Actuarial projections for mesothelioma: an epidemiological perspective

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Who are we?

- I am an epidemiologist/biostatistician from the Australian National University (ANU)
- Geoffrey is an epidemiologist/biostatistician from the University of Sydney
- Jill is a trainee actuary from Mercer HR Consulting (actuarial honours from ANU)

Outline

- Background
- Theoretical model
- Model comparisons
- Discussion

Background

- Compensation for asbestos-related diseases continues to be an important issue for government and industry (Huszczo et al 2004)
- Focus on mesothelioma:
  - Cancer of the pleura and the peritoneum caused by asbestos exposure
  - Very important marker of exposure

Background: Challenges

- Poor measures of asbestos exposure
- Complexity in the epidemiological relationship between asbestos exposure and disease onset
- Uncertainty in the propensity to claim
- Uncertainty in future costs

Background: Aim

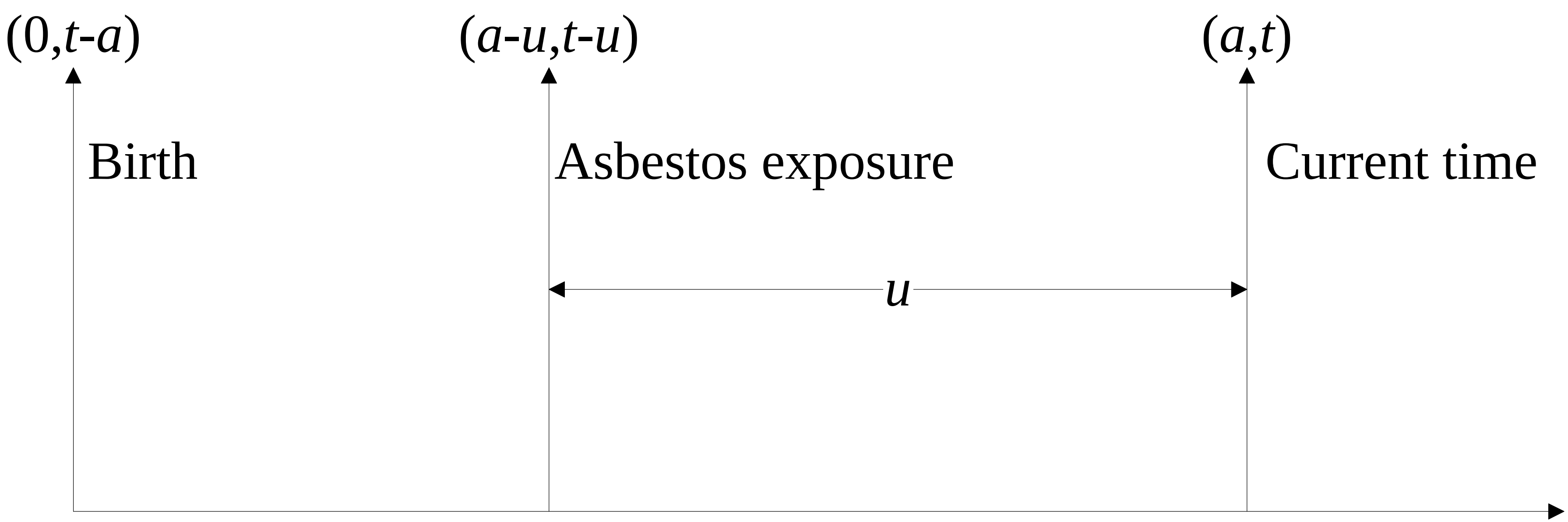
- Prediction of population-level mesothelioma incidence
  - Applicable to portfolios that follow population-wide asbestos exposure
  - We are not:
    - Predicting claims
    - Predicting costs

Too challenging?!

Background: Mesothelioma epidemiology

1. Incidence proportional to linear dose of asbestos exposure
2. Incidence depends on time from exposure
3. Incidence rises by a power of time from exposure
4. Evidence for asbestos clearance from the lungs
5. Several years between initial malignancy and diagnosis
6. Survival is poor and death is rapid.

Theoretical model: Notation for time, where (a,t) = (age, calendar year)



u: time since asbestos exposure

Theoretical model: Individuals

- For an individual i exposed to asbestos at time t-u, the rate function is:

$$rate_i(a,t,u) = dose_i(a-u,t-u)g(u)$$

where

$$g(u) = \beta(u-\tau)^k e^{-\lambda(u-\tau)}$$

for constant β, lag τ, power k and lung clearance rate λ (Armitage-Doll model with clearance).

Theoretical model: Populations

- The population rate is modelled by integrating (summing) across dose and times u since exposure:

$$rate(a,t) = \int_0^a \overline{dose}(a-u, t-u) g(u) du$$

Theoretical model: Simplification

- Hodgson et al (2005):
  - Dose is proportional to an age effect $W()$ and a period effect $D()$
- That is (Equation 1):

$$rate(a,t) = \int_0^a W(a-u)D(t-u)g(u)du$$

Theoretical model: Cases

- The total numbers of cases for a year is:

$$cases(t) = \int_0^\infty rate(a,t) \times Pop(a,t)\, da$$

- The number of cases is Poisson-distributed

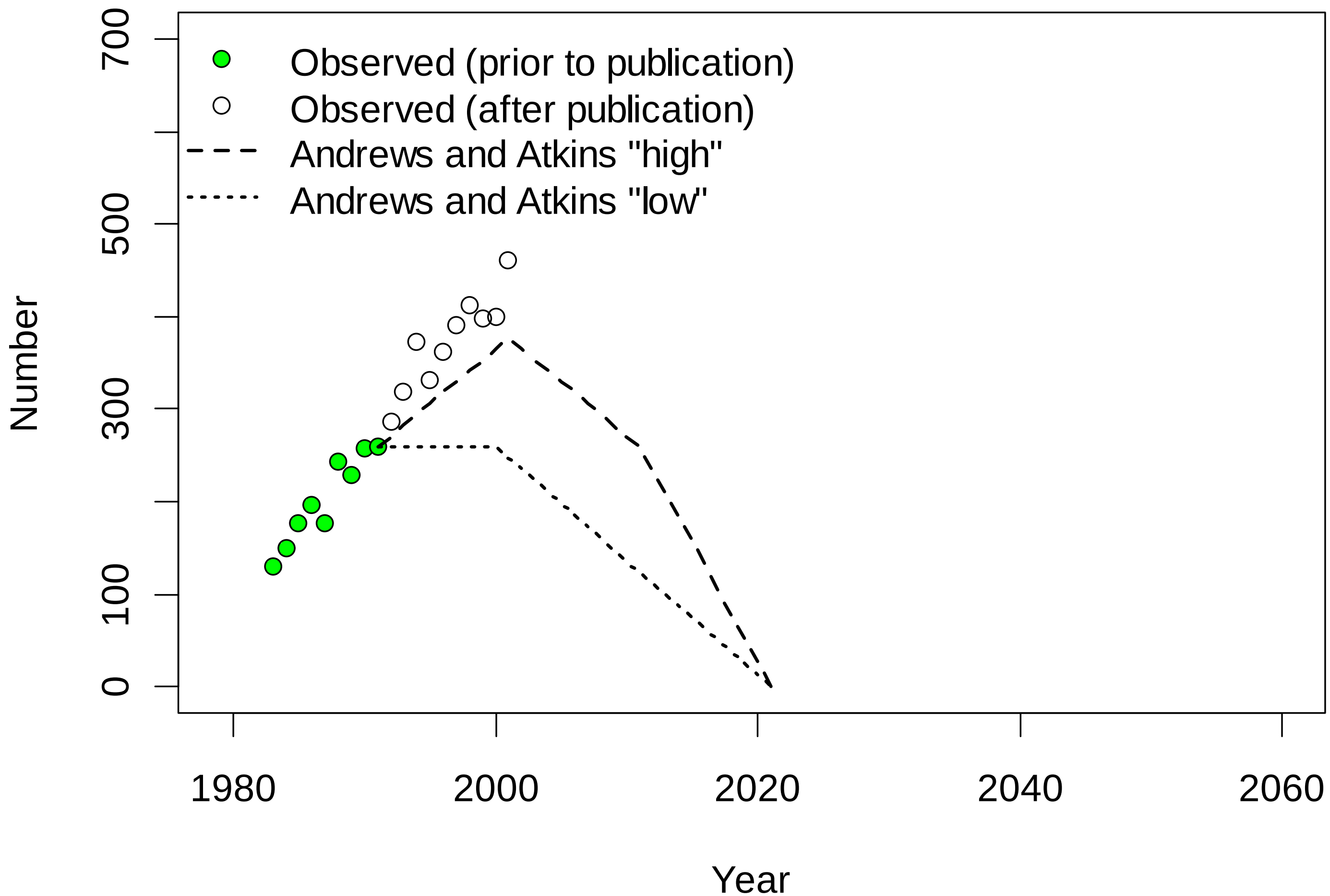
Model comparisons: Data sources

- Mesothelioma incidence for males
  - Australia for 1983-2001
  - New South Wales for 1972-2004

