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# A STRUCTURAL DYNAMIC ANALYSIS OF RETIREMENT BEHAVIOUR IN THE NETHERLANDS

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SUMMARY

This study focuses on determinants of elderly labour force participation and retirement decisions in the Netherlands. This is analysed by a dynamic programming model for the simultaneous choice of retirement age and route, which includes social insurance and private pensions, eligibility conditions for early retirement, lifecycle wage and health profiles, and layoffs. Special attention is given to opportunities for and the effect of participation policies. Results show that institutional structures of benefit and pension programmes are prime determinants of retirement, particularly eligibility conditions and potential substitution between exit routes, and that dynamic aspects are relevant for understanding retirement behaviour. Copyright © 2004 John Wiley & Sons, Ltd.

## 1. INTRODUCTION

Recent studies on retirement behaviour, for example by Rust and Phelan (1997), Benítez-Silva *et al.* (2000) and French (2000), have indicated that the labour supply decision of elderly workers is best represented by a dynamic process in which traditional explanatory variables, such as earnings, benefits, pensions and health conditions, play an important, but not exclusive, role. Incentives for retirement vary between ages, depending on the structure of social insurance, pension provisions and health insurance. A change in one of these incentives has consequences that depend on other incentives within that structure and on the influence of uncertainty about future socio-economic circumstances. Policy measures, for instance to increase labour force participation of the elderly, should therefore not be taken in isolation, but as part of an integral policy to change the structural framework of incentives for retirement.

Like in many other OECD countries with ageing populations, the urge for increasing elderly labour force participation is high in the Netherlands. Dutch elderly participation rates are extremely low. In 1998, only 20% of all males aged 60 to 65 and 6% of all females aged 60 to 65 were still active in the labour market. For people aged 55 to 60, labour force participation rates were 65% for males and 26% for females. Compared to middle-aged groups, this reflects a dramatic fall in participation over age. Compared to the OECD average, elderly labour force participation rates were around 20 percentage points lower for both males and females (see Figure 1). Dependency rates, expressed as the number of people aged 50 and older as a percentage of people aged 20 to 49, are expected to increase from 65% in 1998 to 109% in 2030 (CBS, 1999a).

The decline in elderly labour force participation that started in the 1950s induced researchers to consider retirement as a special case of labour force participation (Bowen and Finigan, 1969; Feldstein, 1974; Quinn, 1977). Since then, the modelling approach in the retirement literature has

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Figure 1. Dutch labour force participation rates, 1998. *Source*: CBS (1999b), Labor Force Survey and OECD (1999), Employment Outlook.

changed from static reduced form models to structural dynamic programming models. Although static models are able to explain part of retirement behaviour as a result of financial incentives and health conditions (Boskin and Hurd, 1978; Parsons, 1980), the theoretical lifecycle framework in Feldstein (1974) made it clear that current income levels by themselves cannot fully explain retirement patterns. Future income opportunities are also important. Later, Burkhauser (1979) and Burkhauser and Quinn (1983) showed that lifecycle compensation and particularly eligibility structures are important explanatory factors for retirement behaviour. Burkhauser (1980) found that not just annual values, but the entire stream of future earnings is a major determinant of early retirement. The main focus of the retirement literature became directed towards the estimation of simple reduced form models that included detailed information on lifecycle income patterns (Fields and Mitchell, 1984a,b). A problem with this approach is that uncertainty about real future values cannot be included in the model. Anderson *et al.* (1986) addressed the issue of uncertainty by estimating the effects of unanticipated changes in economic circumstances on retirement plans. Their results support a lifecycle theory of rational expectations. A structural and empirical retirement model based on the optimization of lifetime utility, determined by consumption and leisure, was developed by Gustman and Steinmeier (1986). It was one of the first models that was able to explain the US retirement peaks at age 62 and 65, using very detailed lifecycle compensation profiles. The model was a big step towards a structural analysis of retirement, but was not yet flexible enough for general applications.

Lazear (1986), Hurd (1990) and Quinn and Burkhauser (1990) point, in their reviews of the retirement literature, at the need for structural retirement models that include lifecycle income patterns as well as uncertainty towards the future decision environment. Starting with the work of Rust (1989), dynamic programming models seem to provide a framework in which these demands can be met. Rust estimated an intertemporal retirement model for the choice between consumption and leisure. In order to reduce computational complexities, Lumsdaine *et al.* (1990) and Stock and Wise (1990) simplify their dynamic programming approach to non-equivalent option value models. Berkovec and Stern (1991) solve the computational complexities of dynamic programming by estimating a discrete time–discrete state model of job exit behaviour by the method of simulated moments. They show that dynamic modelling explains behaviour better than a static approach. Blau (1994), Christensen and Gupta (1994) and Daula and Moffitt (1995) use the dynamic programming framework to derive reduced form retirement models that are easier to estimate. A very sophisticated dynamic programming model that analyses the impact of Social Security and Medicare on the retirement decision of elderly Americans is presented by Rust and Phelan (1997). They show that the main advantage of the dynamic programming structure is the ability to measure the effect of changes in uncertain future circumstances, allowing for an intertemporal evaluation of opportunities.

The present study uses the dynamic programming framework to provide insight into the dynamics between institutions, earnings, health and retirement behaviour in the Netherlands. It shows how early retirement depends on the incentive structure of the Dutch social insurance and pension system, which is represented by multiple paths that distinguish early retirement from disability and unemployment. The demand side of labour is represented by an integrated layoff probability. The basic hypothesis is that the retirement decision is a choice between consumption and leisure, given institutions, working conditions, health conditions and the risk of involuntary retirement. Section 2 provides an overview of the Dutch social insurance and private pension system. Section 3 derives a structural dynamic programming model of retirement behaviour. Data are used from the two-wave CERRA[1] panel survey, held in 1993 and 1995 among 4727 Dutch elderly households. Section 4 shows estimated retirement behaviour in the Netherlands. An analysis of variance is provided in Section 5 by means of model simulations under different policy conditions. Section 6 concludes.

## 2. SOCIAL INSURANCE AND PENSIONS IN THE NETHERLANDS

In the context of retirement, all social insurance and pension programmes available to workers to substitute or complement wages can be considered alternative sources of income that enable more leisure. Benefits from these programmes depend on eligibility rules, labour market history and personal characteristics, such as health and marital status. The purpose of this section is to show the main features of the most common Dutch social insurance and pension programmes.[2]

Three key features of the Dutch social insurance system are particularly important for retirement behaviour. Firstly, the age of normal retirement at 65 is effectively the age of mandatory retirement. Although retirement is not strictly compulsory, all layoffs at age 65 are approved by the regional employment office, which evaluates all involuntary job exits. Therefore, labour force participation beyond age 64 is negligible. Secondly, and as a result, most pensions and benefits prior to age 65 are independent from pension programmes that come into effect after age 65. Income programmes for normal and early retirement must therefore be treated separately, although benefit and eligibility

[1] CERRA stands for Centre for Economic Research on Retirement and Ageing.

[2] Although benefits and pensions may be used to complement wage income, only those benefits and pensions are treated that are collected at zero hours of work, motivated by the small number of part-time workers (<32 hours per week) with these sources of non-wage income in the data (7%). Part-time workers are considered non-retirees.

