Explaining the Female Longevity Puzzle

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Motivation

- Significant increases in life expectancy has been observed for the developed countries.
- However, this decline in mortality rates is not a general pattern.
  - Periods with gender-specific divergence between countries have emerged.
- In the Scandinavian countries in the time period 1980-1995 we have observed
  - A decrease in the mortality rates for Norwegian and Swedish females.
  - A stable or in some cases increasing mortality rate for Danish females.
- A similar mortality divergence between countries has not been observed for Scandinavian males.

Motivation

- Different mortality patterns across countries and gender.
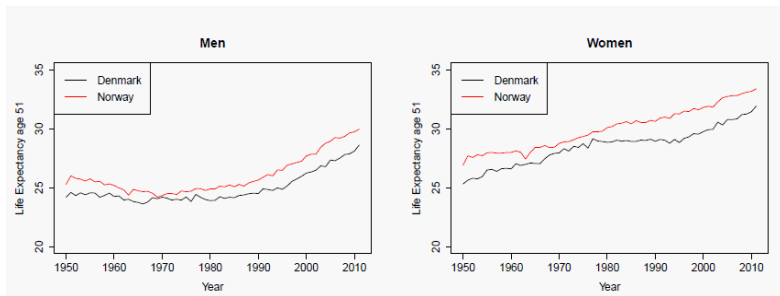
- Danish women (like the Dutch and American) experienced no improvements in longevity from 1980-1995.

Motivation

- This phenomena is not unique to the Scandinavian countries.

  - Meslé and Vallin (2006) showed that the USA and the Netherlands exhibit a similar slowdown in life expectancy like the Danish case.
  - Other countries like France and Japan continue to display a stable positive growth in life expectancy.

- This is an interesting puzzle:

  - Why do women in some developed countries experience increased longevity whereas others a decreased longevity?

Motivation

- Further research is needed in terms of identifying which underlying factors are driving differences in longevity trends.
    - Provide the necessary insight for governments and pension funds to manage their longevity risk as well as quantify future costs.
- Currently, most research is based on aggregated mortality data for total populations, broken down by age and gender.
- However, as Coughlan et al. (2007) point out, population characteristics relevant to mortality also include marital status, social class, health, employment, postcode, etc.

Motivation

- This paper aims to identify which specific socio-economic groups have been driving the slowdown in longevity.
- Moreover, we investigate the forecasting implications of disaggregating data into subgroups.
- Use a very unique and extensive multi-population register data provided by Statistic Denmark and Statistic Norway.
  - Denmark and Norway are similar in their access to health care, social security, labour force participation rates and general living standards.

Motivation

- Construct an affluence measure based on the individual's financial status.
  - Use income and wealth, see Cairns et al. (2016).
  - Obtain a very fine and clear partitioning between 10 subgroups in terms of life expectancy.
- Identify differences in life expectancy of up to 8 years for 50 year old males and 6 years for 50 year old females.
- Convergence between the socio-economic groups is observed in Norway for both genders over time.
  - However the gap for both Danish males and females remains over the 30 year time period.

Motivation

- Naturally, the financial status does not affect the longevity directly.
  - Important to stress that the aim is not to say something about causation.
- Aim is to create a strong predictor.
- Adherence to a particular socio-economic subgroup is closely related to exposures affecting mortality patterns.
  - Smoking, drinking, visits to the doctor, living conditions, work environment, job type, labour force participation, etc.

Literature

- Previous research have investigated the observed low life expectancy for Danish women.
- Jacobsen et al. (2002, 2006) and Jacobsen et al. (2004) found that the lower mortality for Danish women is due to a higher mortality for women born between the first two world wars.
  - Cohort effects not present to a similar extent for Sweden and Norway.
  - They indicate that lower life expectancy for Danish women could be due to smoking habits.
    - Danish women in these cohorts started smoking earlier compared to Norwegian and Swedish women.
- Drinking frequencies have also been considered see Bjørk et al. (2008) and Koch et al. (2015).

