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Panel Data and Structural Labour Market Models
H. Bunzel, B.J. Christensen, P. Jensen, N.M. Kiefer and D.T. Mortensen (eds.)

Employer Pay Policies and Male Retirement Decisions[1]

P. Bingley and G. Lanot

Theories of efficient labour contracts highlight the role of the *employer* in designing tenure-remuneration profiles which can address the problem of asymmetric information regarding worker effort. However, most empirical studies of retirement behaviour focus on responses to the *individual* determinants of current and future flows of income. This paper explicitly incorporates, for the first time in a study of individual retirement choice, the effect of employer pay policy on retirement outcomes. A conventional dynamic structural model is extended to allow employer unobserved heterogeneity. Empirically, identification of the employer effects on income is achieved by exploiting a matched panel of Danish establishments and workers. Identification of the effect of income flows on retirement is through exogenous eligibility to a public early retirement programme. Employer effects are found to be important determinants of work and retirement income flows, but we find no evidence of establishment effects on retirement age.

1. INTRODUCTION

The flow of individuals from the labour force into retirement is an important process which in principle determines the economic status, and the consumption/saving behaviour of a growing fraction of the population along the rest of their life-cycle. In the main, retirement is the last labour supply decision made in a life-time and thereafter individuals are more or less dependent upon their previous saving decisions and/or on existing transfer programs, i.e state pensions and social security, to sustain the expected level of utility. Policy interest in early retirement is motivated by the large consequences for both public financing of social security and the human capital endowment older workers represent to their establishments.

On the demand side, many firms are reluctant to invest in the training of older workers because the time period over which the return can be expected is relatively small. The extent to which this is the case should depend upon the particular technology relevant to the organisation. Timing of retirement for some

[1] Financial support from the Danish National Research Foundation and the UK ESRC is gratefully acknowledged. The paper has benefited from the comments of Bent Jesper Christensen, Nick Kiefer, George Neumann, Peder Pedersen, Ian Walker, Niels Westergård-Nielsen and seminar participants in Amsterdam, Bangor, Keele, Mannheim, Sandbjerg and Århus. Remaining errors are our own.

categories of worker is closely connected to the effect of technological change on the labour demand decisions of firms in a given industry. Indeed, Bartel & Sicherman (1993) show that in industries characterized by high levels of technological change requiring large amounts of on-the-job training retirement will occur later, provided that technological change is positively related to the value of training net of depreciation. Furthermore, they show unexpected positive technology shocks will lead to earlier retirement. Since technological change shocks have the likely effect of making some firms/processes obsolete one can expect that a significant part of the flow to retirement at any time is accounted for by the death or restructuring of firms, provided that worker re-entry into the labour market is sufficiently unlikely. This is credible so far as skills attached to an obsolete technology are obsolete too, and provided pension levels are high enough to "prevent" intensive search for a new job among other occupations.

In another strand of the literature, efficient labour contract theory singles out the role of the employer. In such a setting, the firm has to manage an asymmetric information situation concerning worker effort. In particular, although turnover is costly to the firm (hiring and training), moral hazard arguments suggest that effort is adversely affected by guarantied tenure (assuming non-negligible monitoring costs). Back-loading pay through tenure profiles or pensions raises the expected cost of shirking, since alternative employment offers less net remuneration[2]. On the other hand, adverse selection arguments suggest that tenure-wage profiles and pensions attract more productive workers. An important feature of "tilted" tenure-remuneration profiles is that younger workers earn below productivity and older workers above productivity. Hence there exists associated mandatory retirement for older workers who do not wish to leave when it is optimal for the firm (Lazear 1979, Stern 1987, 1994, Lang 1989). A back-loaded scheme involves redistribution from early leavers to survivors till retirement. Firm moral hazard limits back-loading by the need to attract young entrants and some degree of mobility is optimal to achieve good matches.

These theories suggest that the between-establishment productivity distribution should be reflected in between-establishment retirement behaviour. The retirement behaviour of many workers within a given establishment should be affected similarly. So we should expect establishment-specific policies to be important determinants of individual retirement decisions. In particular, we expect a strong within-establishment correlation between retirement dates once other factors have been controlled for, i.e. individual occupation, education and demographics. Nevertheless, where early retirement plans are financed by the State we would expect establishment-specific policies to have effects on individual decisions which are less pronounced or even non existent. Indeed, if most workers

[2] See Lazear (1981, 1986).

are eligible for such a scheme, it may be very costly for a single establishment to design incentive compatible contracts which exhibit the desired features and survive the effect of the State funded scheme[3].

On the supply side, financial incentives to retire early should be quite worker-specific, not necessarily reflecting the resource loss a establishment would face through the reduction in elderly labour supply. Hence, as far as it is possible, a desirable modelling of the individual retirement process should include elements which pertain to the particular establishment/employer, as well as a coherent modelling of the individual's response to current and future flows of income. The applied literature on this matter has so far paid attention mainly to the latter with varying degrees of complexity. Among others, Gustman & Steinmeier (1986), Stock & Wise (1990), Berkovec & Stern (1991), Lumsdaine, Stock & Wise (1992), Rust & Phelan (1995) propose different structural models of retirement estimated on U.S. data, whereas Heyma (1994) estimates a similar structure on Dutch data. Perrachi & Welch (1994), Ruhm (1990) and Blau (1994) focus on reduced form models fitted on U.S. data. Rust (1995) presents the most complex estimable structure allowing for re-entry into the labour force and accounting for uncertain health and social security payments as well as modelling endogenous saving decisions and bequests. The relationship between health status, health insurance entitlement and early retirement is studied by Sickles & Taubman (1986) and Karoly & Rogowski (1994) with U.S. data. On the whole structural models have been shown to have better power to predict observed patterns in the data (Lumsdaine, Stock & Wise, 1992). Moreover structural models are the appropriate tool to simulate policy reforms.

Our objective is to study the effect of employer wage policy on individual retirement. In particular, to what extent is an establishment-specific quality, say productivity for example, related to retirement. To do so, we present a conventional dynamic programming model of individual retirement behaviour akin to the one proposed in a different context by Wolpin (1987). We extend this to account for unobserved heterogeneity in retirement behaviour between establishments aswell as between individuals. This heterogeneity is assumed to come through employer- and worker-specific effects on income, and is identified by using a matched longitudinal dataset of Danish establishments and workers. To determine the causal effect of income on retirement, we exploit exogenous institutional discontinuities in individual income flows which allow identification of retirement timing decisions. These are provided by public transfer programmes, of which the public early retirement scheme is the most financially attractive.

The next section introduces the various exit routes from the Danish labour market in order to motivate a definition of retirement, and compares early retirement in Denmark with the experience of other countries. Section three presents the main features of the data from the establishment register and com-

[3] However, we still expect to find tilted tenure-remuneration profiles. The effect a State funded early retirement programme has on the shape of the wage profile is left for future work.

pares it with a representative sample of the population. The fourth section presents the economic and econometric models. The penultimate section comments on the estimation results, and finally we conclude.

2. BACKGROUND

In this section we shall put Denmark in its international perspective demographically and in terms of the labour market behaviour of the elderly. The relative importance of financing pension transfers is highlighted. A discussion of the various exit routes from the Danish labour market concludes the background.

2.1 Perspective

Demographic projections for all OECD countries indicate that the elderly proportion of the population will increase over the next 40 years[4]. Denmark is no exception with the ratios of those aged 65 plus to those aged 15-64 projected .22, .32, .38 respectively in 2000, 2020, 2030.

Of those ILO countries for which comparable information is available, Denmark had the highest participation rate for this group in 1960 (90%), and one of the largest subsequent reductions to 1992 (45%). However, all European countries experience a similar evolution.

Public transfers to pensioners constituted 10% (DKK 20Bn) of Danish GDP in 1994[5]. This compares with the OECD average of 9%[6]. So 50% of all transfers to households were in the form of pensions. Of pension transfers 25% were early retirement schemes, making early retirement half as important to the exchequer as Unemployment Insurance Benefits.

Other countries can expect to learn something from Danish retirement experience since the behaviour of its elderly workers is similar to that elsewhere. A large publicly financed early retirement scheme was enacted just prior to the sample period and similar reforms are being discussed and evaluated in other countries.[7]

2.2 Exit Routes

The most important question in a retirement study is the definition and identification of retirees. This sub-section provides the institutional background necessary to motivate our broad definition of retirement as being no longer in labour market work as opposed to no longer in the labour market. Consumption by the elderly in Denmark is largely financed by public transfer programmes. Participants of several of these are officially classified as being in the labour force. Our definition of retirement is essentially a transition to long-term (at least one year) out-of-work for the elderly regardless of the means of financing consumption.