 

rules may be linked. And thirdly, the use of disability and unemployment benefit programmes as pathways into retirement has become common practice with the mutual consent of employers, unions and the Dutch government (see Trommel and de Vroom, 1994; Aarts and de Jong, 1990). Table I shows the distinction between programmes that are available before and after age 65, and between programmes that are part of the social insurance system and which are provided by employers under a collective agreement.

Collective early retirement pensions or VUT schemes (VUT means Early Retirement) were introduced in the late 1970s, designed to create labour market opportunities for the young unemployed. Within two decades they became very popular. VUT schemes were sector or company specific, negotiated with unions, and embedded in Collective Labour Agreements. Only recently, these VUT schemes have changed into less generous flexible pension schemes. In the majority of cases, eligibility depended on age, tenure, or both. The average required age in the CERRA survey is 59. The required tenure varies between 10 and 40 years. VUT pensions equaled a fixed percentage of last earned wage income. In the majority of cases this varied between 70 and 90%. Since early retirement schemes are meant to bridge the income gap between early and normal retirement, they provide fixed pensions up to age 65. A comparison of the main characteristics of early retirement pensions with other benefit programmes is given in Table II.

Disability insurance (DI) protects workers against the loss of income due to physical or mental inability to participate in gainful employment. The programme covers all Dutch citizens between ages 18 and 65. Eligibility depends on the degree of disability, which is based on the earning ability of the individual. Since the 1990s, benefits have been accessible to workers with a degree of disability of at least 15%, lasting for at least one year. Gross benefits for *fully* disabled individuals vary between 70% of minimum wages and 70% of last earned gross wages, depending on labour

Table I. Programmes to support retirement from the labour force

| | Prior to age 65 | From age 65 |
|---|---|---|
| Social insurance programmes | Disability insurance<br>Unemployment insurance | Old age pensions |
| Collective arrangements | Early retirement pensions | Private pensions |

Table II. Comparison of main characteristics of Dutch retirement programmes

| Benefit programme | Eligibility | Benefit level | Benefit duration |
|---|---|---|---|
| Early retirement | Age and/or tenure | Between 70 and 90% of last earned gross wages | Up to age 65 |
| Disability insurance | Health condition | Degree of disability ×70% of last earned gross wages, dropping to 70% of minimum wages after 1 to 6 years | Up to age 65 or re-employment |
| Unemployment insurance | Layoff | 70% of last earned gross wages, dropping to 70% of minimum wages after 3/4 to 5 years | Up to age 65 or re-employment |
| Old age pensions | Age 65 | 70% of minimum wages for singles, 100% of minimum wages for spouses | Until death |
| Private pensions | Age 65 | Together with old age pensions equal to 70% of last earned gross wages on average | Until death |

 

market situation and age. Older employees are entitled to the highest benefits. All disability benefits are restricted to 230% of the minimum wage level, but in the past employers have occasionally offered supplemental benefits to make retirement through these programmes financially more attractive. A disabled person with a positive earning ability receives a lower replacement rate. Benefits last up to age 65, but are decreased depending on benefit duration rules and changes in earning ability.

All employees in the Netherlands are covered by unemployment insurance (UI). The UI programme provides benefits for a limited period of time. Employers may provide additional benefits as a form of annual severance pay. For individuals older than age $57\frac{1}{2}$, the combination of attractive benefit levels, eligibility conditions that no longer involve job search requirements and a benefit duration that can last up to age 65 have made unemployment benefits a serious alternative for early retirement. Unemployed individuals who are no longer eligible for UI benefits may apply for social assistance (SA). SA provides a basic safety net and is available to all Dutch citizens under specific conditions of active job search. Eligibility for wage-related UI benefits, which equal 70% of last earned wages up to 230% of the minimum wage level, depends on the employment duration prior to unemployment. SA provides benefits equal to 70% of the minimum wage level. All benefits end upon re-employment, and at age 65. See Table II for details.

All Dutch citizens are insured against the financial consequences of old age by means of the AOW programme (Algemene Ouderdomswet), and therefore collect old age pensions from age 65 until death. AOW pensions are a flat annual payment, equal to 70% of the minimum wage level for singles and 100% for spouses. For most individuals, these pensions are supplemented by private pensions, which are provided by the employer. The Pensioenkamer (1989) shows that in 1987, 72% of all Dutch workers participated in a private pension programme. In the 1993 CERRA data this equals 94%. Around 20,000 different pension programmes exist with several providers, pension amounts, inclusion rules for old age pensions and regulations for pension rights in case of early retirement, disability, unemployment and job changes. In general, private pensions are collected from age 65 on (95.4% of all pensions in 1987), but earlier pensions exist for particular sectors and occupations. Individuals build up pension rights as long as their contributions are paid, either by themselves or by their former employers in case of early retirement or disability. Unemployed individuals only partly build up pension rights. Most pension funds use replacement rates of 70% of gross wages after 40 years of employment, taking old age pensions into account. The CERRA data does not offer extensive information on private pension rules, but respondents report the pension fund in which they participate, which enables the calculation of private pension amounts by approximation.

Although Dutch retirement programmes are generous, the maximum expected lifetime income is still obtained by retirement at the mandatory retirement age of 65. If one prefers to retire earlier, the early retirement programme generally offers the highest benefits between the age of first eligibility and age 65. Prior to this eligibility, disability is financially the most attractive 'retirement programme', since the duration of wage-related benefits for elderly people is generally longer than in the unemployment programme. However, individuals do not choose a future retirement age at one moment in time, based on a comparison of possible future benefit levels only. This would mean foregoing the benefits of incorporating additional information acquired in the future into the decision. A dynamic model allowing for period-by-period re-optimization is more realistic than such a one-shot decision model. In this paper, the comparison of retirement alternatives at different moments in time is structurally performed by means of a dynamic programming model, to which we now turn.

 

## 3. A STRUCTURAL DYNAMIC PROGRAMMING MODEL OF RETIREMENT

### 3.1. The Consumption–Leisure Framework

In the standard economic theory of consumer behaviour, each hour of labour produces a wage $w$ that can be used for consumption. At the same time, it reduces the amount of leisure time. In a lifecycle context, individuals choose the amount of working hours that optimizes a weighted value of period $t$ specific bundles of consumption $C_t$ and leisure $L_t$, where the weights depend on relative preferences, expressed by a utility function $U(C_t, L_t)$. Future utility values are discounted to reflect time preferences and uncertainty about the time of death. Assuming discrete and equally sized intervals $t$ that go up to a maximum $T$, and assuming intertemporal separable utility, the choice between consumption and leisure over the lifecycle is given by

$$\max_{C_t, L_t} \sum_{t=t_0}^{T} (1+\rho)^{-(t-t_0)} \eta_{t|t_0} U(C_t, L_t) \tag{1}$$