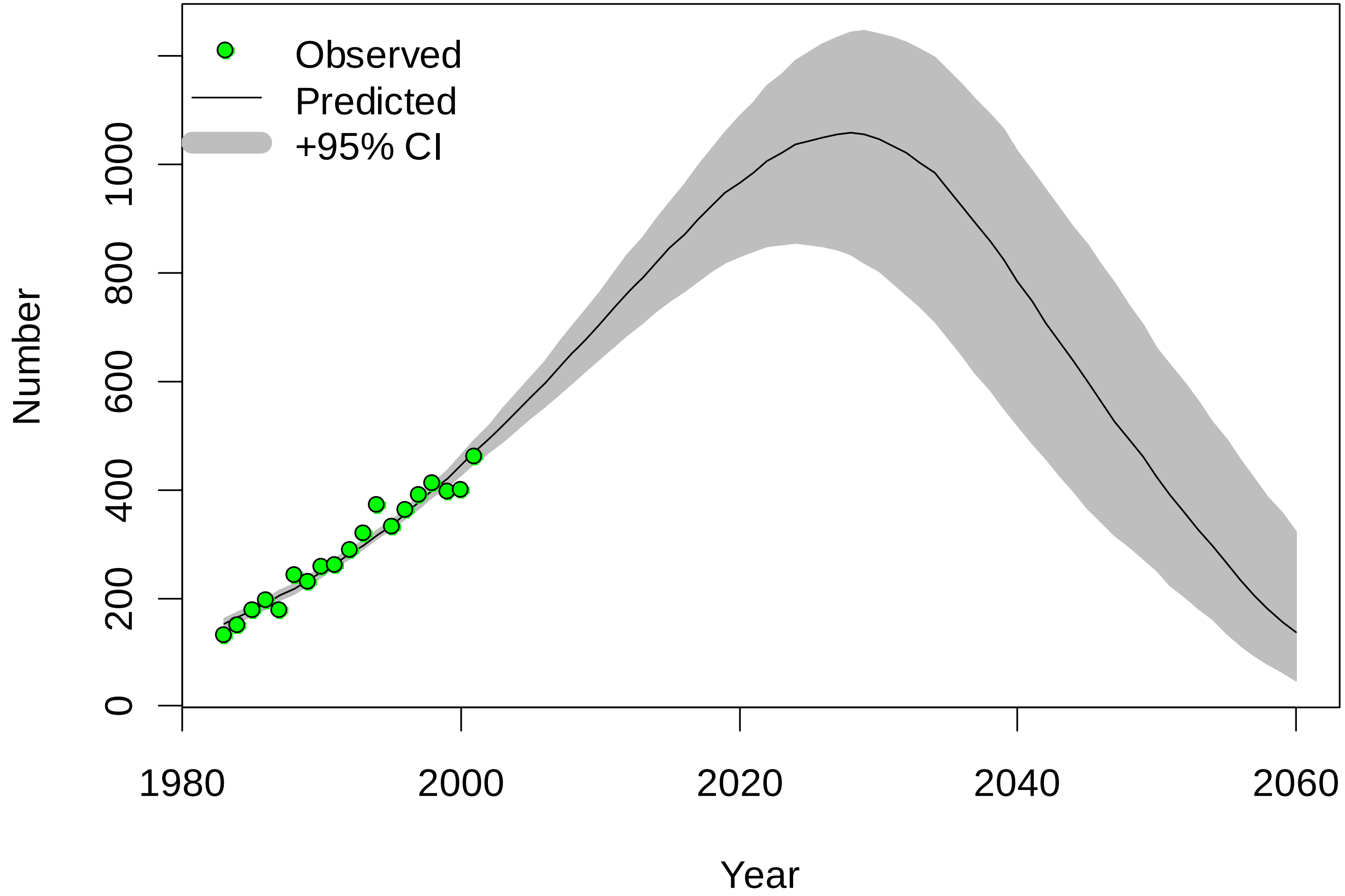
Model comparisons: Outline

Model	*Model description*
Andrews and Atkins (1993)	*cases*(*t*) from Berry (1991)
Peto et al (1995)	Age-cohort model (sub-model of Equation 1)
KPMG	Exposure model with delay distribution (sub-model of Equation 1)
Clements et al (2007)	Equation 1

Mesothelioma incidence, calibrated Andrews and Atkins (1993), Australian males



Mesothelioma incidence, age-cohort model, Australian males



KPMG (2006)

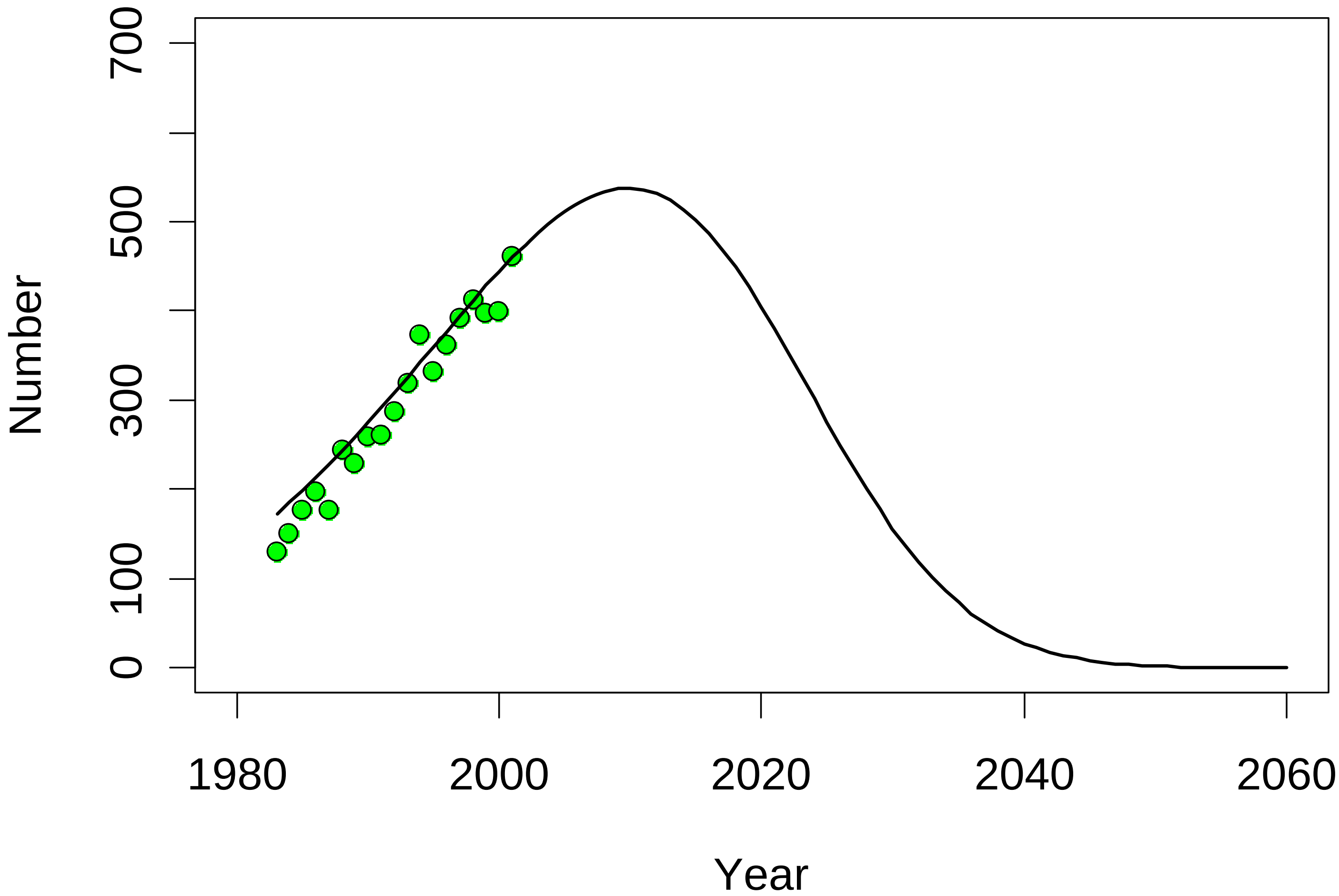
- Model as used to predict mesothelioma claims for former James Hardie entities
- Cases modelled by exposure data $D()$ and a delay distribution $f()$ (Normal($\mu=35$, $\sigma^2=10^2$)):

$$cases(t) = \int_0^\infty D(t-u)\, f(u)\, du$$

- $D()$ based on consumption data:

$$D(t) = \frac{\beta}{16} \int_0^{16} Consumption(t-u)\, du$$

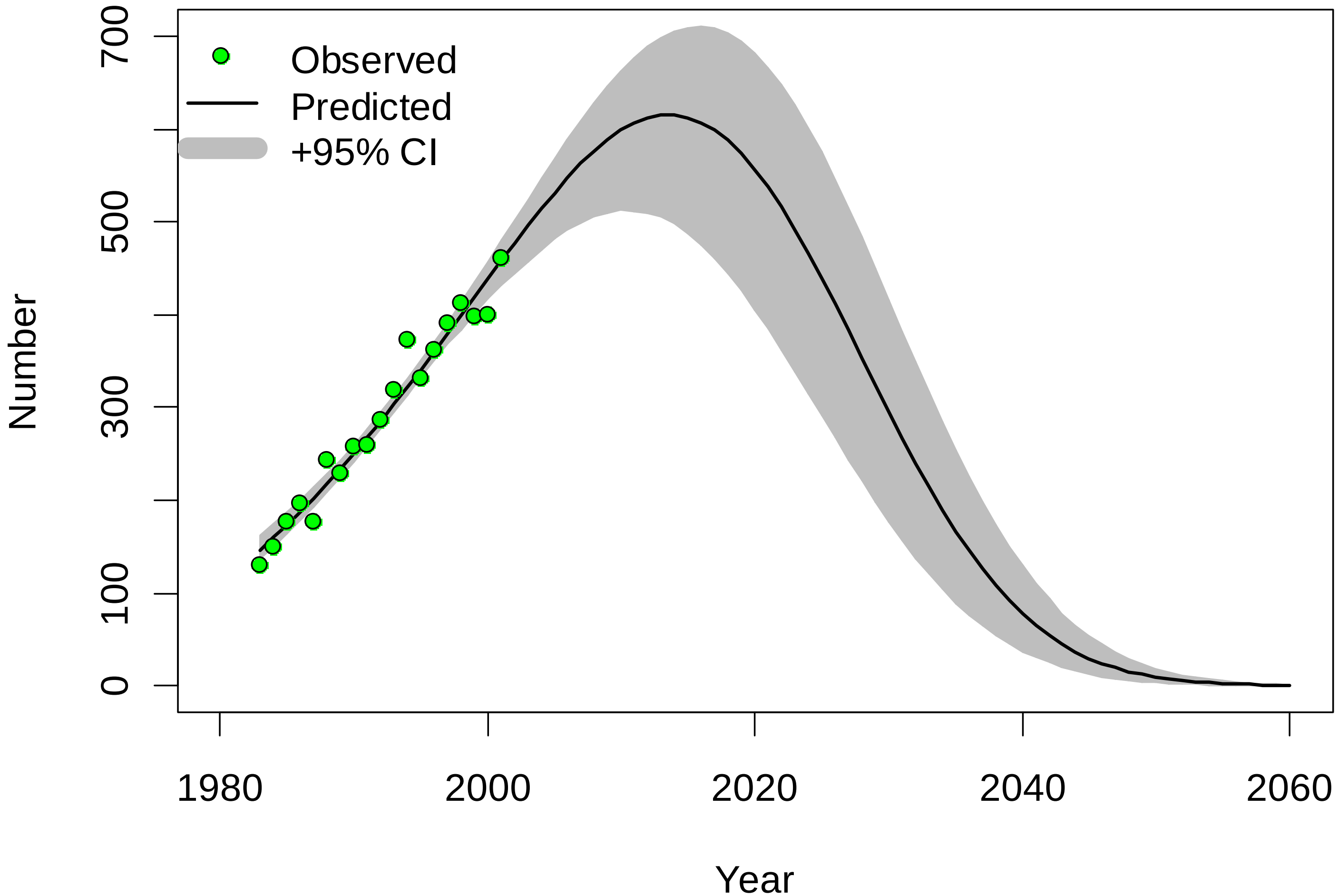
Mesothelioma incidence, calibrated KPMG, Australian males



Re-implementation of KPMG model

- Re-fit the model, estimating the intercept and the mean/SD for the delay distribution
- Maximum likelihood estimates:
  - Mean delay = 39.0 (se=5.0)
  - SD for delay = 10.4 (se=4.5)
- Interval estimation using the bootstrap
  - Assumes SD fixed as estimated (otherwise: uninformative)

