MULTI-BIRTH COHORTS: A METHOD FOR MODELING AGING POPULATIONS

Jeremy Sato, Peter Hovmand, Nishesh Chalise, Nancy Zoellner, Andrew brown, & Ken Carson

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Washington University in St. Louis Project 4 Role of Social Determinants in the Link between Obesity and Cancer Across the Lifespan (Project Leads: Peter Hovmand, Ken Carson and Graham Colditz)

Initial Model Used Aging Chains for At-Risk Populations
TRANSDISCIPLINARY RESEARCH ON ENERGETICS AND CANCER (TREC)

NHL and DLBCL Incidence Trend, 1973-2011

- **NHL Incidence**
- **DLBCL Incidence**

Age adjusted per 100,000

- Years: 1973 to 2011
<table>
<thead>
<tr>
<th>Method</th>
<th>Strengths</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>Aging Chain</td>
<td>• Distinguish Between Age Cohorts</td>
<td>• Cohort Blending ((Eberlein \ and \ Thompson,\ 2013))</td>
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<tr>
<td>Discrete-Time Delay (e.g. Conveyors)</td>
<td>• No Age Distortion</td>
<td>• Continuous-Time Flows (e.g. Immigration and Attribute-based Transitions)</td>
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<tr>
<td>Annual Cohort Tracking</td>
<td>• No Age Distortion</td>
<td>• One-Year Computation Interval</td>
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<td></td>
<td>• Accommodates Migration, Mortality</td>
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<tr>
<td>Continuous Cohorting (Eberlein and Thompson, 2013)</td>
<td>• No Age Distortion</td>
<td>• Software-Specific Implementation</td>
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<td>• Accommodates Migration, Mortality</td>
<td>• Moderate Computational Burden</td>
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<tr>
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<td>• Any Computation Interval</td>
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</tbody>
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ILLUSTRATION OF COHORT BLENDING

Birth Rate
(100 births/year)

Births

Under Target Age
(0-14 yrs)

Aging In
(Under Target Age) / Min Age

Target Age Group
(15-45 yrs)

Aging Out
(Target Age) / (Max Age - Min Age)

Deaths

Mortality FR

Min Age

Max Age

(15 yrs old)

(45 yrs old)
TREC PROJECT CONSIDERATIONS

- Accurate Aging, But Process Is Secondary
- CISNET (Cancer Intervention and Surveillance Modeling Network) Guidance for Cancer Modeling:
  - Multiple Cohorts (e.g. Sex, Race, Age)
  - Time-Varying Factors (e.g. Smoking Prevalence, HIV/AIDS Impact on Non-Hodgkin Lymphoma, Available Cancer Treatments)
- Traditional Aging Methods Time-Invariant
- Switched to Time-Varying Approach

\[
\begin{align*}
\text{Time-invariant models} & : \dot{x} = f(x) \\
\text{Time-varying models} & : \dot{x} = f(x, t)
\end{align*}
\]
Cohorts Defined by Birth Year Instead of Age

Age is Time-Varying

Population Risk Factors are Age- and Time-varying

Age \((\text{cohort } i, \text{year } t) = t – \text{Birth Year } (\text{cohort } i)\).

Cancer incidence fractional rate \((\text{cohort } i, \text{year } t) = f(\text{cohort } i, t)\)
1. Defining Cohorts and Using Arrays
2. Births
3. Deaths
4. Aging Out
IMPLEMENTATION NOTES: ARRAYS

Step 1: Build Model for Representative Cohort

Step 2: Define Cohorts; Convert to Arrays

Step 3: Initialize Stocks and Define Age- and Time-Varying Parameters
IMPLEMENTATION NOTES: BIRTHS

Births \((\text{cohort } i, t)\) = Birth rate \((t)\) * (STEP(1, Cohort Start(\text{cohort } i))) – STEP(1, Cohort End(\text{cohort } i))
Deaths \((\text{cohort } i, t)\) = Cohort_Population \((\text{cohort } i)\) * Data_Mortality_FR \((\text{cohort } i, t)\)
**IMPLEMENTATION NOTES: AGING OUT**

Aging Out \((Cohort \ i, \ t)\) = Population \((Cohort \ i)\) / (Ending Year \((Cohort \ i) + 45 - t\))

*for:*

Starting Year \((Cohort \ i) + 45 \leq t < \) Ending Year \((Cohort \ i) + 45\)
SUMMARY

- Continuous Time-Varying Approach Captures Period-Specific Exogenous Factors Such as Smoking and HIV/AIDS
- Model Focuses on Obesity and Cancer Without Sacrificing Age Distribution Accuracy
- Accommodates Multiple Inflows/Outflows (e.g. Immigration and Weight Transitions)
- Straightforward Implementation Using Stocks and Arrays
- Developed a Re-Usable National Population Dynamics Model