subject to the budget constraint

$$C_t = w_t(TT - L_t) + Y_{Bt} - S_t, \quad \forall t \tag{2}$$

where $\rho$ is the rate of time preference, $\eta_{t|t_0}$ the survival probability up to period $t$ given survival up to period $t_0$ (the first period under consideration),[3] $TT$ the total time available for labour or leisure, $Y_{Bt}$ non-wage income that includes benefits and $S_t$ the amount of savings, ignoring taxes and wealth. In this framework, retirement can be modelled by zero hours of work, but this corner solution is not a unique representation of retirement. There are several exit routes, such as early retirement, disability and unemployment. A choice for one programme over the other is not simply the result of choosing the maximum level of non-wage income at zero hours of work, but is also determined by relative preferences for leisure in each of these programmes. Since a choice of $(C_t, L_t)$ affects future values of consumption and leisure, the labour supply problem cannot be simplified to repetitive one-period optimizations. Therefore, one simplification that is invoked is the assumption that present period consumption can be approximated by present period wage income $C_t \approx Y_t$. This assumption is motivated by a lack of good data on consumption and savings from the CERRA survey. It amounts to imposing that savings $S_t$ are identically zero and follows Rust and Phelan (1997), who motivate this by an incomplete markets assumption. This is supported by the low average level of private savings in the Netherlands as compared to other countries, which can be attributed to fiscally attractive and widely available private pension programmes (see Kapteyn and Panis, 2002). Another simplification is that retirement is modelled as the optimal choice between a limited number of bundles that each contain a specific amount of income $Y_t$ and leisure $L_t$, replacing the general constraint (2). Choices $k$ include labour with a fixed number of hours and several retirement pathways or exit routes. Since future values of $U^k(Y_t^k, L_t^k)$ are not completely known to the decision maker, it is assumed that individuals use expectations in evaluating future opportunities. If all relevant available information up to period $t$ is captured by

[3] Conditional survival probabilities in this study are taken from life tables available on line through the StatLine databank of Statistics Netherlands (see www.cbs.nl).

 

$\Omega_t$, then the labour supply decision in a discrete lifecycle context can be formulated by

$$\max_{d_t^k} E\left[\sum_{t=t_0}^{T}(1+\rho)^{-(t-t_0)}\eta_{t|t_0}\sum_{k\in D_t}U^k(Y_t^k, L_t^k)d_t^k|\Omega_t\right], \quad \sum_{k\in D_t} d_t^k = 1, \quad \forall t \tag{3}$$

with $d_t^k$ taking the value 1 if the $k$th choice is made in period $t$ and 0 otherwise. $D_t$ is the choice set in period $t$ that depends on eligibility rules and decisions in the past. In each period, choices are mutually exclusive, meaning that only one of the alternatives can be chosen from the choice set $D_t$. The retirement decision thus depends on preferences for current and future wages, pensions and benefits, versus leisure. Since workers face several retirement programmes, which differ in income level and accessibility, retirement is a choice for the optimal exit date *and* route. Choice-specific utility values depend on past choices, and current choices restrict the availability of future opportunities.

### 3.2. The Dynamic Programming Framework

Maximization of equation (3) is accomplished by an optimal choice of a sequence of control variables $d_t^k$ for work and non-work states $k$. A recursive solution is given by the dynamic programming method (Bellman, 1957) in which the retirement problem at period $t$ is expressed as a function of the optimal retirement decision at period $t+1$. Starting with an optimal solution for the final period $T$, solutions for all previous periods $t < T$ can be obtained by recursive optimization. Defining the discount factor by $\lambda \equiv (1+\rho)^{-1}$ and writing utility values for each period $t$ as $U_t^k = U^k(Y_t^k, L_t^k)$, the objective function in equation (3) can be rewritten as the value function $V_t$ at time $t$:

$$\begin{aligned}
V_t &= \max_{d_s^k} E\left[\sum_{s=t}^{T}\lambda^{s-t}\eta_{s|t}\sum_{k\in D_s}U_s^k d_s^k|\Omega_t\right] \\
&= \max_{d_s^k} E\left[\sum_{k\in D_t}U_t^k d_t^k + \sum_{s=t+1}^{T}\lambda^{s-t}\eta_{s|t}\sum_{k\in D_s}U_s^k d_s^k|\Omega_t\right] \\
&= \max_{d_t^k}\left(\sum_{k\in D_t}U_t^k d_t^k + \lambda\eta_{t+1|t}E\left[\max_{d_s^k} E\left[\sum_{s=t+1}^{T}\lambda^{s-(t+1)}\eta_{s|t+1}\sum_{k\in D_s}U_s^k d_s^k|\Omega_{t+1}\right]|d_t^k = 1\right]\right) \\
&= \max_{d_t^k}\left(\sum_{k\in D_t}U_t^k d_t^k + \lambda\eta_{t+1|t}E[V_{t+1}|d_t^k = 1]\right)
\end{aligned} \tag{4}$$

where I use $\eta_{s|t} \equiv \eta_{s|t+1}\eta_{t+1|t}$ for $s \geq t+1$. The third equality follows, since the maximum of current and future choices is equal to the maximum of the current choice plus the maximum of all future choices, given the current choice. Since the maximum current choice is not known prior to optimization, future utility is given by the expectation over all possible current choices. Using Bellman's dynamic programming equation, given by

$$V_t^k = U_t^k + \lambda\eta_{t+1|t}E[V_{t+1}|d_t^k = 1] \tag{5}$$

 

the value function is expressed by the dynamic programming problem

$$V_t = \max_{d_t^k} \sum_{k \in D_t} V_t^k d_t^k \tag{6}$$

For the final period $T$, the values $V_T^k$ are equal to $U_T^k$. The empirical implementation of the dynamic programming framework therefore requires specification of this utility function $U_t^k(\cdot)$, determination of the choice set $D_t$ for each period $t$, and determination of all available information at $t$, summarized by $\Omega_t$. Most of this information is obtained directly from the CERRA survey, which is discussed next.

### 3.3. Available Data

Information on current and future individual choice sets, including eligibility conditions, wages, benefits and pensions, and all other individual characteristics that may affect the choice between work and retirement, is provided by the CERRA panel survey, which was held among 4727 households in 1993 and again in 1995. Although both spouses were interviewed, detailed information on work, retirement, income, health and labour market history is only available for the head of household, to which the analysis is restricted. As a consequence, people with low incomes and women are underrepresented.

The analysis is aimed at retirement decisions for each year between age 41 and the last age at which respondents are interviewed. Although the data do not contain information on retirement decisions in every year, it is sufficient to know at which date or age retirement actually took place under the assumption of retirement as a permanent (absorbing) state.[4] For example, if a respondent of 62 years old has retired at age 57, it is assumed that (s)he has chosen to continue employment at all ages between 41 and 57, and that his or her last labour market decision took place at age 57. The analysis is restricted to respondents who were employed at age 40 and are between 41 and 65 years of age at the time of observation. A further selection is made to include (retired) employees only. Self-employed respondents are ignored. Respondents with real wage levels below the minimum wage level or above 150 000 Dutch 1993 guilders per year (approximately 70 000 US dollars) are eliminated from the sample to avoid the influence of outliers. Selection by the availability of data on sector type and health further reduces the sample size. Together, this leaves 1697 heads of household for the analysis of lifecycle retirement behaviour. Respondents are followed for a period between 1 and 24 years, depending on the age at which they are last observed. This amounts to a total of 22,623 observed retirement decisions, of which 95.8% resulted in work, 2.5% in early retirement, 1.1% in disability and 0.6% in unemployment. Of the total 936 retirement decisions, 73% were initiated by the employee (quits) and 27% by the employer (layoffs). Information on whether individuals are restricted by labour demand is taken from a question in the CERRA survey regarding the most important reason for retirement.

