UiO : University of Oslo

Probabilistic demographic projections

Nico Keilman
Department of Economics
University of Oslo

Joint Eurostat-UNECE Work Session on Demographic Projections
Rome, 29-31 October 2013

25 Years of Meeting History

October 1988: International Workshop on National Population Projections in Industrialized Countries, Voorburg (The Netherlands) – NCBS, USCB, NIDI

September 1989: Conference of European Statisticians Seminar on Demographic Projections, Balatonöszöd (Hungary)

Joint Eurostat-UNECE Work Sessions on Demographic Projections:

-Mondorf-les-Bains (Luxembourg) June 1994

-Perugia (Italy) May 1999

-Vienna September 2005

-Bucharest October 2007

-Lisbon April 2010

-Rome October 2013

Purpose

1988:

- " … to explore the variety of approaches that statistical agencies apply for their demographic forecasts
- to identify research needs for the improvement of demographic forecasts."

2013:

- " … to bring together policy makers, demographic researchers from the National Statistical Institutes as well as from other … organisations, academics, and any other producer or user of demographic projections in order to facilitate the communication between them."

Purpose

1988:

- " … to explore the variety of approaches that statistical agencies apply for their demographic forecasts
- to identify research needs for the improvement of demographic forecasts."

2013:

- " … to bring together policy makers, demographic researchers from the National Statistical Institutes as well as from other … organisations, academics, and any other producer or user of demographic projections in order to facilitate the communication between them."

In addition:

EUROSTAT Working Parties on Demographic Projections in 1991, 1992, 1994, 1997, 2002, 2004, …

Conclusions / recommendations on probabilistic projections

1988: "… much work remains to be done before stochastic cohort component models can be applied in national population forecasting by statistical agencies"

.

.

.

2007: "Demographers should produce projections with a degree of uncertainty, but they have also the responsibility to explain to the users how to understand the projections. At the beginning, this effort may take some time to produce results, but it should be rewarding in the long-term."

Conclusions / recommendations on probabilistic projections

1988: "… much work remains to be done before stochastic cohort component models can be applied in national population forecasting by statistical agencies"

.

.

.

2007: "Demographers should produce projections with a degree of uncertainty, but they have also the responsibility to explain to the users how to understand the projections. At the beginning, this effort may take some time to produce results, but it should be rewarding in the long-term."

Why probabilistic?

The Norwegian parliament has decided to buy 52 new JSF jet fighters type F35.

The price for one F35 is unknown, because the plane is still under construction.

Parliament has demanded a total cost forecast that will be kept with 50% chance. è 61.2 billion NOK (appr. 8 billion €).

In addition, they wanted to have a cost estimate that will be kept with 85% chance. è 72 billion NOK.

To request a probabilistic cost forecast with 50% and 85% estimates is established praxis for large (>500 million NOK) public projects in Norway

Planners need probabilistic forecasts

Deterministic projections leave room for political decisions

Example (Washington Post 25 September 2013)
http://www.washingtonpost.com/blogs/wonkblog/wp/2013/09/25/here-is-every-previous-government-shutdown-why-they-happened-and-how-they-ended/?tid=sm_fb shutdown # 17

Probabilistic demographic forecasts

Traditional deterministic population forecasting:

Cohort-component model $K_{t+1} = P_t K_t$ used recursively

- K_t vector of population broken down by age and sex
- P_t matrix of transition probabilities that account for fertility, mortality and emigration (immigration added as a vector)

Developed in 1895 by British economist Edward Cannan.

Generally accepted by statistical agencies of many countries (through ISI) in the 1930s.

Extended in the 1970s to include a regional breakdown as well (multiregional model) or an extra dimension in general (multistate/ multidimensional models).

Forecasts obtained by extrapolating matrix P_t into the future, combined with jump-off population K_0.

Probabilistic forecasts since the 1980s; Törnquist (1949) probably the first one who integrated probabilistic thinking in population forecasting.

Elements of matrix P_t are random variables

Examples

Official probabilistic population forecasts for the Netherlands (since 1999) and for New Zealand
http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP2011.aspx

A few other countries experimenting: Norway, UK, Italy, more?

Also UN World Population Prospects
http://esa.un.org/unpd/ppp/index.htm and
http://www.pnas.org/content/109/35/13915.full.pdf
based on Bayesian methods

Main approach probabilistic population forecasts

Cohort component model

Probability distributions specified for model inputs / model parameters

Issues: autocorrelations (fertility, mortality, migration), correlations across age (age specific rates for fertility, mortality, migration) and across sex (mortality and migration).

Independence assumed between fertility, mortality and migration.

Jump-off population K_0 from a census/register without error.

The computer program samples repeatedly from the uncertainty distributions for those inputs

Result: simulated probability distributions of outcomes

«Changing Population of Europe: Uncertain Future» - UPE

Aim: Probabilistic population forecasts (age & sex) for 18 European countries (EU15 + Norway, Iceland, Switzerland)

2003-2050

Repeated simulations of the cohort component model with stochastically varying input parameters

Normal distributions for input parameters (in the log scale)

Alho's Scaled Model for Error:

- Expected values for fertility, mortality, migration as in deterministic forecasts
- (Co-)variances and (auto-)correlations from

- time series analyses
- errors in historical forecasts
- expert judgements

Volatility in UPE-forecast results similar as historical volatility

See http://www.stat.fi/tup/euupe/index_en.html

Update UPE's UK forecast

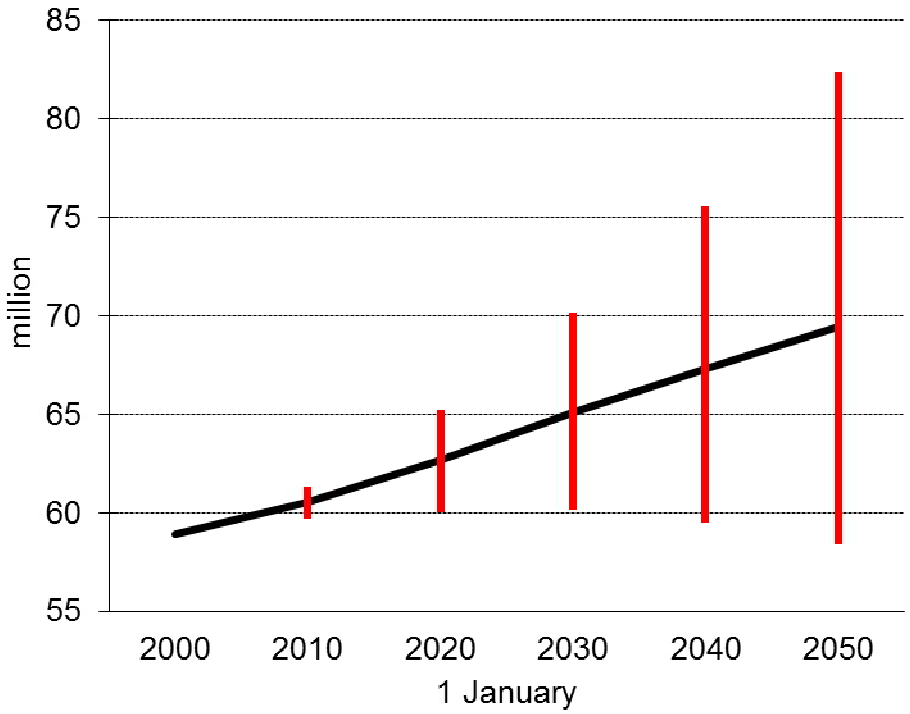
Jump-off population as of 1 Jan 2010 (Census 2011 revised, except for Scotland)

Point predictions for parameters of fertility, mortality, net immigration from ONS 2010 principal projection

