06/2011

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A Multistate Life Table Approach

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Edita Prima Oy
Helsinki 2011

ISSN-L 1795-3103
ISSN 1795-3103 (printed)
ISSN 1797-3635 (online)

FOREWORD

During the past few years, policy makers have been preoccupied with increasing longevity. Life expectancy has risen rapidly and this development has also affected the views on future population development. The aging of society will have many consequences, but for pension policies it raises the question about the division of time spent in work and in retirement.

Postponing retirement and extending time spent in working-life has become a top priority in most industrialized countries. In Finland, the target is to raise the effective retirement age by three years by year 2025. This target should be seen in the light of a more general employment objective.

The Finnish Centre for Pensions is devoting more research energy to measuring how working careers develop. This Working Paper is part of an on-going partnership project between the Research Department of the Finnish Centre for Pensions and Markstat Consultancy. The research objective is to measure the length of and evaluate the development in working careers – and later and even more ambitiously – to assess the role of pension policy and other contributing factors in the process. This first working paper that springs from the project is devoted to measurement issues and has been written by adjunct professor Markku Nurminen, PhD (Stat.), DrPh (Epid.).

Mikko Kautto
Head of Research Department
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ABSTRACT

Working-life expectancy is the estimated future time that a person will spend in employment. This paper is concerned with its estimation jointly with the time spent in the opposite state of unemployment, and their sum, the expected duration of active working-life, that is, the length of a person's working career.

This paper employs a multistate method, which has previously been applied to Finnish data from 1980 to 2001. The multistate life table approach first estimates year- and age-dependent probabilities of being in the working-life states by stochastic regression modeling. Updated estimates of probabilities, and subsequently of expectancies, are given for the data of Finnish men and women aged 15–64 years in the period 2000–2009. Further, model-based extrapolations are calculated for the years 2010–2015.

According to results, a general development of longer working careers is evident. During the past decade, the future employment time increased in all age groups and for both genders. For a 15-year-old male in 2009 the fitted estimate of the length of working career is 34.2 years, while for females, it tails at 33.8 years. During the ten-year period 2000–2009, there was an increase of 10 percentage points or more in the expectancies of future working life spent in the employed state for females starting from age 40 and for males from age 50 on.

The respective predicted working-career lengths for 2015 are longer: 36.0 years for males and 35.5 years for females. The female expectancy for ages 40 years and above is forecast to overtake the respective male figure by year 2010 and to continue to do so up to 2015.

Keywords:

- Working-life expectancy
- Stochastic inference
- Statistics in society

ABSTRAKTI

Työajanodote on luku, joka ilmaisee tietyn ikäisen henkilön jäljellä olevan ajan työelämässä. Tämä tutkimus käsittelee työllisen ajan odotteen, työttömänä oloajan odotteen, sekä niiden yhteenlasketun työvoimaan kuulumisajan odotteen estimointia eli henkilön koko tulevan työuranpituuden mittaamista. Tutkimusmenetelmänä käytettiin tilastotieteellistä monitilamallia, jota on aiemmin sovellettu Työterveyslaitoksessa käyttäen hyväksi Tilastokeskuksen työvoimatutkimuksen otannan tietoja henkilöiden lukumääristä työmarkkina-aseman mukaan ja kuolleisuudesta Suomessa vuosina 1980–2001.

Eläketurvakeskuksen päivitetyssä arvioinnissa laskettiin ensin aineistoon sovitetun stokastisen estimointimallin avulla ikä- ja kalenterivuosittaiset todennäköisyydet olla ansiotyössä, työttömänä tai työvoiman ulkopuolella. Todennäköisyyksistä johdettiin integroimalla odotteet 15–64-vuotialle suomalaisille miehille ja naisille vuosina 2000–2009. Odotteiden ennustemalliin perustuvat eskstrapolaatiot projisoitiin vuosille 2010–2015.

Tulosten mukaan yleinen positiivinen kehitys kohti pidempiä työuria on ilmeistä. Viime vuosikymmenen kuluessa jäljellä oleva työssäoloaika kasvoi molemmilla sukupuolilla kaikissa ikäryhmissä. 15-vuotiaiden miesten työajanodote oli lamavuonna 2009 mallin antaman arvion mukaan 34,2 vuotta, naisten odote oli hieman lyhyempi eli 33,8 vuotta. 10-vuoden ajanjaksolla 2000–2009 työajanodotteen kasvu oli naisilla 10 %-pistettä tai enemmän alkaen ikävuodesta 40, miehillä ikävuodesta 50 lähtien. Yli 40-vuotiaitten naisten odotteen ennustettiin ylittävän miesten vastaavan odotteen vuoteen 2010 mennessä. Ennusteet 15-vuotiaiden henkilöiden työurien kestoille vuonna 2015 ovat entistä pidempiä (olettaen kehityksen jatkuvan samansuuntaisena): miehillä 36,0 vuotta, naisilla lähes yhtä pitkä eli 35,8 vuotta.

Avainsanat:

- Työajanodote
- Stokastinen päätäntä
- Tilastotiede yhteiskunnassa

ACKNOWLEDGMENTS

Dr. Brett A. Davis, Australian Government Department of Employment and Workplace Relations, Canberra, ACT, gave invaluable expert advice in the application of stochastic processes to life sciences.

Dr. Martin Tondel, Section of Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Institute of Medicine, University of Gothenburg, Gothenburg, Sweden, contributed useful methodological points on the validity of the official data used for predicting the working-life expectancies.

Suvi Pohjoisaho, Publications Assistant at the Finnish Centre for Pensions, has taken care of transforming the manuscript into a publication.

Statistics Finland provided the population employment data on labor force and mortality rates.

CONTENTS

1 Introduction

Extending working-life has become a strategic objective in many industrialized countries facing budgetary concerns in the foresight of the demographic aging. Population aging is likely to lead to lower productivity both because the workforce grows older and because a lower proportion of the population is working. Shorter working lives, coupled with increased life expectancy, low fertility and the retirement of the large post-war generation, have an ageing and shrinking effect on the economically active share of the population. This will have major implications for work productivity and overall economic growth (Skirbekk, 2005).

The increase in life expectancy in Finland has been more rapid than projected, resulting in a situation where pension expenditure will be higher than was predicted at the time of planning the 2005 pension reform, unless working careers grow longer accordingly. Measures aimed at lengthening working careers can be divided into two groups: measures related to developing working life and measures aimed at developing pension systems (Prime Minister's Office, 2010).

The Finnish Government and the labor market organizations have agreed that the expectancy for the *effective* retirement age for 25-year-olds should be raised from 59.4 (in 2008) by at least 3 years by year 2025.

The question of postponing retirement should be seen in the context of the entire working career. The working group considering working careers from the perspective of the earnings-related pension scheme held it essential that the length of the working career should not be measured singularly based on the expected exit age to retirement. This measure should be complemented with the expectation of active working life and employment rate (Prime Minister's Office, 2011.)

At present in Finland there are different statistical indicators in use that measure the duration of various phases in life from the separate perspectives of the pension system and the labor market (for a review, in Finnish, see Hytti, 2009). The Finnish Centre for Pensions (Eläketurvakeskus, ETK) has computed the expected effective retirement age indicator (Kannisto, 2006), and later complemented it by publishing the expected duration of employment (or active working-life) indicator developed by Helka Hytti and Ilkka Nio (2004). The former indicator is based on data on insured persons moving into earnings-related pension, and it is computed from age-specific transition frequencies into retirement and from mortality statistics.

The latter indicator is suitable in planning labor force policies and in assessing the efficiency of employment programs. However, this working-life expectancy is preferably estimated from the total population probabilities of being in the three mutually exclusive states of employed, unemployed, and outside the labor force (e.g. on disability pension), rather than just in the two classes of active and inactive, as has been previously customary.

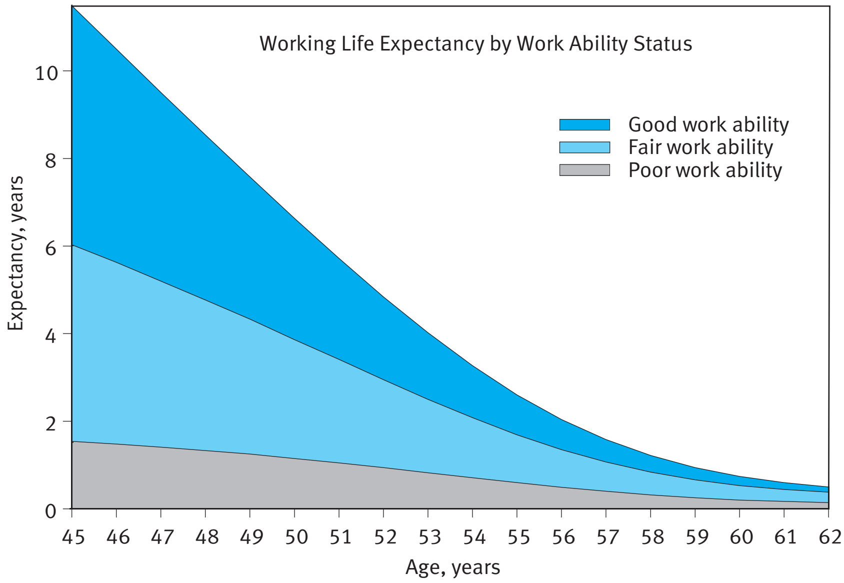
Recently, the EU Commission's study has recommended using the duration of working-life expectancy, which partitions the life expectancy into separate life stages, as a core labor market indicator at European and Member State level (Vogler-Ludwig and Düll, 2008). The expert consultants' report suggests that the application of the expectancy would appear to be useful for the description and analysis of long-term behavioral and institutional conditions in national employment systems rather than for the monitoring of short-term changes.

For a worker of a given initial age, *working-life expectancy (WLE)* is the expected future time a person spends in gainful employment earning wages and benefits (or looking for work) assuming that the prevailing patterns of mortality, morbidity and disability remain unchanged (Nurminen, 2008). It is a period or cohort measure, depending on whether cross-sectional or longitudinal data are available. Life expectancy at birth is naturally somewhat different to that calculated for an actual cohort at the start of follow-up (Myrskylä, 2010).

Usually, in the case of *WLE* studies, only cross-sectional data from official statistics can be readily obtained (cf. Nurminen *et al*., 2004a). This situation is similar to the usual circumstances in which life expectancy is calculated. Our interest in this Working Paper is in *WLE* and similar expectations of times spent in states other than employment, such as unemployment, or being temporally or permanently outside the labor force (e.g. in rehabilitation or on disability pension). The estimation of expectations is *conditional* on having reached a given age. For persons of working age these expectations are termed *partial life expectancies*.

In our previous cohort follow-up study (Nurminen *et al*., 2004) of initially active Finnish municipal workers, aged 45 to 58 years in 1981, we assumed that the earliest commencing date in employment is in the middle of the initial age interval (45–46), and that the retirement date is no later than the 63rd birthday. Thus the maximum duration of work for the cohort members was 17.5 years. The effective expected retirement age was 59.8 or approximately 60 years in Finland in 2009 (Finnish Centre for Pensions, 2011). We found that men permanently leave the work force due to disability or death earlier than women in all age groups, regardless of whether they commenced in better or worse work ability (Nurminen *et al*., 2004b). Women tended to retire on old-age or similar pension before men, especially those women with an initially fair or poor capacity for work. The cross-sectional survey data suggested that the work ability of Finnish aging workers appears to deteriorate prematurely and that individuals leave too frequently employment before the statutory retirement age. Rather remarkably, the work-physiological effect of transition at the age of 45 years from the initial state of 'poor' to 'good or excellent' work ability was estimated to be, on average, four years of gained active work life for both genders. Such an achieved improvement would mean that an advancement of the expectancy for the *effective* retirement age can conceivably reach a higher target than that set for the year 2025, viz. 62.4 years, because 60 + 4 = 64; hence it could also exceed the current lower limit of the *statutory* retirement age, i.e. 63 years.

Figure 1.
WLE of male municipal workers by their work ability and age.



In Figure 1, the *WLE*s are plotted along the age axis with the subsequent values for fair work ability and good work ability 'stacked' on top of the previous ones. E.g., at 45 years, an 'average' male worker is expected to be employed 5.5 (= 11.5 – 6.0) years with 'good or excellent', 4.5 (= 6.0 – 1.5) years with 'fair', and 1.5 years with 'poor' work ability. The *WLE*s add up to 5.5 + 4.5 + 1.5 = 11.5 years. Six years is spent outside work life before the retirement at age of 62.5 (= 45 + 11.5 + 6.0) years. Note that the expectations add up to the duration of maximum remaining work life at age 45, taken as 17.5 (= 63 – 45 – ½) years; ½ is subtracted since persons enter work on average in the middle of the age interval (45, 46).

The additive partition of the *WLE*s in relation to the specified levels of work ability is an appealing methodological property of the *WLE* measure. The decomposition is helpful in understanding at what stages changes in people's health are occurring and in quantifying the magnitude of those transitions *conditionally* on the initial work ability.