Since future circumstances are not known, assumptions are made regarding future values of all explanatory variables. For income and health, individual profiles are constructed in Appendix A and B. Other explanatory factors for retirement are based on their value in 1993, 1995 and 1991 if

[4] This assumption neglects that unemployed people in their forties do return to work from all exit routes, particularly unemployment, but the number is extremely low in the Netherlands. In the CERRA data, only 2% of all non-working people in 1991 have returned to work by 1993. Between 1993 and 1995 this is 1.6%.

 

available.[5] Some variables are constants, for example education, gender and birth cohort, or vary in a deterministic way, like age, experience and tenure. Most other explanatory variables can be considered time dependent. All unknown future values of these variables are assumed to equal the last known value, under the assumption that the most recent situation is the most reliable predictor for future situations.

### 3.4. Empirical Specification

The dynamic programming model is specified in terms of retirement *ages*. This means that every period $t$ is interpreted as age $t$ with length one. It is assumed that choices are made once every year at the birthday of individuals. Apart from retirement age, four major choice alternatives or states, denoted by $k$, are distinguished as[6]

$$\begin{aligned} k &= \mathrm{W} &&: \text{ employment} \\ k &= \mathrm{ER} &&: \text{ early retirement} \\ k &= \mathrm{DI} &&: \text{ disability} \\ k &= \mathrm{UE} &&: \text{ unemployment} \end{aligned}$$

The availability of these alternatives is restricted by three major institutional constraints. First, labour market opportunities for elderly individuals are limited. Once retired, the probability of re-entrance into employment is almost zero for elderly people in the Netherlands (see footnote 4). It is therefore assumed that all retirement alternatives are *absorbing* states, which is formally expressed by

$$d_t^k = 1 \quad \Rightarrow \quad d_{t+1}^k = 1, \quad k \in \{\mathrm{ER}, \mathrm{DI}, \mathrm{UE}\}$$

Absorbing retirement states reduce the retirement problem to a multi-path optimal stopping process, where workers choose the optimal moment for permanent retirement. It considerably reduces the dimension of the intertemporal decision problem and makes estimation of the model much more tractable.

The second institutional restriction is imposed by eligibility constraints. Eligibility is incorporated in the model by the construction of individual and age-specific choice sets $D_t$. These choice sets are based on information about exact eligibility requirements for early retirement pensions. Although participation in disability programmes is formally restricted by health limitations, the information available in the CERRA survey allows neither for the inclusion of such eligibility rules nor for the estimation of inflow probabilities. The absence of eligibility restrictions for disability programmes in the model does not seem unreasonable, given the easy access to disability benefit programmes in the past (see Aarts and de Jong, 1990). In case of unemployment, benefit programmes are assumed to be generally accessible.

Finally, choices are restricted by involuntary retirement. It is assumed that a layoff decision takes place after the work or retirement choice by the employee. The choice set $D_{t+1}$ must then be adjusted to exclude work in the next period, but it is assumed that all retirement programmes remain available as long as individuals meet the eligibility conditions. Involuntary separation rates are assumed to be exogenous to the retirement decision of employees. This does not mean

[5] Data from the 1993 survey contains information on 1991, due to a number of retrospective questions.

[6] For the empirical analysis, a fifth alternative is added identical to unemployment, but with an income level equal to zero. This way, estimated preferences for income are based on relative differences *and* absolute levels.

 

that workers do not take account of the risk of being laid off in evaluating their employment opportunities. Some of the observed retirements would not have been realized if no labour market restrictions had been present. In the model, involuntary retirement, indicated by $O_t$ equal to 1 in case of a layoff and 0 otherwise, is made dependent on observed characteristics of workers and employers, represented by a vector $Z_t$. Error terms, denoted by $\mu_t$, known to the individual worker but not to the researcher, are assumed to follow an extreme value (type I) distribution. This way, the layoff risk at age $t$ is represented by the logit probability

$$\pi_t = P(O_t = 1|\Omega_t) = \frac{\exp(Z_t'\delta)}{1 + \exp(Z_t'\delta)} \tag{7}$$

where $\delta$ is a vector of behavioural parameters that express the effects of worker and employer characteristics in $Z_t$.

It is further assumed that utility levels for work and retirement alternatives can be separated additively into a deterministic and a stochastic part as

$$U_t^k = \overline{U}_t^k + \varepsilon_t^k \tag{8}$$

Assumptions regarding the nature of the unobserved stochastic values of $\varepsilon_t^k$ determine the structure of the retirement model. For instance, if workers have perfect foresight about future retirement opportunities, and $\varepsilon_t^k$ is only used to account for optimization errors or utility-specific shocks that are known to the worker but not to the researcher, then the model boils down to an optimization problem at a single age $t$. An example of such a model, without layoff probabilities, can be found in Fields and Mitchell (1984a). The perfect foresight assumption may however be too strong, either because of uncertainty concerning income, health or other personal characteristics, or because more information about the institutional situation (i.e. retirement opportunities and constraints) becomes available as time evolves. Here it is assumed that workers are certain about current drawings of the error terms $\varepsilon_t^k$, but not about future values, while researchers have no information on either current or future values of $\varepsilon_t^k$. A convenient specification is that the error terms $\varepsilon_t^k$ follow an independent and identical extreme value (type I) distribution. These assumptions produce a model that is similar to the dynamic programming optimal stopping models of Rust (1987) and Daula and Moffitt (1995), with closed form solutions for choice probabilities and expectations of maximum future utility. The value functions for retirement alternatives $k \in \{\text{ER, DI, UE}\}$ are given by

$$V_t^k = \overline{U}_t^k + \lambda\eta_{t+1|t}\left(\gamma + \overline{V}_{t+1}^k\right) + \varepsilon_t^k \tag{9}$$

where $\gamma$ is Euler's constant, $V_{t+1}^k = \overline{V}_{t+1}^k + \varepsilon_{t+1}^k$, $\overline{V}_T^k = \overline{U}_T^k$, and $T \equiv 99$. If workers choose to remain employed, their decision process involves future evaluations of work and retirement opportunities, which can be interrupted by a layoff. A layoff at $t$ is assumed to affect the choice decision in the next period $t+1$, reducing the choice set $D_{t+1}$ to retirement alternatives only. The age $t$-specific value function for employment ($k = W$) is thus equal to

$$\begin{aligned} V_t^W = \overline{U}_t^W &+ \lambda\eta_{t+1|t}(1-\pi_t)\left(\gamma + \ln\left(\sum_{j\in D_{t+1}} \exp(\overline{V}_{t+1}^j)\right)\right) \\ &+ \lambda\eta_{t+1|t}\pi_t\left(\gamma + \ln\left(\sum_{j\in\{D_{t+1}\backslash\{W\}\}} \exp\left(\overline{V}_{t+1}^j\right)\right)\right) + \varepsilon_t^k \end{aligned} \tag{10}$$

 

Known values of $\overline{V}_{t+1}^k$, $\overline{U}_t^k$ and $\varepsilon_t^k$ solve these two-period optimization problems, producing values for $\overline{V}_t^k$. Since $\overline{U}_t^k$ is expressed in observables, for which all future values are either assumed to be known with certainty or predicted based on past values, and $\varepsilon_t^k$ is assumed to be extreme value (type I) distributed, independently over choices $k$ and time $t$, the model produces choice probabilities equal to

$$P(d_t^k = 1|\Omega_t) = \frac{\exp(\overline{V}_t^k)}{\sum_{j\in D_t} \exp(\overline{V}_t^j)} \tag{11}$$

The dynamic programming retirement model thus reduces to a standard logit model with the dynamic value functions (9) and (10) as its arguments.