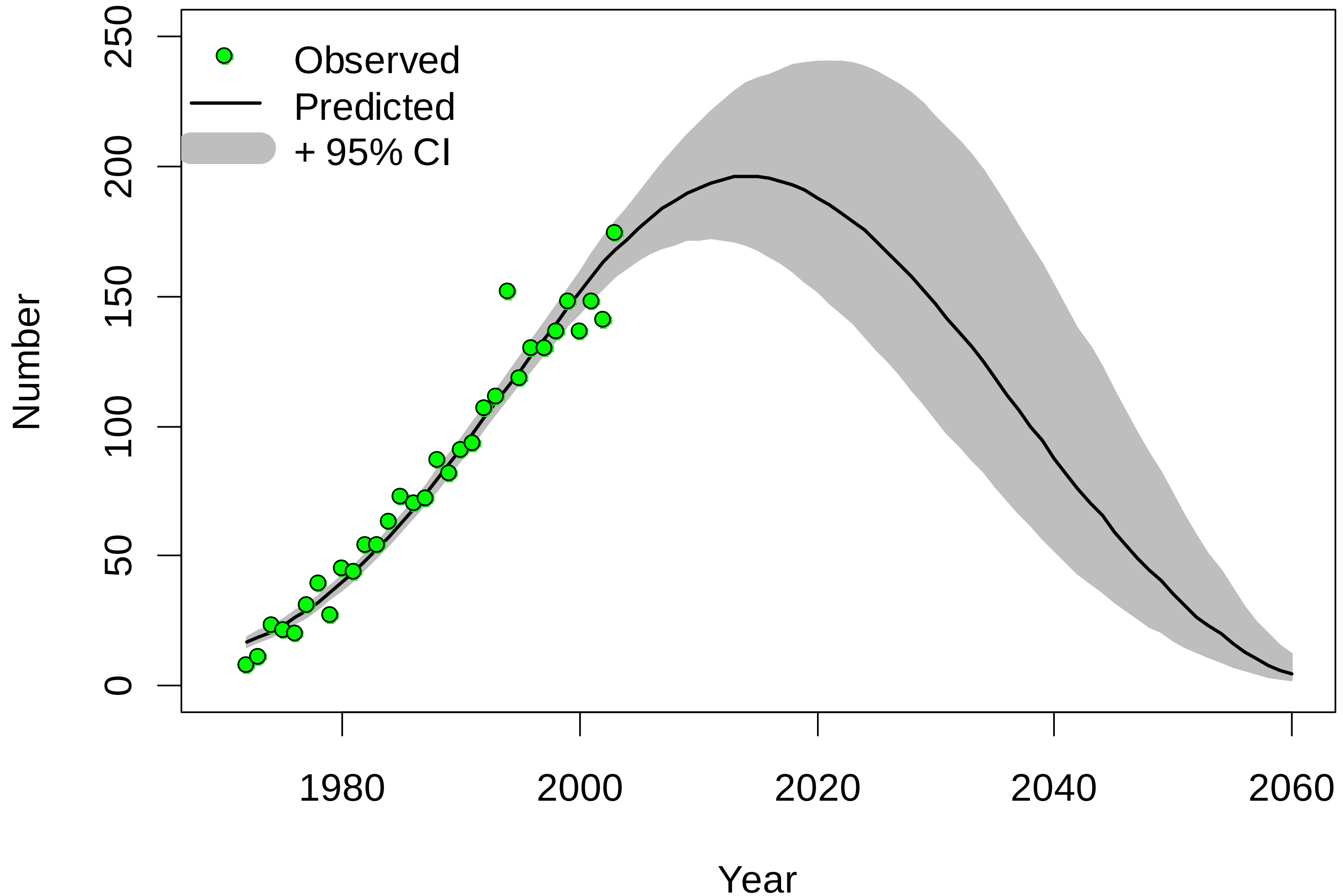
Mesothelioma incidence, KPMG re-implementation, Australian males



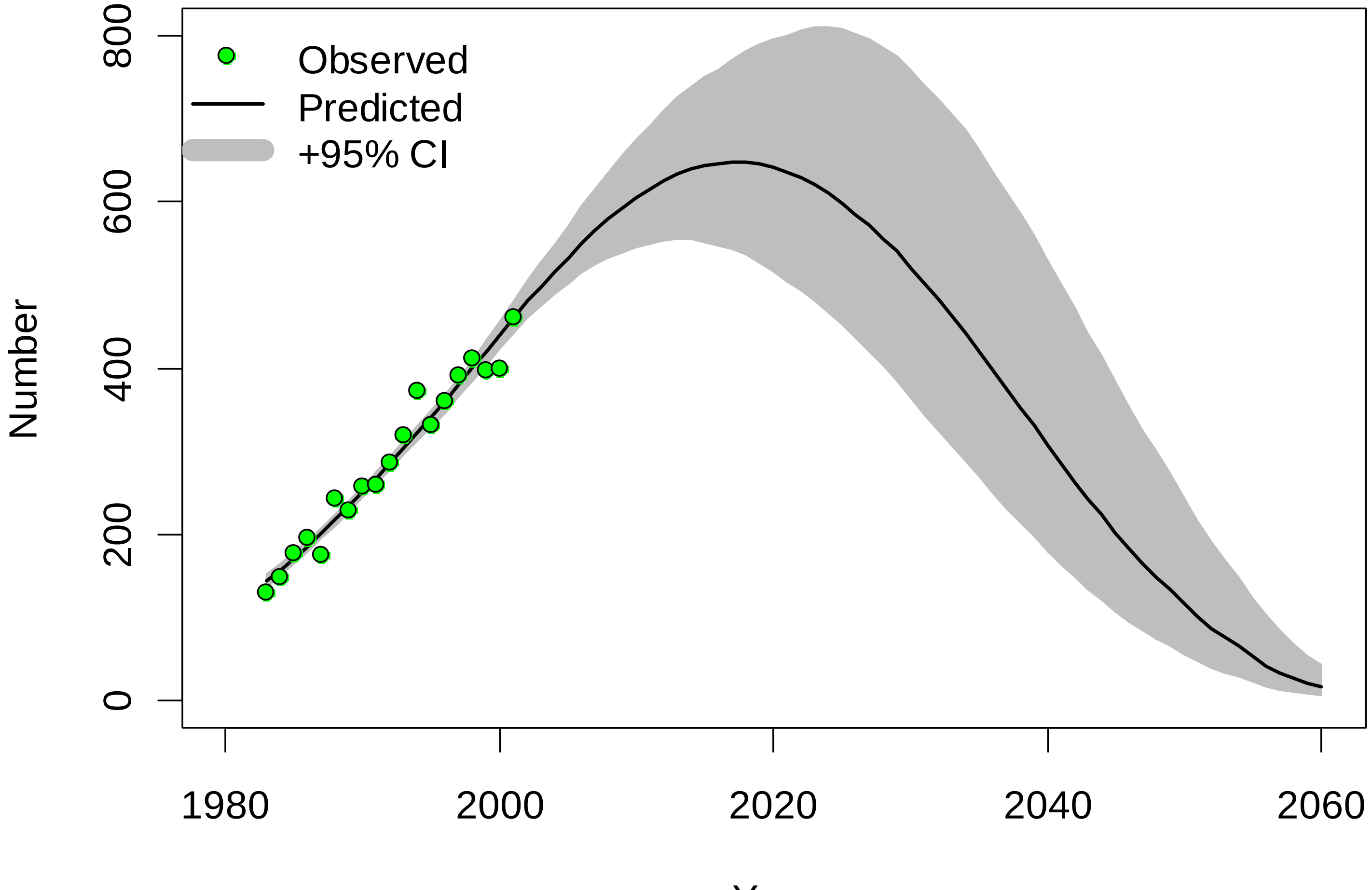
Clements et al (2007)