Uncertainty parameters unchanged

UK Total population; UPE 2003

black: median values; red: 80% prediction intervals

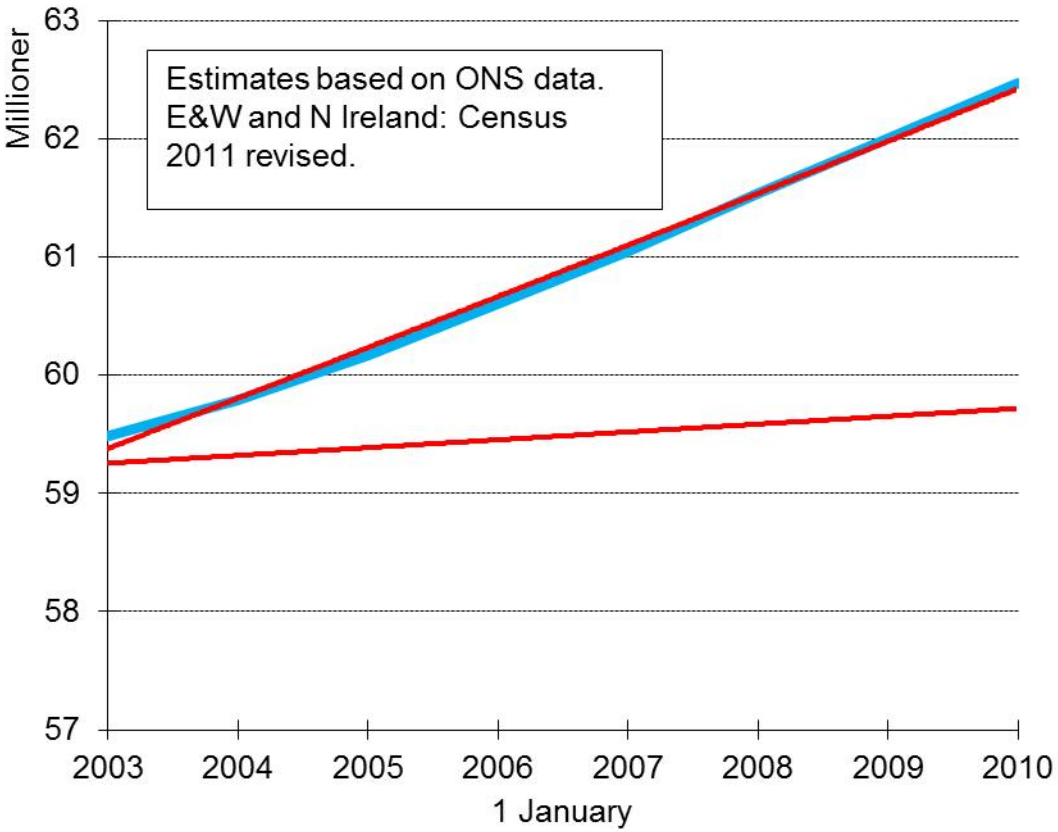


UK total population; UPE 2003

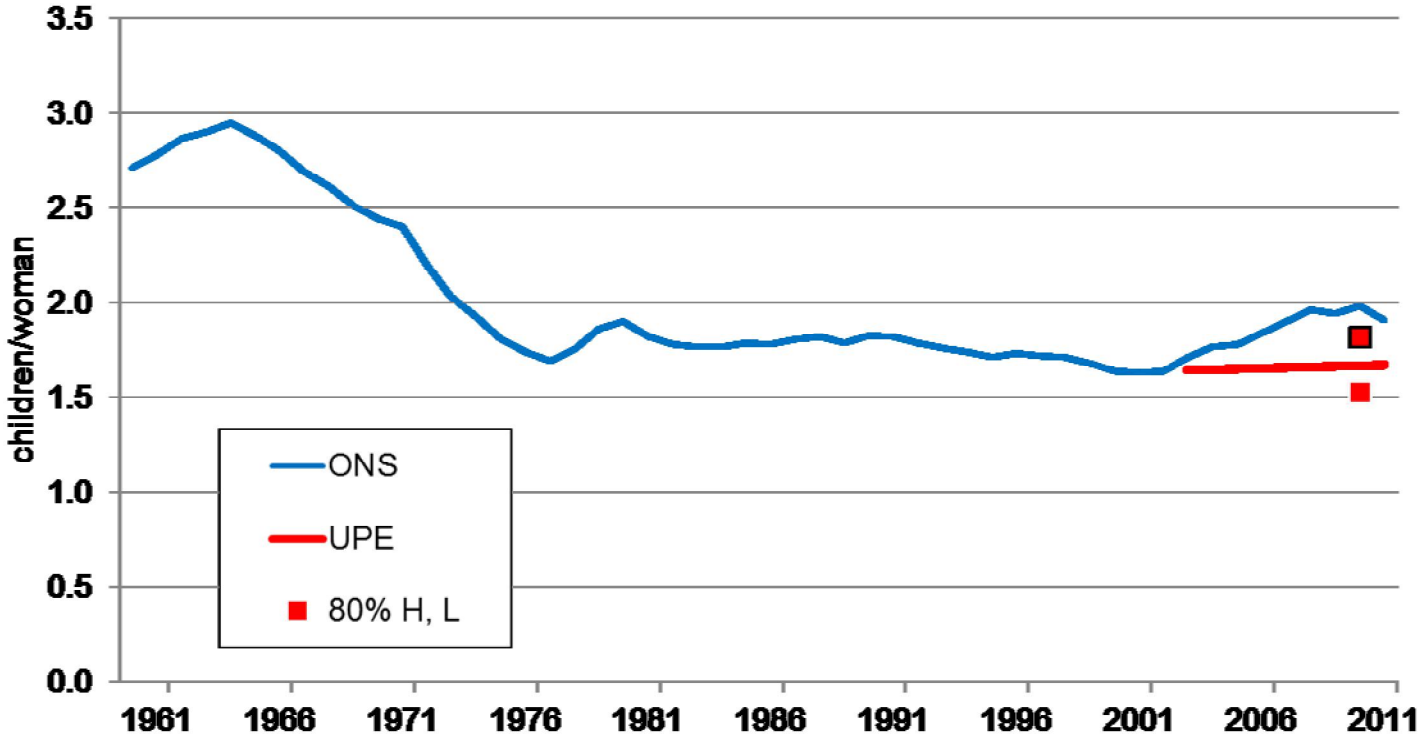
blue: estimates; red: UPE 80% prediction intervals

UPE jump-off population too low by 283,000 persons.

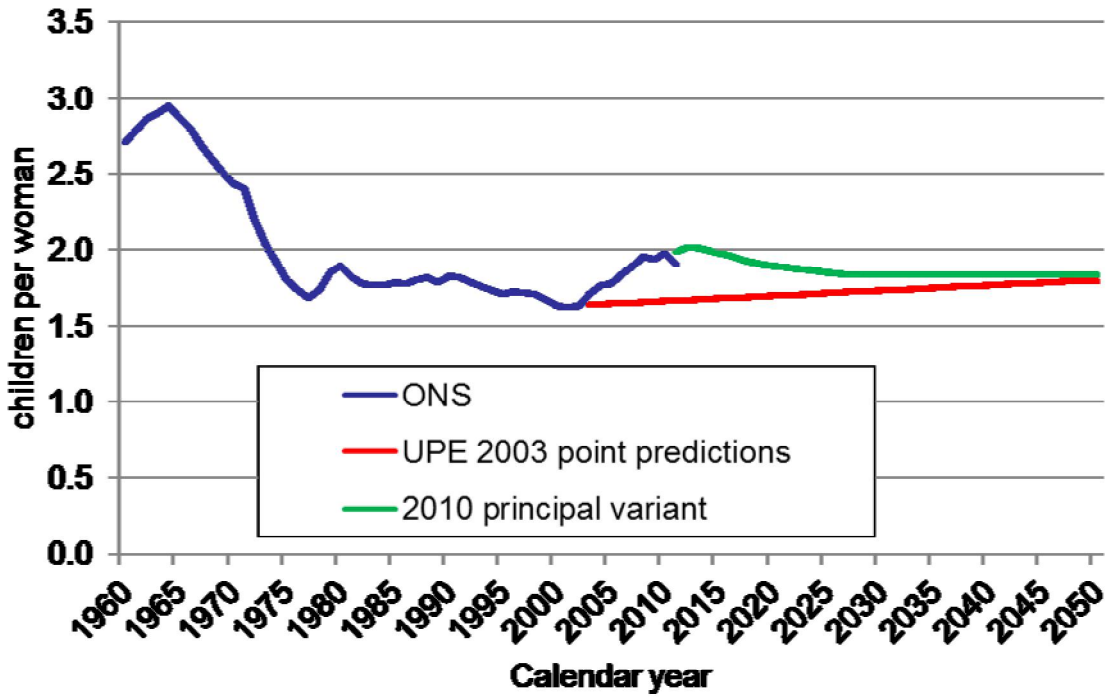
UPE in 2010 too low even with correct jump-off population.



