Towards Dynamic Modelling of Demographic & Socio-Economic Evolution

Presentation in the TMG Workshop,
Population Synthesis Methods for the GTHA
Toronto, December 9, 2020

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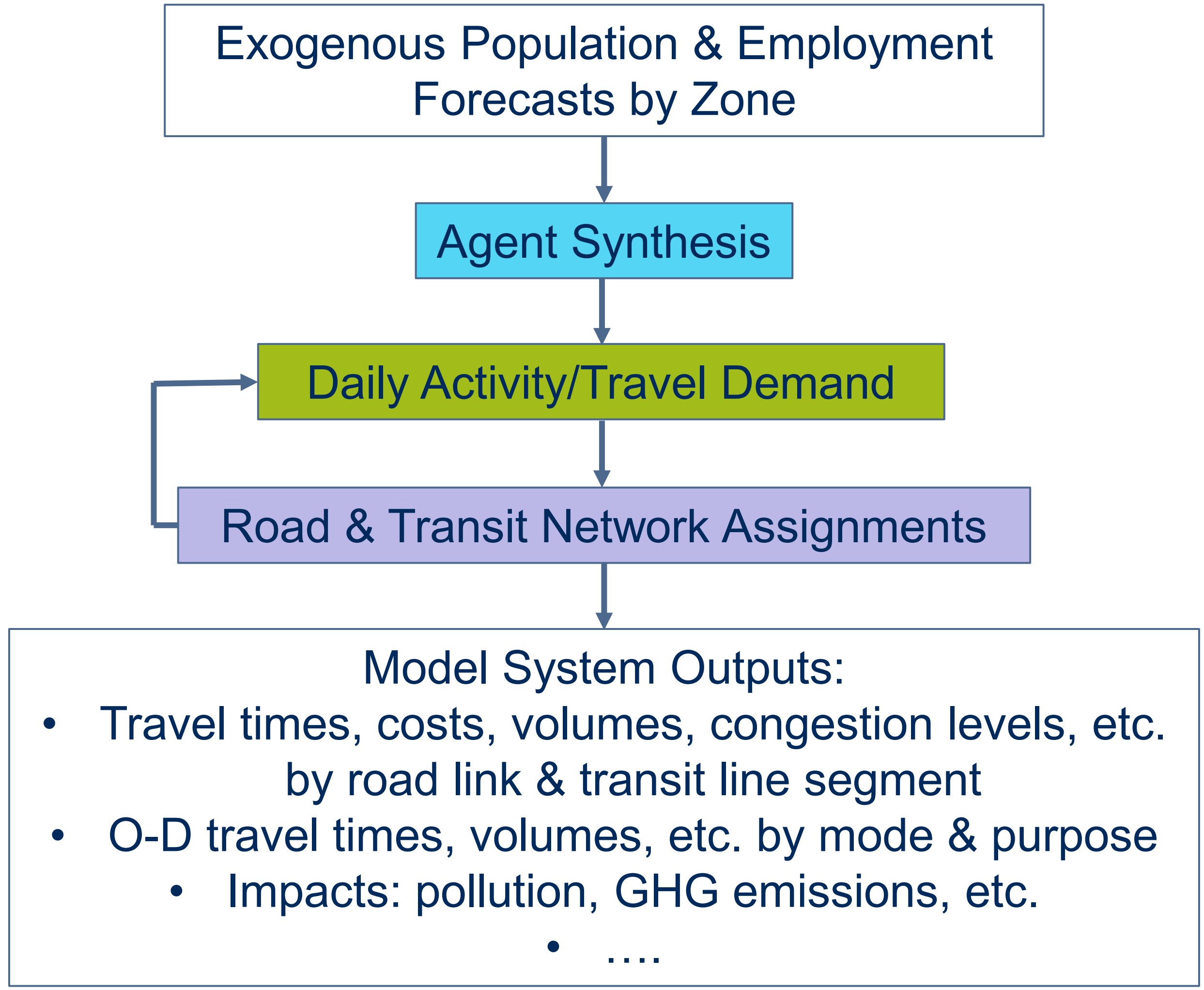
Presentation Outline

- Problem definition.
- Static vs. dynamic forecasting.
- An evolutionary demographic forecasting model.