[4] OECD member country averages are .21, .30, .38 respectively for 2000, 2020, 2030 (OECD, 1995).
[5] See Statistics Denmark (1995) p401.
[6] This compares with Germany 12% and France 13% (OECD, 1988).
[7] Many OECD nations with the exception of Denmark are discussed in OECD (1995).

The second most important question in a causal retirement model is the importance of institutional discontinuities in income flows which allow identification of retirement timing decisions. In Denmark we shall argue that this is provided by public transfer programmes, of which the public early retirement scheme offers by far the most financially attractive exit route.

Statistics Denmark defines retirees as those whose primary income is from a pension, and this measure is always used for aggregate statistics. A distinction made on the grounds of invalidity or unemployment benefit receipt is also problematic. The conditions of active job search for older workers who are long-term unemployed are less stringent, and so those who have effectively left the labour force may still claim Unemployment Insurance Benefit (Pedersen, 1993).

The publicly financed old age pension is available at 67, covers everyone regardless of previous attachment to the labour market, and was worth 40% of average production worker earnings in 1993. However, the average age of retirement was then 61.5[8]. Hence, early retirement is the preferred exit route from the labour market for a large proportion of elderly workers.

There are four transfer programmes relevant to those who are out of work. Social Assistance (SA) is the lowest level of income support available to those who are neither working nor unemployment insured and is means tested. Unemployment Insurance Benefit (UIB) is 90% of former wage up to a ceiling. It is available to those insured during at least 6 of the previous 12 months and currently actively seeking work, and lasts for up to 30 months.

Provision for those not working due to disability or long-term sickness is through the Invalidity Benefit (IVB) programme. It is available to those aged over 17 according to three levels of assessed ability to work on medical and social criteria. The lowest disability benefit is available for people 50-66 when social and health-related factors create a need for permanent provision.

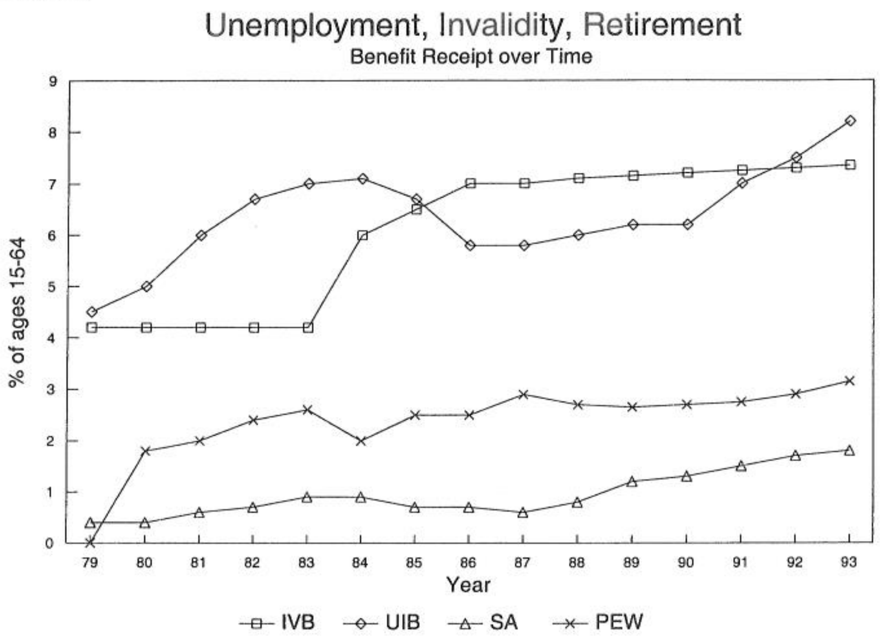
An early retirement scheme called the Post-Employment Wage (PEW) was initiated in 1979. Remuneration is the same as for UIB, but after 30 months, instead of support being withdrawn, it is reduced to 80% until age 67[9]. Eligibility is restricted to those aged 60-66 who have contributed to an unemployment insurance fund for 20 of the last 25 years (about 80% of men of that age)[10]. Recipients cannot work more than 200 hours a year, and if they do, entitlement cannot be re-established. Income from work is disregarded, but other income transfers from the public sector and pensions cannot be obtained at the same time.

Figure 1 shows there is a growing proportion of people out of work, however they are labelled according to all definitions, be they in or out of the labour force. The development of non-work in the labour market as a percentage of the 'working age' population[11] is presented over time according to transfer receipt. A large influx into the PEW programme in 1979 was followed by a slower increase until 1984

[8] See Danish Social Commission (1993).
[9] Those entering from unemployment have this initial duration reduced by the length of the current spell.
[10] Until 1984 this requirement was 10 years of membership in the last 15.
[11] Consequently this understates the relative importance of PEW in our elderly subsample.

when participation stabilised at 100000. Reforms to IVB in 1984 have lead to the subsequent slow increase in retirement. It should be noted that unemployment peaked in 1983 and troughed in 1986, but unemployment among those aged 60-66 was flat until PEW stabilized, and followed the trend thereafter.

Figure 1[12]



It is important to re-emphasise the relative incentives for early exit the various public transfer programmes create. PEW (for those eligible) is as generous as UIB without the job search test, and dominates after 30 months, where SA becomes the alternative. The lowest level of IVB which may be regarded as a substitute to the extent that it is given on social grounds is much less financially rewarding[13]. So the PEW programme is most attractive to workers on low wages.

[12] Invalidity Benefits (IVB), Unemployment Insurance Benefit (UIB), Social Assistance (SA), Post Employment Wage (PEW). Source: Statistics Denmark (1991, 1993, 1995b). Note that the discontinuity in the IVB series is due to a re-classification of widows as part of the reform, which has no consequences for our empirical application to elderly males.

[13] Gross annual remuneration in 1993 was ('000 DKK) 61, 83, 114, 130, 217 respectively for disability pensions 1, 2, 3, PEW, average manufacturing wage. However PEW is fully taxed whereas disability benefits are partly tax-free.

Provision for retirement through private pensions is empirically much less important. Supplementary private pensions in the form of tax-subsidised company or individual pension schemes are widespread with 54% of the work-force contributing[14]. However they are not well developed with a large majority far from maturity and currently represent only a small fraction of total pension income[15].

3. DATA

The purpose of this section is to define and describe the estimation dataset and variables of interest: labour market state and real net income; and compare the dynamics of these in our estimation sample with an individual population-representative sample. This benchmarking is especially important for four reasons. Firstly, the estimation dataset is a random sample of small-to-medium sized private sector establishments, together with all their male workers. To illustrate its representativeness, consider men aged 55: It covers only 27% of this group. The remainder comprises 10% not working, 15% public sector employees, 40% employed in larger establishments and 8% employed in smaller establishments. It is not obvious that this group is representative of all men aged 55. This section aims to compare differences in incomes and retirement outcomes.

Secondly, individuals are only followed for one year after leaving a sampled establishment, and we do not know whether they return to work later. Thirdly, income streams are only observed 1 year after departure, and it is necessary to check whether our income evolution assumptions are valid. Fourthly, this sample attrition under-represents men to a greater degree as they grow older. After defining the datasets we begin the description with a characterization of the establishments in our sample. Description of explanatory variables is relegated to an appendix.

3.1 Samples

The dataset used in estimation is the Statistics Denmark Integrated Labour Market Database (IDA), which is an administrative matched panel of establishment and individual tax records. A representative 5% of the population of Danish private sector establishments is followed from 1980 until 91, with replacement[16]. This is matched with background information on all workers employed in these establishments throughout their attachment to a sampled establishment during the period and one year after leaving, should a separation occur.

[14] See Pedersen & Smith (1995). 15.0% of the labour-force belongs to a personal pension fund and 0.5% to a private firm pension fund (Statistics Denmark, 1995a, p371).

[15] See Ministry of Finance (1995) for some measures. Simply computing the ratio of active to receiving members of private pension funds: 20/1 gives an idea of their immaturity. Mean 1993 receipt (conditional on receiving) was DKK 64,000.

[16] Sampled establishment size is 5-500 primary employees. For detail see Leth-Sørensen (1995).