Total fertility, UK; UPE 2003

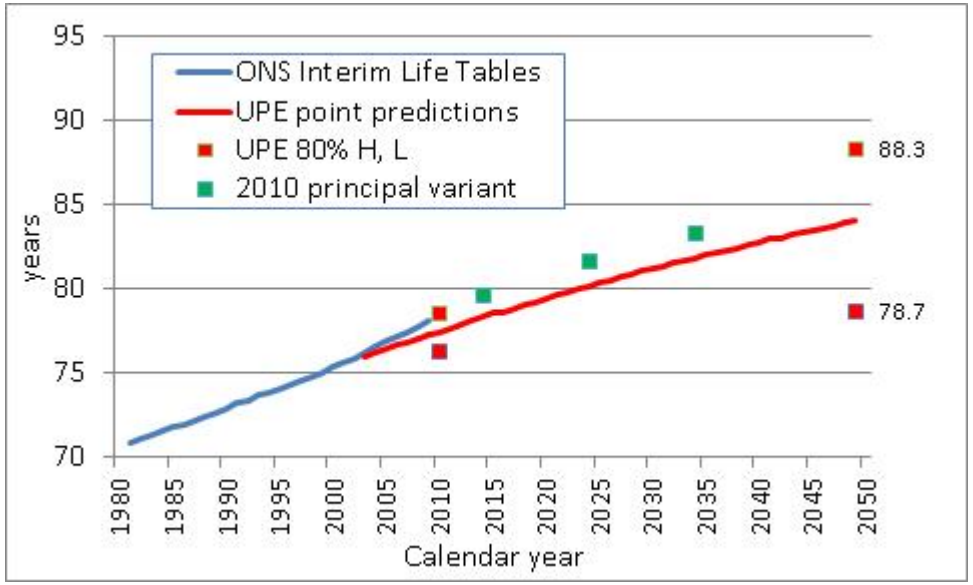


Total fertility, UK; UPE 2003 and ONS 2010 forecast

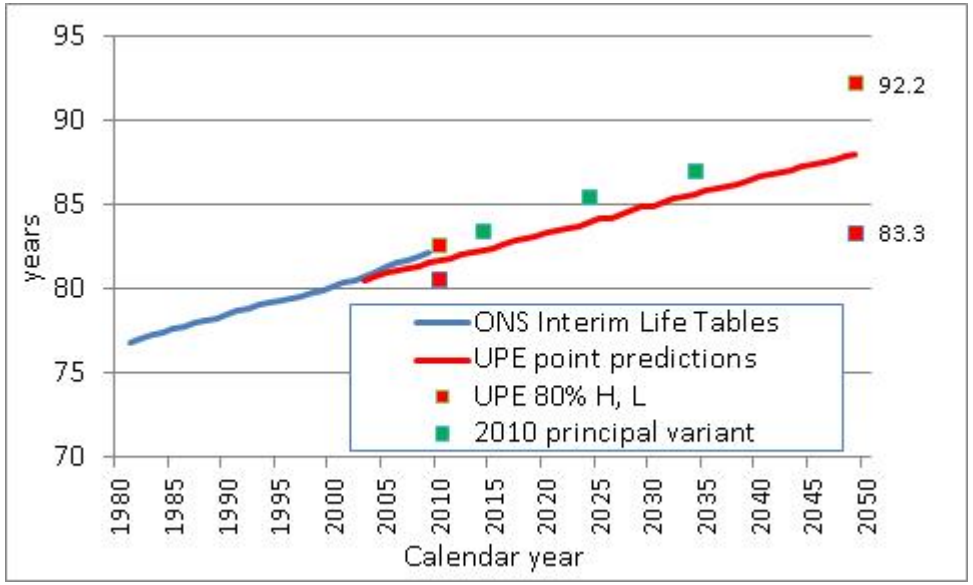


80% prediction interval in 2050: [1.16 2.80] children per woman

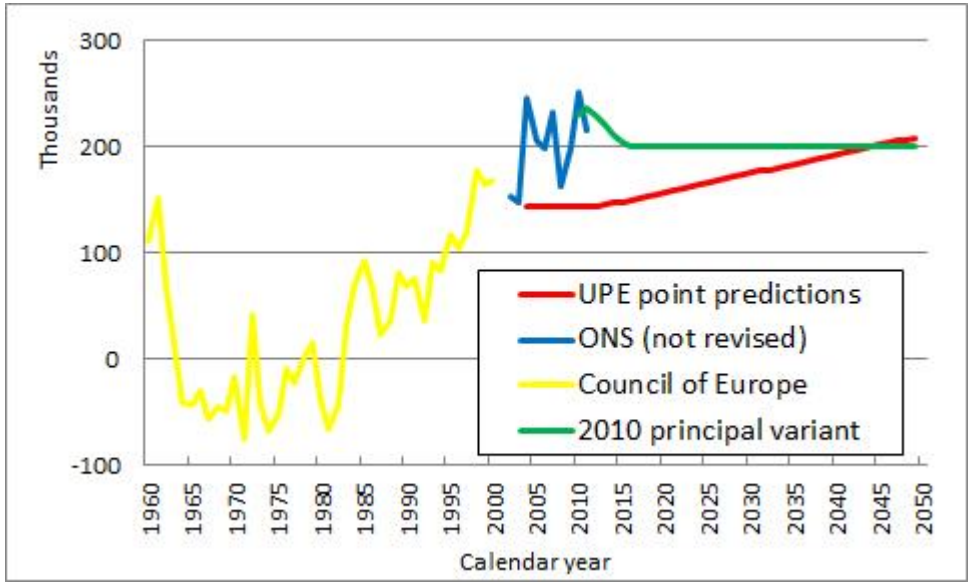
Life expectancy of men, UK; UPE 2003 and ONS 2010 forecast



Life expectancy of women, UK; UPE 2003 and ONS 2010 forecast



Net international migration to the UK; UPE 2003 and ONS 2010 forecast



80% prediction interval in 2050: [-60,000 480,000]

Elderly shares & OADR 2010 (1 Jan.); UPE 2003

	UPE 80% interval (UK)	ONS estimates (E&W)
Proportion 65+ (%)	[16.2 , 16.8]	16.3
Proportion 85+ (%)	[2.0 , 2.3]	2.2
OADR (POP65+/POP20-64)	[0.269 , 0.282]	0.273

Population size grossly underpredicted

- Immigration grossly underpredicted
- Fertility considerably underpredicted

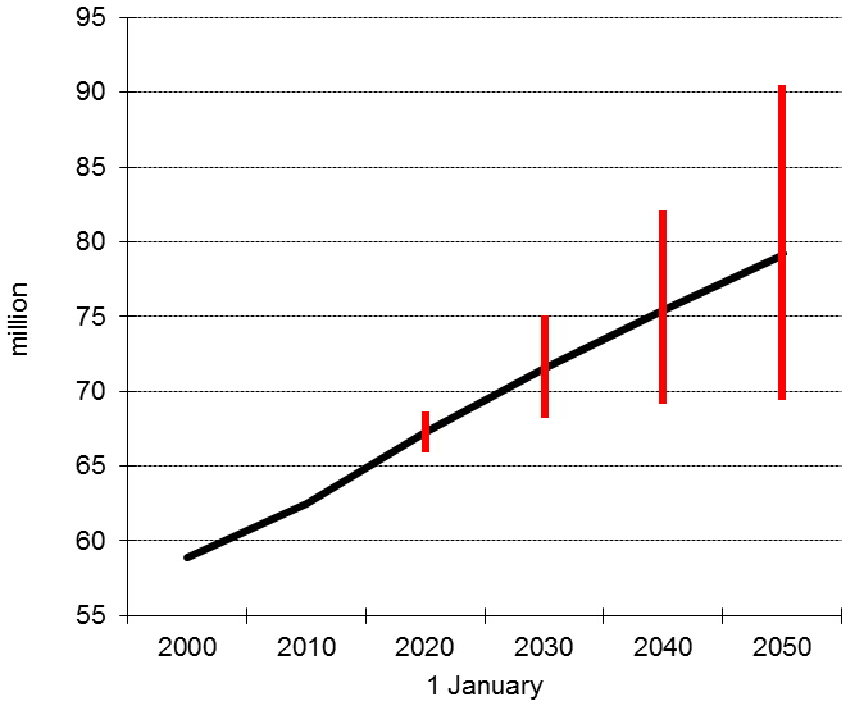
Life expectancy at birth a bit low

Ageing indicators about right

No indications that prediction intervals are too wide or too narrow

UK Total population; UPE update

black: median values; red: 80% prediction intervals



UK Total population 1 Jan 2050 (millions)

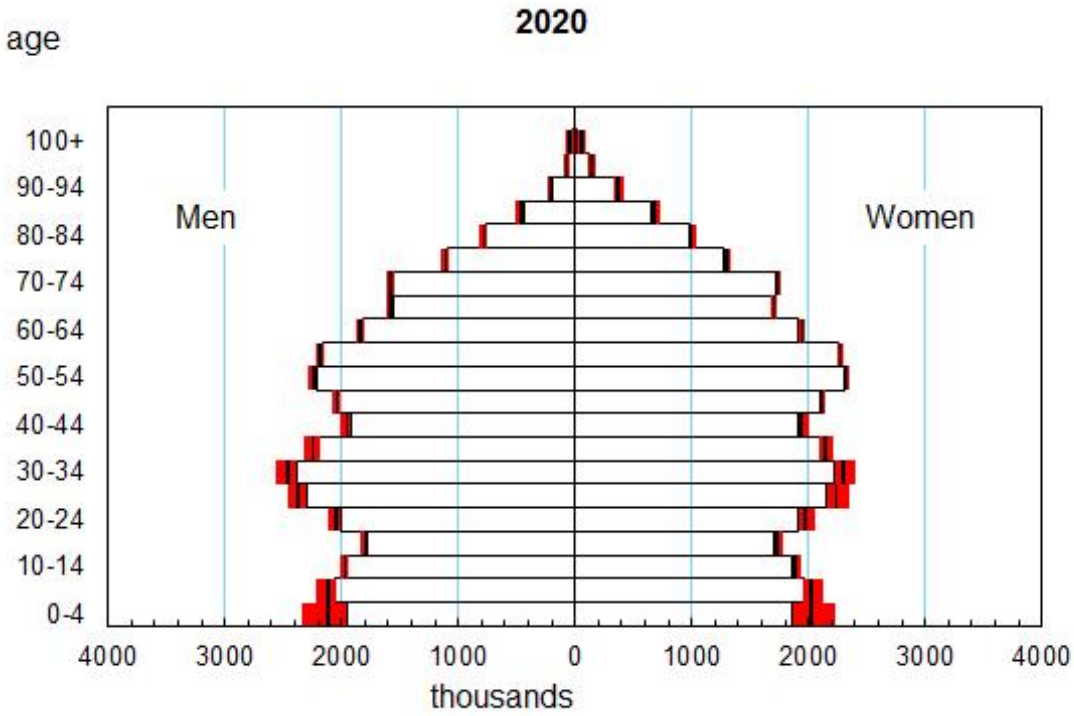
	median	80 % prediction interval	Relative width of PI (% of median value)
UPE update	79.1	[69.4 , 90.5]	27
ONS 2010 (principal, high pop, low pop)	78.2	[68.7 , 87.4]	24
UPE 2003	69.4	[58.4 , 82.4]	35