Literature - Education

Education as a predictor:

- The relationship between social groups and life expectancy by using educational attainment as a measurement for social status has received growing attention.
    - Kitagawa and Hauser (1973), Meara et al. (2008), Rostron et al. (2010), Olshansky et al. (2012), Brønnum-Hansen and Baadsgaard (2012), Bound et al. (2014).
- They find large disparities in life expectancy by level of education.
- Some authors even find increasing inequality in terms of life expectancy.

Literature

The use of educational groups has recently been criticised.

- Missing values in particular for the oldest old.
    - Also in a time perspective.
- Increasing selectivity of individuals with low education: Low education used to be common and now it is rare.
    - Thus by construction the percentage in each group vary from one cohort to the next.
- No consensus regarding the size of the gap in life expectancy.

Literature - Two Interesting Findings

Two interesting results presented in the literature.

1. Behrman et al. (2011) challenged the notion that higher educational attainment causes people to have lower levels of mortality.

- Unique data set that included pairs of twins, both identical and fraternal, as well as unrelated adults.
- Among identical twin pairs with different education levels:
    - Only weak evidence of a relationship between educational attainment and adult mortality.
- Brønnum-Hansen and Baadsgaard (2012) using same register show an increasing gap from 4.8 in 1987 to 6.4 years in 2011 for 30 year old males.

Literature - Two Interesting Findings

2. Brønnum-Hansen and Juel (2004) investigate the impact of smoking on the social gradient in health expectancy for four educational groups.

   - Find that smoking cannot explain the observed differences in health expectancy between education groups.

- This has motivated us to look for a new socio-economic measure to determine differences in life expectancy.

Data

Very unique and extensive multi-population register data.

- Register data for both the Danish and the Norwegian population for the time periods 1980-2012 and 1980-2008 respectively.
    - Track each individual in the population through their Central Person Register number.
- Focus is on advanced ages from 50 to 95 years as both child mortality and adult mortality under the age of 50 have fallen dramatically.
    - Further improvements in life expectancy rely almost completely on mortality decline at old ages.

Data

- Individual specific data contains information on yearly income, wealth, age, gender, year and cause of death, municipality, highest obtained education level, and marital status etc.
  - Individual's medical history and type of drugs they were using on a daily basis.
- Also identify the same information for an individual's spouse or partner.
  - Enabling us to allocate income and wealth between couples and within households.

Data

- The analysis is based on gender specific central death rates calculated as

$$m(t, x) = \frac{d(t, x)}{E(t, x)} \tag{1}$$

where $d(x, t)$ is the death count and $E(x, t)$ is exposure-to-risk, x is age, and t is the time (year).

- Exposure-to-risk is defined as

$$E(t, x) = P(t, x) - d(t, x)/2$$

where $P(t, x)$ is the population aged x on the $1/1$ in year t.

Indexation into subgroups

- We use the key covariates **income** and **wealth** to create the **Affluence** measure see Cairns et al. (2016):

$$A_{it} = Wealth_{t-1} + 15 \cdot Income_{t-1}$$

  - We use the lagged values to circumvent the missing variable problem in the year of death.
- Next we rank the individuals based on this affluence measure.
- Allocate the 10% least affluent to group 1, and so on up to group 10 which contain the 10% most affluent.
  - Thus we obtain ten groups of equal size at each year and age.
- Fix the group at age 67 (retirement age).

Indexation into subgroups - Why the linear combination?

- High wealth or high income $\Rightarrow$ low mortality.
- Low wealth or low income $\not\Rightarrow$ high mortality.

However

- Low wealth **and** income $\Rightarrow$ high mortality.
- Especially for the pension aged individuals.
    - Living off of either income or wealth.

Indexation into subgroups - Why 15?

- Why the use of 15 in the affluence measure:

$$A_{it} = Wealth_{t-1} + 15 \cdot Income_{t-1}$$

- 15 times income represented the approximate value of an individual's future retirement income.
    - The combination gives an estimate of the individuals "total" wealth.
- Equal weighting, as wealth tends to have larger values than income.
- Relatively robust to other choices of alpha.

