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**SEMI-ARTIFICIAL MODELS OF POPULATIONS:
CONNECTING DEMOGRAPHY WITH AGENT-
BASED MODELLING**

WCSS 2012 – Taipei, Taiwan

Outline

- Context
- The Wedding Ring Model
- Extending the model
- Results
- Further work

Context – The Care Life Cycle

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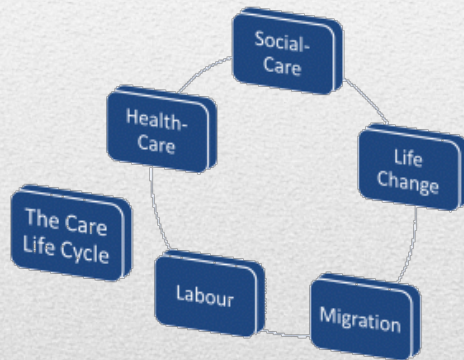
EPSRC

Engineering and Physical Sciences
Research Council

- Funded by the EPSRC
- The Care Life Cycle
 - Multidisciplinary project using computer simulation to investigate care provision in an ageing society
- Collaborators:
 - Centre for Research on Ageing
 - ESRC Centre for Population Change
 - Institute for Complex Systems Simulations
 - Centre for Operational Research, Management Science and Information Systems

Context – The Care Life Cycle

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The Care Life Cycle

- The Care Life Cycle is a novel way to conceptualise care using concepts from complex systems science
- We plan to use these concepts to answer some critical questions:
 - How will the population change over the next several generations?
 - How do labour markets and migration trends affect these changes?
 - How can society adjust to provide care to a growing elderly population?

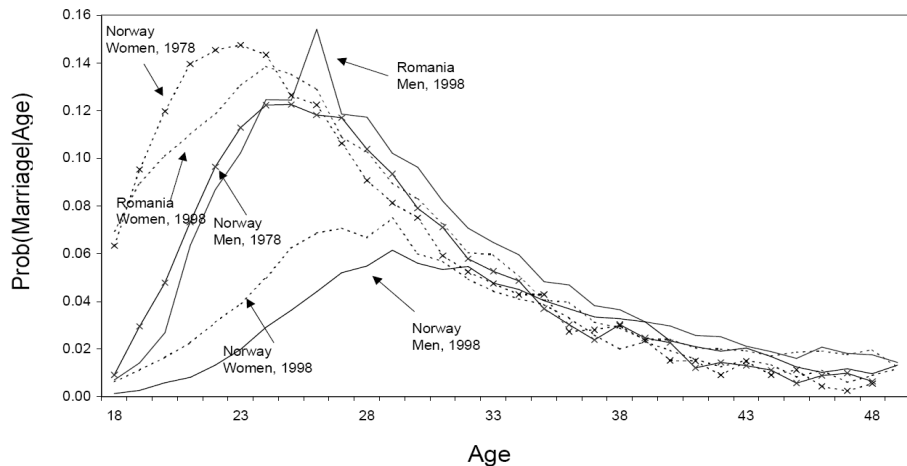
Context – CLC motivations

- Semi-Artificial Population Models:
 - A method for predicting population change
 - Combining statistical demographic approaches with agent-based modelling methodologies
- Intended to enhance the explanatory capacity of models of the UK population
- Will inform/be combined with other CLC models
 - System dynamics models
 - Discrete-event simulation
 - Agent-based
- We propose that combining the strengths of empirically-based demographic methods with the explanatory power of agent-based models will allow us to build more powerful models of population dynamics

Context – Agent-based demography

- We are certainly not the first to propose an agent-based demography!
 - Billari and Prskawetz' 2003 volume *Agent-Based Computational Demography* argues that agent-based methods can enhance the explanatory power of demographic studies
 - Could also enhance the empirical relevance of agent-based methods more generally
- We argue that *directly linking* agent-based and demographic methods allows us to do these things – while *also* allowing us to avoid the pitfalls of *overdependence* on expensive, detailed empirical data
- Increased flexibility of agent-based approaches can allow demographers to look beyond the one-generation predictive horizon of demographic models
- We propose a future for demography focused on scenario-based examinations of possible futures