The present paper is concerned with the joint estimation by year and age of the probabilities and expectancies of working-life states. We applied a modern regression model to cross-sectional life table data from Finland for each of the years 2000 to 2009 with projections to 2010–2015. Our estimates are for ages 15 to 64 inclusive, *conditional* only on a person being alive at age 15. We used the multistate life table modeling approach (Davis *et al*., 2001) to overcome certain limitations of the traditional prevalence life table technique (Hytti and Nio, 2004). The stochastic modeling approach yields a wealth of information about working-life behavior when applied to intrinsically dynamic life processes with multiple decrements, like the labor force process. Thus, for instance, it is possible to test statistically the effect (trend change) of the pension reform that was enforced in 2005 on the *WLE*s.

Working-life and related expectancies are conceptually analogous to health expectancies, both representing expected occupation times; the difference is that the former arise in the context of labor force activity rather than health status. Consequently, given a suitable formulation of the problem, similar methods of analysis can be used, and we employ the large-sample, weighted least squares version of logistic regression modeling originally developed for the Australian health surveys by Davis *et al.* (2001, 2002b). This statistical framework is different to the frequency-based methods previously applied to health expectancies (Sullivan, 1971). A bibliography can be found in the handbook of Réseau sur l'Espérance de Vie en Santé, REVES (2002).

Given discrete-time data from multiple cross-sectional population surveys, a multistate regression model can be used to estimate consistently *marginal probabilities* that a person is in a given work-health state or *transition probabilities* between the states, and, thereby, working-life expectancies (Nurminen and Nurminen, 2005). Expectancies *conditional* on an initial state and based on transition probabilities can be estimated under the Markov assumption from aggregate data that are produced by official statistical agencies' longitudinal time series and were presented and applied in Davis *et al*. (2002a, 2000b, and 2007).

This paper is organized as follows: Section 1 briefly reviews the background to the topic and introduced the working-life expectancy for measuring the future career length. The official data used in the study are described in Section 2. Section 3 presents an outline of the statistical methodology. Estimates of the model parameters are given in Section 4, those of the state probabilities in Section 5, while Section 6 presents current estimates of *WLE*s, followed by forecasts of the *WLE*s in Section 7. Finally, Section 8 discusses the results obtained using modern regression and compares them to those obtained by actuarial techniques. Section 9 proposes recommendations on the applicable methodology. Statistical modeling, estimation, and prediction issues are detailed in the Appendices.

2 Official Data

Estimates of the sizes of the Finnish populations for the years 2000–2009, by labor force status, sex and single-year working-age groups, taken from 15 to 64, were provided by the Information Services of Statistics Finland (SF, 2010) based on the Labour Force Survey (*LFS*) data. In all, the data set consisted of a four-dimensional array of 4,000 frequencies indexed by sex, age (15–64 years), calendar year (2000–2009), and labor force status. Annual Gross Domestic Product (GDP) (as of July 1, 2011) was included as an explanatory variate in the regression model.

The Finnish *LFS* collects statistical data on the participation in work, employment, unemployment and activity of persons outside the labor force, among the population aged between 15 and 74. The *LFS* data acquisition is based on a random sample drawn twice a year from the population database. The monthly sample consists of some 12,000 persons and the data are obtained by means of computer-assisted telephone interviews. The information given by the respondents is used to produce a representative picture of the activities of the entire working-age population.

The concepts and definitions used in the Survey comply with the recommendations of ILO, the International Labour Organisation of the UN, and the regulations of the European Union on official statistics. The quality of the *LFS* is described in detail by SF (2011).[1]

The numbers of annual deaths in the study years were extracted from the files kept by Statistics Finland. The statistics on deaths cover persons permanently domiciled in Finland. Data on the population and age and gender distribution of deaths are used to calculate annual figures on life expectancy.

Figure 2 shows the actual observations which we used to estimate probabilities and expectancies. The fitted values were smoothed by Friedman's local regression spline function. Our interest focused on the three mutually exclusive states: 'employed', 'unemployed', and 'economically inactive'. This complementary 'inactive' or 'other alive' group represents a mixed population and includes persons who are outside the labor force; that is, those individuals who are not employed or unemployed during the survey week, on pensions due to various causes of disability, as well as students, conscripts and civil servants. 'Deceased' was taken as a reference state.

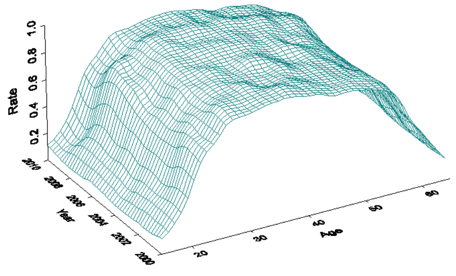
1 The Ministry of Employment and the Economy also publishes data on unemployed job seekers. The Ministry's data derive from register-based Employment Service Statistics, which describe the last working day of the month. The definition of unemployed applied in the Employment Service Statistics is based on legislation and administrative orders which make the statistical data internationally incomparable. In the Employment Service Statistics an unemployed person is not expected to seek work as actively as in the Labour Force Survey. There are also differences in the acceptance of students as unemployed.

Figure 2.
Population rates (per 1,000 people) and probability surfaces fitted by a Friedman's smoothing spline function for (1) males and (2) females:

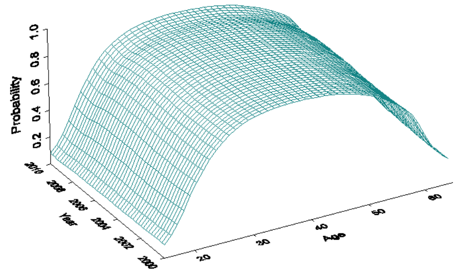
(a) observed, employed *(b) fitted, employed*
(c) observed, unemployed *(d) fitted, unemployed*
(e) observed, inactive *(f) fitted, inactive*
(g) observed, deceased *(h) fitted, deceased*

Figure 2.1
Males

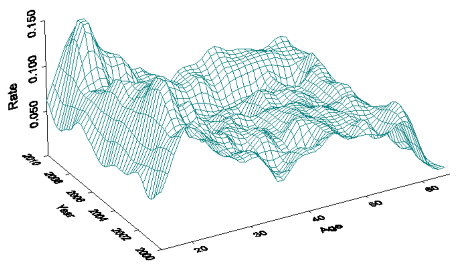
a) Population Employment Rates for Males



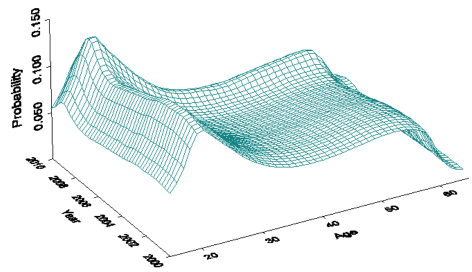
b) Probability Surface of Employment for Males



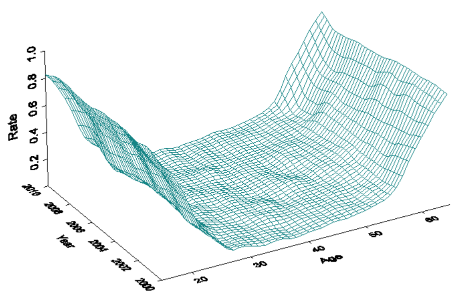
c) Population Unemployment Rates for Males



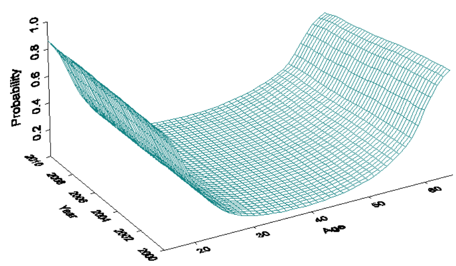
d) Probability Surface of Unemployment for Males



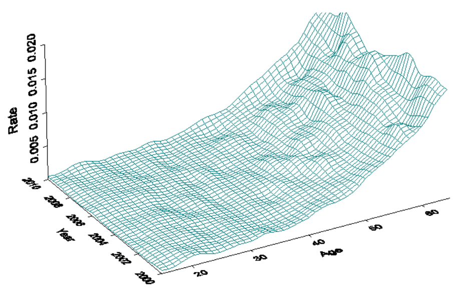
e) Population Rates for Economically Inactive Males



f) Probability Surface for Economically Inactive Males



g) Population Death Rates for Males



h) Probability of Death for Males

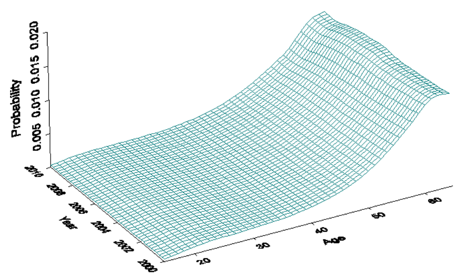
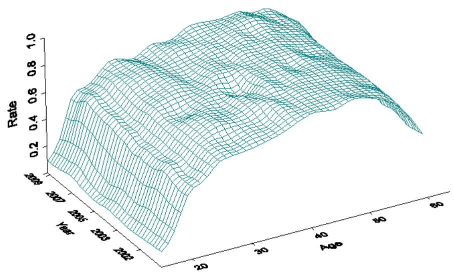
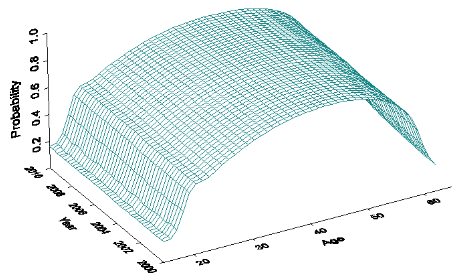


Figure 2.2
Females

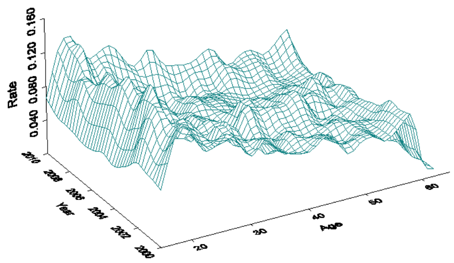
a) Population Employment Rates for Females



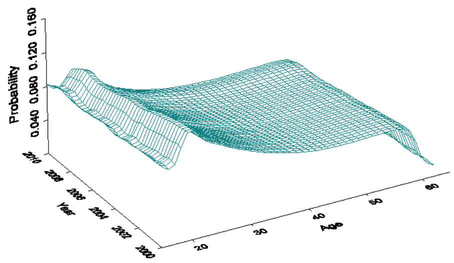
b) Probability Surface of Employment for Females



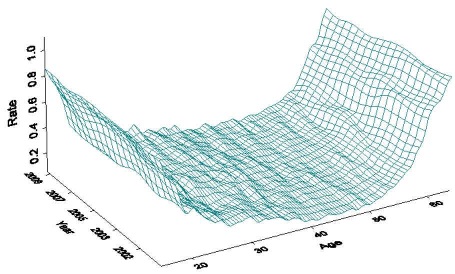
c) Population Unemployment Rates for Females



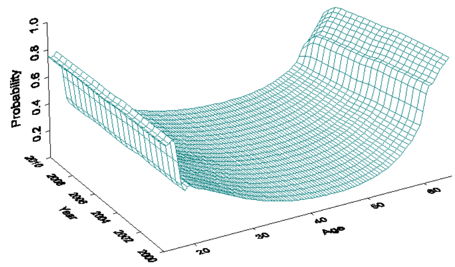
d) Probability Surface of Unemployment for Females



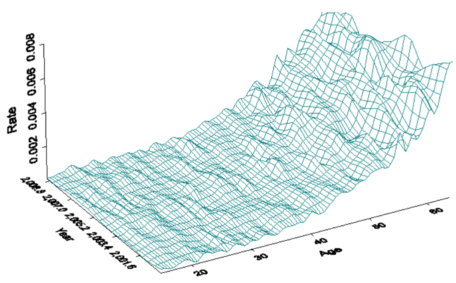
e) Population Rates for Economically Inactive Females



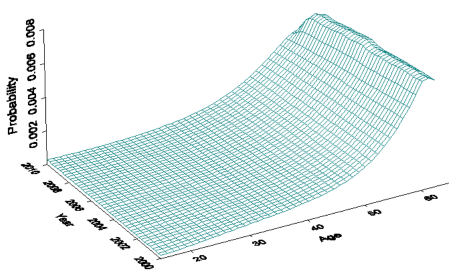
f) Probability Surface for Economically Inactive Females



g) Population Death Rates for Females



h) Probability of Death for Females



3 Outline of the Method

It is convenient to describe the method used in terms of a population cohort of n lives initially aged 15 years. Of particular importance are the probabilities that an individual is in state j at a subsequent age x, written $p_j(x)$. In the present application, j = 0 denotes 'alive' and j = 1,2,3,4 indexes the exhaustive (non-overlapping) states (1) 'employed', (2) 'unemployed', (3) 'economically inactive', and (4) 'dead'. Here our interest is on estimating the marginal probabilities and working-life expectancies that are not conditional on the initial state, but only on the initial age. Aggregate data were available at ages x = 15, ..., 64.

Estimation of the unconditional probabilities $p_j(x)$ is done by a large-sample version of logistic regression. We shall call $p_1(x)$ the *working life survival curve*. Advantage is taken of the fact that official statistics are almost always given in terms of large numbers, which in the present case translates as large n, the number of individuals in the cohort. The theoretical premises of the method are given in Davis *et al*. (2001, 2002b), and in some detail in Appendix A.