This presentation is based on: *Miller, E.J. (2020) Modelling Demographic & Socio-Economic Evolution: Issues, Options & Propositions for Model Improvement, a Discussion Paper prepared for Metrolinx, August. https://tmg.utoronto.ca/files/Reports/Modelling-Demographic-Evolution_EJMiller_August-2020.pdf*

Problem Definition (1)

- At a very high level of abstraction, both GGHM & GTAModel can be represented as consisting of 3 “meta components”.



Problem Definition (2)

Exogenous Population & Employment Forecasts by Zone

Person & Household Synthesis

Population Synthesis:

- Demographic attributes
- Socio-economic attributes
  - Labour force participation
- Create households
- Assign persons to households

PoRPoS Linkages

Job & Labour Market Synthesis

Job Synthesis:

- Synthesize jobs by category

PoRPoW Linkages

Mobility Tool Synthesis*

Driver's Licenses

Household Auto Ownership
And/or car-sharing membership**

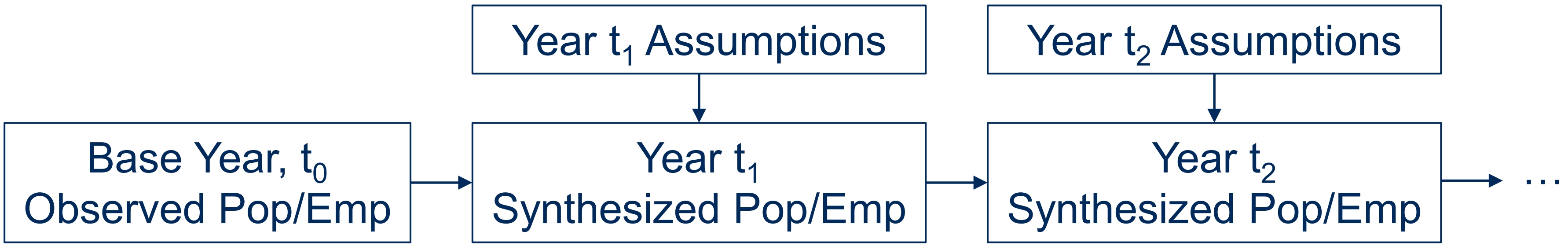
"Agent synthesis" can be decomposed as illustrated.

* GTAModel V4.1 does not synthesize transit pass ownership.
** Car-sharing membership is not modelled in GTAModel V4.1.

Static Forecasting

- Forecast year synthesized population & employment directly generated based on assumptions concerning forecast year rates, parameters, etc.
- No evolution of the system over time.
  - No path dependency.
  - No influence initial, base conditions.
- Strong static, equilibrium assumptions.
  - Although equilibrium conditions are not usually explicitly enforced.