To establish the representative nature of our establishment panel, we shall use an unmatched panel (1%) sample of individual tax records for the period 1980-90. The Statistics Denmark Longitudinal Database (LDB). The main difference in coverage of the two data sources is that IDA excludes the public sector and the (initially) unemployed, and for current purposes that retirees are only observed in their earlier employment and for one year into retirement. Labour force status in LDB is defined as in Pedersen and Smith (1991) , that is according to income, social security contributions and receipt of certain transfer payments. In IDA we are able to use the same criteria, together with additional information which gives us a better idea about retirement timing *during* the year. On the one hand annual (January-to-December) observation period of LDB is maintained, but on the other attachment to the sample, as described above, is defined in the last week of November. So we are able to identify a transition to non-work (NW) that happened any time during the year before this cut. Whereas in LDB, some social security contribution would be made during this year and a transition to NW would not be cleanly identified until the following year.

3.2 Establishments

Figure 2 describes the distribution of workers among the 915 establishments sampled by IDA. As expected a large proportion, 50% , of workers are observed in establishments which employ one or two workers of potential retirement age from 1981 and 1991. Although about 3% of the workers are employed in a establishment employing 30 workers of retirement age or more, the maximum being 94. In other words about 94% of the individuals are observed in a establishment which has employed more than one worker of retirement age during the period from 1981 to 1991.

Figure 2.

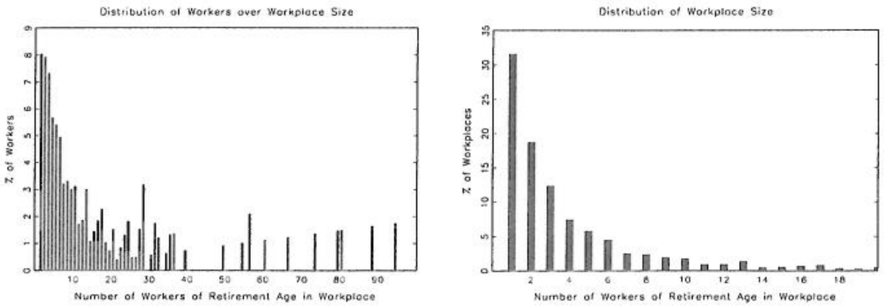


Table 1
Retirement Age & Log Real Net Income Analysis of Variance

Variable	Group	Raw R^2	Raw σ_{within}	Raw $\sigma_{between}$	Raw ρ_{intra}	Residual R^2	Residual σ_{within}	Residual $\sigma_{between}$	Residual ρ_{intra}
Log(Y_{55})	Estab.	0.496	0.264	0.171	0.557	0.458	0.224	0.127	0.550
Log(Y_{60})	Estab.	0.526	0.283	0.184	0.572	0.483	0.260	0.144	0.543
Log(Y_{65})	Estab.	0.578	0.335	0.156	0.509	0.537	0.279	0.099	0.482
Retirement	Estab.	0.437	2.860	1.215	0.468	0.435	1.895	0.795	0.465
Retirement	Size class	0.134	3.031	0.685	0.233	0.157	1.977	0.561	0.215
Retirement	Industry	0.059	3.036	0.662	0.124	0.034	2.034	0.294	0.102
Education	Estab.	0.345	0.020	0.010	0.452	-	-	-	-
Experience	Estab.	0.291	6.924	2.684	0.456	-	-	-	-

Table 1 illustrates the importance of establishment-grouping in the raw data.[17] While intra-establishment correlation in retirement ages is less important than that in incomes, it is more important than intra-establishment correlation in experience and education. It should be remarked that this "naive" measure of establishment-effects on retirement age may be confounded because of the importance (61%) of incomplete spells i.e. periods of employment which terminate with out-of-sample rather than non-work. Moreover, it should be noted (in counterpoint to figure 2) that of establishments where one retiree at least is observed, only 52% have 2 or more. As a result 80% of retirees are accounted for by this 52% of establishments. Indeed, other possible informative groupings like size class and 2-digit industry show a smaller within group correlation.

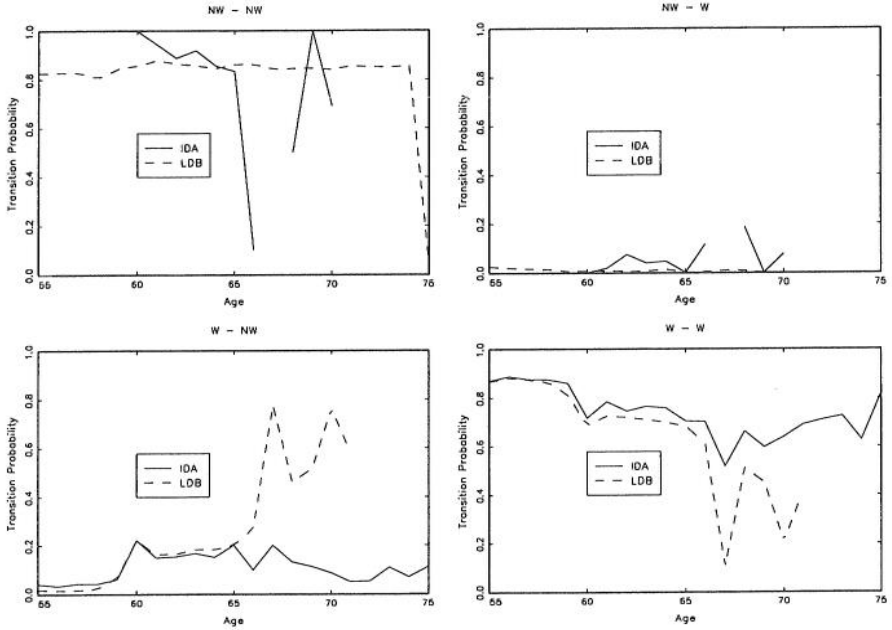
If one bears these warnings in mind, establishments (specific-effects) explain most of the variance in income, somewhat less of the variance in retirement, and even less of education and experience. Controlling for individual observables slightly reduces income variance explained, but not retirement variance explained. Moreover, it does not affect the magnitude of the within group correlation. We may tentatively conclude from this simple analysis of the raw data that there exists substantial between-establishment heterogeneity in incomes, however a similar conclusion is less obvious in the case of retirement ages.

[17] This table summarises the explanatory power of *group* dummies in a regression of *variable* (Y_{55}, Y_{60}, Y_{65} stand for income flow at age 55, 60 and 65) on *group*. Columns headed *raw* use *variable* itself as an explanatory variable, whereas columns headed *residual* use as a dependent variable the *residuals* from a regression of *variable* on observables (cohort, education, experience, occupation). Hence we wipe out observed individual heterogeneity when moving from the *raw* regressions to the *residual* regressions. For each set of regressions we report four measures of explanatory power: R^2 is obtained directly from a within-*group* OLS; as is Within-standard deviation and intra-*group* correlation; Between-standard deviation is obtained from a between-*group* OLS (and consequently is calculated as a function of group-size).

3.3 Transitions

In what follows we shall define a non-work (NW) state as opposed to a work (W) state for a year according to mandatory pension contributions and labour income being below some threshold and the absence of an attachment to a establishment[18]. Transitions between the two states are inspected graphically, and our retiree definition is motivated on the basis of non-work being an absorbing state for men aged over 54. Consequently the long-term unemployed (with a spell lasting at least January-December), those on invalidity benefit and pensioners with limited labour market attachment will all be labelled as retired.

Figure 3. Transition Rate Matrices by Age



In figure 3 we present transition proportions by age for each dataset. Rows of panes relate to origin states, columns relate to destinations. The second row corresponds to transitions from work (W). Discontinuities in the IDA line are due to lack of observations: IDA is smaller sample of persons than LDB and it becomes smaller still as the IDA sample ages and people leave work, therefore attriting from the sample. Spikes are evident at ages 60 and 67, and the proportion staying

[18] See appendix for exact definitions.

W declines until 67. The establishment sampling frame in IDA suggests that we will have no NP origins. This is true in all but a small number of cases, where hours and income criteria for participation in the labour market are not met, but the individual still has an attachment to the establishment. So the erratic IDA NW-NW hazards are due to small cell sizes. This group is deleted from our estimation sample. The main difference between IDA and LDB is exhibited in the W-NW hazard spikes at 67 and 70 found in the population. This is due to the exclusion of public sector workers from IDA, who face mandatory retirement at 67 from junior positions and at 70 from senior positions. Of all Danish employees, 40% work in the public sector, but this falls to 33% for men aged over 54.