With state 4 (dead) as the reference, we formed the log ratios

$$\xi = \log\{p_j(x)/p_4(x)\},\ j = 1,2,3. \qquad \text{(Eq 1)}$$

Exploratory analysis can be used to suggest a parametric form for the partial log ratios, $\xi(x) \equiv \xi(x;\beta)$, and the estimation of β is done by weighted least squares. With the resulting estimate of β we have the derived parameter estimates

$$\begin{aligned} &\hat{\xi}(\mathrm{x}) = \xi(\mathrm{x};\hat{\beta}), \\ &\hat{p}_j(x) = \hat{p}_4(x)\exp[\hat{x}_j(x)],\ \ j = 1,2,3, \\ &\hat{p}_4(x) = \{1 + \textstyle\sum_{j=1}^{3}\exp[\hat{\xi}(x)]\}^{-1} \end{aligned} \qquad \text{(Eq 2)}$$

Thence the estimated working life and related expectancies of interest (for a given age z) are defined as a definite integral function

$$\hat{e}_j(z) = \int_z^{64} \hat{p}_j(x)dx. \qquad \text{(Eq 3)}$$

The expectation of main interest, e_1, yields the *working life expectancy (WLE)*. These quantities are conditional only on the fact that an individual is alive at age 15, and they should be distinguished from working life expectancies conditional on knowledge of the initial work-life or health state. Observe that the expectation $e_0 = \Sigma^3_{j=1} e_j$ is the partial life expectancy to age 65 for an individual known to have been alive at 15, and that $\Sigma^4_{j=1} e_j = 50$.

The large-sample arguments apply to estimating current survival curves and expectancies as functions of age for a given year. However, we had data available for the decade 2000 to 2009 and clearly variation with year is also of interest. It is therefore natural to model the vector of log ratios as a function of both year *t* and age *x*, $\xi(t,x)$, bearing in mind that only cross-sectional data are available.

We also used the S-PLUS program function predict on a generalized linear model object to compute preliminary predicted values for working-life expectancies in a new data frame containing the values at future time points as well as their associated prediction intervals (see Appendix C).

4 Estimates of Model Parameters

A variety of plausible models can be used to describe the same data. Our selection of a multistate model for the four states required the estimation of 33 separate sets of parameters for both genders. The choice of the model covariates was based on significance testing using the original standard errors (uncorrected for population heterogeneity). To motivate the argument, the observed rates for 2009 plotted in Figure 2 were considered. Upon examination of the contours of the surfaces, a cubic function at age x for the log ratios was estimated from the numbers. Similar results were obtained for other years.

Recession effects, episodes of unemployment, effects of the Finnish new pension law (which was put in force in 2005) and interaction effects enter into the formulation of models incorporating change both with year as well as age. The left hand columns of Figures 2.1 and 2.2 give the observed frequency rates. Some experimentation led to the fitted model parameters listed in Tables 1 and 2 (9 + 12 + 12 = 33 parameters for the male odds ratios and 10 + 11 + 12 = 33 for the female log ratios) together with their standard errors. Specifically, to describe the particular behavior of the estimates at the youngest and oldest ages, we included indicators for the age groups 15–17 and 60+. Also an indicator was entered in the model for the years following 2005, when the new pension law was enacted in Finland. For men, the effect was significant for the states of ’unemployed’ and economically ’inactive’ (Table 1) and for women for the state of ’inactive’ (Table 2). The final model form is specified in Appendix A.

Substitution in Equation 1 gives the fitted probability surfaces (interpolating through data points by means of a cubic spline) shown in the right hand column of Figures 2.1 and 2.2. Numerical values of the estimated model parameters with their standard errors are given in Table 1 for males and in Table 2 for females.

Table 1.
Regression model parameter estimates and standard errors of the three working-life states for males.

Regression term	Results for state employed			Results for state unemployed			Results for state inactive		
	Parameter	Estimate	Standard error	Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
Intercept (mean)	β_1	6.06e+0	1.86e-1	β_{10}	3.27e+0	1.96e-1	β_{22}	3.32e+0	1.91e-1
Age (centered at 39.5 years), x	β_2	-7.35e-2§	2.00e-2	β_{11}	-6.95e-2	2.05e-2	β_{23}	-4.68e-2	2.01e-2
Squared term, x^2	β_3	-2.67e-3	8.13e-4	β_{12}	8.13e-5	8.32e-4	β_{24}	4.01e-3	8.18e-4
Cubic term, x^3	β_4	4.41e-5	5.99e-5	β_{13}	-3.50e-5	6.17e-4	β_{25}	5.55e-5	6.01e-5
Teen age indicator, $I(15 \leq x \leq 17)$	*			β_{14}	-1.68e-1	1.48e-1	β_{26}	2.18e-1	9.61e-2
Senior age indicator, $I(x \geq 60)$	β_5	-3.38e-1	3.92e-1	β_{15}	-9.30e-1	4.32e-1	β_{27}	1.85e-1	3.94e-1
Calendar year (ordinally scaled), t	β_6	1.86e-2	6.04e-2	β_{16}	-2.86e-2	6.56e-2	β_{28}	2.13e-2	6.38e-2
Interaction effect product term, tx	β_7	9.64e-4	2.61e-3	β_{17}	-1.66e-3	6.18e-3	β_{29}	-7.75e-4	6.07e-3
Squared term, tx^2	β_8	1.84e-5	1.60e-4	β_{18}	8.12e-5	2.65e-4	β_{30}	-4.27e-5	2.61e-4
Cubic term, tx^3	β_9	4.41e-6	7.14e-5	β_{19}	4.67e-6	1.64e-5	β_{31}	8.39e-8	1.60e-5
Pension year indicator $I(2005 \leq t \leq 2010)$	*			β_{20}	-8.77e-2	9.71e-2	β_{32}	-5.22e-2	6.58e-2
Gross domestic product, GDP	*			β_{21}	-2.60e-2	7.69e-3	β_{33}	4.57e-3	5.11e-3

§ Exponential notation, e.g., −7.35e − 2 = −7.35 x 10−2 = −0.0735
* Insignificant main effect is not represented as a statistical term in the model.

Table 2.
Regression model parameter estimates and standard errors of the three working-life states for females.

Regression term	Results for state employed			Results for state unemployed			Results for state inactive		
	Parameter	Estimate	Standard error	Parameter	Estimate	Standard error	Parameter	Estimate	Standard error
Intercept (mean)	β_1	6.81e+0	3.09e-1	β_{11}	4.09e+0	3.12e-1	β_{22}	4.82e+0	3.12e-1
Age (centered at 39.5 years), x	β_2	-6.39e-2§	3.26e-2	β_{12}	-8.07e-2	3.29e-2	β_{23}	-1.10e-1	3.27e-2
Squared term, x^2	β_3	-1.88e-3	1.54e-3	β_{13}	5.97e-5	1.55e-3	β_{24}	2.38e-3	1.54e-3
Cubic term, x^3	β_4	-1.27e-5	1.05e-4	β_{14}	-2.96e-5	1.06e-4	β_{25}	8.84e-5	1.05e-4
Teen age indicator, $I(15 \leq x \leq 17)$	β_5	-8.84e-1	2.06e-0	β_{15}	-5.15e-1	2.06e-0	β_{26}	5.27e-1	2.06e-0
Senior age indicator, $I(x \geq 60)$	β_6	-3.99e-1	5.96e-1	β_{16}	-1.04e+0	6.26e-1	β_{27}	1.89e-1	5.97e-1
Calendar year (ordinally scaled), t	β_7	3.04e-2	9.95e-2	β_{17}	-2.24e-2	1.00e-1	β_{28}	3.33e-2	1.00e-1
Interaction effect product term, tx	β_8	-3.37e-3	9.66e-3	β_{18}	-2.49e-3	9.75e-3	β_{29}	-3.06e-3	9.68e-3
Squared term, tx^2	β_9	1.31e-5	4.17e-4	β_{19}	1.59e-5	4.20e-4	β_{30}	-1.05e-4	4.17e-4
Cubic term, tx^3	β_{10}	1.13e-5	2.49e-5	β_{20}	7.73e-6	2.52e-5	β_{31}	6.39e-6	2.49e-5
Pension year indicator $I(2005 \leq t \leq 2010)$	*			*			β_{32}	-5.10e-2	6.02e-2
Gross domestic product, GDP	*			β_{21}	-6.05e-3	7.45e-3	β_{33}	9.91e-4	4.76e-3

§ Exponential notation, e.g., –6.39e – 2 = –6.39 x 10 – 2 = –0.0639
* Insignificant main effect not represented as a statistical term in the model.

5 Estimates of State Probabilities

Numerical values for the estimated probabilities of the four occupancy states are given in Table 3 separately for (a) males and (b) females.

After the economic downturn in 2001–2003, the estimated probabilities of being employed increased rather consistently between the years 2000–2008 in all age groups and for both genders, whereas the probabilities of unemployment diminished.

The severe economic recession that started in the late 2008 led to an exceptionally sharp drop in GDP (-8 %), followed by a fairly rapid rebound in the probability of employment in around 2009. Conversely, the probabilities of unemployment were markedly greater than the estimates for the years neighboring 2009. The recession effect was more significant for men than for women. This effect bears some consequences to 2010 and to the following years.

In Table 3a and Table 3b the one-year-ahead forecasts of the work life state probabilities for the year 2010 were determined by estimating parameters from all the data in the interval from 2000 up to 2009. The entries for the estimated probabilities in the columns for 2010 were obtained by first extrapolating the regression fits to the log ratios within the sample and using these to give projected probabilities and thereby expectancies.

These projections are thus essentially those given by standard regression methods. No attempt was made to forecast by altering regression coefficients to reflect possible future case scenarios. The standard errors for the probabilities in Table 3a and Table 3b are not exhibited to conserve space.

Large-sample significance tests can easily be constructed. To take a particular case, consider the difference between males and females in the probability of employment in the economic recession year 2009. The gender difference for an ”average” (or randomly chosen) 25-year-old male worker was greater than that for women (Table 3a and Table 3b):

$$\hat{p}_1^{M,2009}(25) - \hat{p}_1^{F,2009}(25) = 0.7275 - 0.6466 = 0.0809$$

The standard error of the difference was estimated by computing the variance-covariance matrix for the fitted probabilities (using the Liang-Zeger delta method modified for the heterogeneous aggregate data):

$$\begin{aligned}\mathrm{SE}\{\hat{p}_1^{M,2009}(25) - \hat{p}_1^{F,2009}(25)\} &= \{\mathrm{SE}[\hat{p}_1^{M,2009}(25)]^2 + \mathrm{SE}[\hat{p}_1^{F,2009}(25)]^2\}^{½} \\ &= (0.01082^2 + 0.01142^2)^{½} = 0.0157\end{aligned}$$

The difference in the probabilities is multiple times as large as the normal (Gaussian) standard deviation. This test realization corresponds to the two-tailed P-value < 0.001. So the gender gap in employment probabilities was still statistically highly significant, although men typically suffer more from jobs lost in recession. On the other hand, while the estimated probability of employment for 25-year-old men was predicted to rebound from 0.7275 in 2009 to 0.7539 in 2010, no such ascent was foreseen for women (0.6466 in 2009 vs. 0.6480 in 2010).

Table 3a.
Fitted probabilities for men of the four states 1 = 'employed', 2 = 'unemployed', 3 = 'economically inactive', and 4 = 'dead', expressed as percentages, with projections for 2010, for selected years and ages.

Age x	State j	Men 2001	2003	2005	2007	2009	2010
15	1	9.35	8.95	9.06	8.79	7.82	8.15
	2	6.80	6.61	6.03	5.53	7.01	5.47
	3	83.81	84.41	84.88	85.64	85.14	86.35
	4	0.03	0.03	0.03	0.03	0.03	0.03
20	1	44.07	43.83	45.33	45.66	42.51	44.91
	2	12.61	12.35	11.16	10.31	13.25	10.34
	3	43.22	43.72	43.41	43.93	44.15	44.66
	4	0.10	0.10	0.10	0.10	0.09	0.09
25	1	72.56	72.84	74.60	75.41	72.75	75.39
	2	9.90	9.53	8.31	7.51	9.74	7.36
	3	17.42	17.51	16.97	16.97	17.41	17.14
	4	0.13	0.12	0.12	0.12	0.11	0.11
30	1	84.12	88.21	85.92	86.65	84.84	86.84
	2	7.38	5.84	5.90	5.21	6.72	4.96
	3	8.36	5.79	8.05	8.01	8.32	8.09
	4	0.14	0.16	0.13	0.13	0.12	0.12
35	1	87.80	88.39	89.42	90.08	88.65	90.30
	2	6.29	5.66	4.86	4.22	5.39	3.93
	3	5.74	5.72	5.56	5.55	5.81	5.63
	4	0.17	0.22	0.16	0.15	0.14	0.14
40	1	87.96	85.95	89.60	90.24	88.90	90.47
	2	6.15	6.04	4.67	4.02	5.09	3.69
	3	5.66	7.67	5.52	5.52	5.82	5.64
	4	0.23	0.33	0.22	0.21	0.20	0.20
45	1	85.48	80.04	87.31	88.02	86.58	88.29
	2	6.58	6.59	4.98	4.27	5.38	3.91
	3	7.60	12.84	7.38	7.38	7.73	7.50
	4	0.34	0.53	0.33	0.32	0.31	0.31
50	1	79.42	80.04	81.77	82.69	81.14	83.16
	2	7.13	6.59	5.48	4.74	5.98	4.37
	3	12.90	12.84	12.22	12.05	12.39	11.98
	4	0.54	0.53	0.53	0.52	0.49	0.50
55	1	67.29	68.48	71.07	72.63	71.43	73.95
	2	7.04	6.64	5.67	5.01	6.40	4.75
	3	24.79	24.03	22.42	21.54	21.41	20.53
	4	0.87	0.85	0.84	0.81	0.76	0.77
60	1	36.41	38.97	43.02	46.06	47.01	49.91
	2	2.31	2.34	2.16	2.04	2.75	2.11
	3	59.92	57.37	53.48	50.60	49.02	46.74
	4	1.35	1.32	1.33	1.31	1.22	1.24

Table 3b.
Fitted probabilities for women of the four states 1 = 'employed', 2 = 'unemployed', 3 = 'economically inactive', and 4 = 'dead', expressed as percentages, with projections for 2010, for selected years and ages.

