Morbidity Based Mortality

Robert L Eberlein
James P Thompson
David B Matchar

Background

- Thinking about the future is hard
  - Life expectancies are rising
  - Active and healthy life expectancies not as much
    - Developing chronic conditions and limitations
  - Older people more likely to have comorbidities
    - Individuals with many conditions
  - No longer a disease in isolation
    - Implications of interventions less clear

Goal

A flexible population level model that simulates how morbidity to mortality changes over time

- Able to handle multiple overlapping conditions
- Detailed enough to capture age-related effects
- Small enough to simulate in seconds, not minutes or hours
  - Calibration in hours not days or weeks

Managing Overlap Detail

- Compartmentalization
  - Pools of people
  - Clumps of conditions
- Mix and match
  - Many combination (2^n)
  - Hard to organize
  - As expensive computationally as microsimulation
  - As hard to parameterize as individual models

DUKE NUS
GRADUATE MEDICAL SCHOOL SINGAPORE

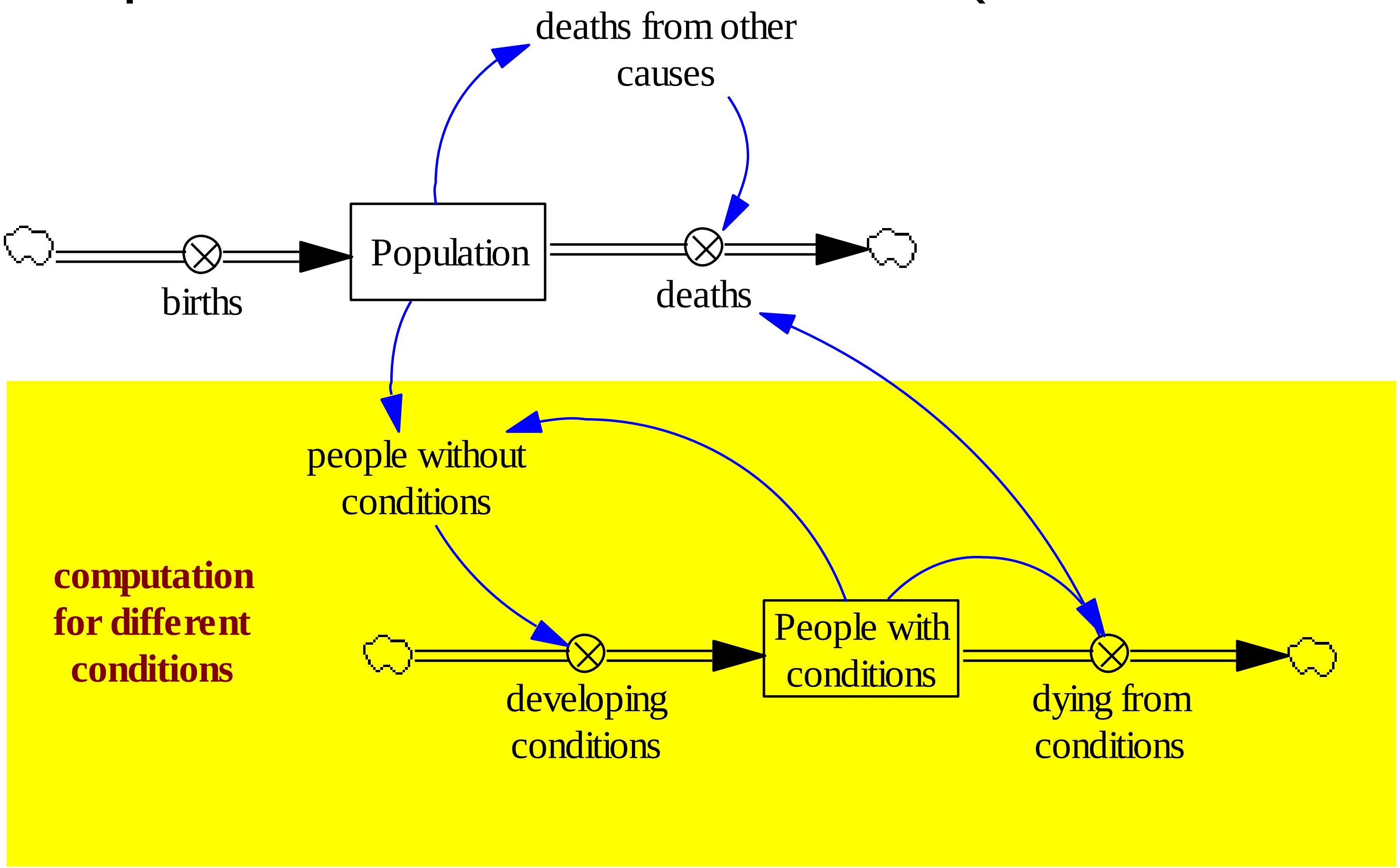
Our Proposed Solution

- Limited Compartmentalization
  - Gender, age, condition
  - With some micro character
    - Computationally fine cohorts
      - Prevent mixing by age
- Coincident flows of individuals into conditions
  - An approximation of complete enumeration
- Many conditions, without tracking individuals
  - Conditions progress with age

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

How it works

- People and chronic conditions (or risk factors)



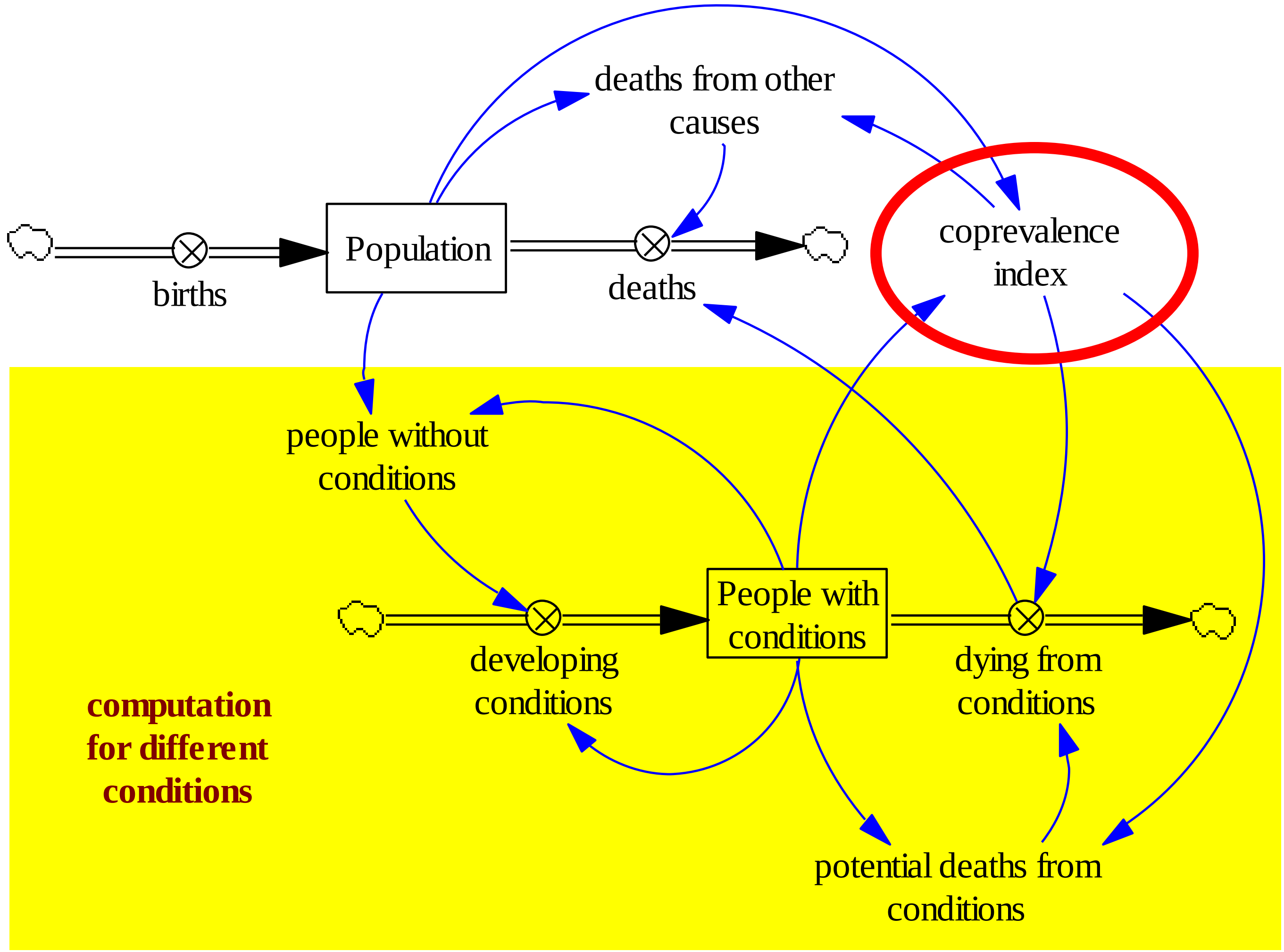
DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Issues with Simplest View