Figure 4. Transition Rate Matrices by Year

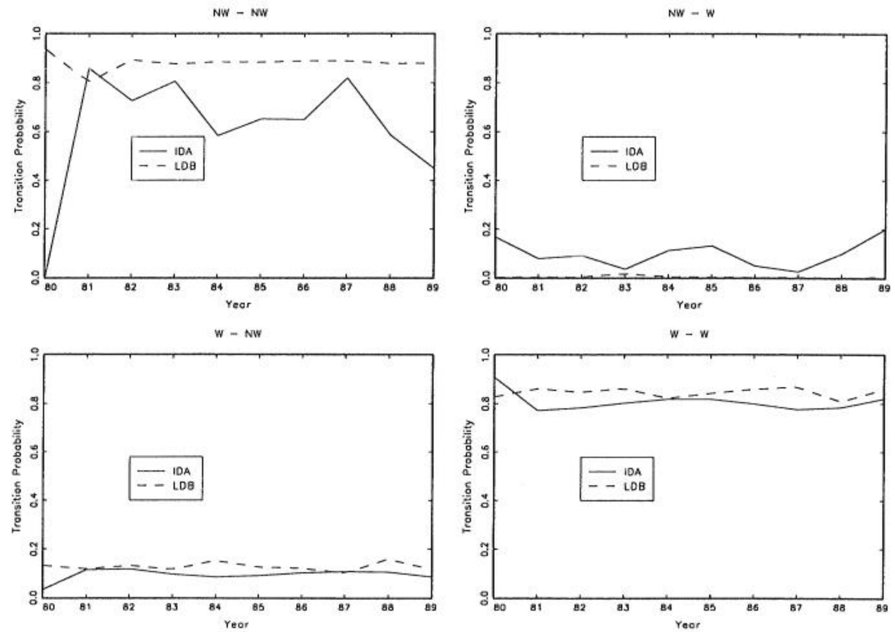


Figure 4 shows the time series of transition proportions for each dataset. There is no evidence of trend or cyclicality over the period in either dataset. Reforms to the pension system occurred in 1979, adjustment to which appears to have taken place before and at the beginning of our sample period, and in 1993, which was announced later than we are able to observe. The similarities between IDA and LDB are striking. We can conclude that exit from IDA is representative of private sector workers, differing most importantly from the population which includes public sector workers who face a uniform mandatory retirement policy.

3.4 Incomes

The purpose of this section is to describe, first, the difference in income streams as retirement age varies and second, income at retirement for various cohorts. IDA only follows people for one year after they leave a sampled establishment, and income streams are missing accordingly. The estimation model requires assumptions to be made about complete income streams. Comparison with LDB, which has out-of-work income streams not subject to this sample attrition, allows us to motivate these assumptions. Real net income (1991 prices) is computed accurately from administrative tax records[19].

Figure 5a (left), and 5b (left) present income streams according to age of retirement. Each line corresponds to a fixed retirement age and indicates, along its length, income at various ages conditional on the retirement date choice, i.e. a line is the stream of income for the representative "median" individual retiring at a given age. Note that several observations of one individual's income are used to define one line. Figure 5a (right) and 5b (right) present the number of observations used to define each point along each line.

As we stated above, the IDA sampling frame allows us to observe at most one period of retirement income, whereas LDB gives us a fuller picture of retirement income flows. LDB shows a large fall in income on retirement which quickly stabilises at a much lower level than in-work. This level is not very different across retirement ages. Since most of the action in income dynamics is in the first year of retirement, the retirement income information IDA is able to provide should give us a good indication of future expected but unobserved flows. Finally, the difference in income level between the two datasets is explained by the composition of the workforce sampled. LDB includes public sector as well as private sector workers whereas IDA samples private sector workers only. Previous studies of Danish public-private sector wage differentials show private sector premia during the early 80's to be 15% and 7% for earnings and wages respectively (Pedersen et.al., 1990). Though these differentials narrow among older men, we should expect to observe a significant difference in the level of income flows.

[19] Deductions and total taxable income are recorded consistently throughout the sample period. Net income is calculated by applying the average tax rate per gross income group (see Statistics Denmark ,1991).

Figure 5a. Income Streams - LDB

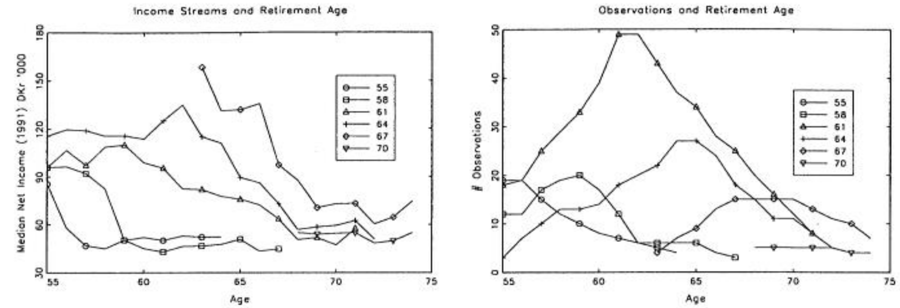
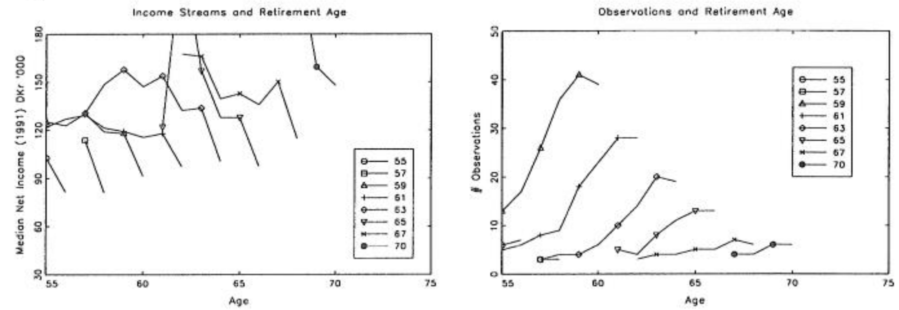


Figure 5b. Income Streams - IDA



Our estimation method does not require us to compute all potential income streams for each individual *throughout* a 20 year time horizon. What we are able to observe in IDA regarding income options does not contradict what we expect to and actually do find in the population. The main difference between IDA and LDB is found to be roughly 20% higher incomes in the private sector. Otherwise income streams are consistent with the population given the IDA sampling frame.

4. MODEL AND LIKELIHOOD SPECIFICATION

4.1 Economic Model for Individual Behaviour

Our starting point is a standard discrete-time optimal stopping markov model in finite horizon. The decision to retire is terminal and retirement is considered to be an absorbing state. The horizon is finite because of the absolute certainty of individual death, i.e. there exists an age such that the probability of surviving thereafter is zero. In effect retirement can occur at any moment of time before death. We take the conventional approach in that we do not explicitly model saving behaviour. Phelan & Rust (1995) make clear that this embeds individuals in a world with incomplete markets where no savings are possible. Rust (1995) is the only example of a model that could allow for modelling of the saving process.

The instantaneous utility of work, $u_{1,t}$, (say, relevant from the beginning of t to the end of t) depends only on the earnings received during the period. Because the earnings level may vary with experience at t, E_t, which is endogenous here we indicate that dependence, $w_t(E_t)$. We have:

$$u_{1,t}(w_t(E_t)) = \alpha \ln(w_t(E_t)) + \gamma_1 + \varepsilon_t(1), \tag{1}$$

Similarly the instantaneous utility of being retired, $u_{0,t}$, depends on the flow of retirement income received during the period, b_t. This may depend on the earnings level during the last period of work, or on the complete work history until retirement. We have:

$$u_{0,t}(b_t) = \alpha \ln(b_t) + \gamma_0 + \varepsilon_t(0). \tag{2}$$

The difference between $\gamma_0 + \varepsilon_t(0)$ and $\gamma_1 + \varepsilon_t(1)$ captures the utility of leisure at any point in time. In a limited way this may reflect variations in health affecting the valuation of leisure relative to the disutility of work. We assume that $\varepsilon_t(0)$ and $\varepsilon_t(1)$ are random error terms, independently distributed across time. We further assume that they are normally distributed such that their difference has zero expectation and the variance of their difference is equal to one[20]. This normalisation is of the same nature as the one which is used in binary response models.