Age x	State j	Women					
		2001	2003	2005	2007	2009	2010
15	1	14.67	14.80	15.51	15.63	15.81	16.40
	2	9.26	8.99	9.00	8.59	9.04	8.24
	3	76.05	76.19	75.46	75.75	75.12	75.33
	4	0.02	0.02	0.02	0.02	0.03	0.03
20	1	47.62	48.53	50.46	51.39	52.13	52.71
	2	12.03	11.29	10.72	9.89	9.99	9.04
	3	40.32	40.15	38.79	38.69	37.85	38.22
	4	0.03	0.03	0.03	0.03	0.03	0.03
25	1	59.93	60.96	60.96	63.87	64.66	64.80
	2	9.74	8.91	8.91	7.37	7.26	6.56
	3	30.29	30.10	30.10	28.72	28.05	28.61
	4	0.05	0.04	0.04	0.04	0.03	0.03
30	1	70.80	71.74	73.29	74.06	74.60	74.60
	2	8.21	7.41	6.71	5.95	5.79	5.79
	3	20.83	20.80	19.95	19.95	19.57	19.57
	4	0.06	0.06	0.05	0.05	0.04	0.04
35	1	78.47	79.08	80.24	80.78	81.08	81.25
	2	7.15	6.45	5.82	5.16	5.01	4.49
	3	14.30	14.39	13.88	13.99	13.85	14.20
	4	0.08	0.07	0.07	0.06	0.06	0.06
40	1	82.47	82.96	83.88	84.31	84.48	84.82
	2	6.54	5.93	5.37	4.80	4.69	4.17
	3	10.88	11.01	10.65	10.80	10.75	10.93
	4	0.11	0.10	0.10	0.09	0.09	0.08
45	1	83.35	83.83	84.73	85.18	85.35	85.87
	2	6.32	5.78	5.28	4.75	4.68	4.13
	3	10.19	10.25	9.86	9.94	9.83	9.86
	4	0.15	0.14	0.14	0.14	0.13	0.13
50	1	80.58	81.31	82.52	83.21	83.64	84.38
	2	6.43	5.91	5.43	4.91	4.87	4.29
	3	12.76	12.56	11.82	11.66	11.28	11.13
	4	0.22	0.22	0.22	0.22	0.22	0.21
55	1	70.82	72.50	74.87	76.42	77.75	78.83
	2	6.52	6.03	5.59	5.07	5.04	4.46
	3	22.28	21.10	19.17	18.15	18.86	16.37
	4	0.38	0.37	0.37	0.36	0.38	0.34
60	1	33.71	37.46	42.53	46.52	50.83	62.21
	2	2.05	2.01	1.99	1.89	1.97	1.43
	3	63.59	59.89	54.84	50.98	46.61	35.90
	4	0.65	0.64	0.64	0.61	0.59	0.46

6 Estimates of Working-life Expectancies

A general development is that during the decade 2000–2009 the future employment time increased in all age groups for both genders (Figure 3). An exception is the year 2009 for which the expectancies are markedly smaller than the neighboring estimates for males. This is an aftermath of the recession in Finland between 2008 and 2010 which affected especially men's employment in private enterprises, whereas women were employed more prevalently in the public sector which was less insecure to discontinuation of the employment contract. Parallel observations are from the recession in the early 1990s (Salonen, 2009).

Figure 3.
Density plots of the working-life expectancies for Finnish males and females at ages x = 15, 25, and 50 years from year 2000 to 2010. The lines are nonparametric estimates of the probability density of the data points, $\hat{e}_1(x)$, with a bandwidth specified as a multiple of the standard deviation of the normal kernel function.

Table 4a and Table 4b give estimates (as of 2011) of the expectancies of states 1, 2 and 3 for selected ages for both genders. The estimates obtained for 2009 were the following: For a 15-year-old male, the *WLE* up to age 64 years is 34.2 years, while for females, it is 33.8 years; the gender difference being only 0.4 years in favor of men. The corresponding projections for 2010 are 35.2 and 34.6 years.

An interesting feature of the development is that for 2000–2010 the estimated *WLE* for males, $\hat{e}_1(x)$, is for ages 30 and under uniformly greater than the corresponding estimate for females. As anticipated in our previous paper (Nurminen *et al.,* 2005), the trend of females having an equally long or greater duration of employment than that for males started already in 2004 at ages 50 to 55 and widened to the age range 35 to 60 by year 2009 (boldface cells in Table 5).

In numerical terms, the expectations for a randomly chosen 50-year-old employed male worker were*:* $\hat{e}_1^{\,M,2004}(50) = 8.5$ yrs; $\hat{e}_1^{\,M,2009}(50) = 9.1$ yrs, i.e. +7.1 %; and for a female they were $\hat{e}_1^{\,F,2004}(50) = 8.6$ yrs, $\hat{e}_1^{\,F,2009}(50) = 9.6$ yrs, i.e. +1.6 %. Projected *WLE*s for 2010 confirm the consistent pattern, with a maximum difference of $\hat{e}_1^{\,F,2010}(50)$ - $\hat{e}_1^{\,M,2010}$ $(50) = 0.7$ yrs, in favor of women.

The standard errors of the expectancies were estimated directly by summing the covariance matrix for the fitted probabilities over age from present age to retirement age. Assuming that the male and female models are stochastically independent, the SEs (unpublished) can be used to make precise comparisons. To take a particular case, consider the male and female expectancies of state 2 (unemployed) for 20-year-olds in 2009. Their difference is 2.87 – 2.32 = 0.55, with a standard error (modified for the aggregate sampling) of $(0.171^2+0.155^2)^{½} = 0.23$, and one may infer that males of that age and in that year expect to spend statistically significantly (P = 0.017) more future time (in this case 6 months) in the unemployed state than females.

Table 4a.
Partial life expectancies for Finnish males, expressed in years, of the three states 1 = ’employed’, 2 = ’unemployed’, and 3 = ’economically inactive’, for the quinquennial ages 15–60, and for the decennial years 2000–2009, with projections for 2010. Women having an equally long or greater expected duration of employment than that for males are shown in Table 4b in boldface figures.

Age	State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
15	1	33.2	33.1	33.3	33.5	33.8	34.4	34.7	34.9	34.7	34.2	35.2
	2	3.4	3.6	3.5	3.4	3.2	2.9	2.8	2.6	2.8	3.4	2.5
	3	12.7	12.6	12.5	12.5	12.4	12.0	11.9	11.8	11.8	11.8	11.6
20	1	32.1	32.1	32.2	32.4	32.8	33.3	33.6	33.9	33.7	33.3	34.2
	2	3.0	3.1	3.0	2.9	2.7	2.5	2.4	2.2	2.4	2.9	2.1
	3	9.2	9.2	9.1	9.0	8.8	8.5	8.4	8.3	8.2	8.2	8.0
25	1	29.3	29.2	29.4	29.6	29.9	30.4	30.7	30.9	30.8	30.4	31.3
	2	2.4	2.5	2.5	2.4	2.2	2.0	1.9	1.8	1.9	2.3	1.7
	3	7.7	7.6	7.5	7.4	7.3	7.0	6.8	6.7	6.7	6.7	6.4
30	1	25.3	25.3	25.5	25.7	26.0	26.4	26.6	26.8	26.8	26.6	27.2
	2	2.0	2.1	2.0	2.0	1.8	1.6	1.5	1.4	1.5	1.8	1.4
	3	7.0	7.0	6.9	6.8	6.6	6.3	6.2	6.1	6.0	6.0	5.8
35	1	21.0	21.0	21.2	21.3	21.6	22.0	22.2	22.4	22.4	22.2	22.8
	2	1.7	1.7	1.7	1.6	1.5	1.4	1.3	1.2	1.3	1.5	1.1
	3	6.7	6.6	6.5	6.4	6.3	6.0	5.9	5.7	5.7	5.7	4.4
40	1	16.6	16.6	16.8	16.9	17.2	17.5	17.7	17.9	17.9	17.7	18.3
	2	1.4	1.4	1.4	1.3	1.2	1.1	1.1	1.0	1.1	1.3	1.0
	3	6.4	6.3	6.2	6.1	6.0	6.0	5.6	5.5	5.4	5.4	5.2
45	1	12.2	12.3	12.4	12.5	12.8	13.1	13.3	13.4	13.4	13.3	13.8
	2	1.1	1.1	1.1	1.0	1.0	0.9	0.8	0.8	0.9	1.0	0.8
	3	6.1	6.0	5.9	5.8	5.7	5.4	5.3	5.2	5.1	5.1	4.9
50	1	8.0	8.1	8.2	8.4	8.5	8.8	9.0	9.1	9.2	9.1	9.5
	2	0.7	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.6
	3	5.7	5.6	5.5	5.4	5.2	5.0	4.9	4.7	4.7	4.6	4.4
55	1	4.3	4.4	4.5	4.6	4.7	4.9	5.1	5.2	5.2	5.2	5.5
	2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.3
	3	4.8	4.7	4.6	4.5	4.4	4.2	4.1	3.9	3.9	3.8	3.6
60	1	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0
	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3	3.2	3.1	3.0	3.0	2.9	2.8	2.7	2.6	2.6	2.5	2.4

Table 4b.

Partial life expectancies for Finnish females, expressed in years, of the three states 1 = 'employed, 2 = 'unemployed', and 3 = 'economically inactive', for ages 15–60 at quinquennial intervals, and for the decennial years 2000–2009, with projections for 2010. Women having an equally long or greater expected duration of employment than that for males are shown in boldface figures.

Age	State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
15	1	31.0	31.2	31.5	31.8	32.1	32.7	33.0	33.3	33.6	33.8	34.6
	2	3.7	3.6	3.5	3.3	3.2	3.1	2.9	2.8	2.8	2.8	2.5
	3	14.8	14.6	14.5	14.3	14.2	13.6	13.5	13.3	13.1	12.8	12.4
20	1	29.7	29.9	30.2	30.5	30.8	31.4	31.6	31.9	32.2	32.3	33.1
	2	3.2	3.1	3.0	2.8	2.7	2.6	2.5	2.4	2.3	2.3	2.1
	3	11.6	11.4	11.3	11.1	11.0	10.5	10.3	10.2	10.0	9.7	9.3
25	1	27.1	27.3	27.5	27.8	28.1	28.6	28.8	29.1	29.3	29.5	30.2
	2	2.7	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.9	1.7
	3	9.8	9.6	9.5	9.3	9.2	8.7	8.6	8.4	8.2	8.0	7.5
30	1	23.9	24.1	24.3	24.5	24.8	25.2	25.4	25.7	25.9	26.1	26.8
	2	2.2	2.1	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.6	1.4
	3	8.5	8.3	8.2	8.0	7.9	7.5	7.3	7.2	7.0	6.8	6.3
35	1	20.2	20.4	20.6	20.8	21.0	21.4	21.6	21.8	22.0	**22.2**	**22.9**
	2	1.8	1.7	1.6	1.6	1.5	1.4	1.4	1.3	1.3	1.3	1.1
	3	7.6	7.4	7.3	7.1	7.0	6.6	6.5	6.3	6.1	5.9	5.4
40	1	16.2	16.3	16.5	16.7	16.9	17.3	17.5	17.7	**17.9**	**18.1**	**18.8**
	2	1.4	1.4	1.3	1.2	1.2	1.2	1.1	1.1	1.0	1.0	0.9
	3	6.9	6.8	6.6	6.5	6.3	6.0	5.9	5.7	5.5	5.3	4.8
45	1	12.0	12.2	12.4	12.6	12.7	**13.1**	**13.3**	**13.5**	**13.7**	**13.8**	**14.5**
	2	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7
	3	6.4	6.2	6.1	6.0	5.8	5.5	5.3	5.2	5.0	4.8	4.3
50	1	7.9	8.1	8.2	8.4	**8.6**	**8.9**	**9.1**	**9.2**	**9.4**	**9.6**	**10.2**
	2	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.5
	3	5.9	5.7	5.6	5.4	5.3	5.0	4.8	4.7	4.5	4.3	3.8
55	1	4.1	4.2	4.4	4.5	**4.7**	**4.9**	**5.1**	**5.2**	**5.4**	**5.6**	**6.1**
	2	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	3	5.0	4.9	4.7	4.6	4.5	4.2	4.1	3.9	3.8	3.6	3.1
60	1	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	**1.9**	**2.4**
	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.6	2.1

Table 5 lists *WLE*s as percentages of the future years in working life up to age 64. For example, the entry for 15-year-old males in 2010 is calculated from Table 4a as follows: $100 \times e_1(15)/e_0(15) = 100 \times 35.2/(35.2+2.5+11.6) = 71$ %. The percentages increased fairly steadily over the 10 years from 2000 to 2009 for both genders, with a slower movement at younger ages compared to ages 35 and above. During this decade, there was an increase of 10 percentage points or more in the future proportion of life spent in employment for females starting from age 40 years and for males from age 50 years. The female percentage for ages 40 years and above is forecast to overtake the male figure by year 2010.