UK Total population 1 Jan 2020 (millions)

	median	80 % prediction interval	Relative width of PI (% of median value)
UPE updated	67.2	[65.9 , 68.6]	4%
ONS 2010 (principal, high pop, low pop)	66.9	[65.3 , 68.2]	4%
UPE 2003	62.7	[60.0 , 65.2]	8%

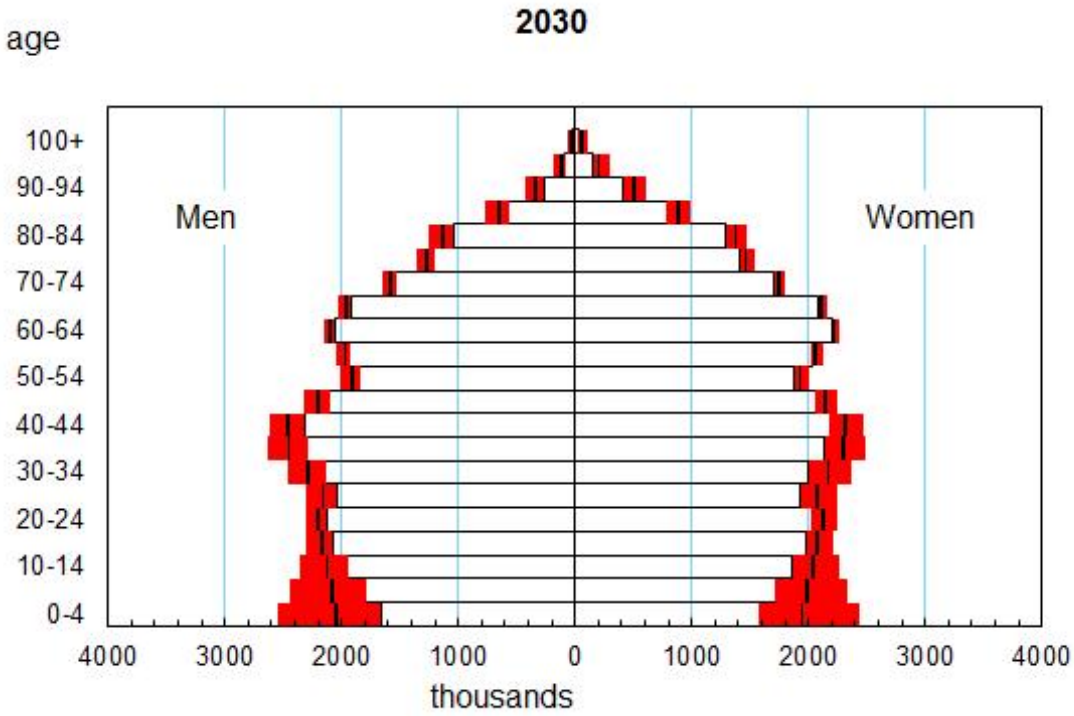
UK Population pyramid 2020

black: median values; red: 80% prediction intervals



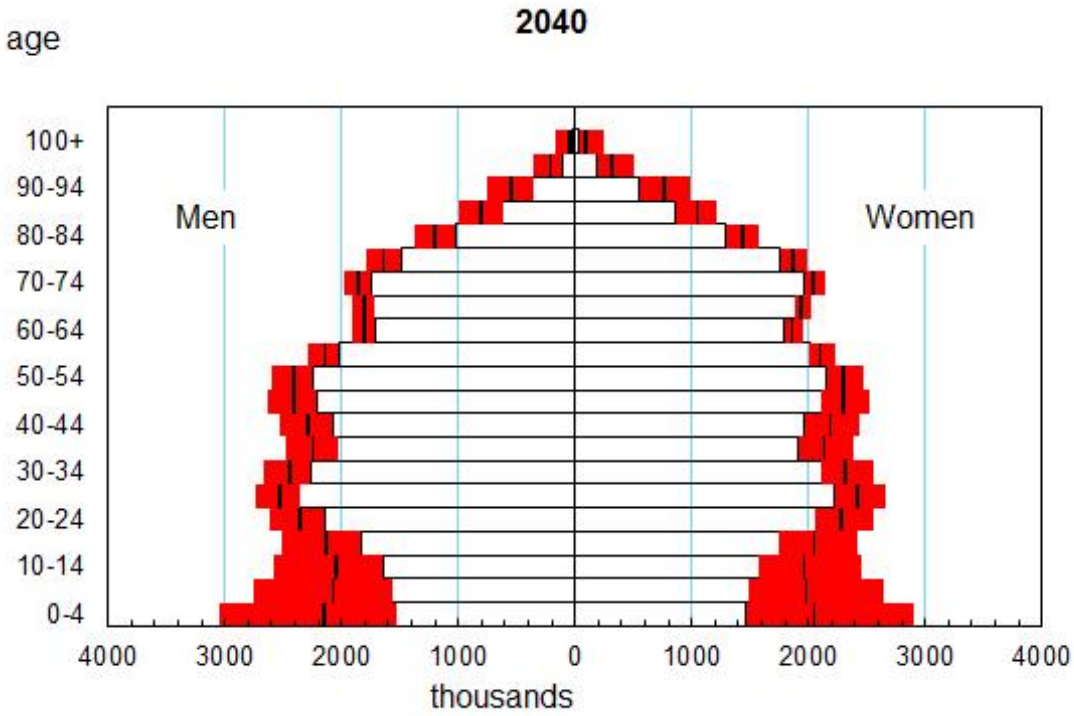
UK Population pyramid 2030

black: median values; red: 80% prediction intervals



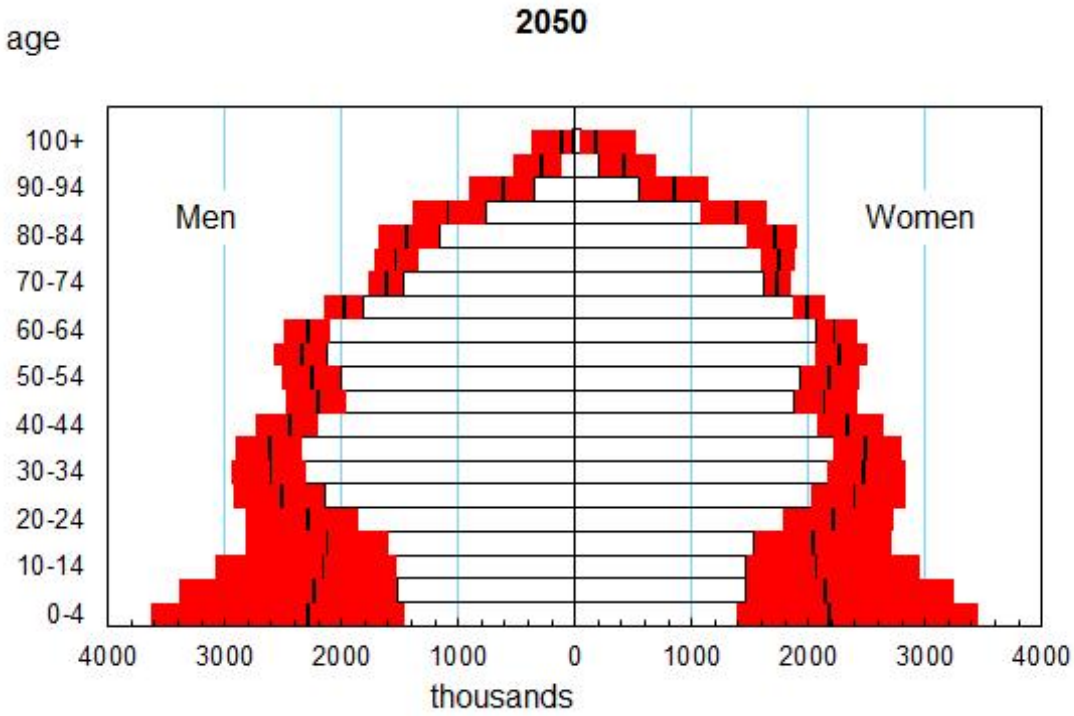
UK Population pyramid 2040

black: median values; red: 80% prediction intervals

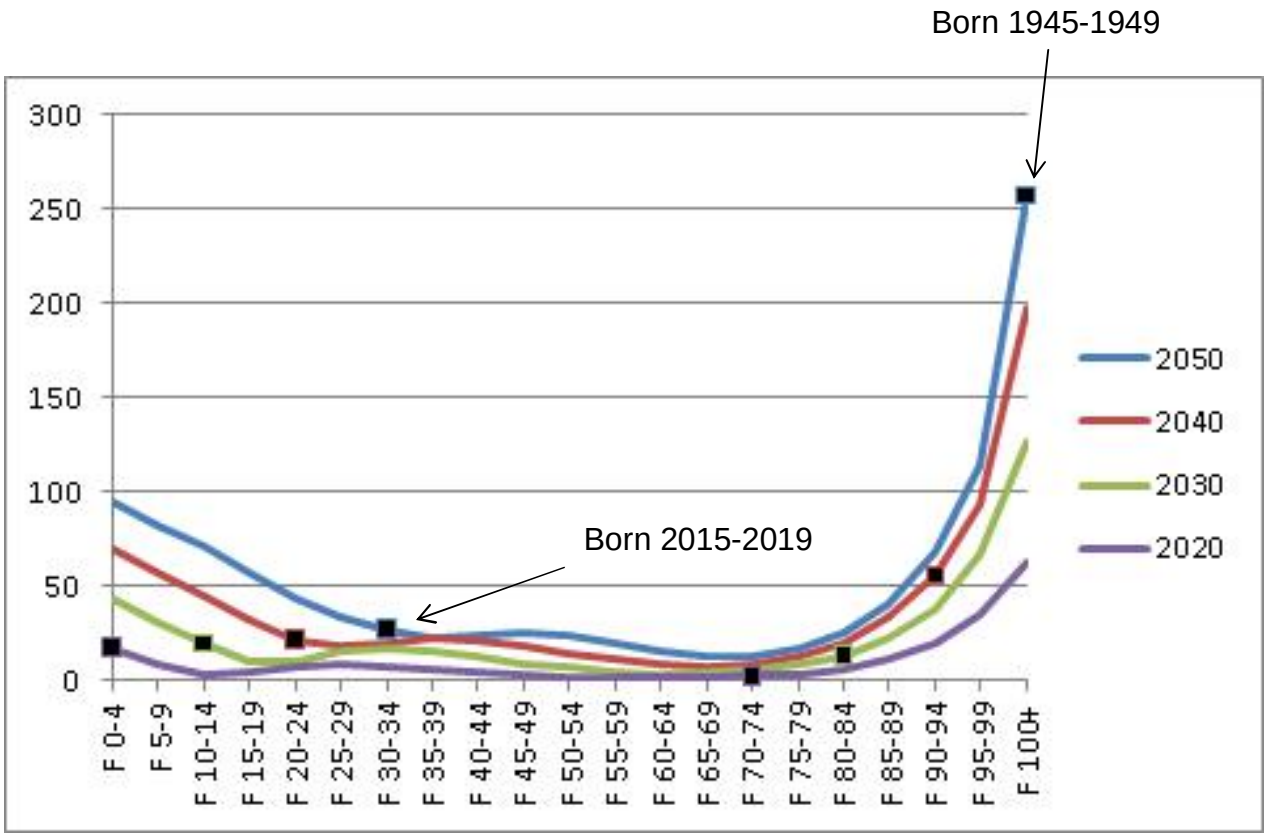


UK Population pyramid 2050

black: median values; red: 80% prediction intervals



Relative width of 80% prediction intervals (width PI/median), women, five year age groups (%)



Ageing is certain (absolute and relative numbers elderly)

But we do not know how fast

Probabilistic *multistate* forecasts

Problem:

hard to obtain empirical estimates for relevant covariances.

N regions (“states”) à covariance between migration flows of the order N^4

in addition 100 ages, 2 sexes, 50 years ahead or more.

Techniques of dimension reduction

Example 1: probabilistic household forecasts by random shares

Applied to Norway, Finland and Denmark

Combine a probabilistic cohort-component forecast for the population broken down by age and sex,

with a model for random shares

The random shares model assigns the population randomly in any future year to different household positions (by age and sex)

Point predictions for shares from deterministic multistate household forecast (LIPRO)

