Analysis of trajectories into retirement using the Danish labour market registry

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The Danish labour market registry

id	month	sex	birthdate	status	hours	start	end
1	January	M	08-03-1950	sick leave	148	01-01-2011	31-01-2011
2	January	F	21-09-1950	employed	10	20-01-2011	31-01-2011
2	Febuary	F	21-09-1950	employed	50	01-02-2011	28-02-2011
3	January	M	02-11-1950	employed	10	01-01-2011	15-01-2011
3	January	M	02-11-1950	employed	10	01-01-2011	15-01-2011
3	January	M	02-11-1950	unemployment benefits	74	16-01-2011	31-01-2011
3	Febuary	M	02-11-1950	unemployment benefits	37	01-02-2011	07-02-2011
3	Febuary	M	02-11-1950	early retirement pension	109	08-02-2011	28-02-2011
4	March	F	07-04-1950	early retirement pension	148	01-03-2011	31-03-2011
5	January	M	08-12-1950	employed	148	01-01-2011	31-01-2011

Table 1: Simulated example of the data contained in the labour market register.

Early Retirement Pension (ERP)

Table 2: Ages at which Early Retirement Pension (ERP) is available according to date of birth.

Date of Birth	ERP age
$<$ 1954	60
$\geq$ 01-January-1954	60.5
$\geq$ 01-July-1954	61
$\geq$ 01-January-1955	61.5
$\geq$ 01-July-1955	62
$\geq$ 01-January-1956	62.5
$\geq$ 01-July-1956	63
$\geq$ 01-January-1959	63.5
$\geq$ 01-July-1959	64
$>$ 1963	computed in relation to life expectancy

Sequence analysis

Sequence analysis

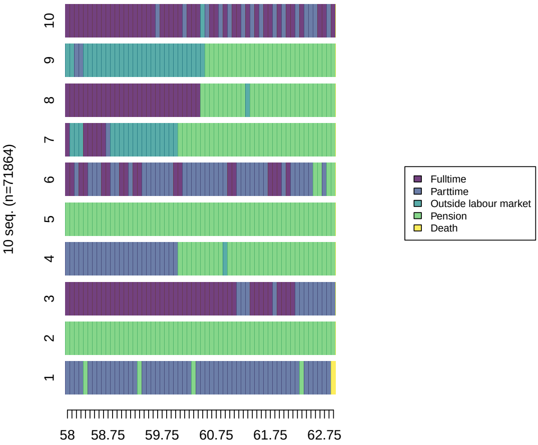


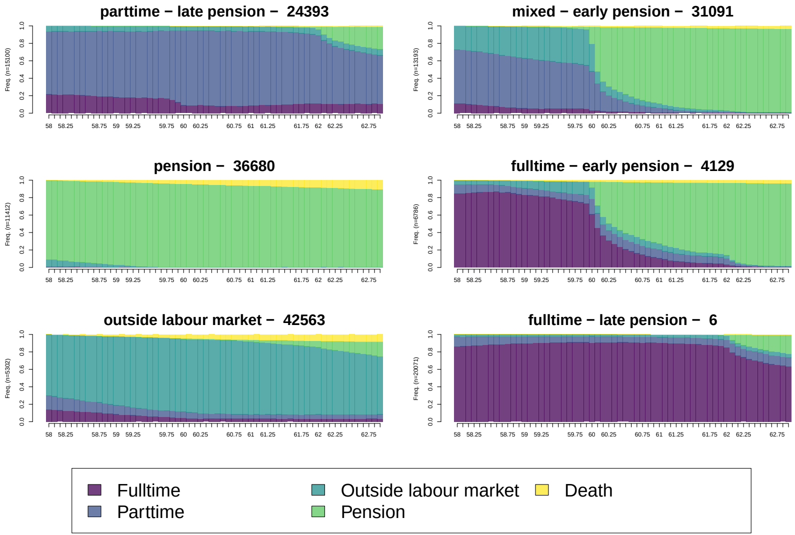
Figure 1: Ten example sequences for the 1950 cohort.

Implementation in R

R-packages:

- `TraMineR`
- `TraMineRextras`
- `WeightedCluster`

Clusters 1950 cohort



Clusters 1954 cohort

Further analyses

- crosstabulations
- separate sequence analyses for each cohort
- predicting of clusters based on covariates (e.g. gender, education level)

But

What if we want to model the time to pension?