- People only die once
  - Even those with multiple morbidities
  - Need to adjust dying from conditions
- Mortality is higher for those with more conditions
- One condition may make another more likely
- People dying must decrease people with conditions
  - Not exclusive pools, but overlapping

DUKE NUS
GRADUATE MEDICAL SCHOOL SINGAPORE

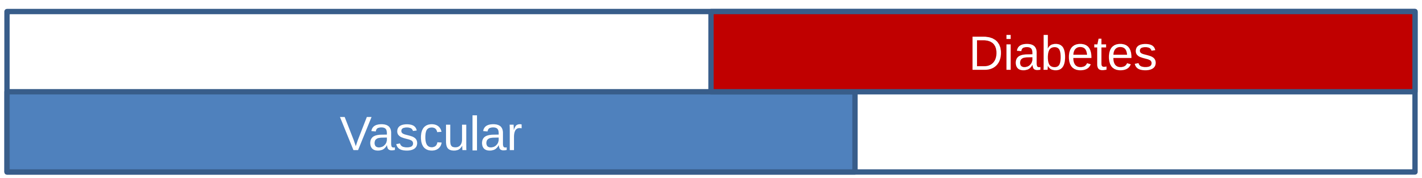
Concurrent Prevalence



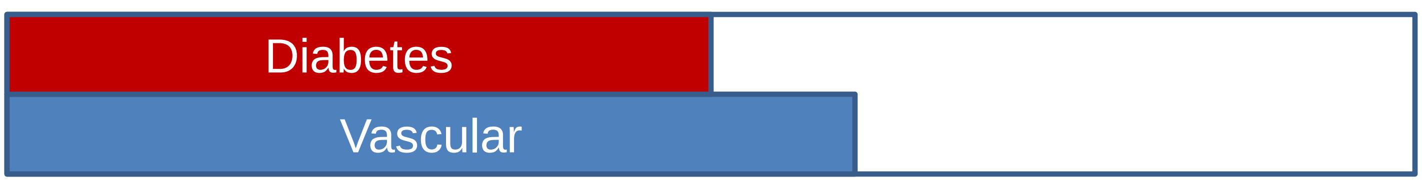
DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Concurrent Prevalence Definition

- Average number of overlapping conditions within the population
- Not directly determinable in aggregate
  - Bound between two numbers
    - Minimum – no overlap till we run out of people