The Benchmark Model

- The Lee-Carter Model (1992) is used as the benchmark model.

$$\ln m_{x,t} = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t}$$

- α_x general death rates for different ages.
- κ_t index variable capturing an overall trend.
- β_x relative speed for improvements at different ages wrt. κ_t.

The Li-Lee Coherent Model

The Li-Lee Model (2005) is a multi-population model

$$\ln m_{x,t}^i = \alpha_x^i + \beta_x^i \kappa_t^i + B_x K_t + \varepsilon_{x,t}^i$$

- B_x is the LC estimate of β_x for the overall population.
- K_t is the LC estimate of κ_t for the overall population.
- α_x^i general death rates for different ages (Identical to LC).
- κ_t^i index variable capturing an overall trend.
- β_x^i relative speed of improvements at different ages wrt. κ_t.

Results - Socio-Economic Status

- Investigate the development in life expectancy for Denmark and Norway in further detail.
    - Specifically interested in 'extracting' information about the diverging and converging periods in life expectancy for women.
- Can the affluence measure based on income and wealth shows a clear difference in life expectancy between socio-economic groups?

Results - Socio-Economic Status
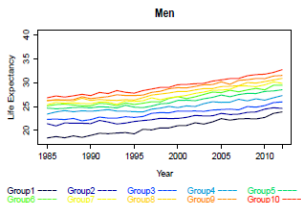
(a) Danish men
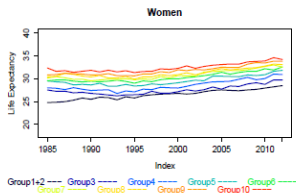
(b) Danish women
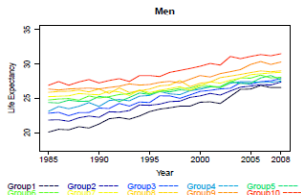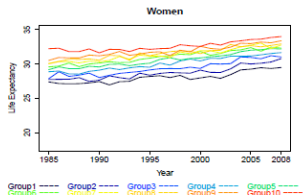
(c) Norwegian men

(d) Norwegian women

- Life expectancy for the affluence groups 1-10 at age 51, for Danish and Norwegian men and women for the period 1985-2008/2012.

Results - Socio-Economic Status

- Yes, life expectancy is found to be regularly increasing across time in both countries from the lowest to the highest affluence group.
  - Resembling the behaviour of the total populations.
- A gap of eight years for males and six years for females between the least and most affluence group.
- No indication that the Danish gap between socio-economic groups is closing.

Results - Ranking Persists

- The clear ranking of life expectancies across subgroups also persist across ages. Here we plot LE at age 70.
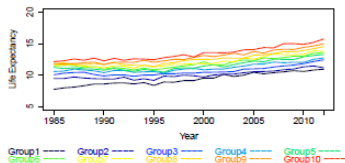
(a) Danish men
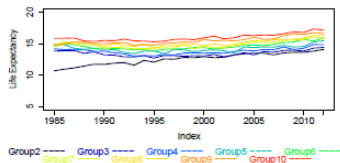
(b) Danish women
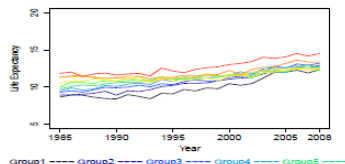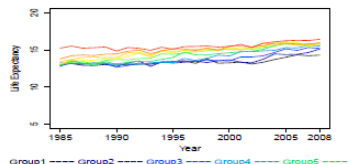
(c) Norwegian men

(d) Norwegian women

- Differences in life expectancy between the subgroups decreases and a less clear pattern emerges as we assess older individuals.