Dynamic Forecasting



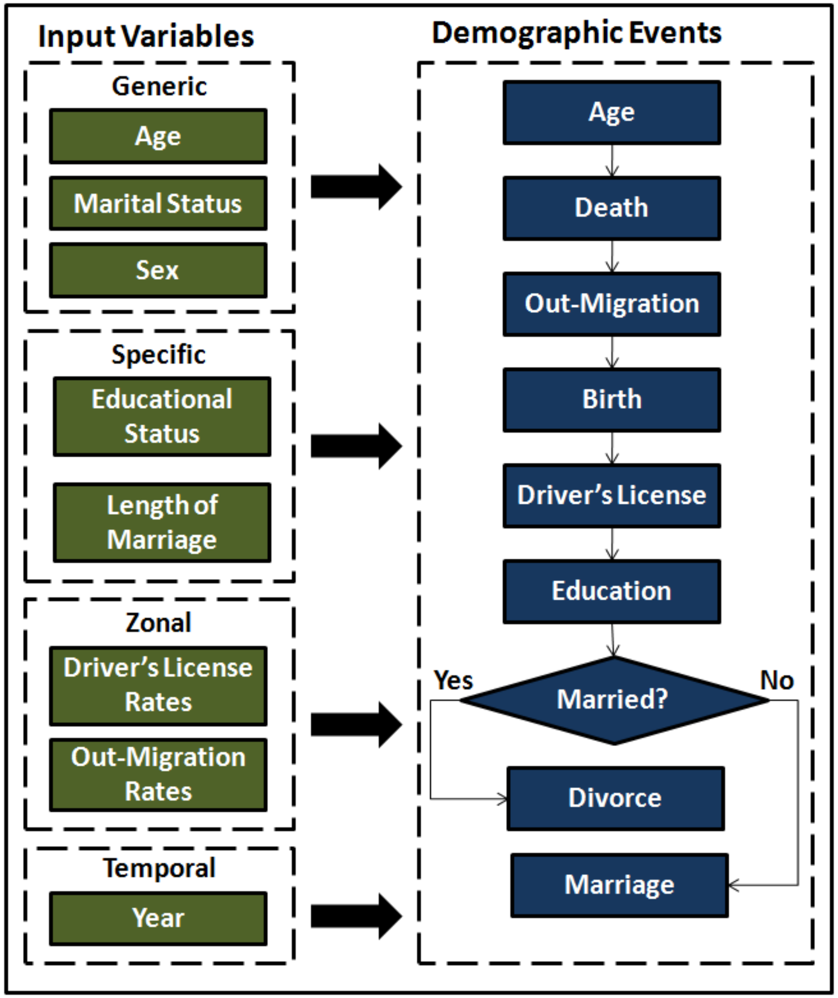
- Population & employment evolves in incremental (annual) steps.
- Path dependent: $Pop(t + \Delta t) = Pop(t) + \Delta Pop(\Delta t)$
- Consistent with / dependent on the initial state.
- Can co-evolve ELF & EMP.
- Travel demand can be consistently generated at intermediate years (if desired), not just the forecast end year.
- Do not need to assume equilibrium at any point in time.
- Can generate multiple futures, if desired.
- Important step towards integrated urban models.

Demographic Updating

- A demographic updating procedure has been developed for the GTHA that updates household, family & person attributes each year in a simulation run.
- Assumed transition rates by year, categorized by agent attributes are used.

Demographic Updating

- Closed and discrete time model
  - social networks are maintained
- Individuals, families and households
  - relationships managed throughout the simulation
- Processes
  - birth & death, marriage & divorce, in-/out-migration, move-out, driver's license and education
  - different model types as appropriate
- Data Sources
  - 12 distinct data series from Statistics Canada, the Transportation Tomorrow Surveys, and Ontario registry data from 1986 to 2006



Updating Variables

Socioeconomic Variables	Events							
	Age	Death	Out-Migration	Birth	Driver's License	Education	Marriage	Divorce
Age	X	X		X	X	X	X	
Marital Status		X		X			X	X
Sex		X			X		X	
Driver's License Status					X			
Educational Status						X		
Length of Marriage								X
Driver's License Possession Rate					X			
Out-Migration Rates			X					
Year		X	X	X	X	X		

Person Agent Updates

- Age
- Determine whether this person dies this time period (*death*).
- If a single adult, determine whether this person out-migrates this time period (*out-migration*).
- If a female of child-bearing age, determine whether she gives birth this time period (*birth*).
- If 16 years of age or older, determine:
  - Driver's license status
  - Education participation status (*education*)
- If single, determine if this person:
  - Marries this time period (*marriage*).
  - Moves out of the household this time period.