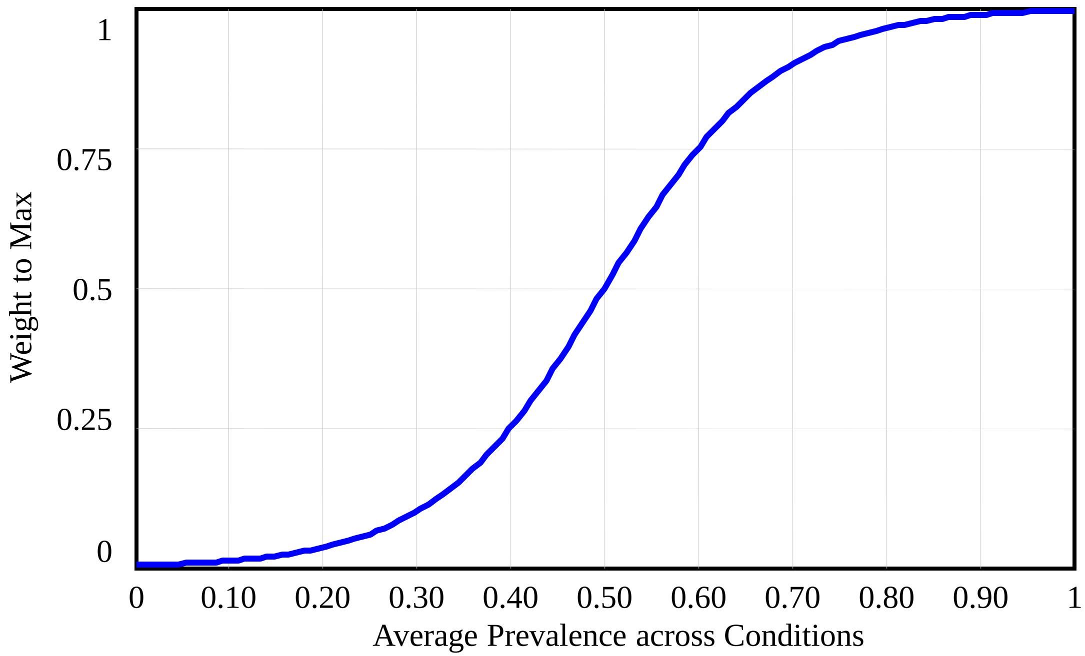


    - Maximum – only overlap till we run out of conditions



Concurrent Prevalence Computation

- A single number for the population
  - Weighted average min and max



- Logistic adjustment toward max
- Set points for 25% and 75%

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Issues with Simplest View

- People only die once
  - Even those with multiple morbidities
  - Need to adjust dying from conditions
- Mortality is higher for those with more conditions
- One condition may make another more likely
- People dying must decrease people with conditions
  - Not exclusive pools, but overlapping

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Example

- Deaths from any cause can decrease people with a condition
  - People with heart disease can die from cancer
- People with conditions are distinct from the total population
  - Smoking causes cancer
  - A higher fraction of people with cancer are likely to smoke

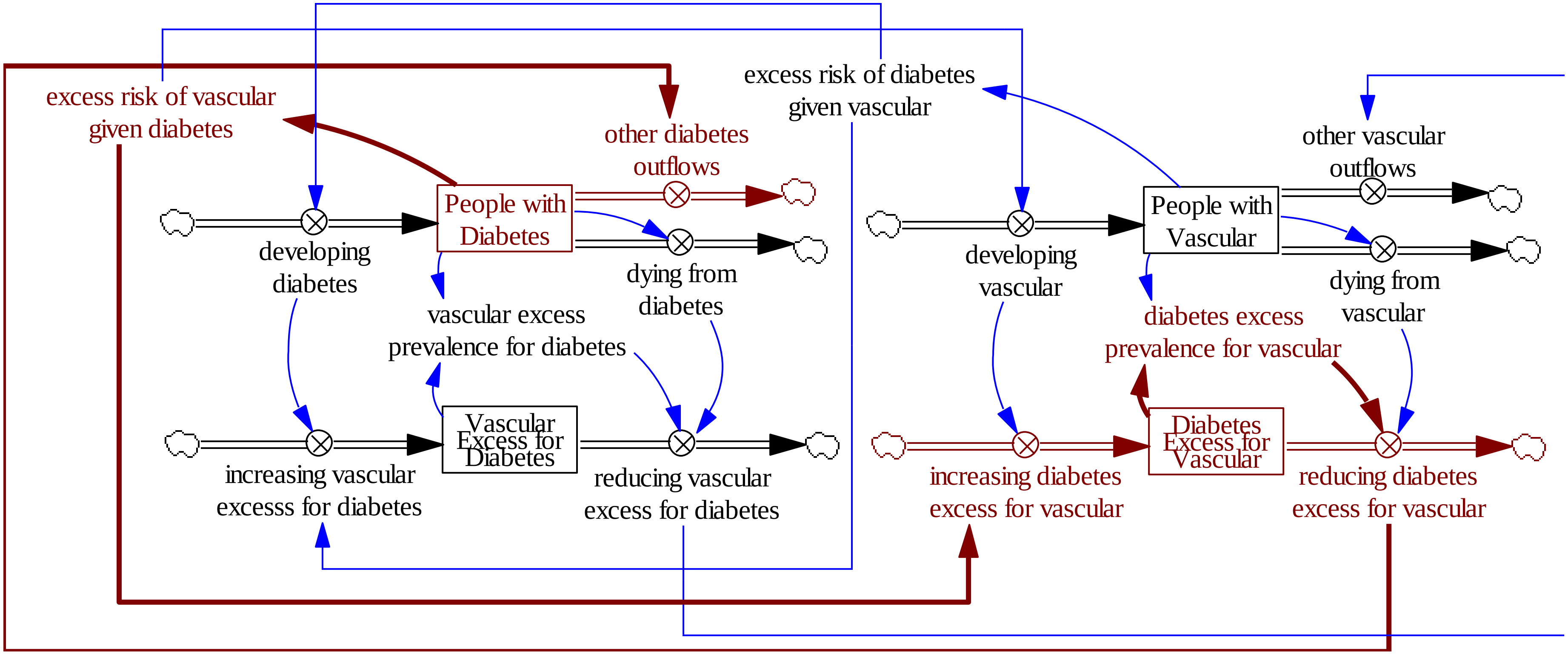
Example (continued)

