liquidation costs act as a tax on consumption during retirement prior to the normal retirement age, which depresses the level of optimal consumption during that period. Let $\bar{c}(a_R)$ denote the consumption level outside the early retirement period, i.e. for $a \notin (a_R, A_N)$ , as a function of the choice for $a_R$. By the lifetime budget constraint, this is given by

$$\begin{aligned} & a_R y(x)(1-\tau) + (A(x) - a_R)p(a_R;x) \\ =& a_R\bar{c}(a_R) + (A_N - a_R)\left[(1-\chi)\bar{c}(a_R) + \chi\bar{c}(a_R)\right] + (A(x) - A_N)\bar{c}(a_R) \end{aligned}$$

where the second term on the left hand side captures the sum of both actual consumption and associated incurred liquidation costs. This implies

$$\bar{c}(a_R) = \frac{1}{A(x)}\left[a_R y(x)(1-\tau) + (A(x) - a_R)p(a_R;x)\right]$$

and hence

$$\begin{array}{ll} c(a) = \bar{c}(a_R) & \text{for } a \leq a_R \text{ and } a \geq A_N \\ c(a) = (1-\chi)\bar{c}(a_R) & \text{for } a \in (a_R, A_N) \end{array}$$

The last thing to compute is the optimal retirement age $a_R$. Given a choice for $a_R$, expected lifetime utility is given by

$$\begin{aligned} U(x) &= \int_0^{A(x)} \log\big((1 - \mathbb{I}_{\{a\in(a_R,A_N)\}}\chi)\bar{c}(a_R)\big)\, da - \int_0^{a_R} \varphi(x)da \\ &= A(x)\log\bar{c}(a_R) + \mathbb{I}_{\{a_R<A_N\}}(A_N - a_R)\log(1-\chi) - a_R\varphi(x) \end{aligned}$$

Differentiating with respect to $a_R$ we obtain

$$\begin{aligned} 0 &= A(x)\frac{\bar{c}'(a_R)}{\bar{c}(a_R)} - \mathbb{I}_{\{a_R<A_N\}}\log(1-\chi) - \varphi(x) \\ &= \frac{[y(x)(1-\tau) + (A(x)-a_R)p'(a_R;x)] - p(a_R;x)}{\bar{c}(a_R)} - \mathbb{I}_{\{a_R<A_N\}}\log(1-\chi) - \varphi(x) \\ &= \frac{y(x)(1-\tau) + (A-A_N)\,p_1 y(x)}{\bar{c}(a_R)} - \mathbb{I}_{\{a_R<A_N\}}\log(1-\chi) - \varphi(x)\ . \end{aligned}$$

The intuition for this expression is as follows. For an individual considering delaying retirement on the margin, the payoff is the increment to consumption (after-tax earnings plus the gain in expected pension), which is valued at the marginal utility of consumption. In addition, the individual possibly economizes on liquidation costs, by reducing the length of time during which he is selling assets. The cost is that he must work a little longer, at cost $\varphi(x)$.

Taking a second derivative, it is straightforward to show that lifetime utility is a concave function of $a_R$. Note, however, that the slope of the first order condition changes discretely at $a = a_R$. There are therefore three possible solutions for optimal retirement, which will depend on the values for $A(x)$, $y(x)$ and $\varphi(x)$.

A type $x$ will optimally retire prior to the normal retirement age iff

$$\frac{A(x)}{\log(1-\chi)+\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)} < A_N$$

A type $x$ will optimally retire after the normal retirement age iff

$$\frac{A(x)}{\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)} > A_N$$

A type $x$ will optimally retire exactly at the normal retirement age iff

$$\begin{aligned} \frac{A(x)}{\log(1-\chi)+\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)} &> A_N \text{ and} \\ \frac{A(x)}{\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)} &< A_N \end{aligned}$$

Next, we will use this characterization of the solution to study a number of special cases.

## 4.1 Case 1: Early Retirement

Assuming early retirement, the first order condition for $a_R$ is

$$\begin{aligned} \frac{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)}{\frac{1}{A(x)}\left[a_R y(x)(1-\tau)+(A(x)-a_R)\frac{A-A_N}{A-a_R}\left[p_0+p_1 y(x) a_R\right]\right]} - \log(1-\chi) - \varphi(x) &= 0 \\ \frac{y(x)(1-\tau)+(A(x)-A_N)\,p_1 y(x)}{\frac{1}{A(x)}\left[a_R y(x)(1-\tau)+(A(x)-A_N)\left[p_0+p_1 y(x) a_R\right]\right]} - \log(1-\chi) - \varphi(x) &= 0 \end{aligned}$$

$$a_R = \frac{A(x)}{\log(1-\chi)+\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{[(1-\tau)+(A(x)-A_N)\,p_1]\,y(x)}$$

The comparative statics are straightforward. A stronger distaste for work (larger $\varphi(x)$) will translate into earlier retirement. Higher earnings while working (larger $y(x)$) will translate into later retirement. A longer expected lifetime (larger $A(x)$) will translate into later retirement. Importantly, more illiquid is retirement savings (larger $\chi$) translate into later retirement. Comparing this optimality condition for early retirement to the optimality condition for late retirement, we learn that liquidation costs of retirement savings will lead to clustering of retirement decisions.