For the deterministic part of the utility function, $\overline{U}_t^k$, it is assumed that preferences for leisure vary with personal characteristics, denoted by a vector $X_t^k$, and health $h_t$. The utility function for alternative $k$ at age $t$ is specified by

$$\overline{U}_t^k = \alpha_k + \vartheta_k \ln(Y_t^k) + \psi_k h_t + (X_t^k)'\beta_k \tag{12}$$

where the parameters $\alpha_k$, $\vartheta_k$, $\psi_k$ and $\beta_k$ are allowed to vary with alternative $k$. Utility is assumed to be linear in its arguments, since there are no clear reasons for using a different specific functional form. The logarithmic specification of income is motivated by the expectation that utility is increasing but concave in wages, pensions and benefits. For $Y_t^k$ and $h_t$, estimated present and future values are used, denoted by $\hat{y}_t^k$ and $\hat{h}_t$, which are determined in Appendix A and B. Present and future values for the variables in $X_t^k$ are constructed from the data as discussed in Section 3.3.

## 4. ESTIMATION RESULTS

The likelihood function requires a distinction between $N_e$ employees who choose to remain employed, $N_v$ employees who voluntarily decide to retire through one of the available retirement routes, and $N_u$ employees who are forced to retire after being laid off. Denoting the minimum of the last observed age and the age of retirement for individual $i$ by $T_i$, the likelihood function is the product of the probabilities for work and retirement into programmes $k$ at time periods $t \in \{t_0, \ldots, T_i\}$. This product is given by

$$L_e = \prod_{i=1}^{N_e} \prod_{t=t_0}^{T_i} (1 - \pi_{i,t-1})\, P(d_{it}^W = 1|\Omega_{it}) \tag{13}$$

$$L_v = \prod_{i=1}^{N_v} \left( (1 - \pi_{i,T_i-1}) \prod_{k\in D_{T_i}} P(d_{iT_i}^k = 1|\Omega_{iT_i})^{d_{iT_i}^k} \right) \times \prod_{t=t_0}^{T_i-1} (1 - \pi_{i,t-1})\, P(d_{it}^W = 1|\Omega_{it}) \tag{14}$$

$$L_u = \prod_{i=1}^{N_u} \left( (\pi_{i,T_i-1}) \prod_{k\in (D_{T_i}\backslash W)} P(d_{iT_i}^k = 1|\Omega_{iT_i})^{d_{iT_i}^k} \right) \times \prod_{t=t_0}^{T_i-1} (1 - \pi_{i,t-1})\, P(d_{it}^W = 1|\Omega_{it}) \tag{15}$$

$$L = L_e \times L_v \times L_u \tag{16}$$

 

using the probability, value and utility functions in equations (7) through (12). For simplicity, the discount factor $\lambda$ is fixed at a value of 0.95. Except for income, all parameters for the employment decision, i.e. $\alpha_W$, $\psi_W$ and $\beta_W$, are normalized to zero. This means that all reported parameters for variables other than income measure the effect on retirement relative to the choice for continued employment. Variables that appeared small and insignificant in the iterative estimation process were left out of the model to speed up optimization. Estimation results are reported in Table III.

The estimation results show that the main determinants of retirement decisions are income, absolute preferences for leisure time (constants) and health, since these have the highest and most significant utility contributions. Comparing parameter values for income shows that preferences for retirement income dominate preferences for earnings. Early retirement pensions are preferred (highest positive value), followed by unemployment benefits. Disability benefits are the least appreciated of the retirement programmes (lowest positive value). This implies that disability programmes are mainly used in the absence of early retirement eligibility and when benefits are higher than from the unemployment programme.

Although people like to retire as soon as possible, indicated by the positive parameters for retirement income, the negative age parameters show that when people become older and normal retirement at age 65 comes closer, the attractiveness of retirement falls. This result corresponds with the general notion in the Netherlands that early retirees have 'earned' their pension, while people who become unemployed or disabled later in life have not been able to negotiate proper early retirement arrangements. Only high benefit levels or special circumstances make elderly employees want to retire through disability or unemployment.

Special circumstances are captured by birth cohort, gender, a working partner, health conditions, sector type, public versus private sector, occupational level, supervision, physical exertion, tiring work and layoffs. The estimation results show preferences by different birth cohorts, relative to employees who were born between 1926 and 1935. This cohort retires at an earlier age than all younger groups, other things being equal. Looking at statistical significance, the World War II generation also retires at a relatively early age. Under equal circumstances, these results suggest an autonomous trend towards later retirement, with a shift from early retirement to unemployment programmes. Compared to male workers, female workers retire sooner. If respondents have a partner who works, they have significantly lower probabilities of retirement, especially through unemployment and disability. These results are consistent with earlier empirical studies, which show that partners take joint retirement decisions (Henkens and Siegers, 1991; Henkens, 1998). The influence of health on retirement decisions is significant. If health deteriorates (HSCL score becomes higher), preferences for retirement grow. The importance of health as a reason for retirement is higher for retirement programmes with lower benefits and proportional to their accessibility. Apparently, people in bad health prefer immediate retirement over income.

Workers in the industrial sector, construction sector and in catering have higher retirement probabilities than workers in other sectors. Relatively high retirement probabilities for disability and unemployment programmes can point at more relaxed entry conditions. Differences between occupational levels show that high-skilled employees generally have lower probabilities of early retirement and disability. Employees who supervise between 5 and 49 employees have significantly higher retirement probabilities, regardless of retirement route. Working conditions also significantly influence preferences for retirement. Labour that is physically demanding increases retirement probabilities, especially through disability. Tiring work causes employees to retire earlier, with higher preferences for early retirement programmes than for disability or unemployment.

 