Variances and covariances for shares from multivariate time series model

Alho & Keilman “On future household structure” Journal of the Royal Statistical Society Series A 173(1)2010, 117-143

Christiansen & Keilman “Probabilistic household forecasts based on register data - the case of Denmark and Finland” Demographic Research 28, 1263-1302

Table 3: Average value, coefficient of variation, and lower and upper bounds of 80% prediction intervals, for the number of private households, by household type. Denmark

	Married couple	One-person household	Cohabiting Couple	Lone parent household	Other private household	All private households
2007						
Observed	990299	944405	283197	168944	91148	2477992
2017						
Average	968171	1036930	302350	181323	86936	2575710
CV (%)	3.3	4.9	8.9	21.3	12.5	1.8
80% low	926441	972475	268641	135234	72368	2517057
80% high	1009953	1103045	336773	234197	100781	2637122
2027						
Average	962468	1167539	321254	177936	90419	2719616
CV (%)	7.2	9.7	17.7	29.5	19.9	3.5
80% low	873445	1025302	251565	115541	68362	2602674
80% high	1051393	1314627	397698	249010	114750	2839892
2037						
Average	957762	1244238	324567	179700	90555	2796823
CV (%)	7.8	17.8	17.8	29.1	20.2	4.8
80% low	862518	1084466	254229	117327	68352	2626514
80% high	1052869	1413500	402241	250377	114791	2968712

Example 2: probabilistic immigrants forecasts by random shares

Applied to Norway

- Combine a probabilistic cohort-component forecast with a model for random shares

- The random shares model assigns the population randomly in any future year to different immigrant groups (by age and sex)

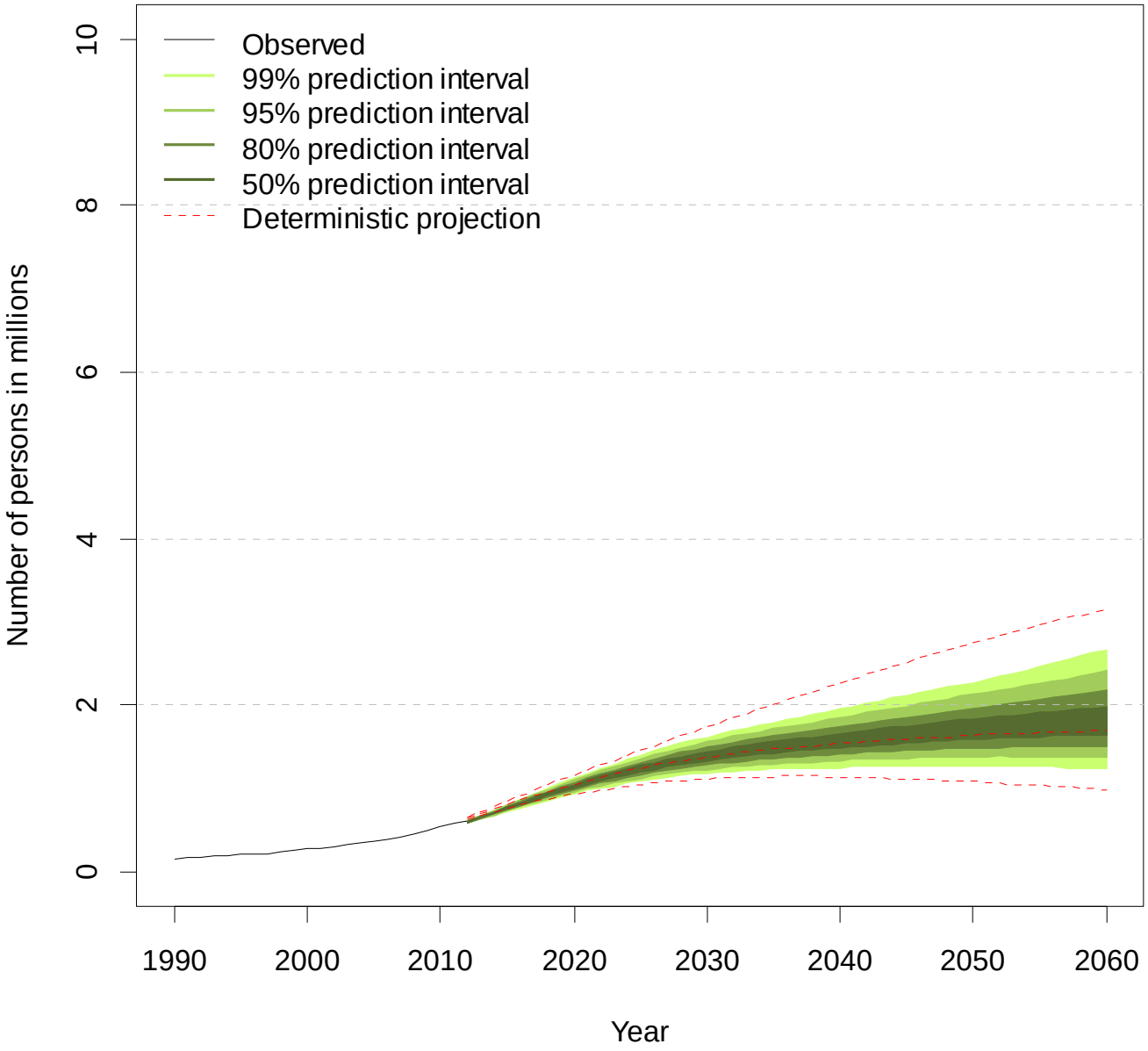
- Point predictions for shares from deterministic official forecast