Figure 4 depicts these percentages as a smooth probability surface for either gender. The upslope trajectories or contour lines from end-points of the age-year area to higher points reach their local maxima for men and women at the age of 25 years in 2007. In the post-recession year of 2010, even more elevated percentages of the future share of time being spent in employment were attained. Therefore, the model can be employed for representing visually in the three-dimensional graph working life processes in the field of demography.

To put these findings into a more general perspective, the bar graph in Figure 5 presents partial life and working-life expectancies for Finnish men and women in 2000–2010. The height of the bar stands for life expectancy divided into four consecutive phases. The tacit assumption – made for the sake of simplifying the graphical presentation – is that there were no intermittent periods of unemployment, leave, disability, or retirement.

The proportion of time in employment between ages 15 up to 64 years increased in the 11-year period from 2000 to 2010 for both genders. Although there was only a slight increase in the male life expectancy (+2.6 yrs) compared to the female figure (+2.4 yrs), the future proportion of working-life at age 15 grew markedly less for men (+2.0 yrs) than for women (+3.6 yrs).

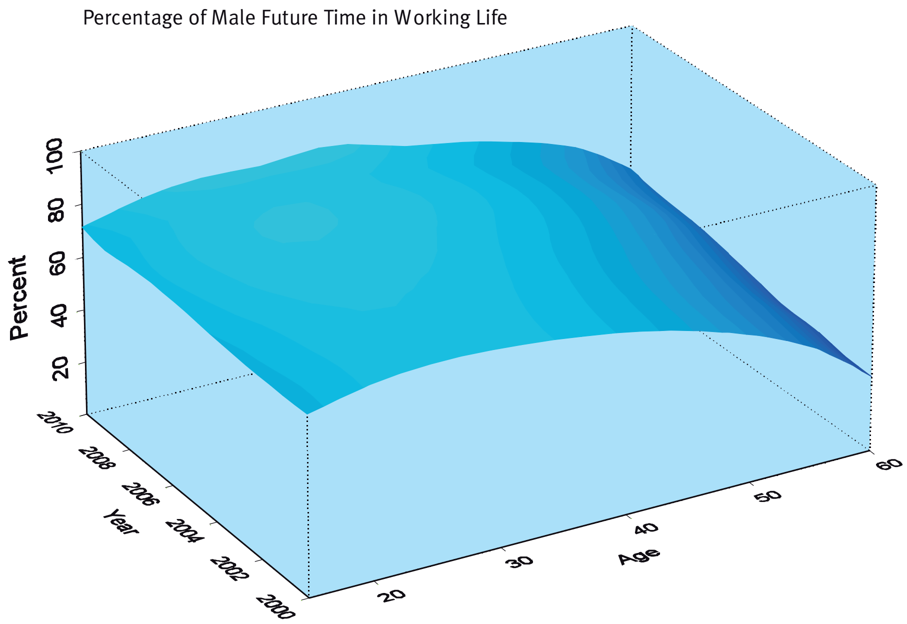
These trends run counter to the negative development in the preceding two decades from 1981 up to 2001: While the life expectancy at birth grew more for men (+5.1 yrs) than for women (+3.7 yrs), the working-life expectancy at the age of 25 years decreased for both genders, although slightly more for males (-4 %-points) than for females (-3 %-points) (Nurminen, 2008, Figure 6).

Table 5.

Expectancies as percentages of future working life, of the three states 1 = 'employed' 2 = 'unemployed', and 3 = 'economically inactive', for selected ages and years, separately for males and females. For example, the expected percentage for a 15-year-old male in 2010 is calculated from the figures in Table 4a as follows: 100 x (35.2/(35.2 + 2.5+11.6)) = 71 %.

		Expectancies (%) for males						Expectancies (%) for females					
Age	State	2001	2003	2005	2007	2009	2010	2001	2003	2005	2007	2009	2010
15	1	67	68	70	71	69	71	64	63	67	68	70	70
	2	7	7	6	5	7	5	7	7	6	6	6	5
	3	26	25	24	24	24	24	30	29	28	27	26	25
20	1	72	73	75	76	75	77	67	69	71	72	73	74
	2	7	7	6	5	7	5	7	6	6	5	5	5
	3	21	20	19	19	19	18	26	25	24	23	22	21
25	1	74	75	77	78	77	79	69	71	73	74	75	77
	2	16	15	13	12	15	11	6	6	5	5	5	4
	3	19	19	17	17	17	16	24	24	22	21	20	19
30	1	74	75	77	78	77	79	70	71	73	74	76	78
	2	6	6	5	4	5	4	6	6	5	5	5	4
	3	20	20	18	18	17	17	24	23	22	21	20	18
35	1	72	73	75	77	76	81	69	71	73	74	76	78
	2	6	6	5	4	5	4	6	5	5	4	4	4
	3	23	22	20	20	19	16	25	24	22	21	20	18
40	1	68	70	71	73	73	75	67	68	70	72	74	77
	2	6	5	5	4	5	4	6	5	5	4	4	4
	3	26	25	24	23	22	21	28	27	24	23	22	20
45	1	63	65	68	69	69	71	63	64	67	69	71	74
	2	6	5	5	4	5	4	5	5	5	4	4	4
	3	31	30	28	27	26	25	32	31	28	27	25	22
50	1	56	58	61	63	63	66	56	58	61	63	66	70
	2	6	5	4	4	4.9	4	5	5	4	4	4	3
	3	39	37	36	33	32	30	39	37	34	32	30	26
55	1	46	48	52	55	55	59	44	47	52	55	59	64
	2	4	4	4	3	4	3	4	4	4	3	3	3
	3	50	47	44	42	40	38	52	48	44	42	38	33
60	1	29	31	36	40	42	44	22	27	31	36	41	52
	2	2	2	2	2	2	2	2	2	2	2	2	2
	3	69	67	62	58	56	53	76	71	67	62	57	46

Figure 4.
Model fitted probability surface (with color draping) of the proportion of future time in working-life by age and year, separately for males and females.



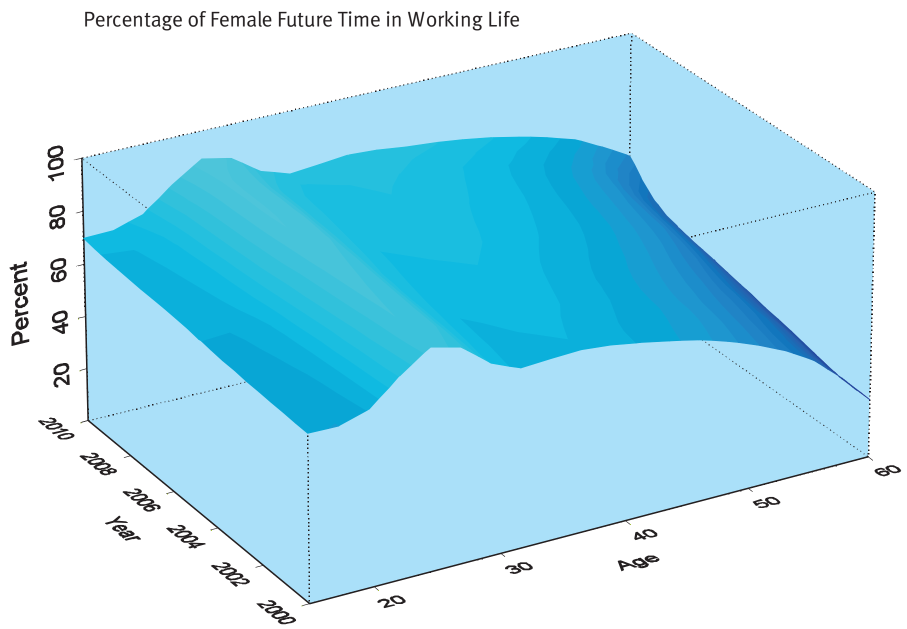
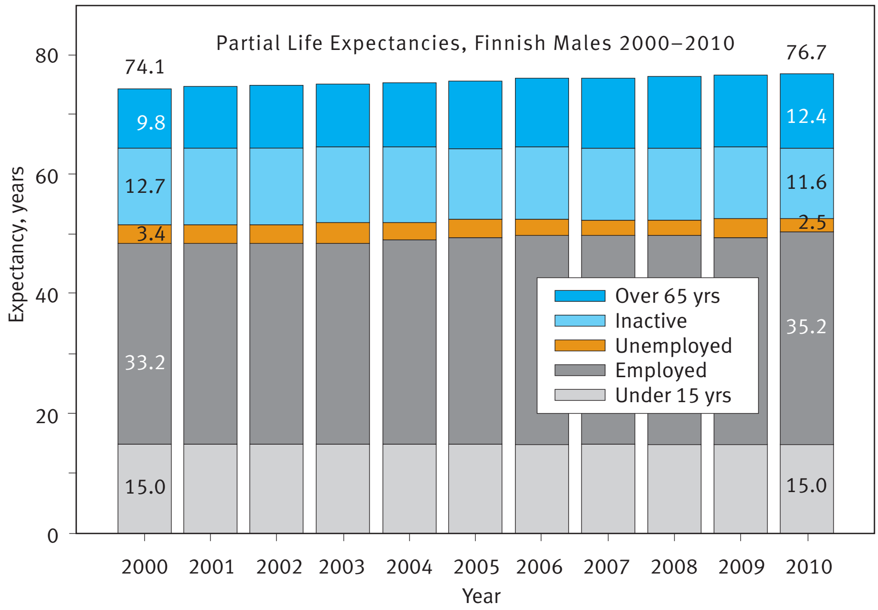
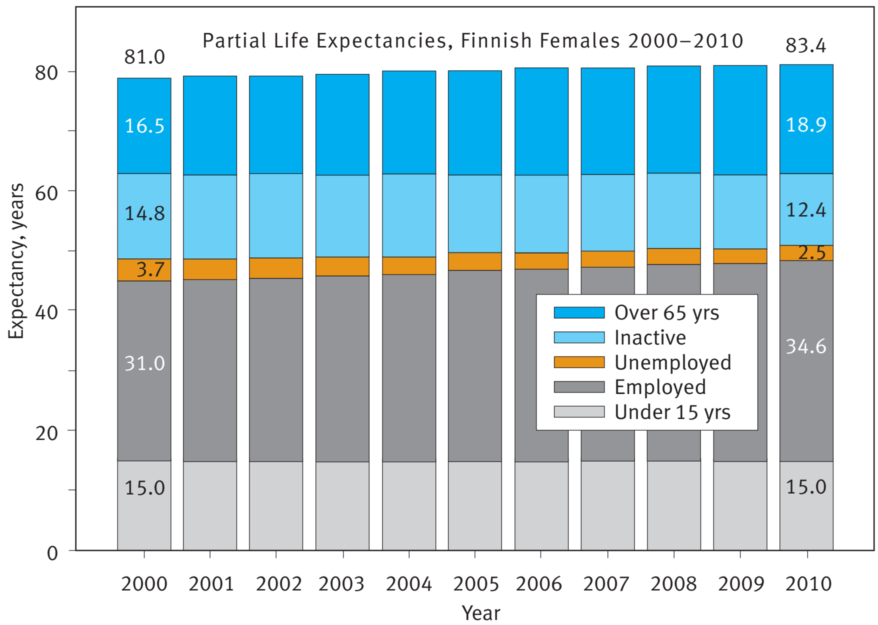


Figure 5.
Partial life expectancies and WLEs for the Finnish male and female populations in 2000–2009, and forecast for 2010.





7 Forecasts of Working-life Expectancies

We can make predictions for the future years 2010–2015 from the estimates $\hat{e}_i(x)^{2000}$,..., $\hat{e}_i(x)^{2009}$ by fitting a generalized linear model using the PREDICT function of S-PLUS. The predictions and their 90 % simultaneous intervals are presented numerically for the quinquennial ages 15 through 60 in Table 6a and Table 6b and graphically for ages 15 and 50 in Figure 6.

An interesting result is that women's *WLE*s for ages 40 years and above are forecast to continue to overtake the respective male figures in the years 2010–2015 (boldface cells in Table 6b). Note that the predictions for year 2010 in Table 4 and Table 6 differ slightly from each other. This discrepancy is due to the different regression models fitted (multistate regression model vs. generalized linear model) and the prediction ranges targeted (extrapolation for a single year vs. simultaneous prediction for six years).

The age- and gender-specific development is clear in Figure 6. While the male *WLE* at age 15 stayed consistently at a higher level than that of females, the rate of increase from 2010 to 2015 was predicted to be faster among women. When people reach the middle age of 50 years, the predicted female expectancy has superseded that of males throughout the prediction period.