Table III. Estimation results for the dynamic programming retirement model

| Variable | | | Employment | | | |
|---|---|---|---|---|---|---|
| | | | Estimate | *t*-Value | | |
| Log wage income | | | −0.025 | (0.66) | | |
| **Variable** | **Early retirement** | | **Disability** | | **Unemployment** | |
| | Estimate | *t*-Value | Estimate | *t*-Value | Estimate | *t*-Value |
| Constant | 0.307 | (0.69) | −1.517 | (6.68) | −2.376 | (8.05) |
| Log retirement income | 0.203 | (3.56) | 0.069 | (1.97) | 0.123 | (4.56) |
| Age/10 | −0.101 | (1.55) | −0.135 | (3.75) | −0.254 | (5.64) |
| Birth cohort | | | | | | |
| 1936–1940 | −0.258 | (4.96) | −0.104 | (4.16) | −0.041 | (1.37) |
| 1941–1945 | −0.254 | (1.09) | −0.036 | (0.72) | −0.068 | (1.19) |
| 1946–1955 | −0.660 | (5.28) | −0.124 | (2.18) | −0.118 | (1.90) |
| Female | 0.217 | (2.49) | 0.092 | (2.49) | 0.164 | (4.00) |
| Partner working | −0.092 | (1.48) | −0.072 | (2.32) | −0.105 | (2.76) |
| HSCL score/100 | 0.438 | (2.42) | 0.627 | (5.02) | 0.797 | (3.87) |
| Sector type | | | | | | |
| Industries | 0.127 | (1.87) | 0.085 | (2.58) | 0.065 | (1.71) |
| Construction | 0.219 | (2.28) | 0.150 | (3.75) | 0.128 | (2.67) |
| Catering | 0.243 | (2.01) | 0.090 | (1.73) | −0.043 | (0.55) |
| Public sector | −0.039 | (0.72) | 0.039 | (1.50) | −0.001 | (0.03) |
| Occupational level | | | | | | |
| Blue collar high | −0.283 | (3.41) | −0.108 | (2.30) | −0.086 | (1.54) |
| White collar low | −0.060 | (0.74) | −0.012 | (0.30) | 0.008 | (0.18) |
| White collar high | −0.116 | (1.68) | −0.077 | (2.33) | −0.055 | (1.45) |
| Medium supervision | 0.106 | (2.00) | 0.090 | (3.46) | 0.081 | (2.61) |
| Physical exertion | 0.041 | (0.69) | 0.107 | (3.96) | 0.054 | (1.69) |
| Exhausting labour | 0.151 | (3.02) | 0.098 | (3.63) | 0.091 | (2.94) |
| **Variable** | | | **Layoff** | | | |
| | | | Estimate | *t*-Value | | |
| Constant | | | −16.308 | (21.23) | | |
| Age/10 | | | 2.495 | (17.21) | | |
| Medium education | | | 0.190 | (1.28) | | |
| Higher education | | | −0.332 | (1.94) | | |
| Living with partner | | | −0.307 | (2.31) | | |
| Sector type | | | | | | |
| Heavy industries | | | 0.250 | (1.33) | | |
| Light industries | | | 0.152 | (0.82) | | |
| Construction | | | 0.102 | (0.42) | | |
| Occupational level | | | | | | |
| Blue collar high | | | −0.129 | (0.50) | | |
| White collar low | | | −0.391 | (1.83) | | |
| White collar high | | | −0.214 | (1.35) | | |
| Experience/10 | | | −0.013 | (3.25) | | |
| Tenure/10 | | | −0.005 | (1.00) | | |
| Log-likelihood | | | −3,119.57 | | | |
| Number of observations | | | 22,623 | | | |
| Number of respondents | | | 1,697 | | | |

The layoff risk increases dramatically with age, but decreases with labour experience. It is tempting to explain these results as an argument for the theory that less productive workers are laid off first. It is generally assumed that productivity declines with age and increases with experience. As a consequence, the estimates would indicate that productivity is relatively high for employees with a high level of education and for employees with a partner. But it must be emphasized that the results are based on a limited number of observations and a very simple functional specification. Still, the estimation results enable the reproduction of relative layoff risks that influence individual labour supply and retirement decisions, which is the main purpose of including them in the model.

Most included variables improve the explanatory power of the retirement model. Evidence is given in Table IV, where log-likelihood values are presented for different model specifications. Associated likelihood ratio values show that the full dynamic model explains individual retirement decisions better than restricted specifications. For example, a model that ignores health is rejected by the likelihood ratio test. The overall pseudo-$R^2$ is equal to 0.15.[7]

The fit of the model for the employment decision by age is graphed in Figure 2. A comparison is made with results from a non-parametric estimator.[8] The figure shows that up to age 59, the dynamic programming model reasonably reproduces conditional employment probabilities. From age 60 on, retirement is overestimated and continued employment underestimated, which can mainly be attributed to the low number of observations after age 60. The model extrapolates information for ages 42 to 60 to the age bracket 60 to 65. It is not clear whether the model misses crucial information to explain retirement after age 60, or whether the few available observations after age 60 are representative for true retirement probabilities.

## 5. POLICY SIMULATIONS

In 1999, the Dutch government requested the Social Economic Council (SER) to advise on how to stimulate labour force participation among Dutch elderly people. The recommendations by the SER (1999) are based on expert opinions about the effect of policy measures on the labour market behaviour of individuals. However, no empirical evidence is given for this. The present section provides some insight into the effectiveness of participation policies. The dynamic programming

Table IV. Measures of fit for the retirement model

| Model | Restricted variables | Log-likelihood | Likelihood ratio | Critical $\chi^2$ (95% significance level) |
|---|---|---|---|---|
| Full dynamic model | 0 | −3119.57 | | |
| Choices restricted to constants | 55 | −3428.86 | 309.29 | 76.88 |
| Layoff rate restricted to a constant | 12 | −3306.42 | 186.85 | 21.03 |
| Full model restricted to constants | 67 | −3684.90 | 565.33 | 91.02 |
| Model without a health variable | 3 | −3156.78 | 37.21 | 7.81 |

[7] The pseudo-$R^2$ is calculated as 1 − (log-likelihood value of full dynamic model/log-likelihood value of model with constants only).

[8] The non-parametric estimator is used to give a description of conditional retirement probabilities, which are derived directly from the data. It allows for smoothing the probability distribution at places where large fluctuations exist, for example due to a lack of information at specific ages.

 

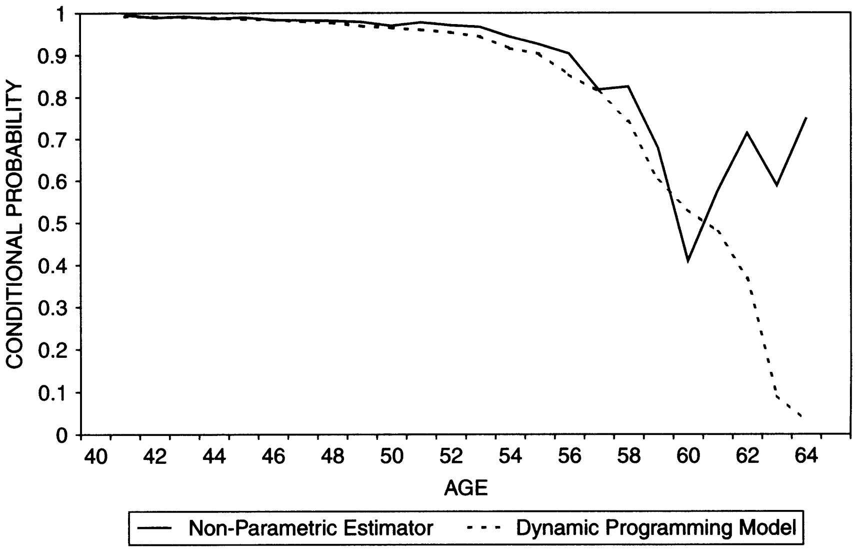


Figure 2. Comparison of estimators for employment

framework provides a powerful tool for simulating labour supply and retirement decisions under different circumstances.

To reduce retirement, policy may restrict eligibility conditions, reduce replacement rates, change the relation between benefits and (final) wages, or change the rise of wages with age. An example of the restriction of benefit eligibility is tighter rules for entry into disability programmes. At present, almost one million people in the Netherlands are on disability benefits, which is close to 10% of the potential labour force. An example of a combination of a reduction in benefits and a change in the relation with wages is the change from the traditional fixed percentage early retirement pensions, with replacement rates between 70 and 90%, to recently introduced flexible pension schemes, in which the replacement rate is based on the age of retirement. In flexible pension schemes, employees are eligible for early retirement pensions at an earlier age, but with actuarially reduced pension levels. This way, employees bear the costs of earlier retirement, and have financial incentives to retire later. An example of a combination of reduced wages after a certain age and easier working conditions is *demotion*. It could stimulate elderly workers to continue employment and keep employers from laying them off. These three examples of labour force participation policies are simulated here, using the estimated lifecycle retirement model. Retirement decisions of the sampled population are calculated in 1000 runs to draw conclusions about average behaviour. Results are shown in Table V.