Results - Socio-economic Status

- Late-life mortality convergence across age observed for the 10 groups.
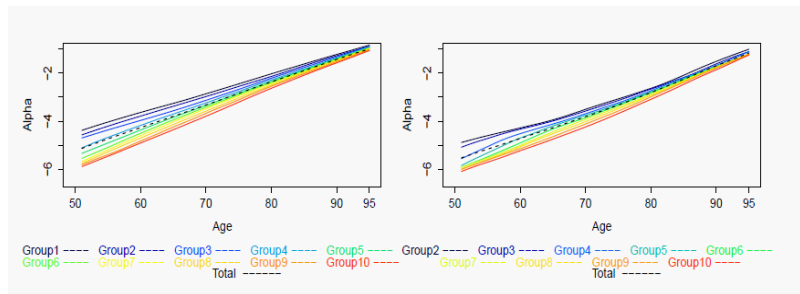
- The individuals degree of affluence becomes less important with age.
  - Affiliation to a particular socio-economic groups has almost no impact for the very old.
  - Similar pattern across gender and country (see results in the paper).
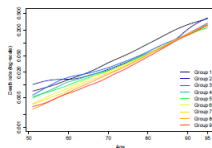
Results - Socio-economic Status

- However, the observed late-life convergence between socio-economic groups across ages have changed over time.
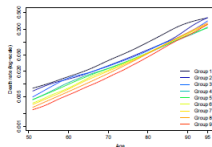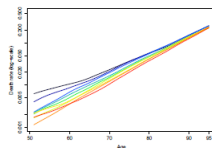

(a) Fitted $m_{x,t}$ for the Lee-Carter model in 1985 (Women)
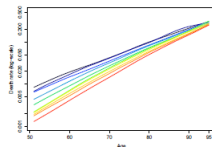
(b) Fitted $m_{x,t}$ for the Lee-Carter model in 2012 (Women)

(c) Fitted $m_{x,t}$ for the Li-Lee model in 1985 (Women)

(d) Fitted $m_{x,t}$ for the Li-Lee model in 2012 (Women)

- Less pronounced for the oldest-old in the 80's and slight divergence for the younger age groups.
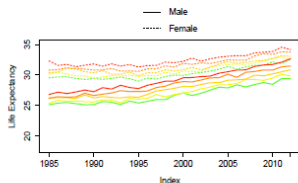
Results - Gender Gap

- All individual subgroups exhibit the regularity from the total population of women experiencing a higher life expectancy than men.
- However, men experience a higher rise in life expectancy compared to women.
- Thus we plot the life expectancy for men and women side by side for the 5 lowest and the 5 highest affluence groups
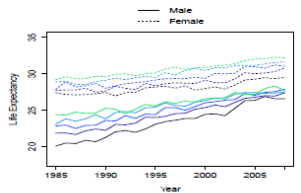
Results - Gender Gap

- Life expectancy for at age 51, comparing men and women by group for the five lowest and highest affluence groups in Denmark and Norway for the years 1985-2008/2012.
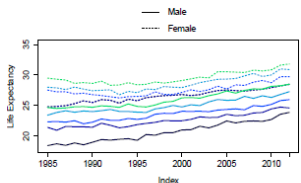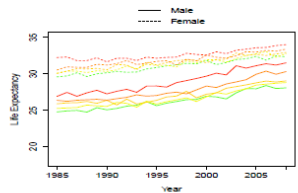

(a) Denmark lowest groups

(b) Denmark highest groups

(c) Norway lowest groups

(d) Norway highest groups

Results - Gender Gap

- Men partly catches up to women in terms of life expectancy over our time period both for Denmark and Norway.

- That fact that men and women convergence in terms of life expectancy might be interpreted in the light of both sexes converging in terms of life style, i.e. work, alcohol and smoking which drives the convergence in life expectancy for the final years.

- Thus, the gender gap seen previously is slowly but firmly closing.
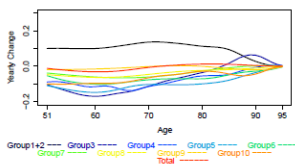
Results - Socio-Economic Status

- Let's return to LE for the affluence groups 1-10 at age 51.