- Hodgson et al (2005) modelled Equation 1 for the United Kingdom
- We re-implemented their model for NSW
  - Natural splines for the dose functions
  - Fitted for five parameters using maximum likelihood estimation
  - Interval estimation using the bootstrap

Mesothelioma incidence, Clements et al (2007), New South Wales males



Mesothelioma incidence, Clements et al (2007) model, Australian males



Model comparison: Summary

	Australian males		New South Wales males	
Model	*Peak*	*Total count 2006-2060*	*Peak*	*Total count 2006-2060*
Andrews and Atkins “high”	2001	2905	2001	1040
Age-cohort model	2028	39850	2029	14855
KPMG (2006)	2010	10970	2010	3530
KPMG re-implementation	2014	15045	2013	4880
Clements et al (2007)	2017	21700	2014	6430

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95% confidence interval: 16460, 30165

95% confidence interval: 4920, 9060

Discussion: Summary

- Support for KPMG (2006), the KPMG re-implementation and Clements et al (2007)
  - Theoretically, these models are closely related
- Reasonable evidence that the peak for mesothelioma is after 2010
  - Total number of cases for 2006-2060 may be in excess of 35% higher than numbers predicted by KPMG

Specific recommendations

- Consider using the KPMG models or the model from Clements et al (2007)
- Investigate methods used by Stallard et al (2005) in the Manville Asbestos Case (also related to Equation 1) for large portfolios
- Investigate using direct estimates of asbestos exposure by occupation

General recommendations

- Fit models to observed data rather than simply calibrate
- Fully represent statistical uncertainty in model predictions
- The epidemiological literature is potentially a very useful resource to actuaries

References

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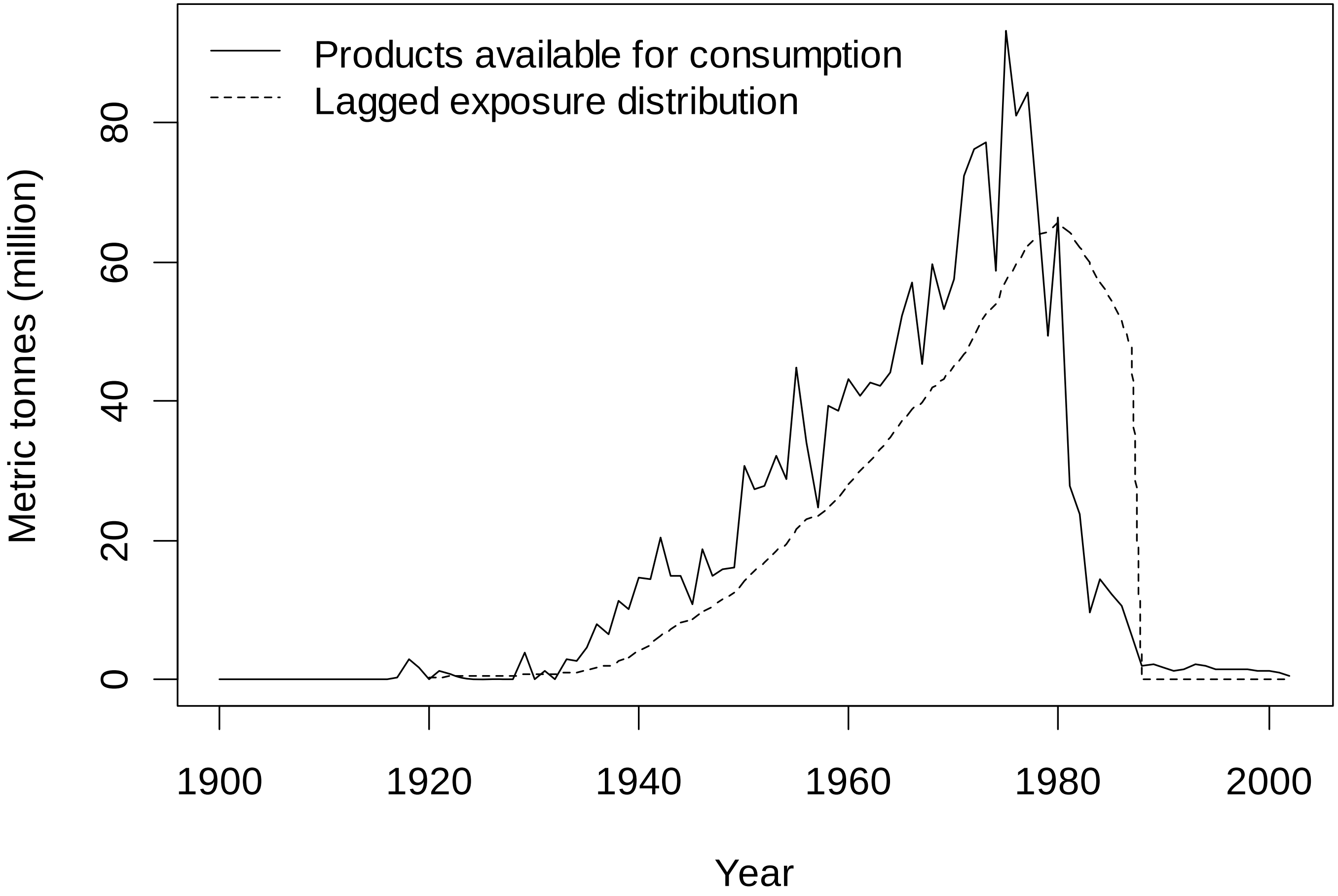
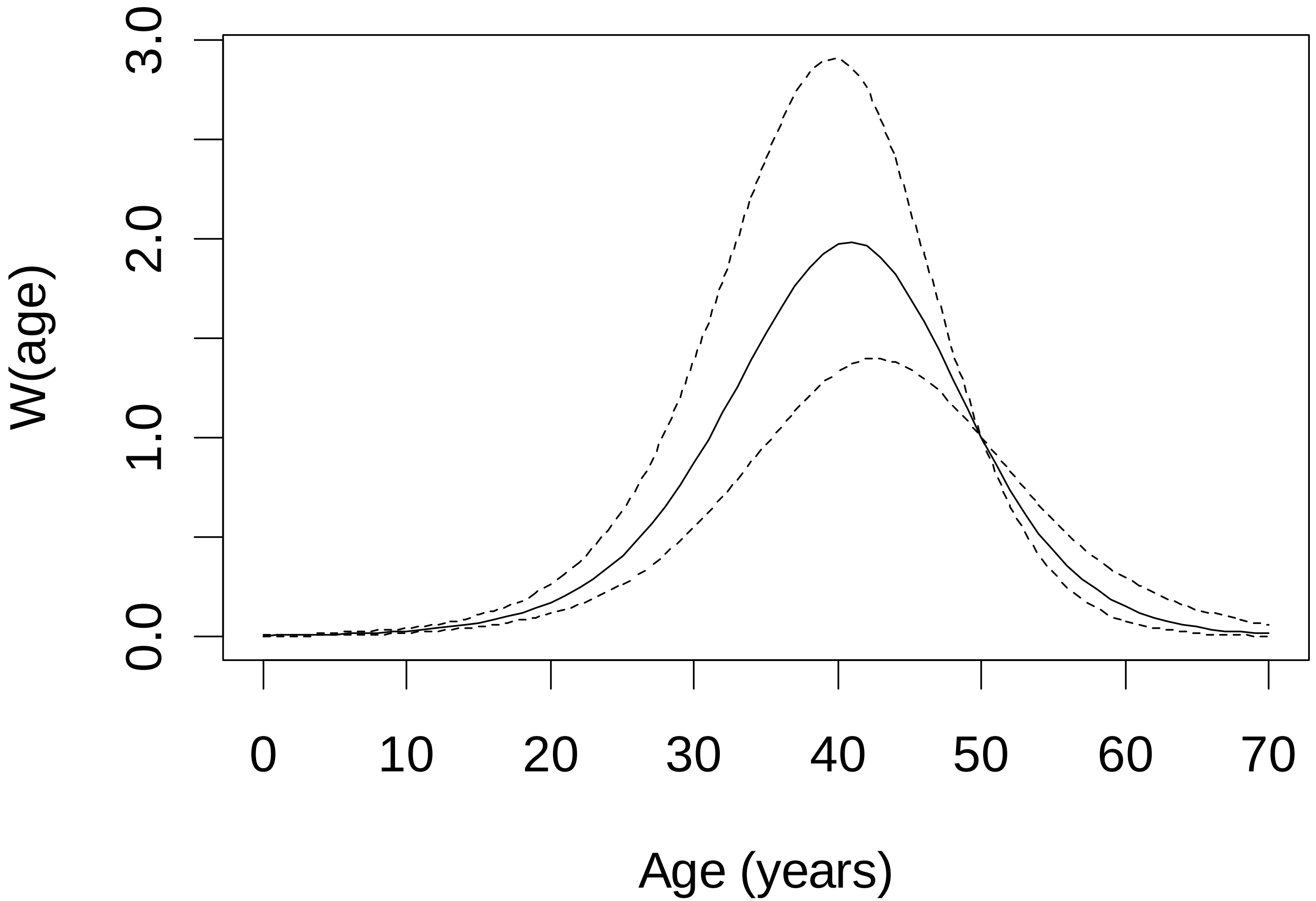
Additional slides