Family Updates

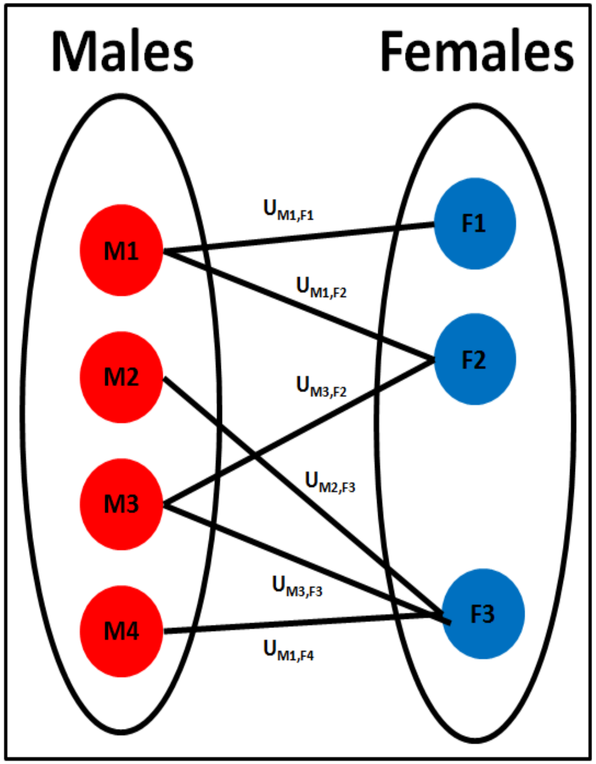
- Determine if the family will out-migrate this time period.
- If a husband-wife family, determine if they will divorce this time period (*divorce*).
- If in a multi-family household, determine if the family will move out of the household this time period.
- Update pointers to family members & family type, as required.
- Family ceases to exist if:
  - A single parent dies. The surviving children are allocated to other families/households.
  - No children remain at home in a single-parent family, either through adult children moving out to form their own households or through death of the children.
  - A husband-wife couple with no children divorces.

Household Updates

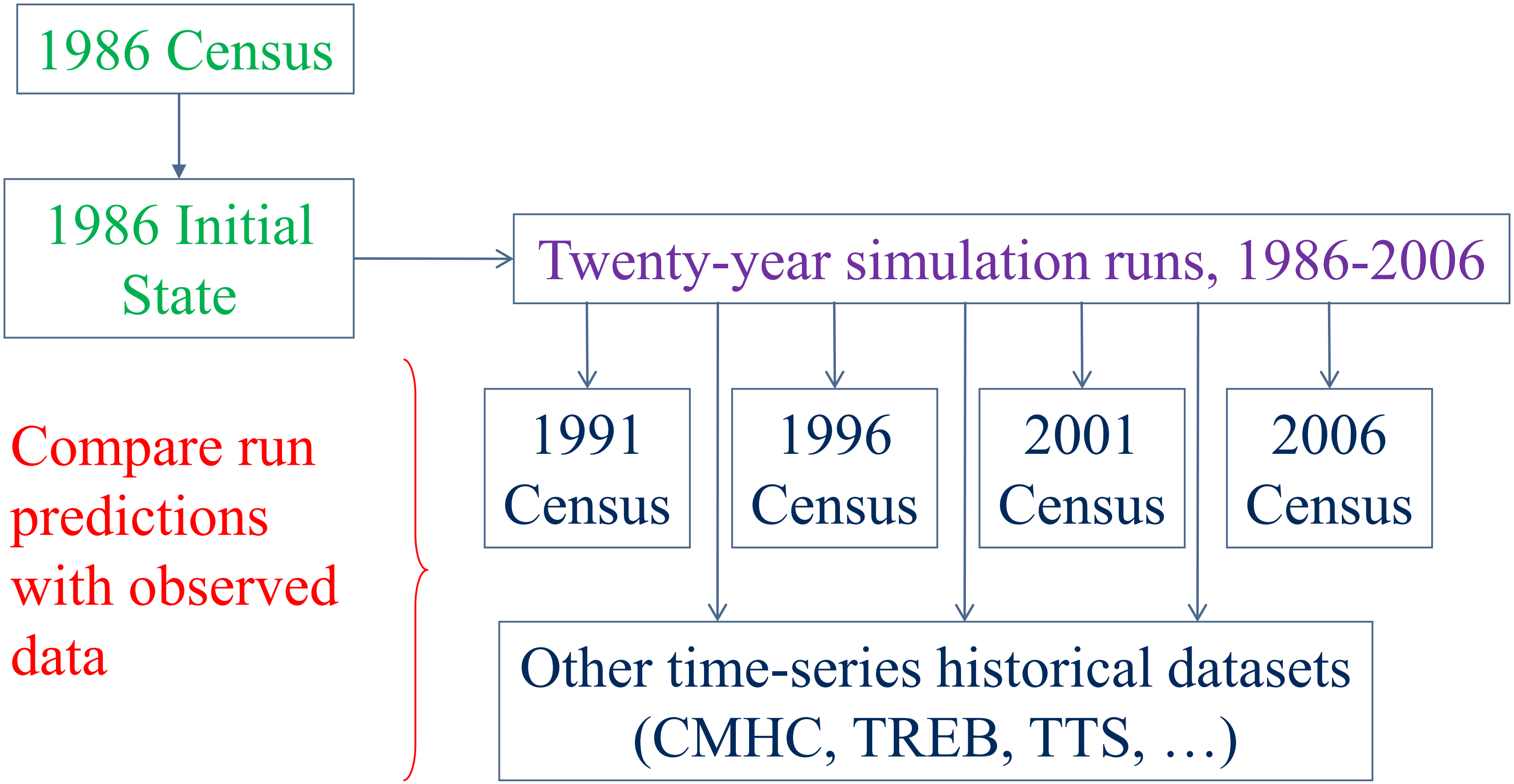
- Update pointers to persons & families, as required.
- Update household type, as required.
- Household ceases to exist if no persons are left in it.