## 4.2 Case 2: Late Retirement

For individuals retiring after the normal retirement age, we have

$$a_R = \frac{A(x)}{\varphi(x)} - \frac{(A(x)-A_N)\,p_0}{[(1-\tau)+(A(x)-A_N)\,p_1]\,y(x)}$$

The comparative statics in late retirement generally follow from the comparative statics for the early retirement case. Provided that individuals retire late, local changes in the liquidation costs do not affect retirement decisions.

## 4.3 Case 3: Normal Age Retirement

It is straightforward to compute ranges of values for $y(x)$, $\varphi(x)$ or $A(x)$ such that retirement exactly at $A_N$ is optimal.

## 4.4 Quantitative Example

To get some idea about the quantities, we construct a numerical example. We take a public policy with $\tau = 0$, $p_0 = 0.75$ and $p_1 = 0$. We will set $A_N = 0.67$, $A = 0.80$, $\varphi = 1.05$ and $y = 1$.

Given the numbers, $A_R = 0.6644$ using $\chi = 0$ and $A_R = 0.6809$ with $\chi = 0.05$. Thus, given the actual system, individuals retire at $A_N$.

More generally, households that will prefer to retire exactly at $A_N$ are all those with $y \in [y_L, y_H]$ where

$$y_L = \frac{p\,(A-A_N)+B_0}{\frac{A}{\varphi+\log(1-\chi)} - A_N} = 0.74407$$

$$y_H = \frac{p\,(A-A_N)+B_0}{\frac{A}{\varphi} - A_N} = 1.06088$$

Low-income individuals ($y < y_L$) choose $A_R < A_N$ and high-income individuals choose $A_R > A_N$.

Suppose we now double $\chi$ from 0.05 to 0.1. The clustering range expands to $y_L = 0.55120$ and $y_H = 1.06088$. So there is quite a wide range of income values that will cluster at $A_N$ even though $\chi$ is pretty small here.

Our takeaway from this simple example is that a reasonable calibration of liquidation costs gives rise to a significant clustering of retirement decisions. We next examine this mechanism in a rich stochastic, quantitative environment which we calibrate to the match the observed variances of lifetime earnings and retirement ages in the Netherlands.

## Appendix A Pension Policy

The Dutch pension system is built on three pillars: a public pension, a collective employer-based pension and private savings, and rests on the idea that each generation should pay their own pension. The pension system is intended to amount to about 70% of average lifetime pay. Most workers have defined-benefit pensions based on average lifetime pay, with accrual rates between 1.75 and 2.25 percent for each year of service.

**Public Pension**. The first pillar of the pension system is a public pension, intended to provide a minimum level of income to all pensioners. Every individual who lives or works in the Netherlands builds up a public pension. Every individual earns 2% of the maximum public pension amount every year before the legal retirement age. So between ages 15 and 65 an individual builds up full entitlement. An individual does not have to work to build up a public pension. In the remainder, we discuss a public pension benefits considering a household with a full public pension.

The level of the public pension is determined in relation to the legal minimum wage. A rule-of-thumb is that single households receive a public pension equal to 70% of the net minimum wage, while couples jointly receive 100% of the net minimum wage. For 2017, this implies that a retired couple receives a total annual benefit of 20,613 euro. Depending on their income level, household pays taxes over their public pension income.

**Employer-Based Pension**. The second pension pillar is employer-based, with premia and payouts varying with lifetime earnings. The employer pension aims to provide households a replacement rate of 70% of average annual earnings upon retirement. This replacement rate incorporates the public pension. Individuals do not have an employer-based pensions if they never worked, when they are self-employed, or in case their employer did not arrange a pension. More than 90% of all firms provide pension arrangements for their employees.

Under the employer-based pension system, an employer pays more than half of the pension premia into a collective investment fund, with the remainder being contributed by the employee. Pension provision through collective investment funds by employers and employees is based on industry-wide or firm-specific agreements (for large firms, e.g. ING, Philips and Shell). The employer pension is deferred income for employees, the employer directly contributes their share of the premium into the investment entity.

To finance the pension system, workers transfer a total of about 18% of their pay into professional pension funds. Employers also contribute to the system, but their payments are capped. Companies, as well as public-sector employers, typically band together by sector in big, pooled pension plans, which hire nonprofit firms to invest the money.

About 94% of all employees are covered by defined-benefit pension schemes. This high pension coverage is because of mandatory participation in industry-wide pension funds when such a pension scheme is set up by trade unions or employment organizations.[1] About 98% of the defined benefit schemes are based on lifetime average earnings. All pension benefits are indexed to wage growth, inflation or a combination of the two.

[1] See Beetsma and Chen, 2013.