- Smoking doubles the risk of cancer
  - Population 1000
    - Smokers 500
  - Cancer incidence 10/1000/year
    - 20 for smokers (risk doubled)
    - Total is ½ @ 10 + ½ @20 or 15 new cancer patient
  - Excess for smokers, cancer is increased by 5
- Suppose 50 people die, including all 15 cancer patients
  - 50 deaths decrease the number of smokers by 25
  - The excess 5 smokers are removed because of cancer deaths
- Smoker prevalence goes from 50% to 49.5%

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Conditional Excess Prevalence

- Crossing flows – simplified



DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Decreasing People With Conditions

= (deaths + emigration) * prevalence

+ Σ death from condition * excess prevalence

By condition, gender and age

- Excess of secondary given primary

Decreasing excess with condition

= (decreasing pwc + progressing + recovering)

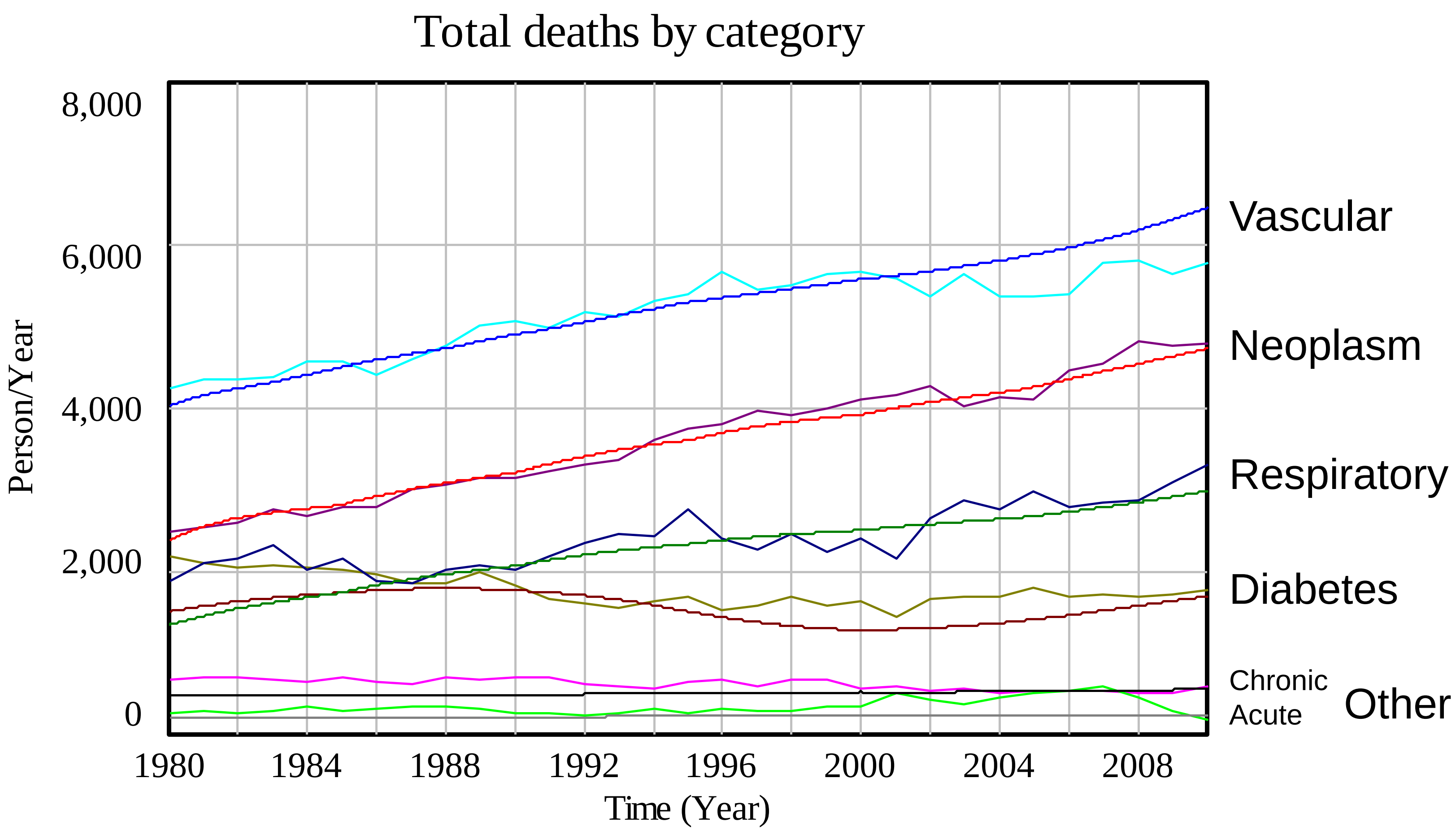
* excess prevalence

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Applying to Singapore

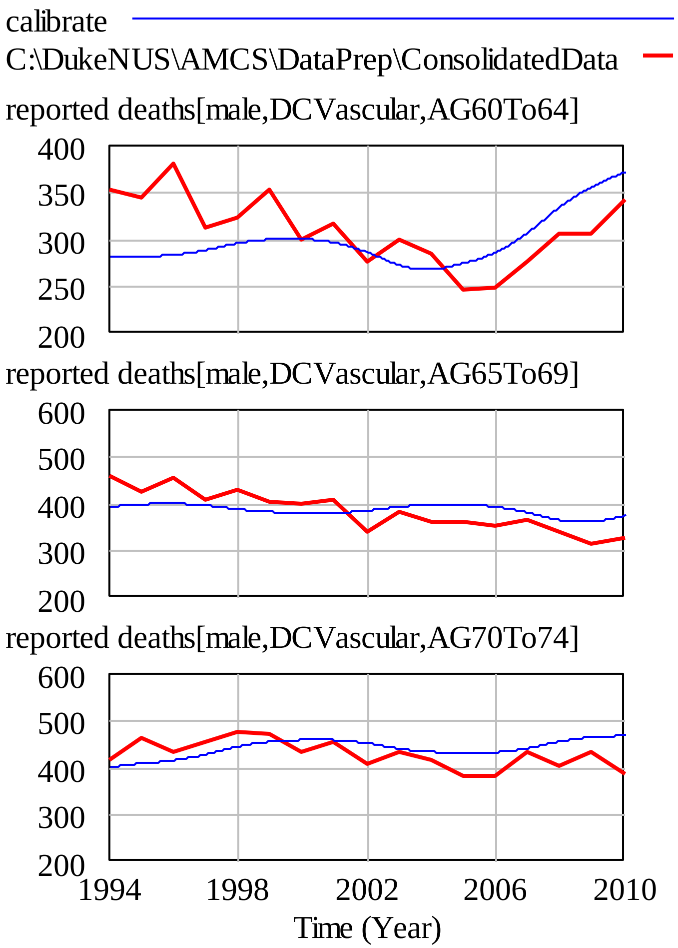
- 5 Chronic disease categories, 1 acute
  - Vascular, Neoplasm, Respiratory, Diabetes, Other
  - 3 risk factors - smoking, hypertension, sedentariness
- Detailed death certificate data
  - 1994-2010
- Less detailed demographic data
  - 1980-2010
- Trend assumptions on mortality per disease