Modelling Marriages

- Marriages can be modelled as a "fixed-price" (=0) "market" in which males and females are matched on a utility maximizing basis.
- The basic algorithm is being applied to other "fixed-price" markets (labour, rental housing, …)



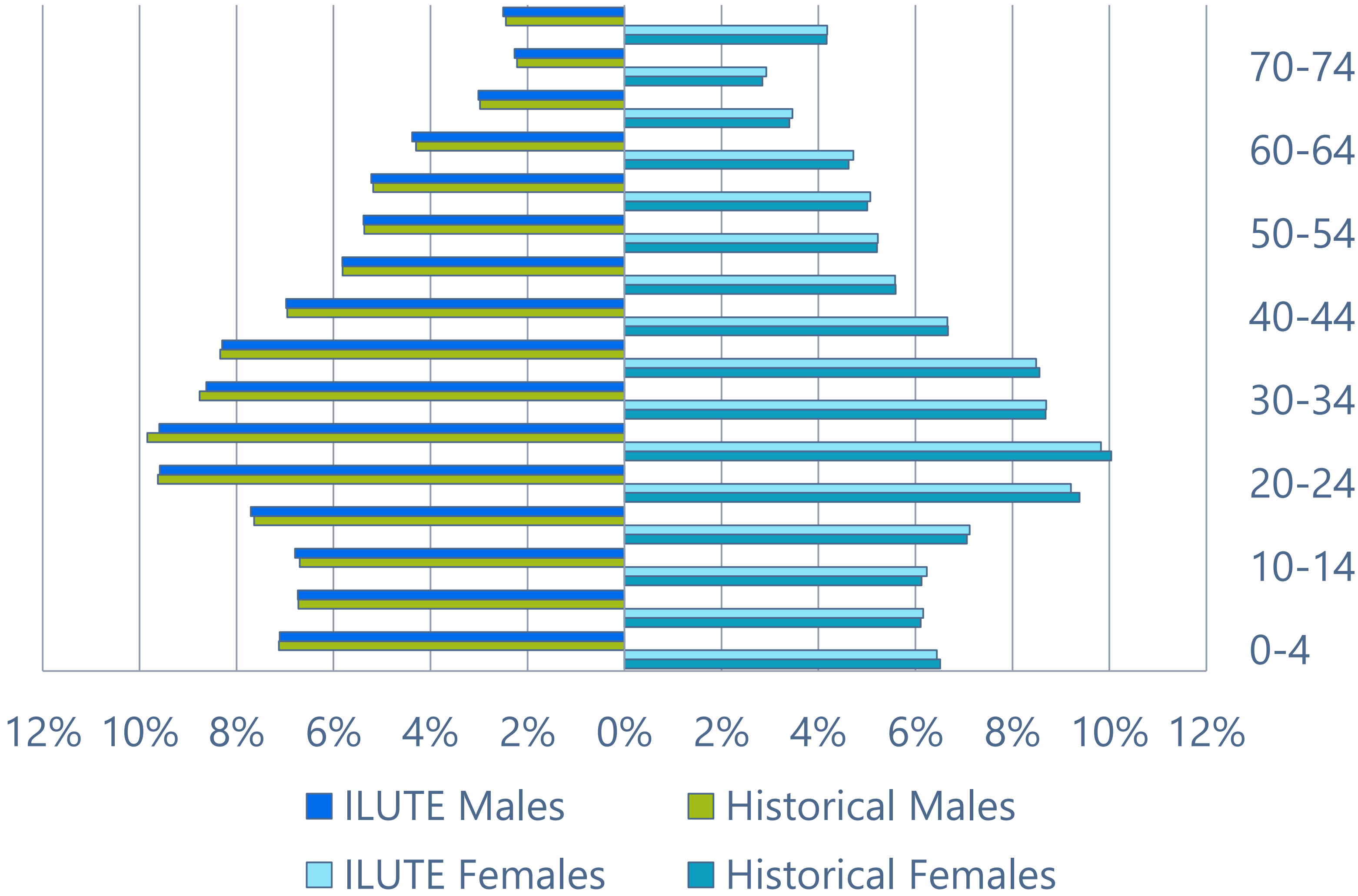