The objective of the individual is to maximise his expected life-time utility over all possible future states:

$$\underset{\{d_t\}_{t=0\ldots T}}{\text{Max}} \quad E_0[\sum_{t=0}^{T} \beta^t (d_t u_{1,t}(w_t) + (1-d_t) u_{0,t}(b_t))], \tag{3}$$

where d_t is the strategy in t, $\{d_t\}_{t=0\ldots T}$ is the sequence of strategies over the life time. Because this problem has an optimal stopping structure the strategy in t is of the reservation value type. In our case, the reservation utility is such that the value of retiring now is equal to the value of working an additional period. In a finite horizon although the reservation utility cannot be expressed analytically,

[20] In a two alternative model this is without consequences.

it is possible to compute it using backward recursion. In the present context this is relatively straightforward. Let us denote $V_t(d_t; w_t, b_t, E_t, \varepsilon_t)$ the value of taking the decision d_t given the state variables. In t the value of taking decision d_t is :

$$\begin{aligned} V_t(d_t; w_t, b_t, E_t, \varepsilon_t) = {} & d_t(\alpha \ln(w_t) + \gamma_1 + \varepsilon_t(1)) + \\ & (1-d_t)(\alpha \ln(b_t) + \gamma_0 + \varepsilon_t(0)) + \\ & \beta E_t\Big[\max_d \{V_{t+1}(d; w_{t+1}, b_{t+1}, E_{t+1}, \varepsilon_{t+1})\} \mid d_t\Big], \end{aligned} \tag{4}$$

given the assumptions we made earlier about the error term distribution it is easy to compute the last term for $d_t = 1$:

$$\begin{aligned} & E_t\Big[\max_d \{V_{t+1}(d; w_{t+1}, b_{t+1}, E_{t+1}, \varepsilon_{t+1})\} \mid d_t = 1\Big] = \overline{V}_{t+1}(0;E_t) + \\ & \Phi[\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)] \quad (\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)) + \\ & \phi[\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)], \end{aligned} \tag{5}$$

where $\Phi[.]$ stands for the univariate normal c.d.f and $\phi[.]$ stands for the univariate normal p.d.f, and where $\overline{V}_t(.;.)$ stands for the expectation of $V_t(.;.)$. Because retirement is an absorbing state the value of retiring is expressed as a discounted sum of expected flows of income in retirement :

$$\begin{aligned} V_t(0; w_t, b_t, E_t, \varepsilon_t) &= \alpha \ln(b_t) + \gamma_0 + \varepsilon_t(0) + E_t\Big[\sum_{\tau=t+1}^{T} \beta^{\tau-t}(\alpha \ln(b_\tau) + \gamma_0 + \varepsilon_\tau(0))\Big] \\ &= \alpha \ln(b_t) + \gamma_0 + \varepsilon_t(0) + \sum_{\tau=t+1}^{T} \beta^{\tau-t}(\alpha E_t[\ln(b_\tau)] + \gamma_0). \end{aligned} \tag{6}$$

Notice that in order to evaluate the value of retirement it is not necessary to observe the future flows of income for each individual in retirement. Only the expectation of future flows of income is needed to evaluate retirement. Hence, provided we are able to calculate the mean of future income flows for a large enough number of groups it is possible to give an expected value to retirement in a straight forward manner. Substituting 5. in 4. gives the value of not retiring in t :

$$\begin{aligned} & V_t(1; w_t, b_t, E_t, \varepsilon_t) = \alpha \ln(w_t) + \gamma_1 + \varepsilon_t(1) + \\ & \beta(\overline{V}_{t+1}(0;E_t) + \Phi[\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)](\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)) + \\ & \phi[\overline{V}_{t+1}(1;E_t+1) - \overline{V}_{t+1}(0;E_t)]) \end{aligned} \tag{7}$$

The last two expressions allow the backward computation of the value of retirement and the value of working one more year. Hence the strategy in t is such that :

$$\begin{aligned} d_t = 1 \quad &\text{if} \quad V_t(1, w_t, b_t, E_t, \varepsilon_t) > V_t(0, w_t, b_t, E_t, \varepsilon_t), \\ d_t = 0 \quad &\text{otherwise.} \end{aligned} \tag{8}$$

It is worth noticing that the last expression together with the other relevant elements allows us to express the conditional valuation functions in terms of the probability of future choices following Hotz & Miller (1994) (hereafter HM). HM results rest on an alternative representation of the conditional valuation function in terms of the probabilities of all future choices attainable given the history followed so far. Moreover, this representation is substantially simplified in the case of optimal stopping problems. Here, HM show that it is theoretically possible to estimate the parameters of the model without calculation of the future value functions, provided the path of future decisions gives enough information about the future choice probabilities[21]. Another interesting output from their work is the interpretation of comparative dynamics, associated with changes in the states variables[22]. This allows them to distinguish between effects on current utility holding the valuation function constant, and the effects on expected future utility. Thus, the distinction between short- and long-run effects of a policy change affecting state variables is then possible.

4.2 Accounting for Establishment Wage Policy

The data available to us allows the introduction of both individual- and establishment-specific effects. Although there are several possible routes for this, perhaps the simplest one (see Berkovec & Stern, 1991) is to endow the stochastic component of the income flows with a random error component structure, as follows :

$$\begin{aligned} \ln(w)_{t,f,i} &= \overline{\ln(w)}_{t,f,i} + \eta_{t,f,i}(1) + \xi_f + \omega_i, \\ \ln(b)_{t,f,i} &= \overline{\ln(b)}_{t,f,i} + \eta_{t,f,i}(0) + \theta_1\xi_f + \theta_2\omega_i, \end{aligned} \tag{9}$$

where the subscripts f and i indicates respectively the establishment and the individual. The error term $\eta_{t,f,i}(.)$ is assumed to be independently and identically distributed across time, individuals and establishments, the error term ξ_f is assumed to be independently and identically distributed across establishments, and the error term ω_i is assumed to be independently and identically distributed across individuals. We further assume that the error components are normally

[21] See Hotz & Miller (1993,1994) for the set of assumptions required and the statistical asymptotic theory.
[22] See Hotz & Miller (1993) equations *3.15* and *3.16*.

distributed. The individual- and establishment-specific effects are assumed to be known by the individual but are unobservable to the econometrician. In this instance the expectation operator in the conditional valuation functions is understood to be conditional on the value of these terms. We introduce the parameters θ_1 and θ_2 in order to allow, in a parsimonious way, a differential incidence of the individual- and establishment-specific effects on the income flow before and after retirement.

The individual-specific effect accounts in a conventional (and perhaps naive) way for unobserved individual heterogeneity in retirement behaviour. Moreover, it accounts for a possible serial correlation between the different flows of income received by the same individual. This is a usual feature of error component models. On the other hand, beside accounting for the correlation of income flows among individuals belonging to a same establishment, the establishment-specific effects allow the correlation of observed retirement dates among individuals belonging to the same establishment. This can be shown directly if we digress to a simplified static structure. Suppose for example that we observe a participant if $\overline{\alpha}_i + \xi_f + \omega_i$ is positive and a non-participant otherwise. ξ_f and ω_i are defined as previously and $\overline{\alpha}_i$ describes the individual-specific deterministic term of the decision equation. The covariance between the observed decisions of two individuals in the same establishment is :

$$\begin{aligned} &\mathrm{E}\Big[\Big\{\mathbf{1}_{\{\overline{\alpha}_i+\eta_f+\omega_i>0\}} - \mathrm{E}\big[\mathbf{1}_{\{\overline{\alpha}_i+\eta_f+\omega_i>0\}}\big]\Big\}\Big\{\mathbf{1}_{\{\overline{\alpha}_j+\eta_f+\omega_j>0\}} - \mathrm{E}\big[\mathbf{1}_{\{\overline{\alpha}_j+\eta_f+\omega_j>0\}}\big]\Big\}\Big] = \\ &\Phi_2\left[\frac{\overline{\alpha}_i}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}, \frac{\overline{\alpha}_j}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}, \frac{\sigma_\eta^2}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}\right] - \Phi\left[\frac{\overline{\alpha}_i}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}\right]\Phi\left[\frac{\overline{\alpha}_j}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}\right] \end{aligned} \tag{10}$$

where $\Phi_2[.]$ stands for the bivariate normal c.d.f. This expression is easily shown to be positive[23]. In the dynamic setting which interests us here the covariance between the observed date of retirement of two individuals belonging to the same establishment is more complex but it is likely that a similar conclusion can be obtained[24]. Therefore, the magnitude of the variance of the establishment specific effect informs us about the magnitude of the covariance between the observed retirement dates of two different individuals belonging to the same establishment.

[23] Without loss of generality normalise $\sqrt{\sigma_\eta^2+\sigma_\omega^2}$ to one. The derivative of the covariance with respect to σ_η^2 is the bivariate density $\phi_2\left[\frac{\overline{\alpha}_i}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}, \frac{\overline{\alpha}_j}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}, \frac{\sigma_\eta^2}{\sqrt{\sigma_\eta^2+\sigma_\omega^2}}\right]$ which is positive for all σ_η^2. When σ_η^2 is zero the covariance is zero, hence when σ_η^2 is positive the covariance is positive as expected.
[24] Given an identical work-history until date t, the covariance between the observed decisions in t of two individuals belonging to the same establishment is similar to the covariance in the static case.