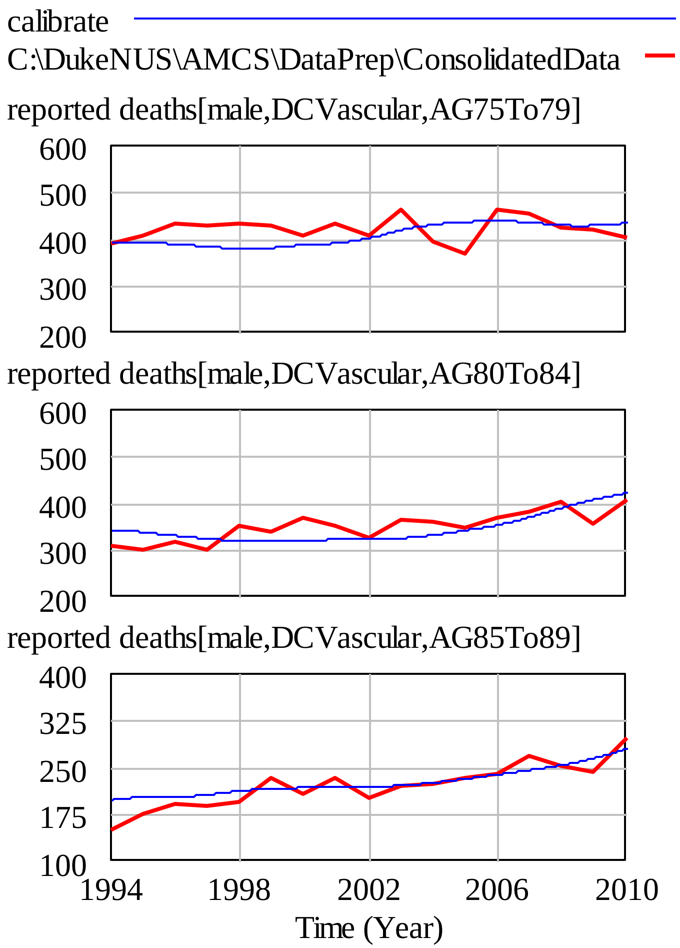
Singapore Historic Comparison



DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Detail – Male, Vascular, 60-89