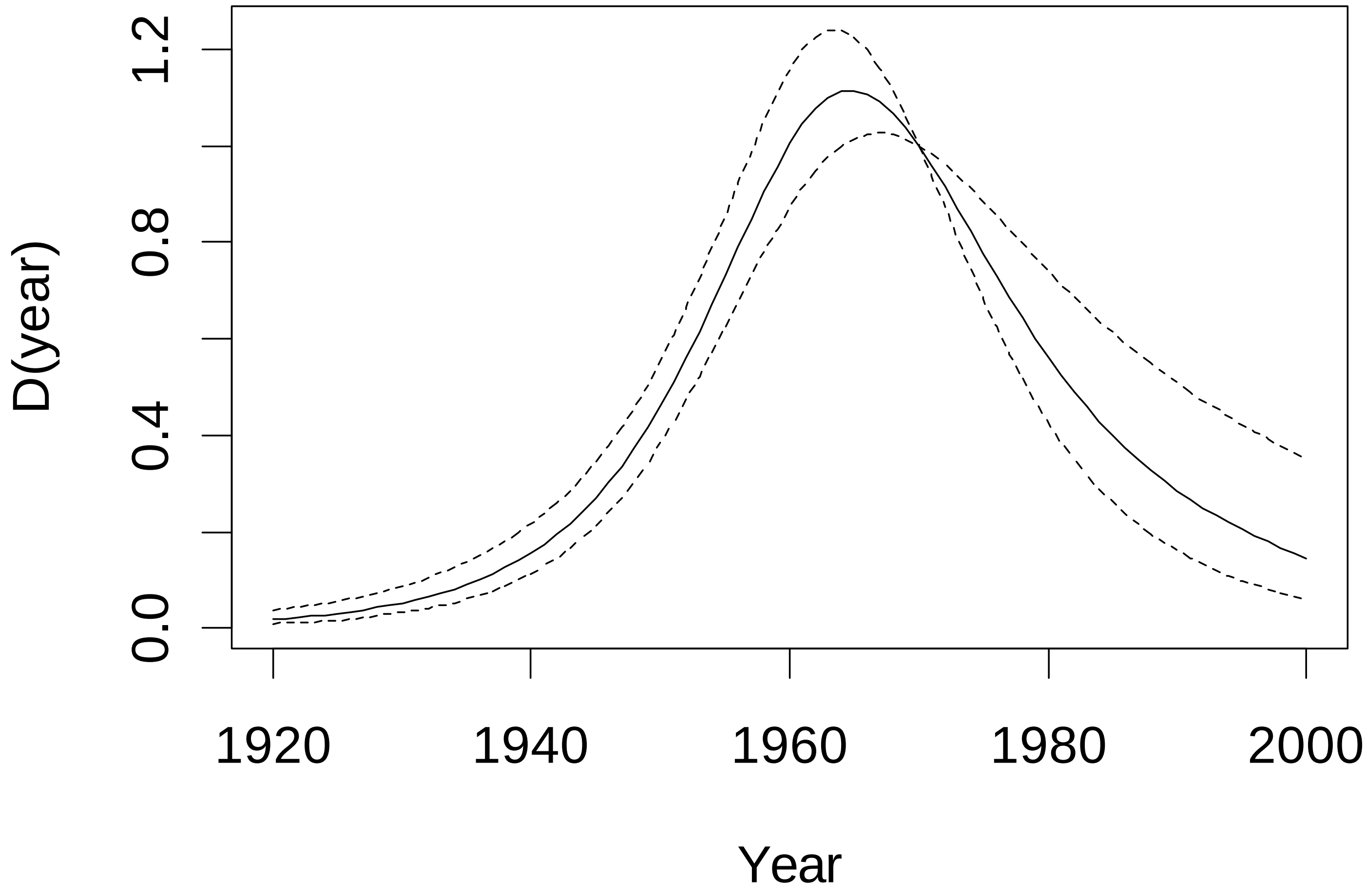
Asbestos products available for consumption and a lagged exposure distribution, Australia