The restriction of disability benefits leads to a decrease in conditional disability probabilities at age 60 by 50%, but it hardly increases the conditional probability of continued employment. Apparently, most of the employees who are no longer eligible for disability benefits still prefer to retire. Since early retirement benefits are generally higher than disability benefits, these employees are unlikely to be eligible for early retirement benefits. As a result, the only retirement alternative is unemployment, for which the conditional probability almost doubles. In sum, restricting eligibility for disability benefits hardly increases Dutch elderly labour force participation, as these employees still retire early, ending up in unemployment.

 

Table V. Conditional probabilities of retirement under different policies

| Policy | At age | $k = \mathrm{W}$ | $k = \mathrm{ER}$ | $k = \mathrm{DI}$ | $k = \mathrm{UE}$ |
|---|---|---|---|---|---|
| Base case | 50 | 96.5% | 0.6% | 1.9% | 1.0% |
| | 60 | 53.0% | 39.8% | 2.9% | 4.4% |
| Restricted disability eligibility | 50 | 97.3% | 0.6% | 0.2% | 1.9% |
| | 60 | 54.7% | 36.8% | 1.5% | 7.0% |
| Flexible pension schemes | 50 | 97.4% | 0.0% | 1.7% | 0.9% |
| | 60 | 58.9% | 29.7% | 4.8% | 6.7% |
| Demotion | 50 | 96.0% | 0.6% | 2.1% | 1.3% |
| | 60 | 57.3% | 35.8% | 2.6% | 4.3% |

Flexible pension schemes that replace existing early retirement programmes allow participants to retire from an earlier age on (age 55 in the simulations). If one retires at this age, the replacement rate is reduced to less than 40%. If one postpones retirement, benefit levels are increased. Simulation results show that before age 55, the conditional probability of entering early retirement is reduced to zero, while that of continued employment is slightly increased. Once eligible for flexible pensions at age 55, a substantial fraction of the sample population prefers to retire through these programmes (up to 30% at age 60), regardless of the decreased pension amount. Apparently, flexible pension schemes are attractive enough for part of the sample population to retire as soon as possible. Several studies have pointed out that 'a considerable proportion of older employees is willing to make a considerable financial sacrifice to be able to quit working soon' (Henkens and Siegers, 1994). Delsen (1996) finds that pension delay is very scarce, despite an actuarial growth in pensions with age. The total effect of flexible pension schemes is therefore ambiguous. They may result in higher, but also in lower elderly labour force participation.

In the third simulation, attention is paid to the potential mismatch between productivity and labour costs of elderly workers and demanding working conditions, both of which can induce early retirement. This mismatch causes employers to prefer younger workers, and elderly employees to feel stressed trying to live up to expectations. In order to reduce the impact of this mechanism, a number of reports have suggested two main solutions: schooling and demotion. Demotion lowers labour costs by cutting wages, and provides better and easier working conditions for elderly workers (Pelle, 1997). For simulation purposes, it is assumed that from age 55 on, real wages no longer rise. At the same time, labour conditions are improved. This means that older employees no longer supervise colleagues, reducing the burden of responsibility, and no longer suffer from physical exertion or exhausting labour. The results show an increased conditional work probability at age 60. Improved working conditions make it more attractive for elderly workers to remain employed. Prior to age 55 however, it is less attractive to continue employment, since it does not increase wages beyond age 55.

The simulations show that several policy measures can be used to increase elderly labour force participation, but that the effects depend on competitive institutional opportunities and constraints. They also show the relevance of using dynamic instead of static models, in which individuals are myopic and would not react on changes in future circumstances.

 

## 6. CONCLUSION AND DISCUSSION

The empirical analysis of retirement behaviour and the policy simulations contain important lessons for policy that is aimed at increasing elderly labour force participation. In general, elderly employees retire early because of five main reasons: attractive retirement programmes that combine high replacement rates with more leisure time, early opportunities to use these programmes, high preferences for retirement, a layoff risk that rises with age, and health conditions that force people to retire. Each of these reasons by itself is important for retirement behaviour. But they are also strongly interrelated. Influencing one of these reasons with policy measures does not necessarily result in the desired adjustment. From the policy simulations, it becomes clear that retirement opportunities serve as substitutes.

A strong effect on retirement behaviour is found for eligibility conditions, which restrict opportunities for early retirement. Retirement can also be effectively reduced by lowering benefit levels. For early retirement programmes, the reduction of benefits may be an efficient change of the pension system, increasing labour force participation, decreasing labour costs and helping to resolve financial problems that result from an ageing population. But a reduction of disability or unemployment benefits implies that people with health problems or who are laid off at early ages bear most of the costs of such a policy, which may be socially undesirable.

Two main situations that force people to retire, layoffs and health, can only be indirectly influenced by policy. However, such a policy becomes more urgent when labour force participation is successfully increased. Higher labour force participation means that more of the relatively less productive and unhealthy workers are employed, who have higher probabilities of being laid off or becoming disabled. The layoff probability is highest for less educated employees at lower occupational levels and with only a few years of experience. The productivity of employees can be increased by initial schooling and by training on the job.

Another important lesson from the analysis is that preferences for early retirement must not be underestimated. The simulations show that low benefit levels do not keep elderly people from early retirement. People generally prefer to retire as soon as they reasonably can. Since the fraction of layoffs is small, retirement is for the largest part a preferred and voluntary choice. Apparently, people can afford to 'consume' more leisure. Elderly individuals are willing to trade considerable amounts of income for earlier retirement, which could imply that they have wealth levels to fall back on. This could make collective policy directed to benefit and pension programmes less effective in the long run.

To increase the valuation of employment, attention must be directed to working conditions that reduce motivation for employment. The empirical results show that physical exertion, exhausting labour, stress and high responsibility all contribute to higher preferences for retirement. The idea of demotion, a situation in which labour income is reduced and working conditions improved, defines a policy measure that is aimed at this. Simulation results show that it does not substantially affect labour force participation. A policy that aims at changing attitudes towards retirement of both employees and employers, for example by means of public information as proposed by the SER (1999), seems to be a necessary measure to support elderly labour force participation. However, this policy remains ineffective as long as generous and easy to access (early) retirement programmes exist.

The results of the retirement analysis may be put into perspective by repeating a number of crucial assumptions. First of all, the analysis ignores the role of savings and wealth. This could partly explain the high valuation of leisure time and preferences for early retirement at low benefit levels. Secondly, the analysis of dynamic decisions between ages 40 and 65 is based on observations of individuals surveyed at two moments in time only. This may lead to an overestimation of the elasticities of retirement behaviour and a limited model fit. Thirdly, the assumptions made about future values of all explanatory variables, including certainty about future income values and benefit rules, reduce the estimated value of behavioural parameters (measurement error) and their significance (lower variation). Finally, all elasticities based on the estimation results are only valid for small changes in the associated explanatory variables. Policy simulations that assume structural changes must thus be interpreted with care.