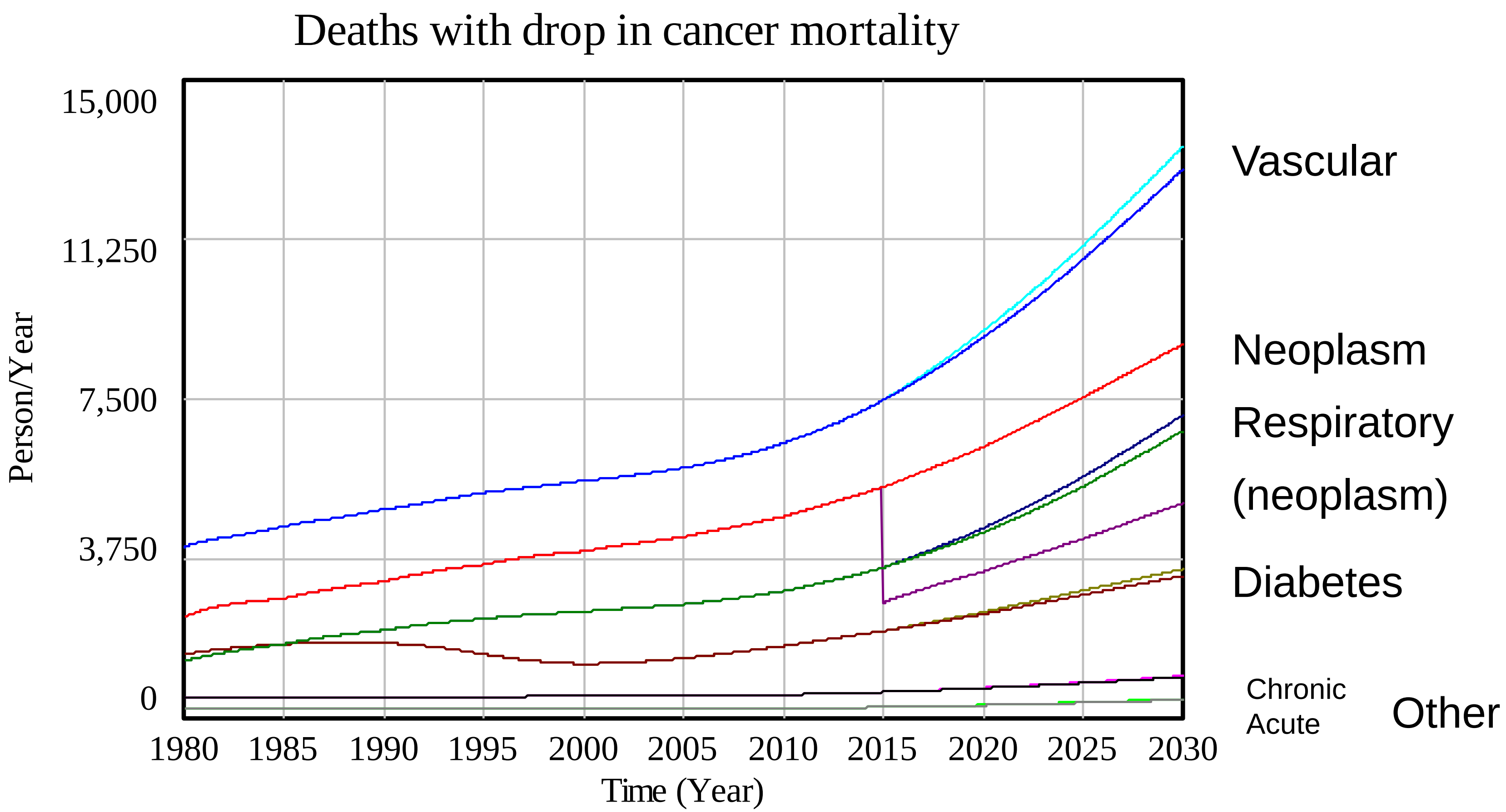


DUKE NUS
GRADUATE MEDICAL SCHOOL SINGAPORE

Experiment

- Cut cancer mortality rate by 50% in 2015
  - Cancer deaths immediately drop in half
  - Rebuild to 58% of base case by end
- Other deaths compensate
- Total deaths down
  - 14% in 2015
  - 8% in 2030
- Population over 85 up 8% in 2030

Experimental Results



Life Expectancy Changes

Female							
	2015				2030		
	Base	Test	Change		Base	Test	Change
at Birth	84.5	86.1	1.6		85.3	86.7	1.4
at 25	59.8	61.3	1.5		60.5	61.9	1.4
at 45	40.1	41.6	1.5		40.9	42.2	1.3
at 65	21.7	22.9	1.1		22.4	23.4	1.0
Male							
	2015				2030		
	Base	Test	Change		Base	Test	Change
at Birth	80.5	82.0	1.6		81.5	82.9	1.4
at 25	55.8	57.3	1.5		56.8	58.2	1.4
at 45	36.4	37.9	1.5		37.4	38.8	1.3
at 65	18.9	20.1	1.2		19.8	20.8	1.0

Observed Shortcomings Current Model for Singapore

- Vascular Overestimation
- Diabetes (big drop in data)
  - Needs to be investigated
- Infant mortality
  - Current formulation insufficient
- Other Chronic
  - Apparently different trending

Microsimulation Comparison

- Use an individual level model
  - Large sample size but need not be representative
- Generate aggregated data
  - Level of detail flexible
  - Can have holes (for example no new people)
- Calibrate aggregate model to that data
  - Much like the Singapore work
- Policy test in both models

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Advantages of Combining Methods

- Achieve robustness in the macro model
  - Or at least understand the limitations
- Leverage the micro model to be more representative of the population
  - Response characteristics generalized
- Have a platform for experimentation
  - Fast simulation speed is a big asset

DUKE NUS GRADUATE MEDICAL SCHOOL SINGAPORE

Conclusions

- Aggregate modeling possible
  - Easy to simulate and get results
  - Comparable with readily available data
  - Supports flexible analysis
- More work needs to be done
  - Detailed assumptions need to be grounded
  - Disease progression representations improved
- Connecting with microsimulations is promising
  - Would allow best of both worlds

Ongoing Validation Work

- Continued literature search
  - Parameterizations in finer detail
- Make use of hospitalization data
  - Also helps with system cost estimates
- Microsimulation comparison
  - Testing policy responses

DUKE NUS
GRADUATE MEDICAL SCHOOL SINGAPORE