This specification allows us to test easily whether there exists a within-establishment correlation between retirement ages. Indeed, if θ_1 is close to 1 then the differences in values at any point in time do not depend on the establishment-specific effect[25],i.e. the difference makes it disappear. In this case, the model does not account for any within-establishment correlation between retirement ages induced by establishment-specific wage policies. The result of the test is the main contribution of this paper.

4.3 Likelihood Specification

In this section we describe the likelihood functions corresponding to the model without and with establishment- and individual-specific effects. Given the stochastic assumptions we have made previously, the value in t of each possible alternative is :

$$V_t(0) = \alpha\,\overline{\ln(b)}_t + \gamma_0 + \varepsilon_t(0) + \alpha\eta_t(0) + \sum_{\tau=t+1}^{T} \beta^{\tau-t}(\alpha\,\overline{\ln(b)}_\tau + \gamma_0), \qquad (6')$$

$$V_t(1) = \alpha\,\overline{\ln(w)}_t + \gamma_1 + \varepsilon_t(1) + \alpha\eta_t(1) + \beta E[\max\{V_{t+1}(0), V_{t+1}(1)\}]. \qquad (7')$$

As usual with multi-regime models, because of partial observability the correlation between income flows is not identified and therefore set to zero. We have :

$$\begin{pmatrix} \varepsilon_t(1) + \alpha\eta_t(1) - \varepsilon_t(0) - \alpha\eta_t(0) \\ \eta_t(0) \\ \eta_t(1) \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \sigma_{10,0} & \sigma_{10,1} \\ \sigma_{10,0} & \sigma_0^2 & 0 \\ \sigma_{10,1} & 0 & \sigma_1^2 \end{pmatrix} \right), \qquad (11)$$

where the two digit subscripts in the variance-covariance matrix refer to terms involving a difference in value function between two alternatives, whereas the single digit numbers refer to income flows.

The sample of N individuals is composed of N_1 individuals who retire in $t_{1,i}$, and N_+ individuals who have an uncompleted spell of participation of length l_i. The contribution to the likelihood of each sub-sample is :

$$L_1 \propto \prod_{i=1}^{N_1} \prod_{\tau=1}^{t_{1,i}-1} \left\{ \frac{1}{\sigma_1}\phi\left[\frac{e_{\tau,1,i}}{\sigma_1}\right] \Phi\left[\frac{e_{\tau,10,i} - \rho_{10,1}e_{\tau,1,i}/\sigma_1}{\sqrt{1-\rho_{10,1}^2}}\right]\right\} \left\{\frac{1}{\sigma_0}\phi\left[\frac{e_{t_{1,i},0,i}}{\sigma_0}\right]\left(1-\Phi\left[\frac{e_{t_{1,i},10,i} - \rho_{10,1}e_{t_{1,i},0,i}/\sigma_0}{\sqrt{1-\rho_{10,0}^2}}\right]\right)\right\}, \qquad (12)$$

$$L_+ \propto \prod_{i=1}^{N_+} \prod_{\tau=1}^{l_i} \left\{ \frac{1}{\sigma_1}\phi\left[\frac{e_{\tau,1,i}}{\sigma_1}\right] \Phi\left[\frac{e_{\tau,10,i} - \rho_{10,1}e_{\tau,1,i}/\sigma_1}{\sqrt{1-\rho_{10,1}^2}}\right]\right\}, \qquad (13)$$

where $e_{t,k,i} = \ln(y)_{t,k,i} - \overline{\ln(y)}_{t,k,i}$ with $\ln(y)_{t,1,i} = \ln(w)_{t,i}$, and $\ln(y)_{t,0,i} = \ln(b)_{t,i}$, and $e_{10,t,i} = \overline{V}_{t,i}(1) - \overline{V}_{t,i}(0)$. If income flows are not observed during part of the history the unconditional probabilities of participation/retirement can be substituted into these expressions, provided that the reason why the data are missing is not correlated with the error terms of the model.

The likelihood of the model with individual-specific effects only can be derived directly from the previous expressions since given the specific effect the error structure is identical to the error structure without the specific effect. The contribution to the likelihood of one individual belonging to the first group becomes :

$$L_{1,i} \propto \int_{-\infty}^{+\infty} \prod_{\tau=1}^{t_{1,i}-1} \left\{ \frac{1}{\sigma_1}\phi\left[\frac{e_{\tau,1,i}(\omega)}{\sigma_1}\right] \Phi\left[\frac{e_{\tau,10,i}(\omega) - \rho_{10,1}e_{\tau,1,i}(\omega)/\sigma_1}{\sqrt{1-\rho_{10,1}^2}}\right]\right\} \left\{\frac{1}{\sigma_0}\phi\left[\frac{e_{t_{1,i},0,i}(\omega)}{\sigma_0}\right]\left(1-\Phi\left[\frac{e_{t_{1,i},10,i}(\omega) - \rho_{10,1}e_{t_{1,i},0,i}(\omega)/\sigma_0}{\sqrt{1-\rho_{10,0}^2}}\right]\right)\right\} \frac{1}{\sigma_\omega}\phi\left[\frac{\omega}{\sigma_\omega}\right] d\omega, \qquad (14)$$

A similar expression can be obtained for the contributions to the likelihood of individuals belonging to the second group. In practice the integral can be computed at relatively low cost using quadrature methods[26].

When both the individual- and the establishment-specific effects are present the likelihood contributions are more difficult to obtain since we have to integrate the conditional contribution to the likelihood of every individual belonging to the same establishment over all possible values of the individual- and establishment-specific effect. Here again we use a quadrature method to compute the

[25] In fact, if $\theta_2 = 1$ it does not depend on the individual-specific effect either for the same reason.

[26] For a detailed description see Press, Flannery, Teukolsky & Vetterling (1986), and for applications in econometrics see Butler & Moffitt (1982) and Sickles & Taubman (1986).

integral[27]. Assume the N individuals are distributed among F establishments, each of which are of size N_f. In general, the contribution to the likelihood of establishment f is :

$$L_f \propto \int_{-\infty}^{+\infty} \left[\prod_{i=1}^{N_{f,1}} \int_{-\infty}^{+\infty} \prod_{\tau=1}^{t_{1,i}-1} \left\{ \frac{1}{\sigma_1} \phi\left[\frac{e_{\tau,1,i}(\xi,\omega)}{\sigma_1} \right] \Phi\left[\frac{e_{\tau,10,i}(\xi,\omega) - \rho_{10,1} e_{\tau,1,i}(\xi,\omega)/\sigma_1}{\sqrt{1-\rho_{10,1}^2}} \right] \right\} \right. \tag{15}$$

$$\left\{ \frac{1}{\sigma_0} \phi\left[\frac{e_{t_{1,i},0,i}(\xi,\omega)}{\sigma_0} \right] \left(1 - \Phi\left[\frac{e_{t_{1,i},10,i}(\xi,\omega) - \rho_{10,0} e_{t_{1,i},0,i}(\xi,\omega)/\sigma_0}{\sqrt{1-\rho_{10,0}^2}} \right] \right) \right\} \frac{1}{\sigma_\omega} \phi\left[\frac{\omega}{\sigma_\omega} \right] d\omega \Bigg]$$

$$\left[\prod_{i=1}^{N_{f,*}} \int_{-\infty}^{+\infty} \prod_{\tau=1}^{t_i} \left\{ \frac{1}{\sigma_1} \phi\left[\frac{e_{\tau,1,i}(\xi,\omega)}{\sigma_1} \right] \Phi\left[\frac{e_{\tau,10,i}(\xi,\omega) - \rho_{10,1} e_{\tau,1,i}(\xi,\omega)/\sigma_1}{\sqrt{1-\rho_{10,1}^2}} \right] \right\} \frac{1}{\sigma_\omega} \phi\left[\frac{\omega}{\sigma_\omega} \right] d\omega \right]$$

$$\frac{1}{\sigma_\xi} \phi\left[\frac{\xi}{\sigma_\xi} \right] d\xi.$$

5. ESTIMATION RESULTS

Our aim is to estimate retirement preference parameters recovered from the structural model. Income flows in- and out-of-work are the main economic determinants of interest, and our objective is to pay careful attention to modelling these flows. Specifically we want to measure the effects of two income determinants: Establishment heterogeneity and public transfer programme eligibility. The former is the novelty of this paper, and the latter provides identifying variation in income flows. Hence we respectively address the personnel economics literature and the endogeneity problem faced by purely structural (as opposed to natural experimental) approaches.