- Variances and covariances for shares from multivariate time series model

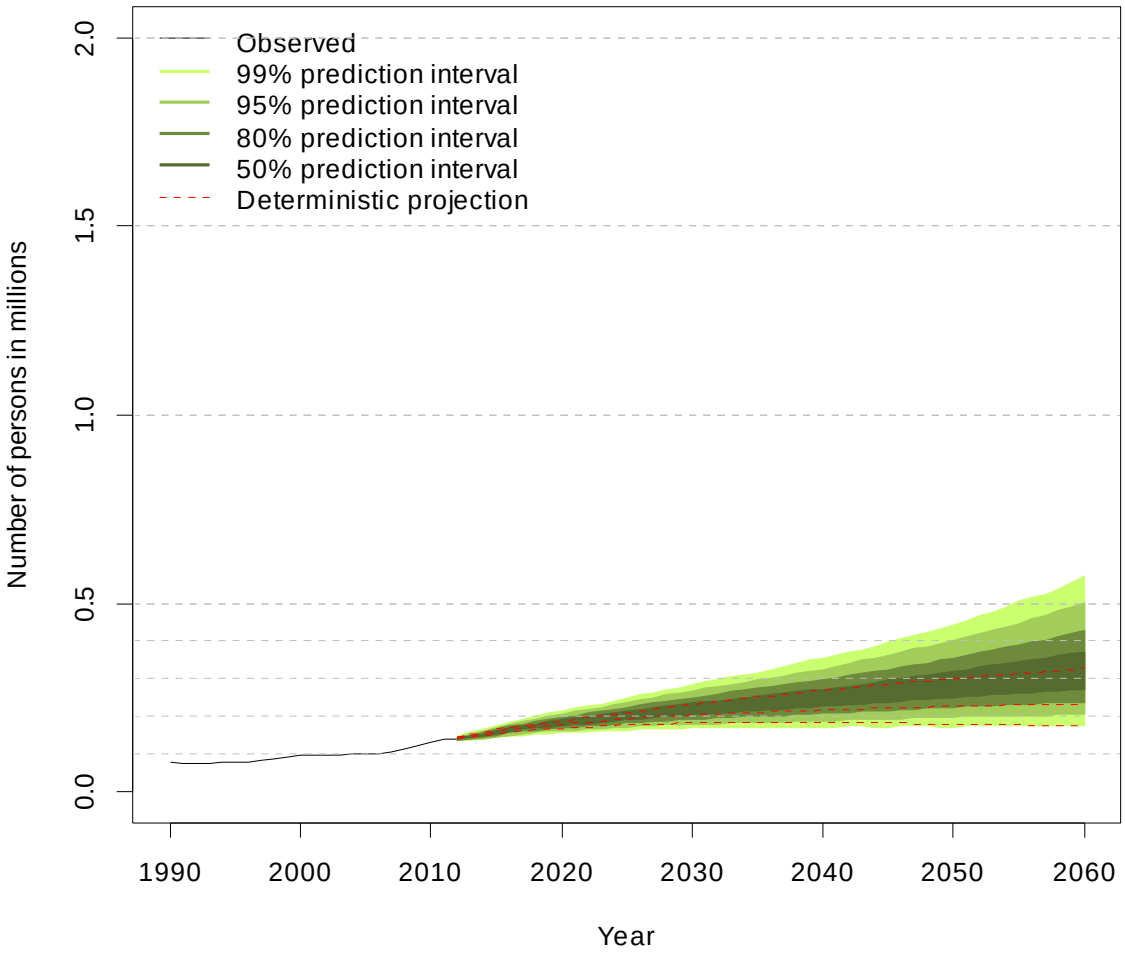
Foss «Stochastic forecast of immigrant population» paper Nordic Demographic Symposium Tønsberg (Norway) September 2012.

UiO : University of Oslo

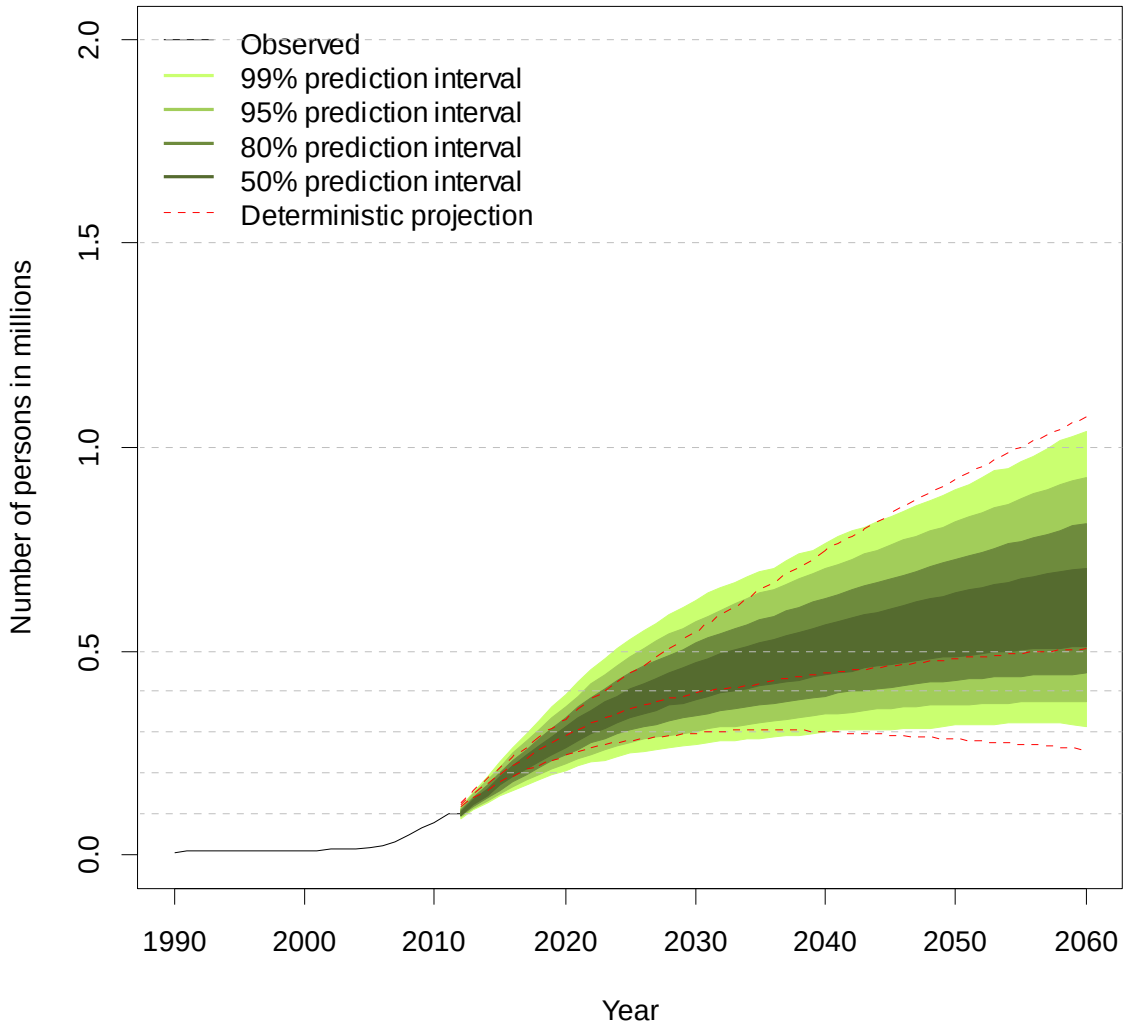
Stochastic Immigrant forecast, Norway



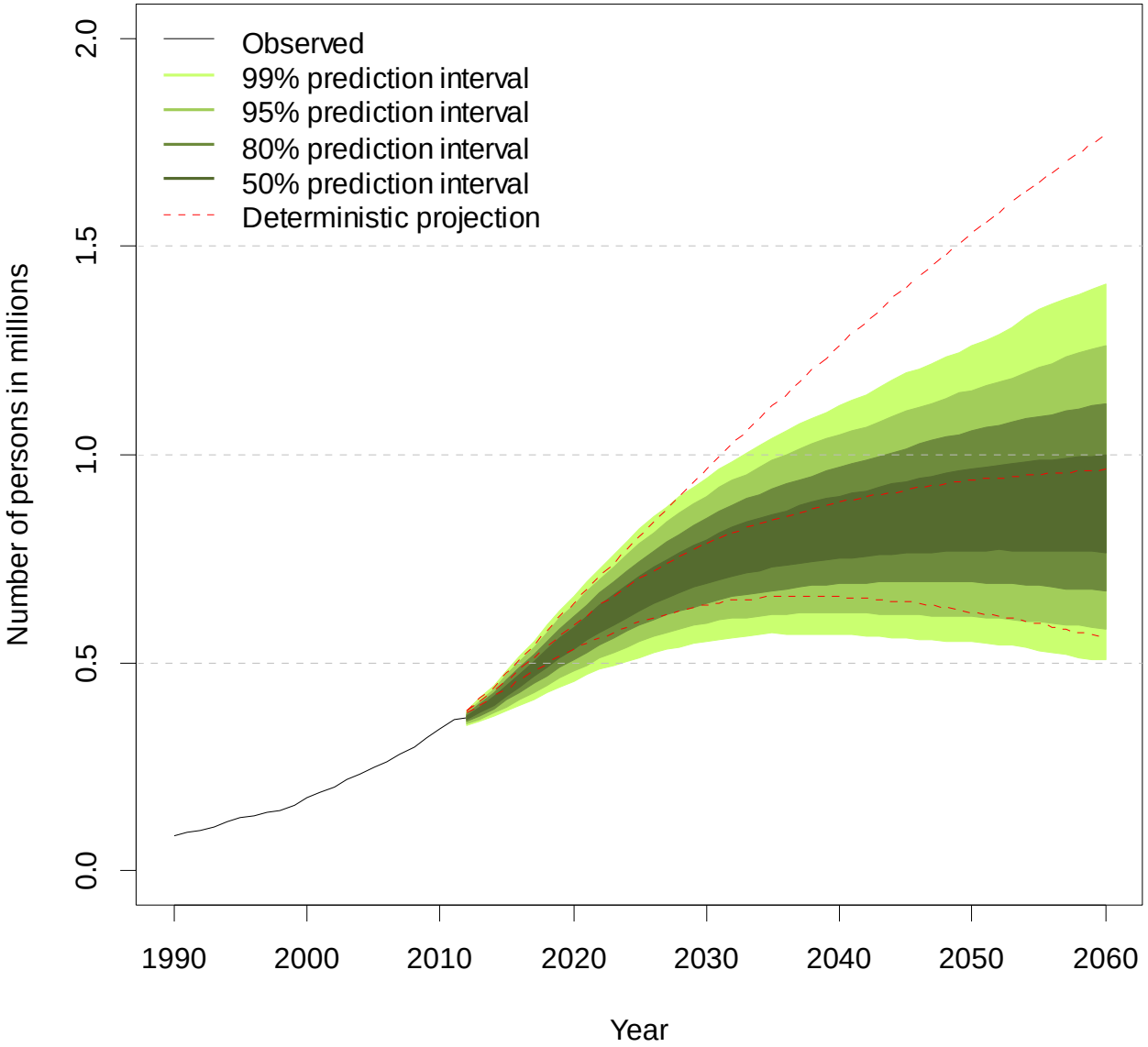
Immigrants from EU/EEA/EFTA countries in Western Europe and from USA, Canada, Australia and New Zealand