(a) Danish men   (b) Danish women
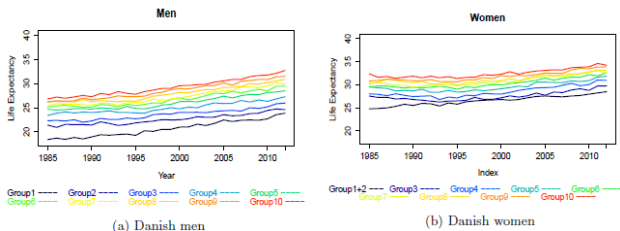
- Is the observed stagnation due to changes in particular subgroups or is it an overall pattern.
- Clearly observe a standstill and for some of the lower affluence groups for Danish women a decrease in life expectancy from 1985 to 1995.
  - Not observed for either the men or Norwegian women who increase more or less regularly over the full period.
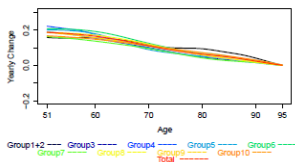
Results - Socio-Economic Status

- Yearly improvements in life expectancy for women from 1985-1995 (left) and 1995-2012 (right) for the ages 51 to 95.
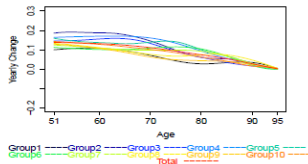

(a) Danish women 1985-1995
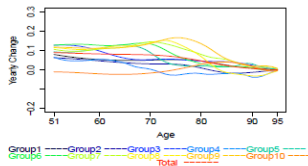
(b) Norwegian women 1985-1995

(c) Danish women 1995-2012

(d) Norwegian women 1995-2012

Results - Socio-economic Status

- The groups 3-5 have been driving the stagnation in life expectancy for Danish women.
- The decline in mortality for Danish women is present for all subgroups
  - Particular large decreases for the middle income groups 3-5
- Subgroups for Norwegian women all exhibit positive improvements over the period.
- Interestingly, we see that the two groups with lowest affluence measure for Danish women actually see large improvements in life expectancy
- This corresponds well with the findings in Brønnum-Hansen and Juel (2004)
  - The decline in longevity for Danish women cannot solely be explained by higher smoking prevalence for the lower socio-economic groups.

Results - Goodness Of Fit

- To examine the in-sample goodness of fit of the models in the period 1985-2012, we calculate coefficients of determination,
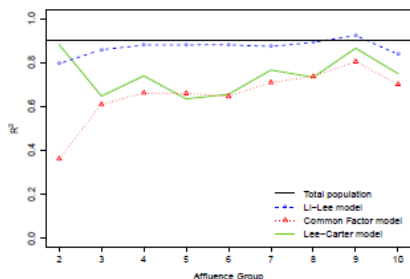
$$R2 = 1 - \frac{SSR}{SST}$$

  for the three different models.

- This is a measure of how much of the variability in the data that is explained by the models.

- Include the common factor model for comparison purpose.

  - See if it is worthwhile to include sub-group specific parameters as in the Li-Lee model.

Results - Goodness Of Fit
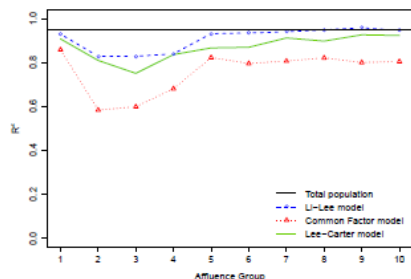
(a) Men

(b) Women

Figure 5.6 – R^2 for three different models for each affluence groups for men and women.