Historical Test Runs, 1986-2006



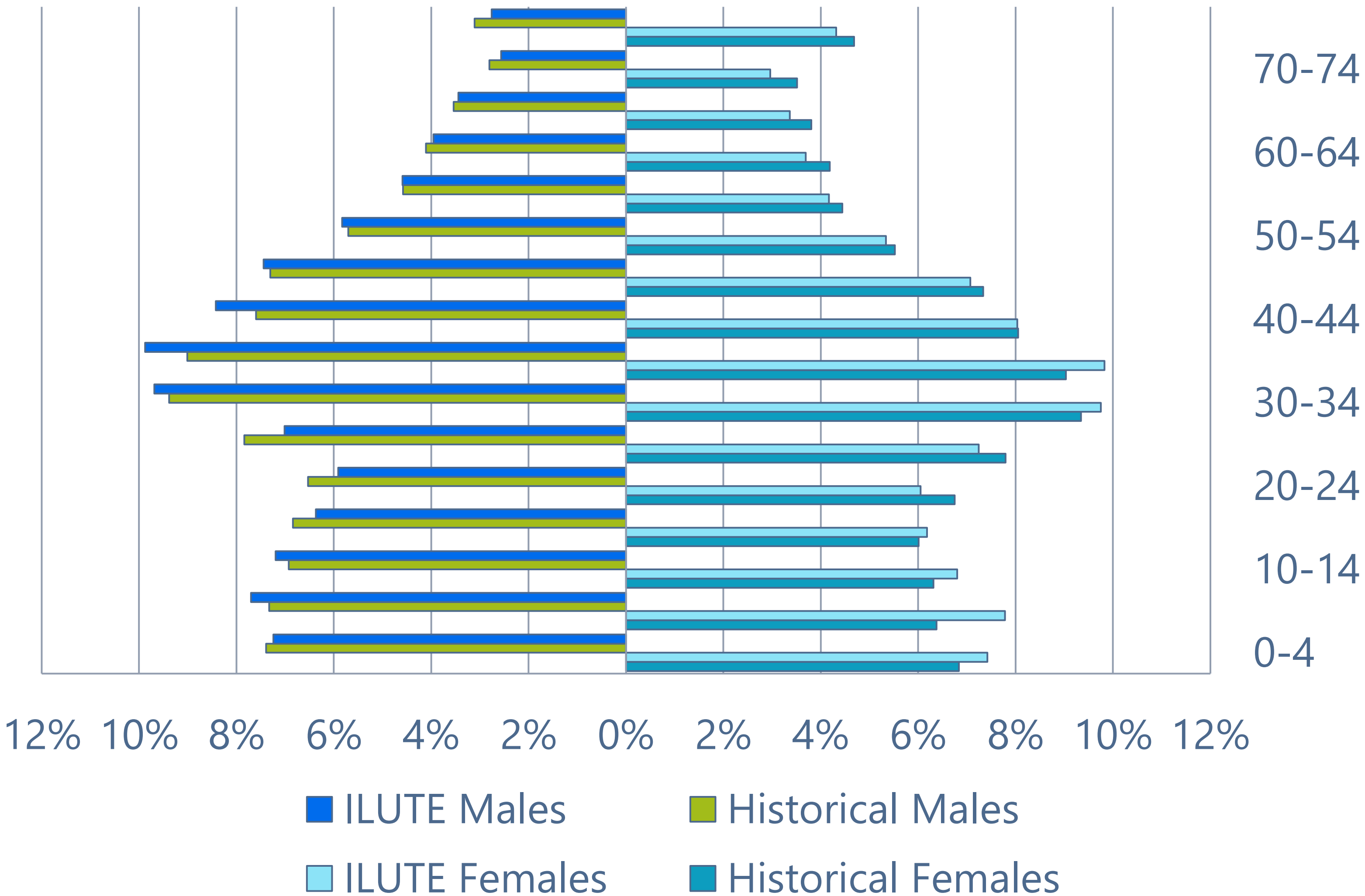
Sample Results

- Full population run
  - 20 years from 1986 to 2006
  - ~4 million to ~6 million people
  - ~1.5 million to ~2 million households
- Parallelized implementation