Joint Models for Longitudinal and Survival data

Joint Model

Longitudinal:

$$\pi_{itk} = P(Y_{it} = k) = \begin{cases} \dfrac{1}{1 + \sum_{h=1}^{K-1} \exp(\mathbf{X}_{it}\beta + b_{ih})} & \text{if } k = K \\ \dfrac{\exp(\mathbf{X}_{it}\beta + b_{ik})}{1 + \sum_{h=1}^{K-1} \exp(\mathbf{X}_{it}\beta + b_{ih})} & \text{if } k = 1, \ldots, K-1, \end{cases}$$

$k \in \{1, \ldots, K\} = \{\text{Fulltime}, \text{Parttime}, \text{Outside the labour market}\}$, b_{ih} = random intercepts.

Time-to-event:

$$\log \mu_{it} = \log t_{it} + \mathbf{X}_{it}\boldsymbol{\eta} + \alpha_t + u_i,$$

μ_{it} = retirement hazard, $\alpha_t = \log \lambda_t$ = log baseline hazard, t_{it} = time at risk (offset), u_i = frailty, $\log \lambda_t = \mu_\lambda + N(\log \lambda_{t-1}, \sigma_\lambda)$.

Joint Model

Random intercept b_{ih} and frailty u_i assumed to follow a multivariate normal distribution with the following variance-covariance matrix:

$$\mathbf{\Sigma} = \begin{bmatrix} \Sigma_{\boldsymbol{b}} & \Sigma'_{\boldsymbol{b}u} \\ \Sigma_{\boldsymbol{b}u} & \sigma_u^2 \end{bmatrix},$$

$$\Sigma_{\boldsymbol{b}} = \begin{bmatrix} \sigma^2_{\boldsymbol{b}_{FT}} & \sigma_{\boldsymbol{b}_{FT},\boldsymbol{b}_{PT}} \\ \sigma_{\boldsymbol{b}_{2PT},\boldsymbol{b}_{FT}} & \sigma^2_{\boldsymbol{b}_{PT}} \end{bmatrix}, \;\; \Sigma_{\boldsymbol{b}\boldsymbol{u}} = (\sigma_{\boldsymbol{b}_{FT},\boldsymbol{u}}, \sigma_{\boldsymbol{b}_{PT},\boldsymbol{u}})^t$$

Why?

Bias when using labour market status as covariate in 'standard' survival models (e.g. Cox proportional hazards):

- Endogeneity
- non-random dropout
- measurement error

Implementation in R

- Bayesian model
- `Rstan`

Results

1. Fixed Effects: Survival Submodel

	1950 cohort		1954 cohort	
	HR	CI	HR	CI
sex	1.47	(1.14, 1.87)	1.92	(1.45, 2.49)
education	0.78	(0.59, 1.01)	0.64	(0.46, 0.85)

2. Fixed Effects: Longitudinal Submodel

		1950 cohort			1954 cohort		
		β	OR	CI	β	OR	CI
fulltime employment	intercept	2.65	14.15	(1.91, 3.37)	3.00	20.09	(2.12, 3.90)
	sex	-2.23	0.11	(-3.28, -1.23)	-2.06	0.13	(-3.25, -0.88)
	education	1.81	6.11	(0.69, 2.97)	2.29	9.87	(1.05, 3.52)
parttime employment	intercept	1.51	4.53	(1.00, 2.05)	1.19	3.29	(0.43, 1.97)
	sex	0.65	1.92	(-0.07, 1.34)	0.31	1.36	(-0.68, 1.30)
	education	0.53	1.70	(-0.28, 1.39)	1.71	5.53	(0.60, 2.77)

3. Random Effects/Frailties

	1950 cohort		1954 cohort	
	mean	CI	mean	CI
$r_{(\boldsymbol{b}_{FT},\boldsymbol{b}_{PT})}$	0.61	(0.53, 0.69)	0.64	(0.56, 0.72)
$r_{(\boldsymbol{b}_{FT},\boldsymbol{u})}$	-0.79	(-0.95, -0.58)	-0.77	(-0.95, -0.53)
$r_{(\boldsymbol{b}_{PT},\boldsymbol{u})}$	-0.35	(-0.59, -0.11)	-0.49	(-0.76, -0.20)
$\sigma_{\boldsymbol{b}_{FT}}$	5.67	(5.16, 6.25)	6.31	(5.73, 6.98)
$\sigma_{\boldsymbol{b}_{PT}}$	3.90	(3.55, 4.28)	5.21	(4.70, 5.79)
$\sigma_{\boldsymbol{u}}$	0.50	(0.32, 0.70)	0.44	(0.25, 0.65)

Sequence analysis vs. Joint Models

- typification of trajectories (duration and pattern)
- holistic vs. model based
- inclusion of covariates
- computation (RAM, computation time, `waspr`)

References

Cremers, J. waspr: an R package for computing Wasserstein barycenters of subset posteriors. [Github]

Cremers, J., Mortensen, L.H. & Ekstrøm, C.T. (submitted). A Joint Model for Longitudinal and Time-to-Event Data in Life Course Research: Employment Status and Time to Retirement.