The model described in the previous section is estimated on an IDA subsample of men aged 55 or above (4940 individual observations, 915 establishments). We assume everyone dies before age 100 and retires before 76. Following Berkovec & Stern (1991) we allow for the possibility of death occurring before 100 years of age. This makes the discount rate time-dependent as follows : $\beta_t = \beta\,\pi_t$, where β is a constant time preference element and π_t reflects the mortality rate[28]. Net income flows are defined as log of the flows presented in Section 3.3. These flows are explained by occupational dummies (reference group : salaried white collar), regional dummies (reference: Fyn), experience for the in-work net income equation

[27] The difficulty is that the product can involve in some cases almost one hundred individual terms. This makes numerical evaluation quite difficult since these products converge quickly to zero. On simulated data, we have tried several method to control the products. Multiplying each component by a fixed constant (say 10) gives satisfactory results.

[28] From life tables Statistics Denmark (1975, 1985, 1995a). Over this period cohort effects were negligible for our purposes.

and, age at retirement and benefit eligibility for the retirement net income equation. The difference between γ_0 and γ_1 depends linearly on years of education and age. This specification choice is arbitrary. The models are estimated sequentially from the simplest specification ($\beta = 0$, no specific effects) to the most complex one ($\beta = 0.9$ individual- and establishment-specific effect). The results are presented in Table 2.

The significance of PEW eligibility as a determinant of retirement income supports our identifying assumption that public transfers provide sufficient income variation to address the problem that observed income flows are endogenous to the retirement decision. Being eligible for the public early retirement scheme (PEW) increases out of work net income by about 3% when dynamic behaviour is taken into account, and by about 6% in the static case. The PEW window is from age 60 to 66 and the static model over-estimates its instantaneous effects compared to the dynamic model. This is in contrast to age of retirement in the out-of-work net income equation which becomes insignificant in every dynamic specification. As predicted by life-cycle theory, the return to experience is economically negligible although statistically significant. Across all specifications, the results show a similar structure of net income in-work and net income out-of-work i.e., the hierarchy of skill groups and regional differentials are maintained in retirement.

The introduction of unobserved heterogeneity by way of establishment- and person-specific effects has the expected consequence of reducing the variance of the transitory component of the income flow error terms. Tables 3 and 4 present the implications of the estimate of the error components on the decomposition of the total variance. Table 3 shows that establishment heterogeneity accounts for around 20% of the residual variance of log net incomes, and worker unobserved heterogeneity accounts for around 50%.

If establishment heterogeneity is not modelled, then it is spuriously attributed to the individual-specific effect. Comparing individual- with individual- and establishment-heterogeneity estimates shows that one third of individual unobserved heterogeneity in the former (standard) model is due to establishment heterogeneity. This should be considered an upper bound on the unobserved establishment effect which is missing from standard models, since those models often contain establishment observables such as size and industry for example.

The most complex specification implies that individual heterogeneity accounts for 50% of out-of-work log net income variance and about 60% of in-work log net income variance. This compares well with results from a descriptive error component model for IDA which allocates 38% of log *wage* variance to workers and 26% to establishments (Bingley and Westergård-Nielsen, 1996).

Table 4 presents the implied correlations between two successive values of log net incomes. As expected, it shows that two realisations of in-work incomes are more correlated than in-work income is with out-of-work income. The correlation between out-of-work incomes is the smallest, although still substantial. Note however that this correlation is not identified by the data since no-one in our sample is observed with two successive out-of-work incomes.

Table 2
Full Information Maximum Likelihood Estimates

	$\beta=0$		$\beta=0.90$		$\beta=0.90$ Individual Effect		$\beta=0.90$ Individual & Estab. Effect	
	Param.	Std. Err.	Param.	Std. Err.	Param.	Std. Err.	Param.	Std. Err.
α	6.9827	0.7761	6.108	1.125	6.110	0.981	6.085	1.544
$\gamma_0-\gamma_1$:								
Constant	0.879	1.535	1.012	1.361	0.961	1.028	1.091	0.963
Educ/100	3.739	0.361	1.170	0.117	1.205	0.118	1.469	0.116
Age/100	1.723	2.000	1.467	1.708	1.422	1.333	1.469	1.181
Work Log Net Income Equation								
Intercept	4.925	0.007	4.975	0.007	4.982	0.006	4.942	0.007
Manag.	0.308	0.003	0.311	0.003	0.278	0.003	0.266	0.003
Skilled	-0.076	0.004	-0.077	0.004	-0.088	0.003	-0.131	0.004
Unskilled	-0.136	0.004	-0.137	0.004	-0.237	0.003	-0.199	0.004
Others	-0.315	0.007	-0.305	0.007	-0.344	0.005	-0.336	0.006
København	0.081	0.004	0.087	0.004	0.089	0.003	0.120	0.003
Fred'berg	0.106	0.005	0.112	0.005	0.151	0.004	0.161	0.006
W.Sjæland	0.088	0.005	0.095	0.005	0.105	0.004	0.158	0.005
S.Jylland	0.088	0.006	0.091	0.006	0.186	0.005	0.205	0.008
E.Jylland	0.109	0.005	0.115	0.004	0.136	0.004	0.220	0.005
W.Jylland	0.069	0.005	0.073	0.005	0.132	0.005	0.168	0.006
N.Jylland	0.109	0.006	0.113	0.006	0.113	0.005	0.200	0.007
Exper/100	0.238	0.015	0.106	0.016	0.096	0.012	0.069	0.016
Retirement Log Net Income Equation								
Intercept	3.831	0.224	4.518	0.183	4.533	0.148	4.465	0.144
Manag.	0.298	0.006	0.309	0.004	0.276	0.003	0.262	0.004
Skilled	-0.041	0.007	-0.066	0.005	-0.078	0.004	-0.121	0.005
Unskilled	-0.097	0.007	-0.126	0.005	-0.225	0.004	-0.186	0.005
Others	-0.359	0.016	-0.314	0.009	-0.355	0.007	-0.343	0.008
København	0.072	0.006	0.087	0.004	0.088	0.004	0.118	0.004
Fred'berg	0.107	0.008	0.114	0.006	0.153	0.005	0.161	0.006
W.Sjæland	0.091	0.008	0.097	0.006	0.108	0.005	0.158	0.006
S.Jylland	0.097	0.009	0.095	0.007	0.190	0.006	0.210	0.009
E.Jylland	0.116	0.007	0.119	0.005	0.141	0.005	0.223	0.005
W.Jylland	0.070	0.008	0.075	0.006	0.135	0.006	0.170	0.006
N.Jylland	0.122	0.010	0.118	0.007	0.118	0.007	0.205	0.008
RetAge/100	1.109	0.293	0.239	0.246	0.239	0.198	0.214	0.186
Eligibility	0.059	0.007	0.033	0.006	0.033	0.005	0.034	0.009
σ_1^2	0.101	0.001	0.101	0.001	0.031	0.001	0.024	0.001
σ_0^2	0.109	0.006	0.101	0.001	0.047	0.002	0.047	0.004
$\rho_{10,1}$	0.562	0.018	0.580	0.017	0.777	0.016	0.811	0.020
$\rho_{10,0}$	0.328	0.103	0.069	0.087	0.249	0.104	0.375	0.106
σ_ξ	-	-	-	-	-	-	0.168	0.001
σ_ω	-	-	-	-	0.291	0.001	0.265	0.001
θ_1	-	-	-	-	-	-	0.995	0.003
θ_2	-	-	-	-	0.999	0.002	0.999	0.002
Log Lik.	-17988		-17805		-12558		-11106	

The general model with individual and establishment heterogeneity produces larger correlations between each income flow and the differences in values. Note that the latter are positive irrespective of the type of income considered. A structure similar to a Roy model (Heckman & Honoré, 1990), that is where the occupation choice is based on a comparison of (discounted) earnings only, would lead the two correlations between the difference in values and the income equations to have opposite signs (see equation 11.). The structure we present here allows the choice to depend on an additional source of unobserved heterogeneity, i.e. $\varepsilon_i(1)-\varepsilon_i(0)$, which allows for more complex correlation patterns. Alternatively, it may well reflect the mispecification of the income flow equations. For example, the omission of a variable in both the income flow equations and the utility may have such an effect.