Recall the following model specifications:

LC: $\ln m_{x,t} = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t}$

LL: $\ln m_{x,t}^{(i)} = \alpha_x^{(i)} + B_x K_t + \beta_x^{(i)} \kappa_t^{(i)} + \varepsilon_{x,t}^{(i)}$

CF: $\ln m_{x,t}^{(i)} = \alpha_x^{(i)} + B_x K_t + \varepsilon_{x,t}$

Results - Goodness Of Fit

- Lower model fit when using the affluence groups compared to the overall population.
    - Natural consequence of more variability in the data due to using only 10% of the original sample size in each subgroup.
- A tendency towards higher R^2 values for higher affluence groups.
    - Especially pronounced for women.
- For both men and women: A clear ranking of the three models with the Li-Lee model showing the best performance.
    - Interestingly, despite the reduction in sample size, the Li-Lee model performs almost as good as the total population.
    - A rationale for using the more homogeneous populations and exploiting the specific trends within them.

Forecasting - Why is it Important?

- Vital to understand future trends - can we expect a catch-up effect for Danish women?

Governments

- Pressure on government expenses through commitments to
    - Early and old age pension - indexing pension benefits to life expectancy.
    - Healthcare.
    - Caretaking in retirement homes.
    - Demographic changes on economic growth.

Pension Funds

- Unable to meet their financial commitments.
    - Guaranteed individuals a lifelong income stream independently of how long they live.
    - Challenged in terms of pricing, managing and hedging longevity risk.

Forecasting

Once k_t is estimated,

- Standard Box-Jenkins methods are used to determine the optimal forecasting model.
- In the Lee and Carter (1992) model a random walk with drift, $ARIMA(0, 1, 0)$, is chosen

$$k_t = k_{t-1} + c + \epsilon_t.$$

- This gives us the following forecast

$$\dot{k}_{t_n+s} = k_{t_n} + ck.$$

Forecasting

- This implies forecasted mortality rates given by

$$\dot{\mu}_x \left(t_n + s \right) = \exp \left(\widehat{m}_x \left(t_n \right) + \widehat{\beta}_x \left(\dot{k}_{t_n+s} - \hat{k}_{t_n} \right) \right)$$

- The period life expectancies at age x in calendar year t are:

$$
\begin{aligned}
\overline{e}_x^{\uparrow} \left(t \right) &= \int_{\xi \geqslant 0} \exp \left(- \int_0^{\xi} \mu_{x+\eta} \left(t \right) d\eta \right) d\xi = \frac{1 - \exp \left(-\mu_x \left(t \right) \right)}{\mu_x \left(t \right)} \\
&+ \sum_{k \geqslant 1} \left[\left(\prod_{j=0}^{k-1} \exp \left(-\mu_{x+j} \left(t \right) \right) \right) \frac{1 - \exp \left(-\mu_{x+k} \left(t \right) \right)}{\mu_{x+k} \left(t \right)} \right].
\end{aligned}
$$

Forecasting

- As noted by Li and Lee (2005)
  - In order to avoid long-term divergence, it is important that each of the κ_t^i factors tend toward some constant level over time.
- If not, the short- and medium-term divergence will persist and the approach would be unsuccessful.
- Therefore, in terms of forecasting, Li and Lee (2005) model the κ_t^i as a first-order autoregressive model AR(1).
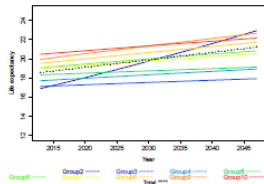
Results - Forecasting

- Constructed 35-year ahead forecasts with both the Lee-Carter and Li-Lee model.
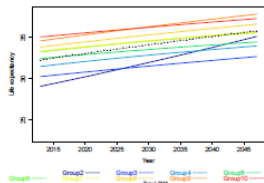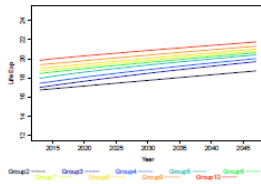

(c) Women LC forecast at age 51
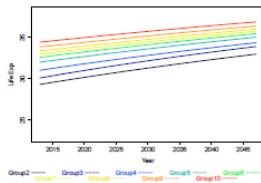
(d) Women LL forecast at age 51

(g) Women LC forecast at age 67

(h) Women LL forecast at age 67

Results - Forecasting

- Cross-over between the most and second most affluent groups for women in Denmark (Norway as well).