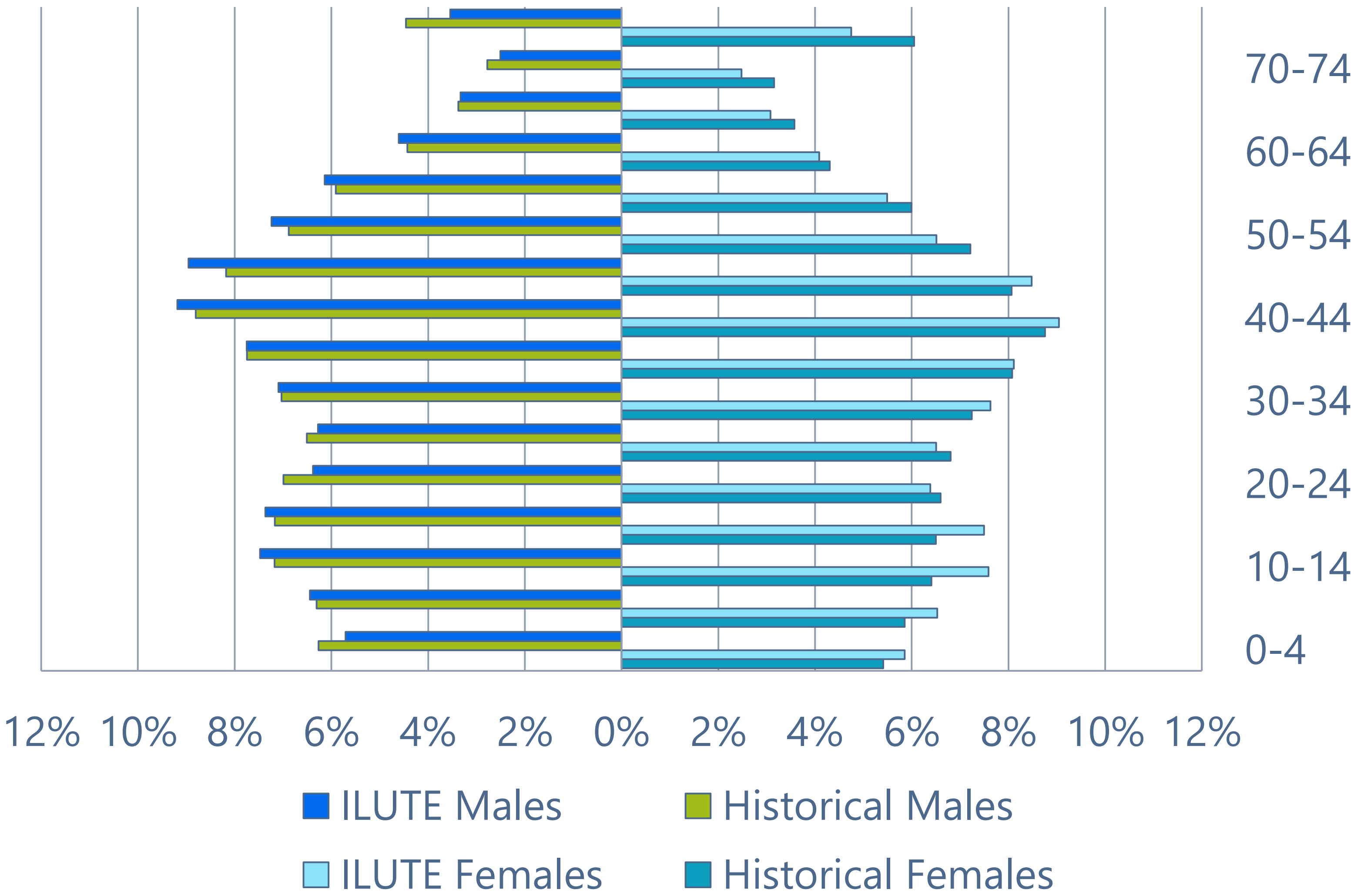
1986 Age