An interesting finding is that for men aged 15 in 2015, the predicted future duration of employment is estimated to be 36.0 (35.7–36.4) years. This estimate agrees with the expected value of 36.3 years (computed at ETK) that would be needed in the development of the length of working careers, if the ratio of the time spent on pension to that at work would remain constant with the elongation of general male life expectancy (Laesvuori, 2011).

Table 6a.

Predicted male future years of employment, with 90 % prediction intervals[2], given for the years 2010–2015, for selected ages. Women having an equally long or greater predicted duration of employment than that for males are shown in Table 6b in boldface numbers.

Age	Estimate	Predictions for males					
		2010	2011	2012	2013	2014	2015
15	Mean	35.3	35.5	35.6	35.7	35.9	36.0
	Lower	35.1	35.2	35.3	35.4	35.6	35.7
	Upper	35.5	35.7	35.8	36.0	36.2	36.4
20	Mean	34.3	34.5	34.6	34.8	34.9	35.1
	Lower	34.0	34.1	34.2	34.3	34.5	34.6
	Upper	34.6	34.8	35.0	35.2	35.4	35.6
25	Mean	31.3	31.5	31.6	31.8	32.0	32.1
	Lower	31.2	31.3	31.4	31.6	31.7	31.8
	Upper	31.5	31.7	31.8	32.0	32.2	32.4
30	Mean	27.3	27.5	27.6	27.8	28.0	28.1
	Lower	27.1	27.3	27.4	27.6	27.7	27.9
	Upper	27.4	27.7	27.8	28.0	28.2	28.4
35	Mean	22.8	23.0	23.1	23.3	23.4	23.6
	Lower	22.7	22.8	23.0	23.1	23.2	23.3
	Upper	22.9	23.1	23.3	23.4	23.6	23.8
40	Mean	18.3	18.5	18.6	18.8	18.9	19.1
	Lower	18.2	18.3	18.5	18.6	18.7	18.8
	Upper	18.4	18.6	18.8	18.9	19.1	19.3
45	Mean	13.8	13.9	14.0	14.2	14.3	14.4
	Lower	13.6	13.7	13.8	13.9	14.1	14.1
	Upper	14.0	14.2	14.3	14.5	14.6	14.8
50	Mean	9.5	9.6	9.7	9.9	10.0	10.1
	Lower	9.3	9.4	9.5	9.6	9.7	9.8
	Upper	9.7	9.8	10.0	10.1	10.3	10.4
55	Mean	5.5	5.6	5.7	5.8	5.9	6.0
	Lower	5.3	5.4	5.5	5.5	5.6	5.7
	Upper	5.6	5.7	5.9	6.0	6.1	6.3
60	Mean	2.0	2.1	2.1	2.2	2.3	2.3
	Lower	1.7	1.8	1.8	1.9	1.9	1.9
	Upper	2.2	2.3	2.4	2.5	2.6	2.7

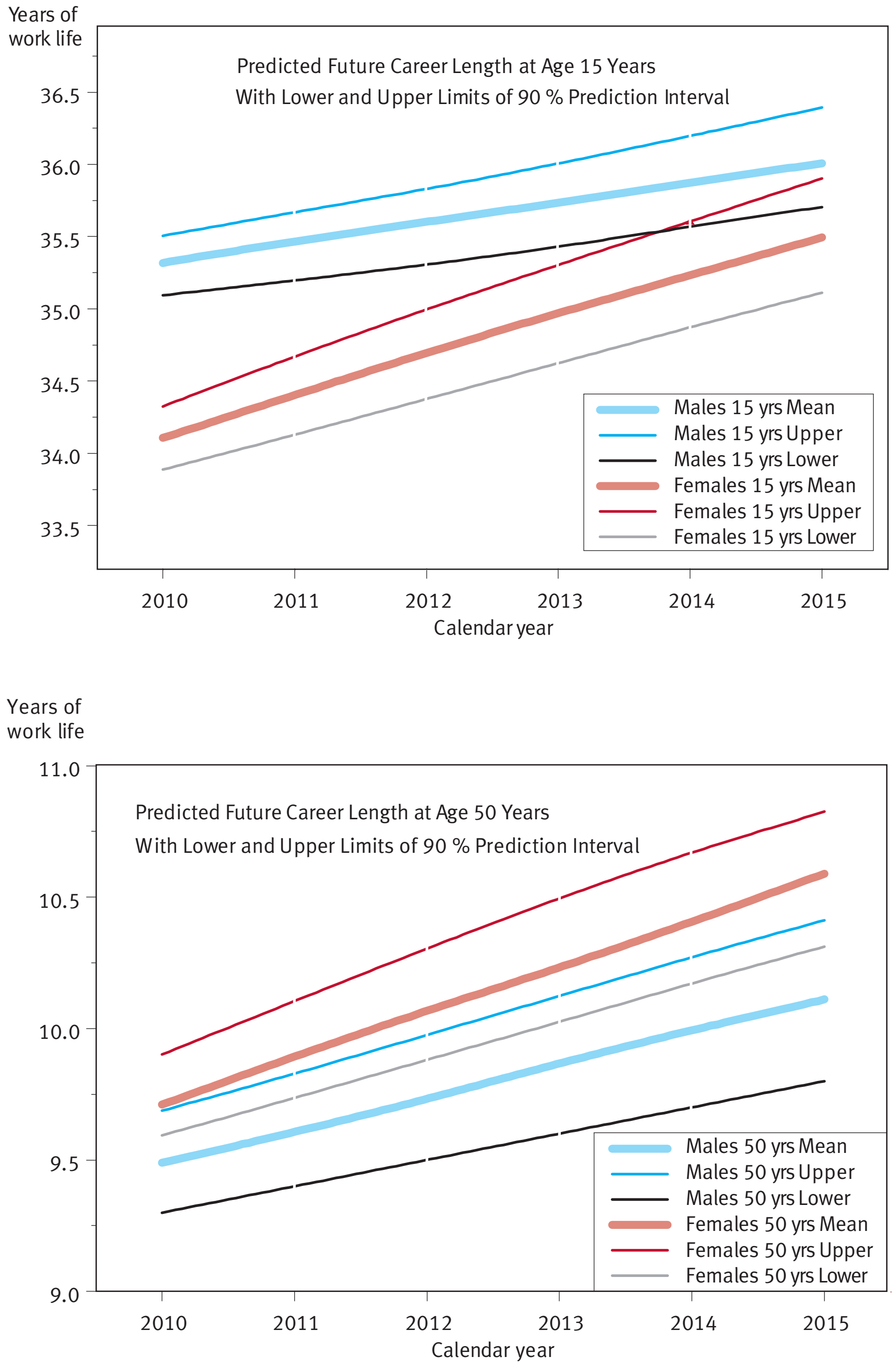
2 The simultaneous prediction intervals (given by lower and upper limits) adjust for the fact that we are estimating from the whole data of 10 years 2000–2009, and hence are wider than the pointwise intervals.

Table 6b.
Predicted female future years of employment, with 90 % prediction intervals, given for the years 2010–2015, for selected ages. Women having an equally long or greater predicted duration of employment than that for males are shown in boldface numbers.

Age	Estimate	Predictions for females					
		2010	2011	2012	2013	2014	2015
15	Mean	34.1	34.4	34.7	35.0	35.2	35.5
	Lower	33.9	34.1	34.4	34.6	34.9	35.1
	Upper	34.3	34.7	35.0	35.3	35.6	35.9
20	Mean	32.7	33.0	33.3	33.6	33.8	34.1
	Lower	32.5	32.8	33.0	33.3	33.5	33.8
	Upper	33.0	33.3	33.6	33.9	34.2	34.5
25	Mean	29.8	30.1	30.3	30.6	30.8	31.1
	Lower	29.7	29.9	30.1	30.4	30.6	30.8
	Upper	30.0	30.3	30.5	30.8	31.1	31.4
30	Mean	26.4	26.6	26.8	27.1	27.3	27.5
	Lower	26.2	26.4	26.6	26.8	27.0	27.2
	Upper	26.5	26.8	27.0	27.3	27.5	27.8
35	Mean	22.4	22.6	22.8	23.0	23.2	23.4
	Lower[3]	22.4	22.6	22.8	23.0	23.2	23.4
	Upper[3]	22.4	22.6	22.8	23.0	23.2	23.4
40	Mean	18.3	18.5	**18.6**	**18.8**	**19.0**	**19.2**
	Lower	18.1	18.3	18.4	18.6	18.8	18.9
	Upper	18.4	18.6	18.9	19.1	19.3	19.5
45	Mean	**14.0**	**14.2**	**14.4**	**14.6**	**14.8**	**15.0**
	Lower	13.9	14.0	14.2	14.3	14.5	14.7
	Upper	14.2	14.4	14.6	14.8	15.1	15.3
50	Mean	**9.7**	**9.90**	**10.1**	**10.2**	**10.4**	**10.6**
	Lower	9.6	9.72	9.9	10.0	10.2	10.3
	Upper	9.9	10.1	10.3	10.5	10.7	10.8
55	Mean	**5.7**	**5.8**	**6.0**	**6.2**	**6.3**	**6.5**
	Lower	5.5	5.7	5.8	5.9	6.1	6.2
	Upper	5.9	6.0	6.2	6.4	6.6	6.8
60	Mean	1.9	2.0	2.1	**2.1**	2.2	**2.3**
	Lower	1.7	1.7	1.8	1.8	1.9	2.0
	Upper	2.1	2.2	2.3	2.4	2.6	2.7

3 The residual deviance of the model fit is negligible for females aged 35 years, because of the straight regression line on either side of year 2005. Hence the widths of the associated prediction intervals are zero.

Figure 6.
Predicted mean future years of employment shown by boldface solid line, with simultaneous 90 % prediction intervals (lower and upper limits) shown by thinner lines, for 15- and 50-year-old men and women are given for the years 2010–2015.



8 Discussion

8.1 Longer Working Lives Tackle Aging Societies

Population aging is not looming in the future, it faces us already. Economic challenges come about when the increasing number of people in an advanced age and the younger generation supporting them cause the growth in society's consumption needs to outpace growth in its productive capacity. Maestas and Zissimopoulos (2010), Professors of Economics at Pardee RAND Graduate School, CA, argue that encouraging work at older ages serves a variety of social goals, including counteracting the slowdown of labor force increase and supporting the finances of social security and medical care. As men and women extend their working lives, they can enhance their own retirement income security and may ease the strain of an aging population on economic growth. Prolonging working life is similarly an essential element of a successful policy to meet the concerns confronting Finland. Thus it is important to use accurate statistics to quantify the *WLE*'s.

In the present paper, stochastic process analysis was applied for estimating the future time that an individual of a given initial age in the Finnish working-age population belongs to one of the following three sub-groups:

- gainfully employed
- currently unemployed, but has actively sought employment and would be available for work
- economically inactive, i.e., persons outside the labor force prior to permanent departure from work life by retirement or death.

These projected estimates were obtained (in 2011) for 2010: For a 15-year-old male the *WLE* up to age 64 years is 35.3 years, while for females it is 34.1 years. The corresponding forecasts for 2015 are 36.0 and 35.5 years.

The comparable expected employment durations computed at the ETK (Lampi, personal communication, August 3, 2011) for 2009 were [our figures in brackets]: 33.5 [34.2] years for males and 33.7 [33.8] years for females. In the European Union, the difference between men and women was smallest in Finland (1.3 yrs), followed by Sweden (2.5 yrs) and Denmark (3.7 yrs) (Laesvuori, 2010). The expected employment participation years of the 15- to-74-year-old population computed by the Social Insurance Institution of Finland (Hytti and Valaste, 2009) for 2005 were [our figures in brackets]: 33.4 [33.4] years for men and 32.2 [32.7] years for females. These estimates are quite comparable taking into consideration the differences in the estimation approaches: viz. prevalence-based vs. regression modeling; Finnish vs. European *LFS;* age bracket 15–64 vs. 15–74 years.

The four major demographic determinants that shorten working careers in the Finnish workforce are: delayed start of employment due to prolonged duration of education; unemployment (268,200 persons, June 29, 2011); disability (267,200 pensioners, in 2010); and early retirement. Lengthening the working careers has become to be regarded as a possible solution to the economic problems of the public sector due to the rapid population aging in Finland (Kiander, 2010). It is argued that if people continued working longer, revenue from taxation would increase, and there would be less need for austerity measures. Basically, the extension of working careers determines the rise in employment rate. Roughly, it can be estimated that extending the working life from 35 to 40 years would mean a rise in the employment rate from 68 % to 77 % (i.e., 200 000 new workplaces). An assertion is that work careers can only grow longer if a sufficient number of new workplaces will spring up in the enterprises (as against in the public sector).

The efficacy of national measures adopted in Finland (up to 2005) aimed at extending working life has been analyzed as successful comprehensive reforms because they are simultaneously punitive and long term and stress incentives (Sigg and De-Luigi, 2007). These measures appear to have made prolonging labor force participation an attractive option. During the last decade, social policy has been adjusted in many ways to take better account of the challenges created by population aging and substantial progress has been made in many sectors. Yet the success of Finnish pension reforms and employment policies aimed at strengthening the sustainability of public finances has been assessed still to be insufficient in a report issued by the Prime Minister's Office (2009; Vihriälä, 2009).

8.2 Prevalence versus Multistate Life Table Analysis

The methodological interest in this working paper has been in the application of inferential tools for discrete time stochastic processes for application to register data which are readily available. It is contended that this modern approach has multiple advantages over the currently used practices.