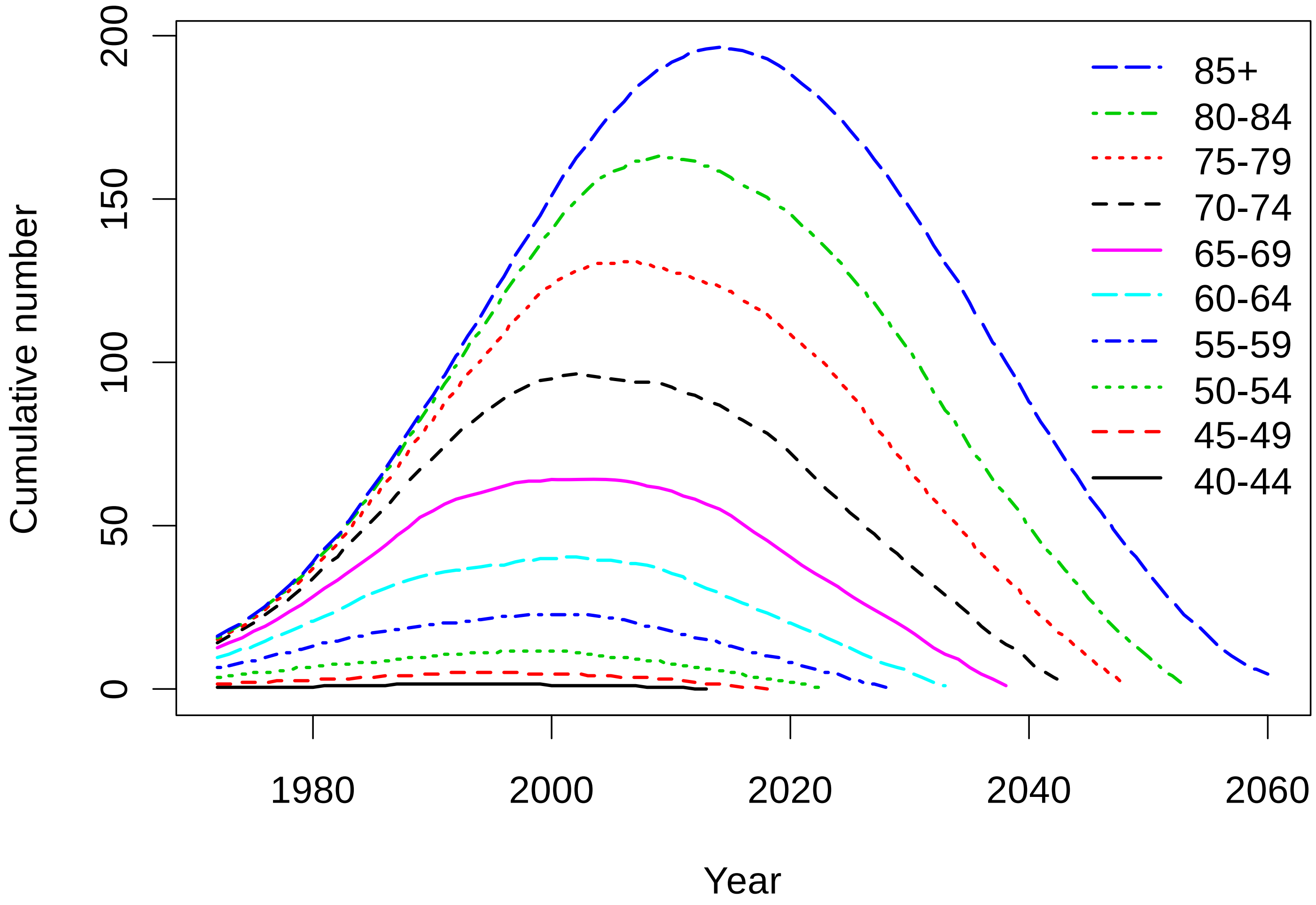
Estimated dose function by age, Clements et al (2007), NSW males



Estimated dose function by calendar period, Clements et al (2007), NSW males



Number of cases, by age at cancer, Clements et al (2007), NSW males



Number of cases, by period of exposure, Clements et al (2007), NSW males