The Wedding Ring Model

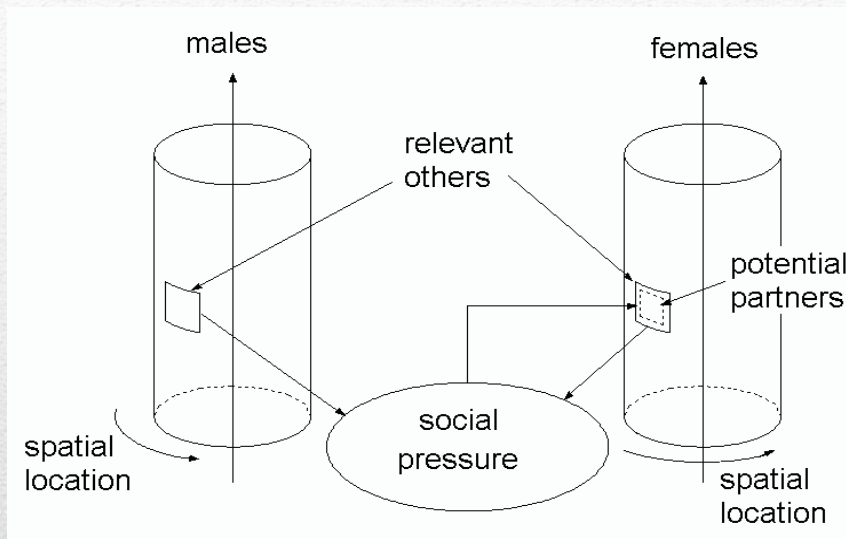


Hazard functions for marriage in European populations

Billari, FC, Prskawetz, A, Diaz, BA, Fent, T (2007). The 'Wedding Ring': An agent-based marriage model based on social interaction. *Demographic Research*, 17(3), 59-82.

- Model intended to reproduce age-at-marriage patterns as seen in European populations, using a model based on social interaction
- Fundamental assumptions:
 - Willingness to marry depends on the availability of partners, but also *social pressure*
 - Social pressure relates to the share of *relevant others* in a given agent's social network who are already married
- Marriage is thus viewed as a sort of diffusion process
- Marriage differs from most diffusion processes though!
 - Even agents experiencing very high social pressure *cannot* get married without an available unmarried partner

The Wedding Ring Model

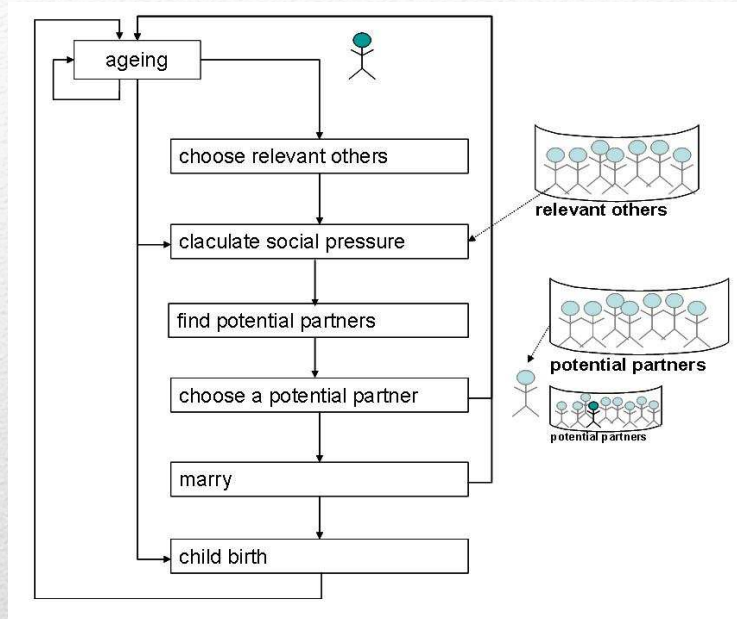


Implementation of Wedding Ring model

Billari, FC, Prskawetz, A, Diaz, BA, Fent, T (2007). The 'Wedding Ring': An agent-based marriage model based on social interaction. *Demographic Research*, 17(3), 59-82.