  - Natural implication of extending the in-sample patterns where the 9th affluence group have experienced larger improvements over the period.

- Most pronounced is the cross overs from the lowest to the middle affluence groups.

  - Problematic as we have no economic, political, or intuitive explanation as to why the lowest socio-economic groups suddenly should start living longer compared to more affluence groups.
  - Expect catch-up effects or convergence in life expectancy across time, but not a cross over.
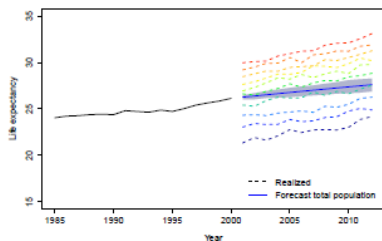
Results - Forecasting

- Cross-over Issue is eliminated with LL model.
  - Clearer ranking obtained.
  - It account for the general population trend in the group-specific forecasts.

- However, we also observe a slight convergence in life expectancy between groups across time.
  - No reasonable explanation for this given the past 30 years observations.
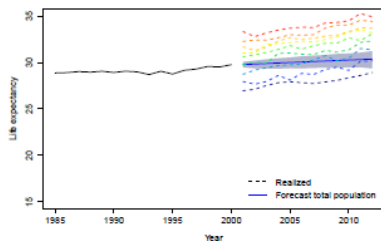
Results - Forecasts Performance

- We now turn our attention to evaluation of the forecast performance.
- Fit the models for the period 1985-2000 and then perform pseudo out-of-sample forecasts from 2001-2012
- For each affluence group, we compare the forecasts with the realized values in the forecasting period by computing mean squared forecast errors (MSFE) of the life expectancy.

Results - Forecasts Performance

- Let us first take a look at the forecasted life expectancy for the total
  population together with the realization for all affluence groups.

(a) Men   (b) Women

Results - Forecasts Performance

- It is clear, that for both men and women, the total population is far from a good predictor of life expectancy for the majority of the affluence groups.
  - Only a couple of the groups stay within the 95% confidence band of the forecast.
  - Catch-up effect for Danish females as only the group 3 stay within the 95% confidence band in 2012.

Results - Forecasts Performance

- Significant lower MSFE for each of the affluence groups compared with the realization of the total population (very high values of the MSFE (black line)).
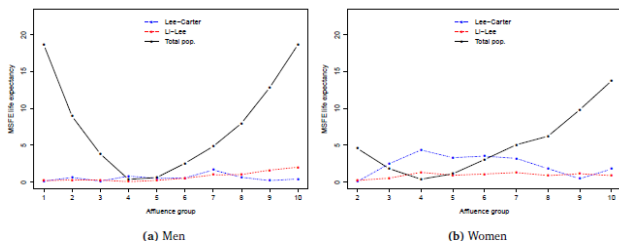

Figure 5.8 – Mean squared forecast errors on life expectancy

- Again, a clear indication of a catch-up effect for Danish women as the lesser affluent groups have much low values of the MSFE for the total population.

Conclusion

- The ability to account for population characteristics through the affluence measure provide insight.
- We find significant differences in life expectancy between socio-economic groups
    - Up to 8 years for 50 year old males and 6 years for 50 year old females.
- The groups 3-5 have been driving the stagnation in life expectancy for Danish women.
    - Catch up effect has occurred.
- The Li-Lee model produces more realistic forecasts than the LC model in the sense that they do not cross.
    - However, an undesirable convergence between the socio-economic groups is observed.

Future Research

- Kallestrup-Lamb (2012) showed that it is single individuals that are driving the slowdown in female life expectancies.
  - Investigate further whether singles are overrepresented in the lower to middle affluence groups.
- Started investigating cause-of-death for the 10 affluent groups.
- Visualize why education might be a poorly choice for adherence to a specific socio-economic group.
- Consider index-based hedges on the total population and evaluate whether hypothetical pension plans, determined by a given affluence group, could achieve a satisfactory degree of hedge effectiveness.

Thank you for your attention!

- Comments and questions are much appreciated.