Table 3
Log Real Net Income Equation Error Components

Heterogeneity	Net Income	%Unexpl.	Error Component %Individual	%Estab.
Individual	W	0.268	0.732	-
	NW	0.357	0.643	-
Individual & Establishment	W	0.196	0.574	0.231
	NW	0.323	0.482	0.194

Table 4
Log Real Net Income Correlations

Heterogeneity	W/W	Net Incomes W/NW	NW/NW
Individual	0.732	0.686	0.643
Individual & Establishment	0.804	0.738	0.677

The estimated values of θ_1 and θ_2 are indistinguishable from 1 . As we pointed out earlier this implies that although individual and establishment heterogeneity are important in describing the log net income process they do not have an effect on individual retirement decisions since they difference out. In particular, the model does not detect any within-establishment correlation of individual retirement age related to the income process. This is an unexpected result since theoretical arguments suggest some dependence of individual retirement age on establishment-specific wage policies. Our preliminary inspection of the raw data, though somewhat inconclusive, gave more support to intra-establishment income correlations than retirement correlations.

In the current setting, a possible explanation for this estimation result is to appeal to the State funded early retirement scheme which denies establishments the use of one instrument, i.e. setting the mandatory retirement age. The extent to which this is very costly is difficult to assess without more information describing the establishments and their technology. On the other hand, the model we present here only allows the establishment to affect the retirement decision through variations of the in-work income.

A longer education increases the utility of leisure (retirement) compared to the utility of work. Hence for an equal stream of income flows from work and during retirement a more educated person would retire earlier than a less educated person. This is common to all specifications, although those involving a dynamic process make the effect smaller, as far as instantaneous utility is concerned. Moreover, no specification recognizes an effect of age on the disutility of work. This last statement has to be moderated since age has an important effect through the discount rate (the survival probabilities are age-dependent).

Comparison of likelihood values supports the more complex model. If one considers the variation in likelihood from the simplest specification it is clear that taking into account the dynamic nature of individual decision making as well as the heterogeneity among individuals and establishments improves model fit.

Figure 6.

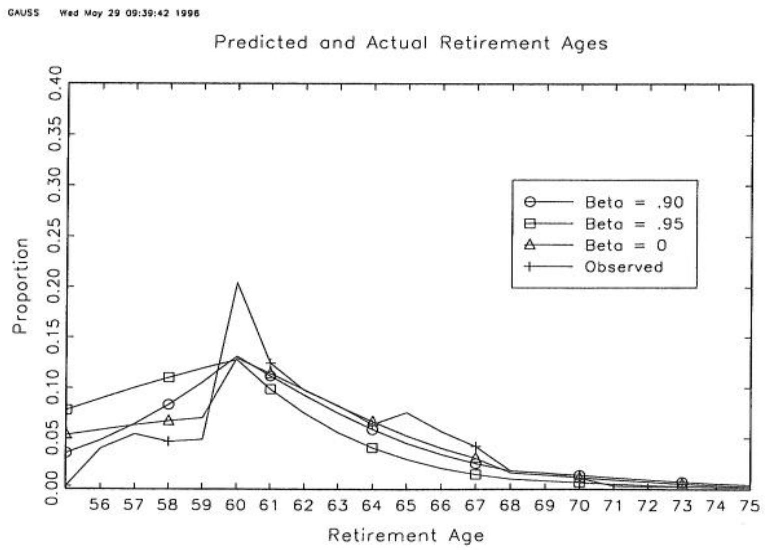


Figure 6. illustrates how the static model ($\beta = 0$) and the simple dynamic model ($\beta = 0.90$ and $\beta = 0.95$ and no specific effects) predicts the age of retirement among the population of men observed to retire. Each of the models reproduce the observed peak at 60. This is driven by the effect of PEW eligibility on out-of-work income.

6. CONCLUSION

We have analysed, for the first time, the effect of establishment remuneration policy on individual worker retirement ages. A conventional structural dynamic programming model is extended to allow employer unobserved heterogeneity to influence retirement decisions through income streams in-work and out-of-work. These employer effects are identified by exploiting a matched panel of Danish establishments and workers, and they are found to be empirically important. Exogenous eligibility to a public early retirement programme identifies the effect of income flows on retirement.

Estimated coefficients on observable characteristics determining income and retirement (age, experience, education) are found to be entirely consistent with economic theory. Employer pay policy accounts for about one fifth of unexplained (log real net) income variance, and unobserved worker heterogeneity accounts for about half. The continuity of employer effects into retirement supports the compensating differentials argument that pensions be treated as deferred pay.

Tilted tenure-remuneration profiles, according to efficient labour contracts, should be accompanied by employer-specific retirement policies according to the between-employer productivity distribution. However, we find no evidence of a direct establishment effect on retirement age, after controlling for observables.

Pay policy is an important instrument through which employers may influence workers retirement ages, together with mandatory retirement rules. The potential for this instrument is made clear since employer effects on income in-work are found to carry over strongly into retirement. The relatively attractive public early retirement scheme, which is available to the majority of male workers from the age of 60, may disguise or reduce the importance of establishment retirement schemes. This transfer is not means-tested against private unearned income, and so employer-effects on non-work income remain, thought they are not important enough to generate employer-effects on retirement age.

APPENDIX

Table A1
Descriptive Statistics for Estimation Sample

Variable	Mean	S. Dev	Minimum	Maximum	# Valid
Education/100	0.1081	0.0225	0.090	0.180	4940
Experience	38.6054	7.4264	12.924	59.000	4940
Single Estab. Firm	0.5178	0.4997	0.000	1.000	4940
Construction	0.0947	0.2929	0.000	1.000	4940
Trade	0.2302	0.4210	0.000	1.000	4940
Transport	0.1014	0.3019	0.000	1.000	4940
Finance	0.0887	0.2843	0.000	1.000	4940
Services	0.0905	0.2869	0.000	1.000	4940
Management	0.1796	0.3839	0.000	1.000	4940
Skilled	0.1816	0.3855	0.000	1.000	4940
Unskilled	0.2660	0.4419	0.000	1.000	4940
Others	0.0128	0.1122	0.000	1.000	4940
København	0.3018	0.4591	0.000	1.000	4940
Fred'derg	0.0836	0.2768	0.000	1.000	4940
S. Jylland	0.0579	0.2336	0.000	1.000	4940
E. Jylland	0.1370	0.3439	0.000	1.000	4940
W. Jylland	0.0696	0.2546	0.000	1.000	4940
N. Jylland	0.0476	0.2129	0.000	1.000	4940
Age at entry	57.9761	4.0376	55.000	75.000	4940
Age at exit	61.1431	4.3356	55.000	75.000	4940
Duration from 55	6.6881	4.2451	0.000	21.000	4940

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Panel Data and Structural Labour Market Models
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The Relation Between Wages and Labor Market Frictions: An Empirical Analysis Based on Matched Worker-Firm Data

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This paper addresses the relationship between search frictions and the wage formation of firms. According to the Burdett-Mortensen model, firms exploit frictions by setting lower wages. Moreover, if we allow for productivity dispersion of firms within a single labor market, this results in less competition between these firms. With the IDA data, a large database of survey data from the Danish labor market, we first reconstruct the labor market histories of individual workers to estimate parameters that determine the degree of search frictions across labor market segments. Second, we estimate wage regressions that incorporate the effect of search frictions. In doing this, we do not fully impose the structure of the equilibrium search model in all cases.

1. INTRODUCTION

In recent years, an empirical literature has emerged that stresses the importance of worker and firm characteristics in explaining wage dispersion. With the release of matched worker-firm data, it has become possible to distinguish individual effects from firm and match-specific effects in the wage earnings of individual workers, see e.g. (Abowd, Kramarz and Margolis 1999, Bingley and Westergård-Nielsen 1996). The evidence suggests that firm effects are also an important source of wage dispersion. At the same time, a large literature has been written on labor market flows. Labor markets are characterized by large flows to and from unemployment and between jobs The presence of these flows indicates that the labor market is not a standard competitive market. It takes effort and time to locate a suitable partner and to complete a transaction. Moreover, employed individuals have an incentive to find job opportunities that are more attractive than their current job. The discovery of these opportunities can be modeled as the outcome of a random process, and the resulting delays are often referred to as search frictions.

If jobs are only characterized by a wage level, the existence of wage dispersion and worker turnover are interrelated. If there would be no wage dispersion, and jobs are only characterized by wages, workers have no incentive to search for jobs with higher wages. On the other hand, if workers would not search on the job, (identical) firms have no interest in raising the wages to attract workers from other firms. Thus, if workers search for a better job while working, employers are faced with a trade-off between the wage and the work force of a firm. Burdett and Mortensen (1998) and Mortensen (1990) have developed this idea in an equilibrium search model, in which both labor market dynamics and wage determination are incorporated. According to this model, wage dispersion is directly related to the degree of search frictions.

The Mortensen equilibrium search model satisfies a number of stylized facts of the labor