- Agents live in a one-dimensional ring-shaped world
- Effectively a cylindrical space, where the vertical dimension represents time
- Each agent has a network of *relevant others* defined as a two-dimensional neighbourhood on that cylinder
- Within each neighbourhood, the proportion of married relevant others determines the level of *social pressure*
 - As social pressure increases, partner search range increases
- Search is mutual: marriage only occurs if both agents are in each other's acceptable ranges

The Wedding Ring Model

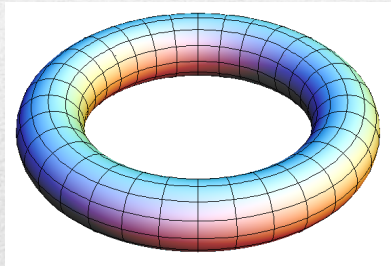


Flow diagram of Wedding Ring model

- In addition to social pressure, each agent has an *age influence* parameter
 - 5 types of agent, according to which age ranges they are most influenced by
- The combination of age influence and social pressure determines a given agent's partner search range
- Once suitable partners find each other and get married, they may then bear children
 - Child agents are placed into the ring at a random spot in their parents' neighbourhood

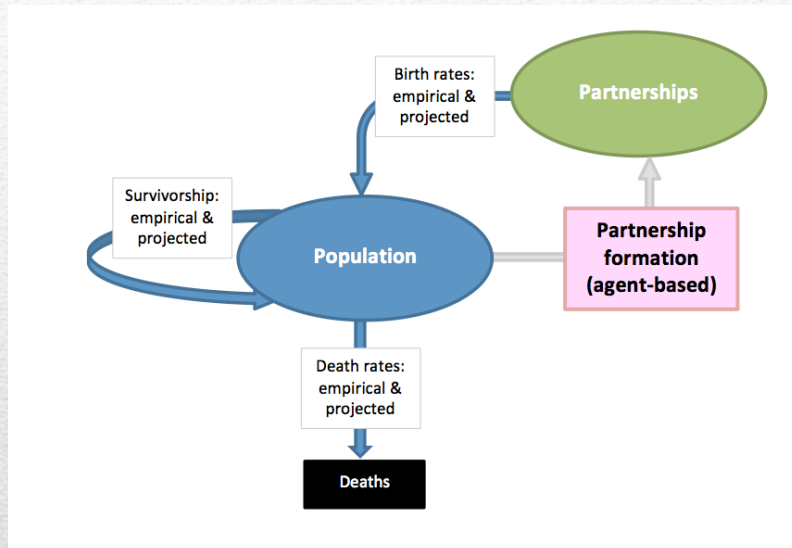
Billari, FC, Prskawetz, A, Diaz, BA, Fent, T (2007). The 'Wedding Ring': An agent-based marriage model based on social interaction. *Demographic Research*, 17(3), 59-82.

Extending the model



- Using the Wedding Ring as a basis, we made several large alterations:
 - Agents are in a *toroidal* space
 - Agents who form a new partnership *migrate* to a new location with their partner
 - Realistic models of *fertility and mortality* added
 - Simplistic model of *health status* added
- Goals:
 - Further test the concept of *social pressure* as a mechanism for partnership formation
 - Demonstrate a platform which combines agent-based and statistical demographic methods
 - Test the feasibility of this type of model for *scenario generation* in health/social care context

Wedding Doughnut – The basics



Flow diagram of extended 'Wedding Doughnut' model

- The Wedding Ring made significant simplifying assumptions regarding birth/death:
 - Agents simply die at age 100
 - Birth rates adjusted to keep population constant
- The Wedding Doughnut *removes* these restrictions
- Added demographic elements to enhance realism:
 - Initial population based on 1951 census from England and Wales
 - Mortality rates based on age-specific empirical rates from Human Mortality Database (1951-2009)
 - Age-specific fertility rates obtained from ONS England and Wales (1950-1972), and Eurostat (1973-2009)