Earlier applications of population health measures (Nurminen, 2004) such as *active life expectancy* have been numerous, especially in the US (Katz *et al*. 1983). These measures have also been recently applied in Finland for working life (Hytti and Nio, 2004) and for retirement (Kannisto, 2006). Active life expectancy answers the question: Of the remaining years of life for a cohort of persons, what proportion is expected to be spent disability free? The correct answer has implications for individuals, families and societies. The specific term of *labor market activity rate* is the percentage of the population that *reports*, e.g., in a labor survey that they have been working during the month of the interview. This measure might overstate the labor market activity of persons with disability (or defect or disease), because some people may have experienced the onset of disability, for instance, in the middle of the survey period and did not work after that.

Our approach to estimating *working-life expectancy* differs from the traditional actuarial method in many fundamental facets. First, although we also use data from the life tables and the *LFS*s of Statistics Finland, we estimate the *WLE*s jointly for multiple years throughout the study period. The alternative approach to the analysis is to carry out separate estimations for a series of survey or census years and then fit a curve to describe trends, as was done in Hytti and Nio (2004) in their monitoring of cross-sectional employment activity data over a number of years. Since these data span 10 years and a large number of individuals, the results may not be as sensitive to economic conditions as a survey that would rely on only one year of data, unless period-specific effects are explicitly modeled.

Second, we base our analysis of panel or cohort data on a large-sample regression model fitted to a multistate life table, instead of a simple relative frequency calculation using the average demographic experiences of the synthetic cohorts at each given age. This stochastic inferential approach allows us to draw probabilistic inferences on markedly more information about work life characteristics and also permits much more detailed working-life tables to be estimated, for example stratifying by socioeconomic factors. We explicitly modeled the state probabilities as a function of age, year, GDP, etc. The set of variates describing demographic and economic conditions faced by persons can be expanded, but not at will. This modeling approach enables one to circumvent the problem of small cell sizes encountered in modest disaggregation of data.

Third, the traditional prevalence life table (*PLT*) technique is limited when applied to intrinsically dynamic processes with multiple decrements, like the labor force process. In a similar manner, the life table calculated from prevalence rates cannot provide the occurrence/exposure rates in a continuous time frame. If labor force participation rates change over time, these trends are incorporated more accurately in the multistate life table (*MSLT*) method than in the *PLT* technique. However, the former method is very sensitive to particular fluctuations in labor force activities. Calculations could therefore overstate the labor force involvement in times of expansion and understate in a recessionary period (Richards, 2000).

In reviewing the alternative employment activity measures, Hytti (2009) discussed the relative advantages and limitations of the retirement exit age versus active-life expectancy. She pointed out that exit age acts rapidly and to the correct direction of the changes in the transitions to retirement. However, the exit age measure does this ignoring the cumulative experience up to the present time. By comparison, the expectancy was said to react slowly to the changes in the usage of pension scheme and in the participation of labor market. But the expectancy measure – which can be regarded as a far-sighted feature – is influenced by the behavior of the studied population in the preceding years. Another advantage is that expectancy shows whether or not the development tends towards the targets set in the official employment and pension policies.

Evidently, the above criticism of the insensitiveness property is unfounded, and derives as a defense against the fact that the retirement age indicator is an inferior measure of the total career length (see Nurminen [2008] for the comparative advantages and limitations pertaining to the actuarial-type and regression-type expectancy measures). By definition, the Sullivan method cannot supply estimates of cohort health expectancies which are of importance to persons now living and to planners of future health services, except in so far that a period measure is a surrogate for the analogues cohort quantity (Myrskylä, 2010). We argue that the fundamentally different Davis *et al*. approach may be helpful in this regard. In fact, the regression function can be estimated based either on a long time span (e.g. a decade) or on a shorter time period (e.g. a year).

Then again, the working-life expectancy has been characterized as being sensitive to volatile labor market variations by the report of the Government's working group (Prime Minister's Office, 2011), who gave an example: In 2008 the Finnish *WLE* at age 15 was 34.6 years but it reduced due to the rapid decline in employment in the recession year 2009 by one whole year (1.7 years for men). Actually, the expectancy was computed using the traditional actuarial (Sullivan) *PLT* technique on a year-by-year basis. The *MSLT* regression (Davis) approach to expectancy, which is based on fitting a smooth model over the studied interval, say 2000–2009, does not overestimate the effect of such changes on the total length of working career. In order to react to the short-term fluctuations, the model can be specified to include terms to describe the recession period (2008–2010). Entering a single indicator for the particular year 2009, the developed model yielded the following estimates of male *WLE*s for the years 2008, 2009, 2010: 34.7, 34.2, 35.2 (Table 4). The drop from 2008 to 2009 was only half a year, but the counteractive rise from 2009 to 2010 was one year.

Fourth, the *MSLT* methods were developed to overcome the limitations of the traditional *PLT* techniques. The states are defined to be multiple, some of which are transient (or recurrent) while others are assumed non-transient. We enhanced the customary life table by explicitly defining a three-state employment state space: (1) employed (permanently employed, employed for fixed-term, and self-employed); (2) unemployed; (3) persons outside the labor force (students, conscripts, disability and old-age pensioners, etc.). This definition is different to the two-state system which estimates the duration of ’active working life’ by classifying persons as ’active’ (in the labor force) or ’inactive’ (out of the labor force) (Hytti and Nio, 2004). The tabular analysis of further disaggregated data (e.g. allowing various modes of exit from the labor force) would necessarily turn out to be cumbersome or impossible without resorting to modeling. The regression analysis of panel or cohort data is applicable when the numbers are reasonably large; frequencies of 10 or more in the non-absorbing cells of the multistate life tables – say at 10 tables – should be sufficient (Prof. C.R. Heathcote, ANU, personal communication, December 3, 2001).

Finally, because working-life tables are generated from survey data, sampling variation may be important (e.g., due to population dynamics, economic fluctuations, interview methods), especially in small samples. Although the Finnish official research institutes acknowledge this fact, they do not provide standard error estimates for their active working life expectancies (Appendix Table 4, Kannisto 2006). Under stationary conditions (i.e. independence of an initial health state), a new ’equilibrium’ estimate of the prevalence rate and its approximate variance has been developed by Diehr et al. (2007). In the Davis *et al.* (2001) approach, standard errors (and covariance) can be found by using the delta method based on the maximum likelihood function or, alternatively, by the Monte Carlo sampling from the estimated asymptotic normal distribution of the estimated regression coefficients.

9 Methodological Recommendations

A study for the EU Commission sought to investigate the working life expectancy (*WLE*) indicator which should complement the monitoring instruments of the European Employment Strategy by focusing on the entire life cycle of active persons and persons in employment (Vogler-Ludvig, 2009). The study suggested three indicators for the measurement of *WLE*:

- duration of active working life indicator based on average annual activity rates
- duration of employment indicator based on average employment rates
- duration of working time indicator based on annual working hours

All three indicators have their counterparts in the form of duration of inactive working-life, duration of unemployment, and duration of non-working time.

The *WLE* indicators were assessed to provide sufficiently accurate and easily understandable results, in that they:

– are highly stable over time, even for single ages
– show great continuity over the lifespan
– react directly to changes of activity rates and working hours
– reveal expected differences between gender, ages, and countries

A limitation of these actuarial indicators *appear* (sic) to be that they are descriptions of the whole life cycle rather than specific periods of working life. Moreover, they describe the present state of working life participation over all ages, rather than providing forecast of future working life. However, these limitations pertain only to the traditional *PLT* (Sullivan) method, not to the modern *MSLT* (Davis) regression modeling approach.

Based on the positive assessment of the considered indicators, the study recommended using the *WLE* indicator as one of the core labor market indicators at European and national level (Dr. Kurt Vogler-Ludvig, personal communication, November 9, 2009). Out of the considered indicators, the duration of active working life received a dominating position. The *PLT* indictor has been discussed in the Employment Committee Indicators Group (Guido Vanderseypen, Directorate-General Employment, personal communication, November 4, 2010), and there has been a rather broad approval for the proposed formula (Eric Meyermans, European Parliament, Committee on Employment and Social Affairs (EMPL), personal communication, April 22, 2011).

Considering the comparative advantages and limitations of the actuarial life table method (Hytti and Nio) and the multistate life table regression approach (Davis *et al.*), our stand is that, while the former prevalence-type indicator is suitable and easy for the purpose of routine statistics, the modern regression model-based expectancy is appropriate for more demanding research objectives. This conclusion is reached because the latter statistical measure is theoretically founded on large-sample, weighted least squares theory, and therefore allows reliable data analyses and stochastic inferences (*inter alia*, with respect to significance tests, interval estimates, interaction effects, time tends, and projections).

APPENDICES

Appendix A: Details of Modeling and Estimation Methods

The details are extracted from the method description in Nurminen *et al*. (2005). For full explication of the stochastic modeling, see Davis (2003).

The major difference and the novelty of the method of, for example, Davis *et al.* (2001), compared to the method of Millimet *at al.* (2003), is that it first proves the asymptotic normality of the empirical log-odds. The step is the estimation of the parameterized true log-odds by weighted least squares. It is only possible to proceed in this way because the method deals with a large number of individuals. Millimet *et al*. do not exploit the large number of individuals and they use a standard package for maximizing the likelihood. In a sense the method of Davis *et al*. is not logistic regression since it ends up with weighted least squares as opposed to solving non-linear likelihood equations by Newton-Rafson or some other numerical devise. That is why Davis *et al*. often refer to their approach as a large-sample version of logistic regression.

Here our interest is on estimating the marginal probabilities and working-life expectancies that are not conditional on the initial state, but only on the initial age x. For j = 1,2,3,4 and 14< x <65, let $\tilde{l}_j(x)$ be the random variable denoting the number of lives in state j at age x, and let the vector of the frequencies be $\tilde{l}(x) = (\tilde{l}_1(x), \tilde{l}_2(x), \tilde{l}_3(x), \tilde{l}_4(x))'$

Then define the expectations $l_j(x) = E[\tilde{l}_j(x)]$, $l(x)= E[\tilde{l}(x)]$, j = 1,2,3,4, and assume (Davis 2001, 2002b):

A1. The expectations $l_j(x) = np_j(x)$, where n is the number of lives in a hypothetical cohort.

A2. As n tends to infinity, $n^{-1/2}\{\tilde{l}(x)-l(x)\}$ is asymptotically normally distributed with zero mean and covariance matrix B of rank 3.

A3. Birth cohorts are stochastically independent, and for each age x the random vector $\tilde{l}(x)$ is, for large n, follows approximately a multinomial distribution with parameters n and $p_j(x)$.

These assumptions are plausible in a wide variety of circumstances involving the collection of official statistics and can clearly be rephrased to cover the case when the number of states is different from four. The requirement in A2 that the rank of B is one less the number of states is due to the fact that the four states are exhaustive and $\Sigma_{j=1}^{4} \tilde{l}_j(x)$ = n for all x. The covariance matrix is left general at this stage since a version of the asymptotic normality given below continues to hold when the multinomial requirement of A3 is not true (Davis *et al*., 2002b). In particular, our argument can easily be modified to accommodate the case of a covariance matrix including finite sample corrections or other features reflecting the sampling scheme (see Appendix C).

For the present purposes, failure of the multinomial assumption in A3 results in an incorrect weight matrix in the weighted least squares estimation described below, leading to inefficient but still consistent estimators.

With state 4 (dead) as the reference, form the log ratios

$$\xi_j(x) = \log\{p_j(x)/p_4(x)\} = \log\{l_j(t,x)/l_4(t,x)\},\ j = 1,2,3, \qquad \text{(Eq A.1)}$$

which are estimated consistently by $\tilde{\xi}_j(x) = \log\{\tilde{l}_j(,x)/\ \tilde{l}_4(,x)\}$.

Exploratory analysis can be used to suggest a parametric form for the log ratios, $\xi_1(x) \equiv \xi_1(x;\beta)$, and the estimation of β is done by weighted least squares. With $\hat{\beta}$, the resulting estimate of β, we have the estimates:

$$\hat{\xi}(\mathrm{x}) = \xi(\mathrm{x};\hat{\beta}),$$

$$\hat{p}_4(x) = \{1 + \textstyle\sum_{j=1}^{3} \exp\,[\hat{\beta}(x)]\}^{-1}, \qquad \text{(Eq A.2)}$$

$$\hat{p}_j(x) = \hat{p}_4(x)\exp[\hat{\xi}_j(x)],\ j = 1,2,3,$$

and thence the estimated working-life and related expectancies (for age z)

$$\hat{e}_j(z) = \int_z^{64} \hat{p}_j(x)dx,\ \mathrm{j} = 1,2,3,4. \qquad \text{(Eq A.3)}$$

These integrals can be evaluated using a discrete approximation but we applied the S-PLUS function INTEG.SPLINE, which integrates under a spline function through a set of points. Standard errors can be found with the delta method (Liang and Zeger, 1986) or, alternatively, by the Monte Carlo sampling from the estimated asymptotic multivariate normal distribution of $\hat{\beta}$ by using the S-PLUS-function RNVNORM. The inverse $V(x)^{-1}$ is the covariance of a multinomial distribution with probabilities $p_j(x)$, $j = 1,2,3,4$.