This study has shown that dynamics in the model enable a much richer sort of analysis than a static one, in which choices are based on temporary situations only. The uncertain evolution over time in variables like income, health and personal circumstances is allowed to have an impact on retirement decisions. This allows for much more detailed policy evaluations. However, the dynamic approach is more sensitive to data limitations and errors in the model setup. It requires more detailed information on the evolution of explanatory variables. These issues need to be addressed when improving the dynamic analysis of retirement behaviour.

Finally, since there is a complete absence of (natural) experiments with regard to retirement choices in the Netherlands, an empirical–economic analysis of elderly labour supply, such as the one in this study, seems to be the only way to understand retirement behaviour and to design new and well-founded labour force participation policies.

## APPENDIX A

This appendix describes the calculation of wage profiles for elderly people between ages 40 and 65. Wages are only observed for workers, with different probabilities of labour force participation than retirees, partly caused by a difference in potential wage levels. Both processes must therefore be treated jointly to avoid sample selection bias in the parameter estimates. Following Keane *et al.* (1988), using panel data on $N$ individuals ($i = 1, \ldots, N$) who are observed for $T_i$ periods of time ($t = 1, \ldots, T_i$), a sample selection model is given by

$$\ln y_{it} = X_{it}^{y\prime}\beta_y + \alpha_i^y + \varepsilon_{it}^y \tag{A1}$$

$$A_{it}^* = Z_{it}^{A\prime}\delta_A + \gamma_i^A + \mu_{it}^A \tag{A2}$$

$$A_{it} = \begin{cases} 1 & \text{if} \quad A_{it}^* > 0 \\ 0 & \text{if} \quad A_{it}^* \leq 0 \end{cases} \tag{A3}$$

where $y_{it}$ is the net hourly real wage rate for individual $i$ at time $t$, $A_{it}$ a dummy variable indicating whether individual $i$ is employed at time $t$, $X_{it}^y$ and $Z_{it}^A$ vectors of explanatory variables, $\beta_y$ and $\delta_A$ their associated parameter vectors, $\alpha_i^y$ and $\gamma_i^A$ individual effects and $\varepsilon_{it}^y$ and $\mu_{it}^A$ stochastic error terms. The participation equation is a very simple competitor of the dynamic programming retirement model and only used to correct for sample selection. The error terms $\varepsilon_{it}^y$ and $\mu_{it}^A$ are assumed to be bivariate normally distributed, allowing for cross-correlation. The individual effects $\alpha_i^y$ and $\gamma_i^A$ are assumed to follow a discrete bivariate distribution with two points of support. Data for estimation are taken from the CERRA survey. Net hourly real wages in 1991, 1993 and 1995 are constructed from reported wages and hours worked. All wage rates are deflated by the consumer price index and are expressed in 1993 guilders (one 1993 Dutch guilder ≈0.45 1993 US dollar). Hourly wage rates of less than 5 or more than 50 guilders are excluded from the analysis.

 

The analysis includes 5151 observations of workers, of which 1370 have no data on wages, and 3772 observations of non-workers. This amounts to a total of 8923 observations concerning 3411 individuals. To identify a time effect, growth in the per capita gross domestic product is used as a time-varying variable. Estimation of a multi-period wage equation with an indicator for attrition by OLS shows that attrition does not significantly affect the estimation results. The full random effects model is estimated by maximum likelihood. No exclusion restrictions are imposed, since the vector $Z_{it}^{A}$ contains some variables that on logical grounds are not included in $X_{it}^{y}$, such as the number of children. Estimation results can be obtained from the author upon request. Projected wages for all individuals between ages 40 and 65 are estimated by

$$E[\hat{y}_{it}] = \exp(X_{it}^{y\prime}\beta_y + \alpha_i^y) \tag{A4}$$

where it is assumed that after 1995, the per capita gross domestic product increases by 3% per year. All other variables have values as defined in Section 3.3. The individual wage effects $\alpha_i^y$ are adjusted to the difference between real and expected log wages in 1993 as

$$\hat{\alpha}_i^y = \ln y_{i,1993} - X_{i,1993}^{y}{}^{\prime}\beta_y \tag{A5}$$

Using this crude approximation of the individual effect, estimated individual wage profiles pass through observed wage levels in 1993. For non-workers in 1993, wage levels are constructed from 1993 benefits and pensions, applying the appropriate rules as described in Section 2.

## APPENDIX B

This appendix describes the calculation of individual health profiles that depend on age and labour market state. A measure of health is needed that influences labour supply decisions, can sufficiently be corrected for endogeneity to the labour market state, and must preferably be dynamic and available for all ages in the retirement model. As suggested by Anderson and Burkhauser (1985), health indices created from information on several observable physical and mental problems may be superior to straightforward subjective and objective health measures. From the answers to 57 questions in the CERRA survey concerning physical and mental symptoms, known as the Hopkins Symptom Checklist (HSCL), such a health index is constructed by adding the values of all answers. The total score varies between 0 (healthy) and 171 (very unhealthy). The HSCL score is known to have an excellent rate of internal consistency, is highly correlated with objective medical reports on patients' true health conditions, and is consistent across respondents. Compared to subjective or work-related health measures, it suffers less from reporting errors that depend on the labour market state. Following Kerkhofs and Lindeboom (1997), using the panel data character of the CERRA survey, with $N$ individuals ($i = 1, \ldots, N$) observed for $T_i$ periods of time ($t = 1, \ldots, T_i$), health is modelled by

$$\ln h_{it} = X_{it}^{h\prime}\beta_h + \alpha_i^h + \varepsilon_{it}^h \tag{B1}$$

where $h_{it}$ is the HSCL score *plus one* for individual $i$ at time $t$, to allow for HSCL scores of zero, $X_{it}^{h}$ is a vector of explanatory variables, $\beta_h$ its associated parameter vector, $\alpha_i^h$ an unobserved individual time constant effect that exhibits elements of the initial stock of health and decisions made in the course of life concerning labour market status and health, and $\varepsilon_{it}^h$ error terms that represent unforeseen health shocks that are independent of variables in $X^h_{it}$. To simplify the calculation of health profiles, first differences of equation (B1) are taken as

$$\Delta \ln h_{it} = \Delta X^{h\prime}_{it}\beta_h + \Delta\alpha^h_i + \Delta\varepsilon^h_{it} \equiv \Delta V^{h\prime}_{it}\varpi + \zeta^h_{it} \qquad \text{(B2)}$$

where $\Delta \ln h_{it} = \ln h_{it} - \ln h_{i,t-1}$. The vector $\Delta V^h_{it}$ contains first differences of all non-constant variables in $X^h_{it}$, $\varpi$ is its associated parameter vector and $\zeta^h_{it}$ a vector of error terms, which are assumed to be independently and identically distributed. OLS estimation results for equation (B2) can be obtained from the author upon request. To produce individual health levels for all ages in the retirement model, estimated HSCL scores are calculated by the formula

$$\hat{h}_{it} = \exp(V^{h\prime}_{it}\hat{\varpi} + (\ln h_{i,1993} - V^{h}_{i,1993}{}'\hat{\varpi})) \qquad \text{(B3)}$$

This way, estimated health levels pass through observed health levels in 1993.

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