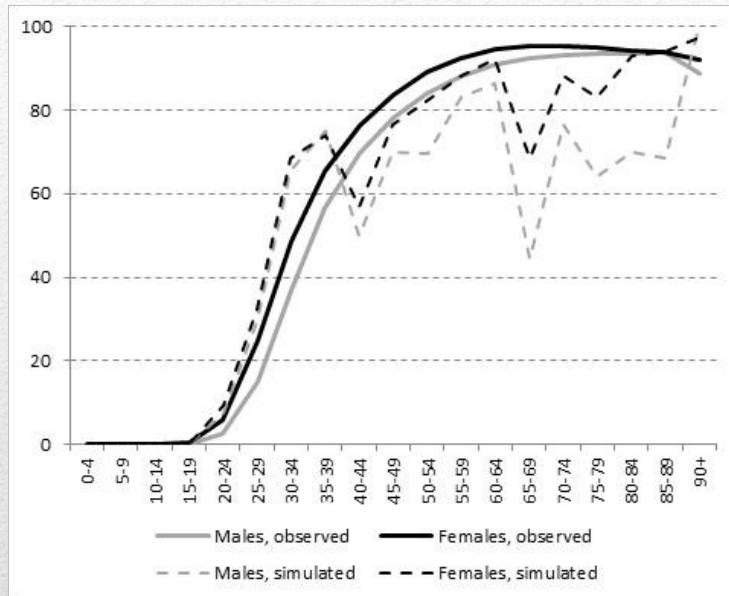
Wedding Doughnut – Demographic Elements

- Mortality rates projected forward using Lee-Carter method
 - Model with only one time-varying element
 - Uses leading vectors of single-valued decomposition of matrix of centred mortality rates
 - Projections show continual but slow increase in life expectancy through 2250
- Fertility projections use similar methods
 - Two components of decomposition matrix better captured trends in fertility
 - Projections show initial increase in fertility rate before converging at a level just above replacement fertility
 - Continued trend toward later child-bearing

Details of Lee-Carter method:

Lee, R. D. and Carter, L. R. (1992). Modeling and Forecasting U.S. Mortality. *Journal of the American Statistical Association*, 87(419): 659–671.

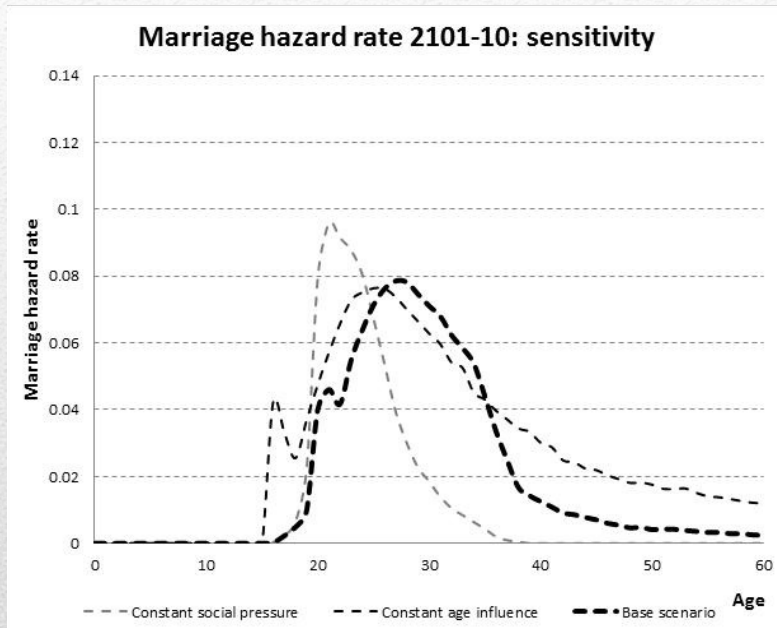
Results – Marriage rates



Percentage of ever-married population in real and simulated populations

- Initial tests of the Doughnut showed results comparable to the Ring
- Once demographic modifications were complete, we conducted a set of 1800 runs
 - Qualitative similarity to patterns of marriage observed in modern Britain
 - Greater stochasticity, perhaps due to short running times and random initial population