The covariance matrix for the parameter estimates $\hat{\beta}$ indicates standard errors for the regression coefficients, given in Table 1 and 2, that initially appeared implausibly small. This casted doubt on the premise that labor force movement frequencies are binomially distributed, and suggested that the populations are heterogeneous. In particular, this may hold in the context of people who are out of the labor force. A way to correct this is given in Appendix C.

If the vector of log ratios is modeled by $\xi(t,x) \equiv \xi(t,x;\beta) = Z(t,x)'\beta$, with $Z(t,x)$ an appropriately chosen design matrix, then the loss function to be minimized with respect to β is

$$L(\beta) = \sum_{t=2000}^{2009} \sum_{x=15}^{64} \{\tilde{x}\,(t,x) - Z(t,x;\beta)\}'V(t,x)^{-1}\{\tilde{x}\,(t,x) - Z(t,x;\beta)\}. \qquad \text{(Eq A.4)}$$

Due to dependence along birth cohorts, that is along diagonals of the (t,x) plane with c = t–x constant, the variance-covariance matrix of $\hat{\beta}$ was calculated by the method of Liang and Zeger (1986). The part of assumption A3 asserting the stochastic independence of birth cohorts is important here.

Finally, the estimation of expectancies conditional on having reached an age z greater than 15 can be done as follows. For a fixed year, let

$$\begin{aligned}
p_j(x) &= p_j(14;x) = \Pr(\text{Individual is alive \& in state } j \text{ at } x \mid \text{Alive at 14}) \\
&= \Pr(\text{Individual is alive at } z\text{, and alive \& in state } j \text{ at } x \mid \text{Alive at 14}) \\
&= \Pr(\text{Alive at } z \mid \text{Alive at 14}) \cdot \Pr(\text{Alive \& in state } j \text{ at } x \mid \text{Alive at } z) \\
&= \{\textstyle\sum_{j=1}^{3} p_j(14;z)\}\, p_j(z;x).
\end{aligned}$$

Hence the expectancy of state j for a person of initial age z is

$$e_j(z) = \int_z^{64} p_j(z,x)\mathrm{d}x = \{\textstyle\sum_{j=1}^{3} p_j(z)\}^{-1} \int_z^{64} p_j(x)\mathrm{d}x. \qquad \text{(Eq A.5)}$$

This is estimated consistently by substituting the $\hat{p}_j(x)$ of Eq A.2.

The second-order moments of the probabilities can be estimated using the delta method. That is, the covariance matrix of $\hat{p}_j(x)$ is obtained from the following expression:

$$\mathrm{Var}(\hat{p}_j(x)) = \{\partial\hat{p}_j(x)/\partial\beta^{T}\}\ \mathrm{Cov}(\hat{\beta})\ \{\partial\hat{p}_j(x)^{T}/\partial\beta\} \qquad \text{(Eq A.6)}$$

The partial derivatives of the probabilities with respect to β can be easily found.

With state 4 as the reference, let $\xi_j(t,x) = \log\{p_j(t,x)/p_4(t,x)\}$, $j = 1,2,3$. After some experimentation the male models chosen were linear, quadratic or cubic in age x, linear in year t (measured from 2000), with cross-product terms. Explicitly, the state-specific models selected for the male log ratios guided by significance testing have the following form, with $I(\cdot)$ the standard indicator function for the years of the new pension legislation from 2005 onwards as well as for the teen ages (15 to 17 years) and senior ages (60+ years):

$$\begin{aligned}
\xi_1(t,x) &= \beta_1 + \beta_2 x + \beta_3 x^2 + \beta_4 x^3 + \beta_5 I(x\geq 60) + \beta_6 t + \beta_7 tx + \beta_8 tx^2 + \beta_9 tx^3 \\
\xi_2(t,x) &= \beta_{10}\, x_2(x,t) + \beta_{11} x + \beta_{12} x^2 + \beta_{13} x^3 + \beta_{14} I(15\leq x\leq 17) + \beta_{15} I(x\geq 60) + \beta_{16} t \\
&\quad + \beta_{17} tx + \beta_{18} tx^2 + \beta_{19} tx^3 + \beta_{20} I(2005 \leq t \leq 2010) + \beta_{21} t\cdot GDP \\
\xi_3(t,x) &= \beta_{22} + \beta_{23} x + \beta_{24} x^2 + \beta_{25} x^3 + \beta_{26} I(15 \leq x\leq 17) + \beta_{27} I(x\geq 60) + \beta_{28} t \\
&\quad + \beta_{29} tx + \beta_{30} tx^2 + \beta_{31} tx^3 + \beta_{32} I(2005 \leq t \leq 2010) + \beta_{33}\cdot GDP
\end{aligned} \qquad \text{(Eq A.7)}$$

The models selected for the female log ratios are very similar and are as follows:

$$\begin{aligned}
\xi_1(t,x) &= \beta_1 + \beta_2 x + \beta_3 x^2 + \beta_4 x^3 + \beta_5\, I(15\leq x\leq 17) + \beta_6 I(x\geq 60) + \beta_7 t + \beta_8 tx \\
&\quad + \beta_9 tx^2 + \beta_{10} tx^3 \\
\xi_2(t,x) &= \beta_{11} + \beta_{12} x + \beta_{13} x^2 + \beta_{14} x^3 + \beta_{15}\, I(15\leq x\leq 17) + \beta_{16} I(x\geq 60) + \beta_{17} t \\
&\quad + \beta_{18} tx + \beta_{19} tx^2 + \beta_{20} tx^3 + \beta_{21}\cdot GDP \\
\xi_3(t,x) &= \beta_{22} + \beta_{23} x + \beta_{24} x^2 + \beta_{25} x^3 + \beta_{26}\, I(15\leq x\leq 17) + \beta_{27} I(x\geq 60) + \beta_{28} t \\
&\quad + \beta_{29} tx + \beta_{30} tx^2 + \beta_{31} tx^3 + \beta_{32} I(2005\leq t\leq 2010) + \beta_{33}\cdot GDP
\end{aligned} \qquad \text{(Eq A.8)}$$

Appendix B: Forecasting from the Regression Model

Just as future development of life expectancy cannot be predicted without error, we can only assess the possible expected duration of working-life risks probabilistically. As the development of future labor force movements is unknown, it is of interest to consider the level of uncertainty with which one can forecast the *WLE* (cf. Alho, 2003).

Predictive estimates of the duration of working-life can be important in two ways. First, they can be communicated to the working-age population, so that they may help workers to prepare better for their own retirement. Second, predictive estimates of career length are needed for the economic analyses of retirement decisions to properly account for the risk aversion of future retirees (cf. Alho, 2003).

Prediction intervals for forecasts can be calculated in a number of ways. The first one is to use the statistical variance of the residuals and the parameter estimates extracted from the maximum likelihood regression model fit. However, this approach may yield misleading interpretations if we are not aware of the methodological constraints, since it is not plausible that we could predict with any confidence how future social, economical and political interventions diverge from the historical rates of change. It is thus quite courageous to try to predict the *WLE*s at an upcoming point in time. There are large uncertainties as it depends on various factors such as political decisions and legislations on retirement age, economic benefits from sick leave, compensation from work-related diseases, and the GNP. These factors are often more important than population aging and disease incidence. For example, economic recessions tend to take place at a short notice (e.g. after a fiscal shock) and are by and large unpredictable (Heathcote and Higgins, 2001).

Another method to construct prediction intervals would be to estimate the variance for a model developed without indicators or non-linear terms, because long-term prediction of exceptional events or irregularities is not possible. For example, it can be argued that the normal density ordinate that was used to model the disability hump during the previous economic recession in the early 1990s (Nurminen *et al*., 2005) should be omitted. The variance of the model can be significantly greater than before, yet it will provide us with a less misleading measurement of uncertainty.

Heathcote and Higgins (2001) further point out that a feature of the regression models is that the boundaries of the fitted probability surface are a poorer fit to the observed data than the parts of the surface close to the mean of the predictor variates. For example, it is reasonable to suppose that the most recent observed employment rates are the most accurate indicators of future employment; this alerts us to be prudent when predicting by extrapolation from the fitted regression surfaces.

Van Hoorn and De Beer (2001) argue that for long-term forecasts, qualitative arguments about (working) life expectancy levels based on expert opinion or human judgment should carry more weight than historical extrapolations. This is despite the subjective element inherent in stochastic processes, with unknown covariates and a dynamic non-stationary time series. Alternative means of incorporating expert opinion to base the regression model can be achieved by changing the parameters of the fitted model (Heathcote and Higgins, 2001).

Appendix C: Approaches to Setting Prediction Intervals

Forecasting beyond the observed data is risky because an improper forecasting method or wrong model may be chosen or the premise of the underlying regression model may change. This explains why the out-of-sample forecast errors are typically found to have much larger sampling errors than the residuals (model fitting error, i.e. the difference between the sample and the estimated value). Thus it is important to supplement point forecasts by computing *prediction intervals* (Chatfield, 1993).

The initially small standard errors (and hence narrow confidence intervals) are fundamentally due to us modeling aggregate log-odds of the state probabilities (for the Finnish population) rather than directly modeling observations corresponding to the individuals in the base population. There are several means of coping with this extra-binomial variation due to population heterogeneity (Williams, 1982). In the present case, the problem was solved by calculating standard errors pertaining to prediction intervals in lieu of confidence intervals. The term confidence interval is usually applied to interval estimates for fixed but unknown parameters. In contrast, 'a prediction interval' is an interval estimate for an unknown future value.

By 'prediction interval' we mean an interval based on a standard error (for the predicted probability) that includes the residual variance (of the regression model for the partial log odds) as well as the variance of the model parameter estimates. As a basic rule, the ratio of the length of the prediction interval to the length of the confidence interval is approximately equal to the square root of the number of data points: n = 50 (1-year age groups) × 10 (calendar years) = 500. Applying this factor to the standard errors makes their size more appropriate for the regression and consequently for probabilities and expectancies.

The rationale of our way of dealing with unduly small SEs is explained in the following (Dr. B.A. Davis, personal communication, June 27, 2011).

The idea of (Dr. Brett A. Davis) using $\sqrt{n}$, where n is the number of observed data points, to convert from confidence to prediction intervals can be justified and explained like this:

Our model function involving time (t) and age (x) arguments is

$$\theta(t,x) = Z^T(t,x)\beta + \varepsilon(t,x),$$

where $Z(t,x)$ is a vector of explanatory (e.g. economic) covariates, β is a parameter vector to be estimated, and $\varepsilon(t, x)$ is the error term. So, for fixed values of t_0 *and* x_0,

$$\begin{aligned} Var\left(\theta(t_0,x_0)\right) &= Z^T(t_0,x_0)Var\left(\hat{\beta}\right)Z(t_0,x_0) + Var\left(\varepsilon(t_0,x_0)\right) \\ &= Z^T(t_0,x_0)\left\{\sum_{i=1}^{n} Z^T(t_i,x_i)V^{-1}(t_i,x_i)Z(t_i,x_i)\right\}^{-1} Z(t_0,x_0) + V(t_0,x_0) \end{aligned} \quad (1)$$

In confidence interval calculations the last term in Equation (1), viz. the residual variance, $V(t_0,x_0)$ would not be included.

When no covariates are included in the model (i.e. we just have intercept parameters) the formula (1) can be approximated by

$$Var\left(\theta\left(t_0,x_0\right)\right)=Z^T\left(t_0,x_0\right)\left\{n\times V^{-1}\left(t_0,x_0\right)\right\}^{-1}Z\left(t_0,x_0\right)+V\left(t_0,x_0\right)$$

That is,

$$Var\left(\theta\left(t_0,x_0\right)\right)=\frac{V\left(t_0,x_0\right)}{n}+V\left(t_0,x_0\right)$$

If covariates are included in the model, then the first term on the right-hand side is reduced, so multiplying (the variance) by

$$\frac{\frac{1}{n}+1}{\frac{1}{n}}=n+1$$

is quite conservative. Therefore, the prediction interval half-width is equal to the confidence interval half-width multiplied by

$$\sqrt{n+1}\cong\sqrt{n}.$$

Rather than using the approximate method, in a forthcoming study we plan to apply a superior approach to deal with the problem of population heterogeneity based on fitting a mixed model with separate parameters for the extra variance.

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The Finnish Centre for Pensions is a statutory co-operation body, expert and producer of joint services for the development and implementation of earnings-related pension provision. The aim of our research is to produce high-quality, widely applicable information for the evaluation and development of pension provision.

Eläketurvakeskus on työeläketurvan kehittämisen ja toimeenpanon lakisääteinen yhteistyöelin, asiantuntija ja yhteisten palveluiden tuottaja. Tutkimustoiminnan tavoitteena on tuottaa korkeatasoista ja laajasti hyödynnettävää tietoa eläketurvan arvioimiseen ja kehittämiseen.

Pensionsskyddscentralen är ett lagstadgat samorgan och sakkunnig inom verkställigheten och utvecklingen av arbetspensionsskyddet. Vi producerar gemensamma tjänster för arbetspensionssystemet. Vår forskning har som mål att ta fram högklassig information som nyttiggörs på bred front vid bedömningen och utvecklingen av pensionsskyddet.

ISSN-L 1795-3103
ISSN 1795-3103 (printed)
ISSN 1797-3635 (online)

Finnish Centre for Pensions
ELÄKETURVAKESKUS