Immigrants from EU countries in Eastern Europe



Immigrants from the rest of the world, i.e. rest of Europe, Asia, Africa, Latin America and Oceania except Australia and New Zealand

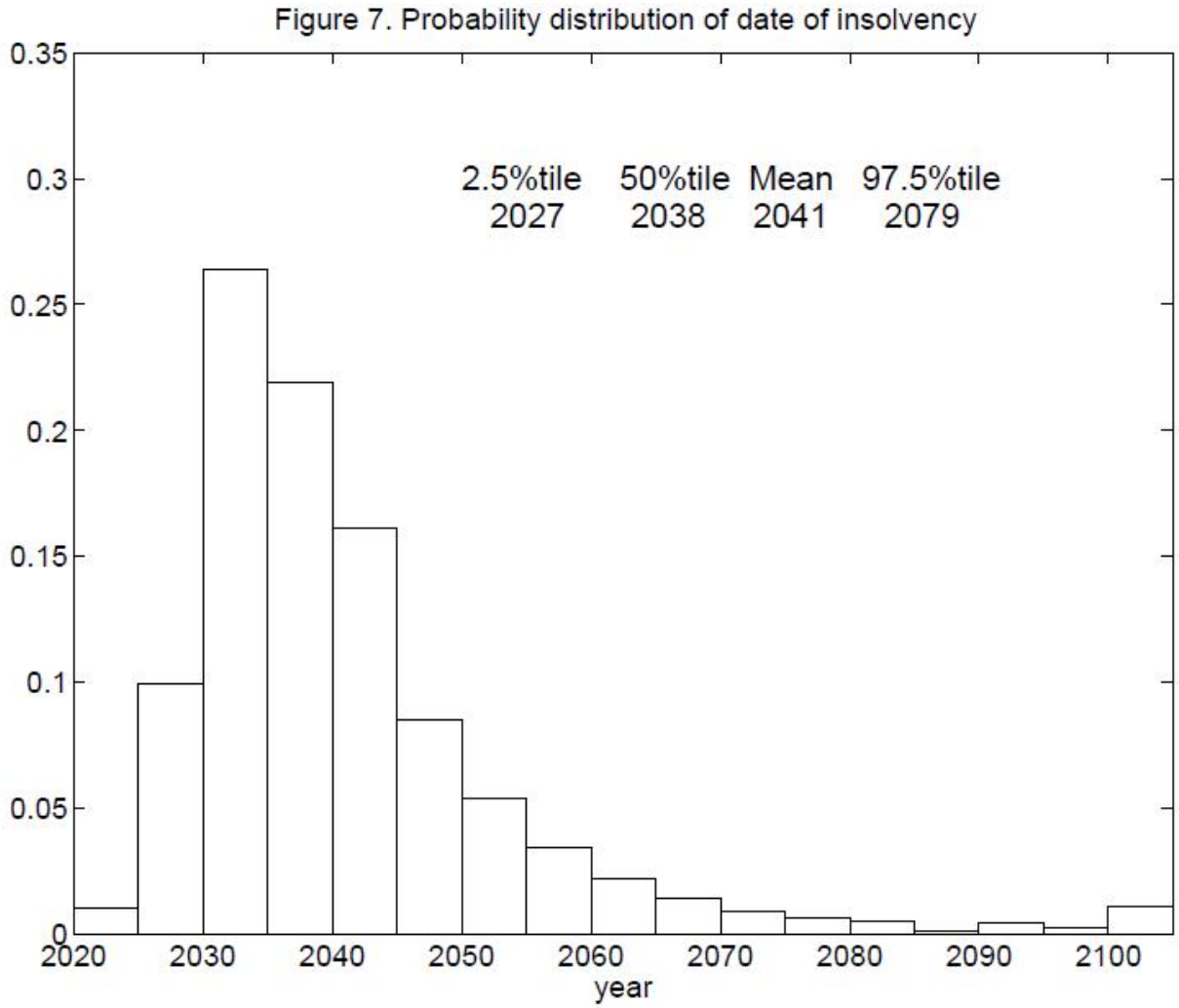


Derived forecasts - examples

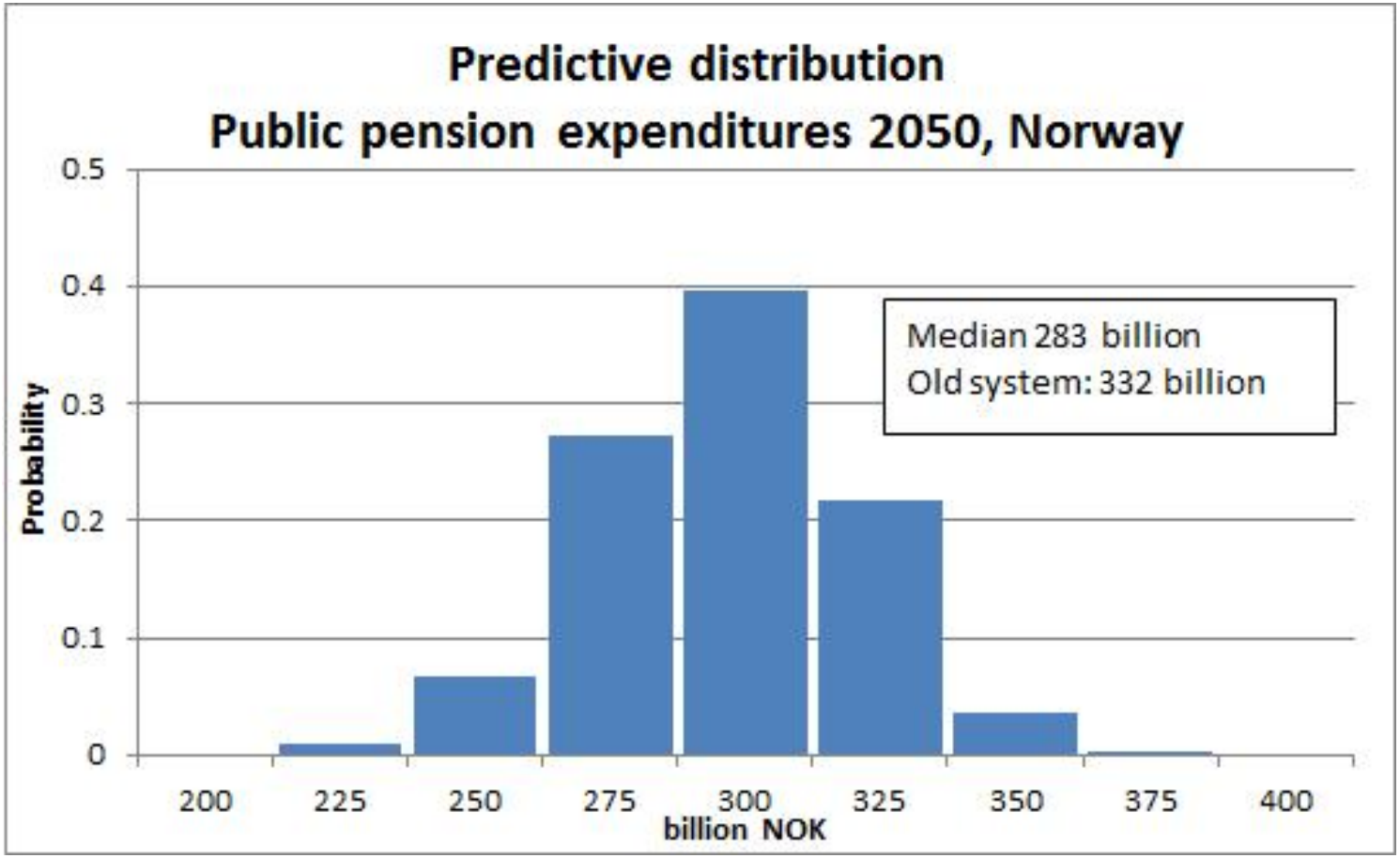
Government budgets (Lee, Tuljapurkar & Miller “Uncertain Demographic Futures and Government Budgets in the US” 2003; Tuljapurkar “Population Forecasts, Fiscal Policy, and Risk” 2006; Alho, Lassila & Hougaard Jensen «Uncertain Demographics and Fiscal Sustainability”. Cambridge University Press 2008)

Pension expenditures (Lee & Tulja; Keilman & Keller)

Environmental migration – Bayesian approach Abel, Bijak, Findlay, McCollum , Wisniowski “Forecasting environmental migration to the United Kingdom: An exploration using Bayesian models” Population and Environment 2013.