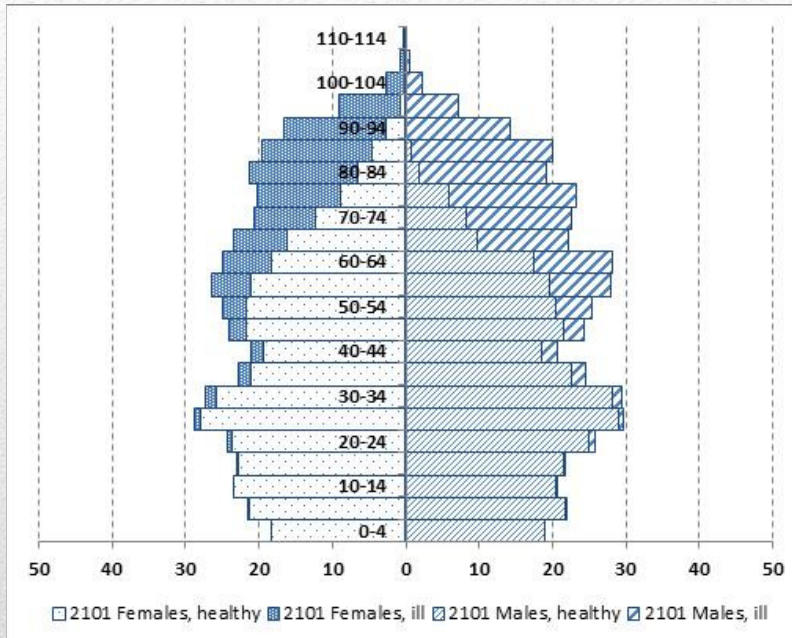
Results – Marriage rates



Marriage hazard rate results in 3 scenarios:
base scenario; constant age influence;
constant social pressure

- We tried alternative scenarios which significantly altered base assumptions of the simulation:
 - Constant age influence
 - Constant social pressure
- Alternative scenarios produce hazard rates inconsistent with reality
- Base scenario (age influence varies with age, social pressure as a sigmoid function) produced results consistent with observed marriage hazard rates in European states

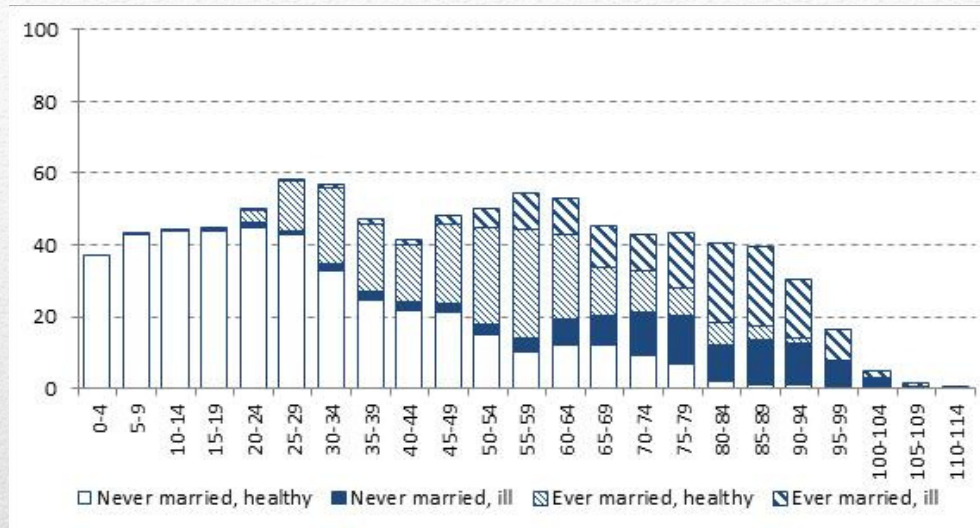
Results – Health and ageing



Population for year 2101 in simulation

- Patterns observed in simulation fit our expectations for future population dynamics
- Population increasingly dominated by higher age brackets
- Increasing numbers of agents displaying long-term limiting illness
- Long-term decrease in marriage/fertility rates mean large numbers of ill agents have no family available to provide care

Results – Health and ageing



Population for year 2101 in simulation

- The breakdown of our simulated population in 2101 shows the increasing tendency toward a large elderly/infirm population
- Our projections suggest that the current worries regarding a lack of social care for future generations are well-founded

Future work

- While our results are encouraging, there are clear areas which need improvement:
 - Overly-simplistic model of health status
 - Lack of data on long-term limiting illness in the UK
 - No possibility of partnership dissolution
 - No provision for same-sex partnerships
 - Limited agent movement
- Future work will address these limitations via links with other CLC project models
 - SD/DES models of health institutions
 - Models of social care provision, ageing, and disability
 - Migration (domestic and international)

Conclusions

- Results support our initial hypothesis: agent-based models of demographic processes, augmented with empirical mortality/fertility projections, can produce sensible results
- Our health status projections, despite being based on minimal data, produce plausible distributions given our expectations of population dynamics in modern European states
- This suggests that our model captures enough essential elements of population dynamics to form a useful starting point for detailed models of the UK population
- More broadly, we propose that this kind of approach may bring us closer to the ideal expressed by British demographer John Hajnal, who encouraged the development of demographic models which involve 'more cognition than has generally been applied'

Thank you!

謝謝