"Stochastic Forecasts of the Social Security Trust Fund" Lee, Anderson, Tuljapurkar 2003



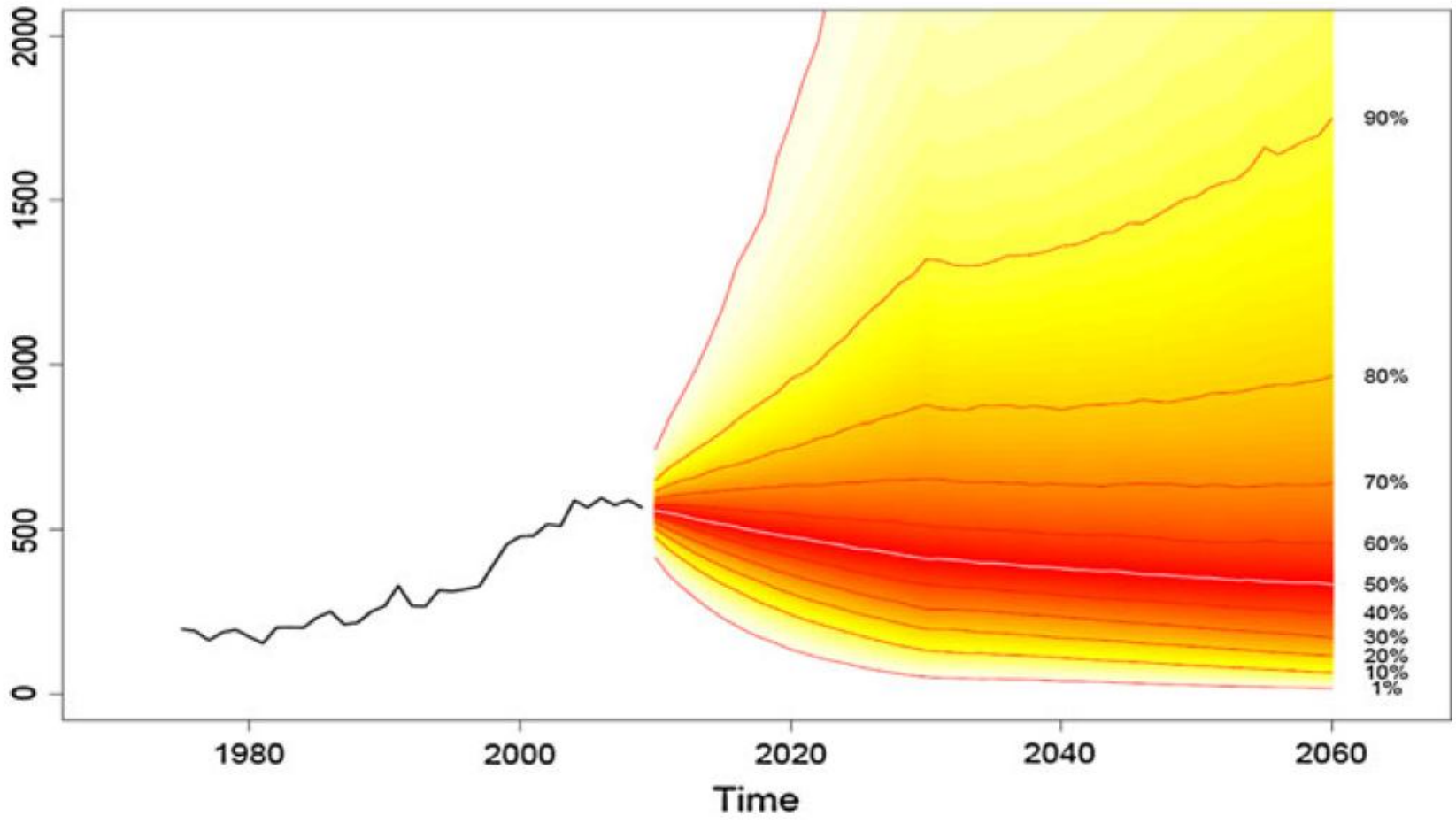


Fig. 2 Forecasts of total immigration to the United Kingdom, averaged univariate models (in thousands). *White line* on the forecast fan denotes the median forecast of total immigration to the United Kingdom. *Source* data—ONS; Forecasts—own elaboration in OpenBUGS/R

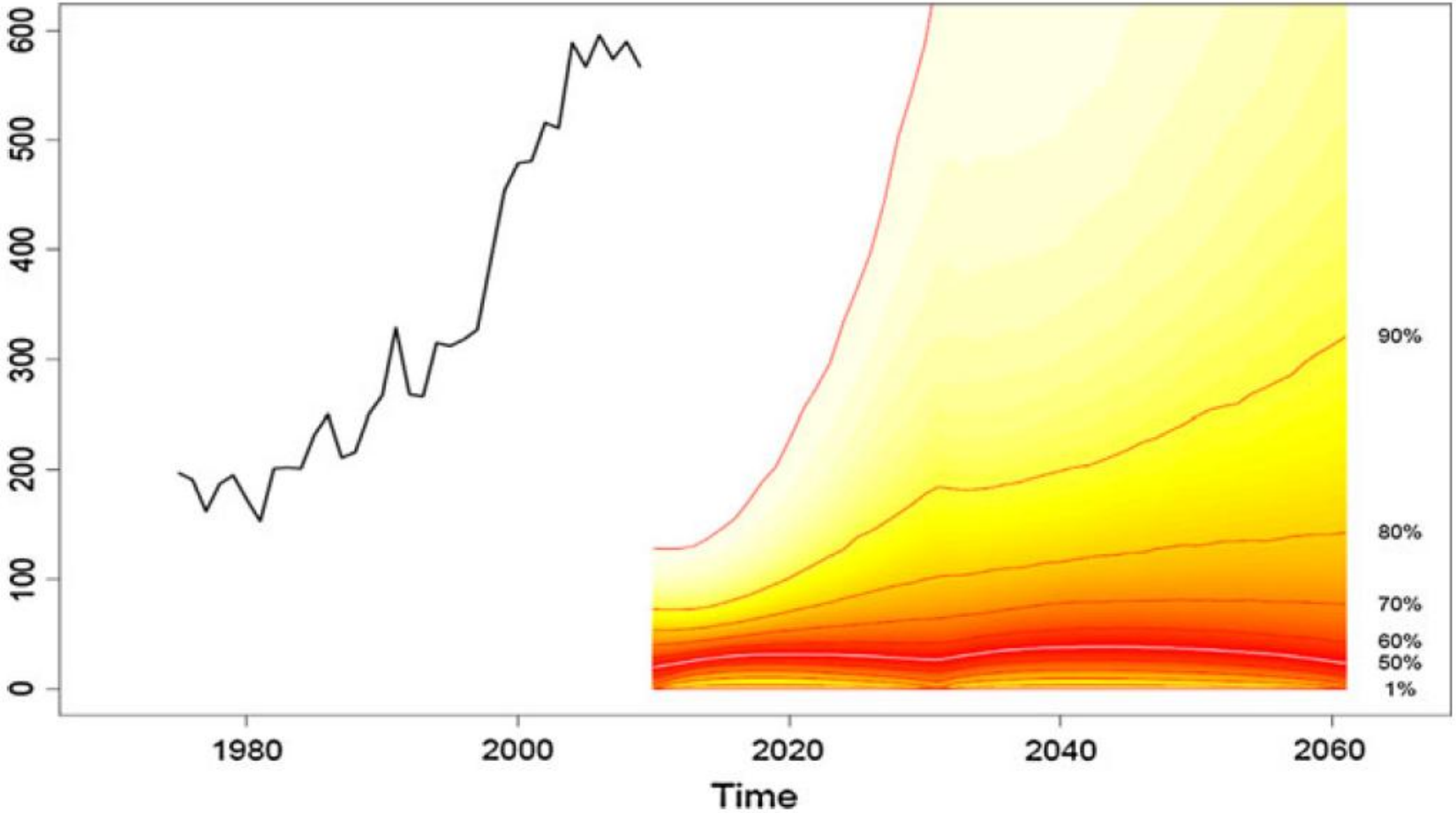


Fig. 3 Forecasts of environmental immigration to the United Kingdom, averaged models (in thousands). *Black line* denotes historical total immigration—the same series as in Fig. 2 (rescaled). *White line* on the forecast fan denotes the median prediction of environmental immigration to the United Kingdom. *Source* data—ONS; Forecasts—own elaboration in OpenBUGS/R

John Wilmoth, director of UN Population Division

"…I expect that demographers will continue to be surprised by trends that do not follow our prior expectations. It is for this reason that the Population Division has worked hard in recent years to be more explicit and precise about the degree of uncertainty affecting projections of future population trends."

http://www.un.org/en/development/desa/news/population/population-division-director.html

« … the Dutch in old Amsterdam, do it,

the Lithuanians and Lets, do it …»

[Ella Fitzgerald, Let's do it]

http://www.youtube.com/watch?v=2RPerSEvP4Y

Probabilistic forecasting

- Weather forecasters do it
- Inflation forecasters do it
- Climate change forecasters do it

Let’s do it!

We have the necessary experience, data, and computer programs

The users will benefit from it