Distribution

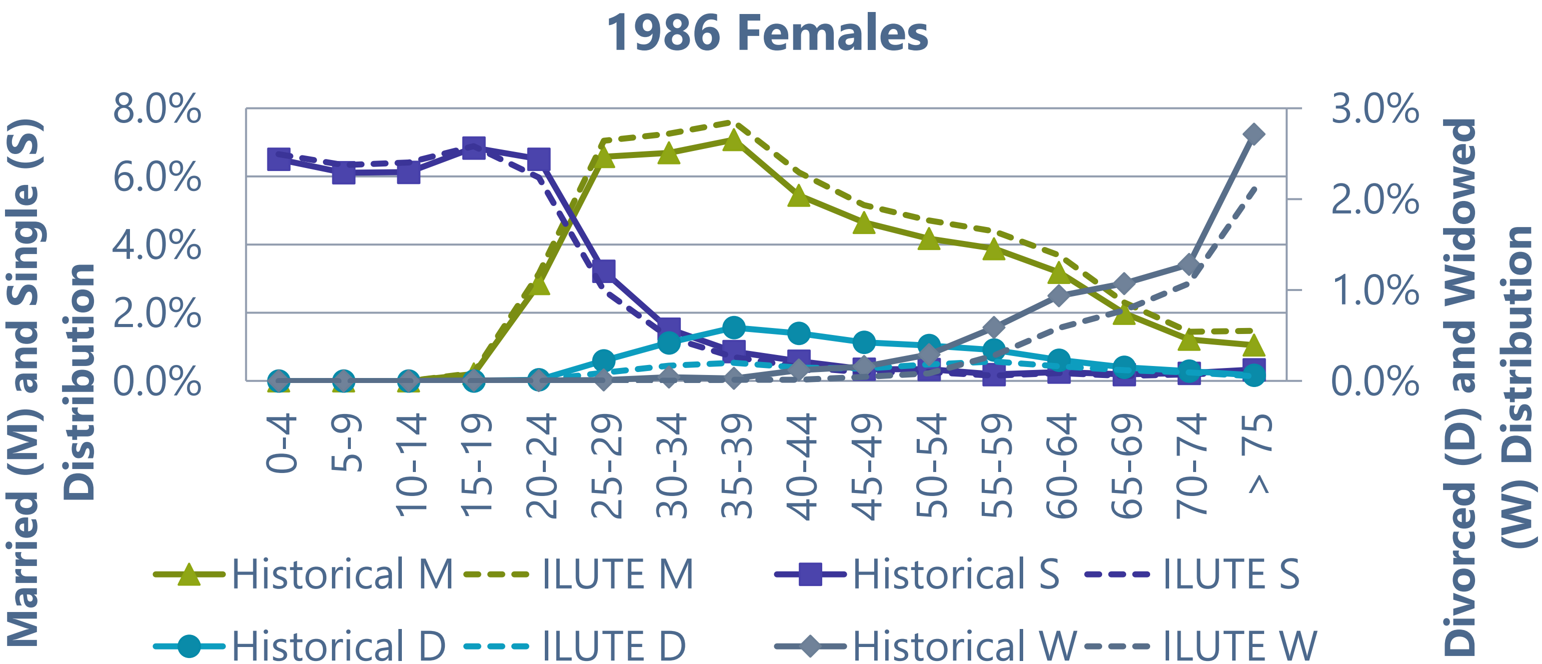


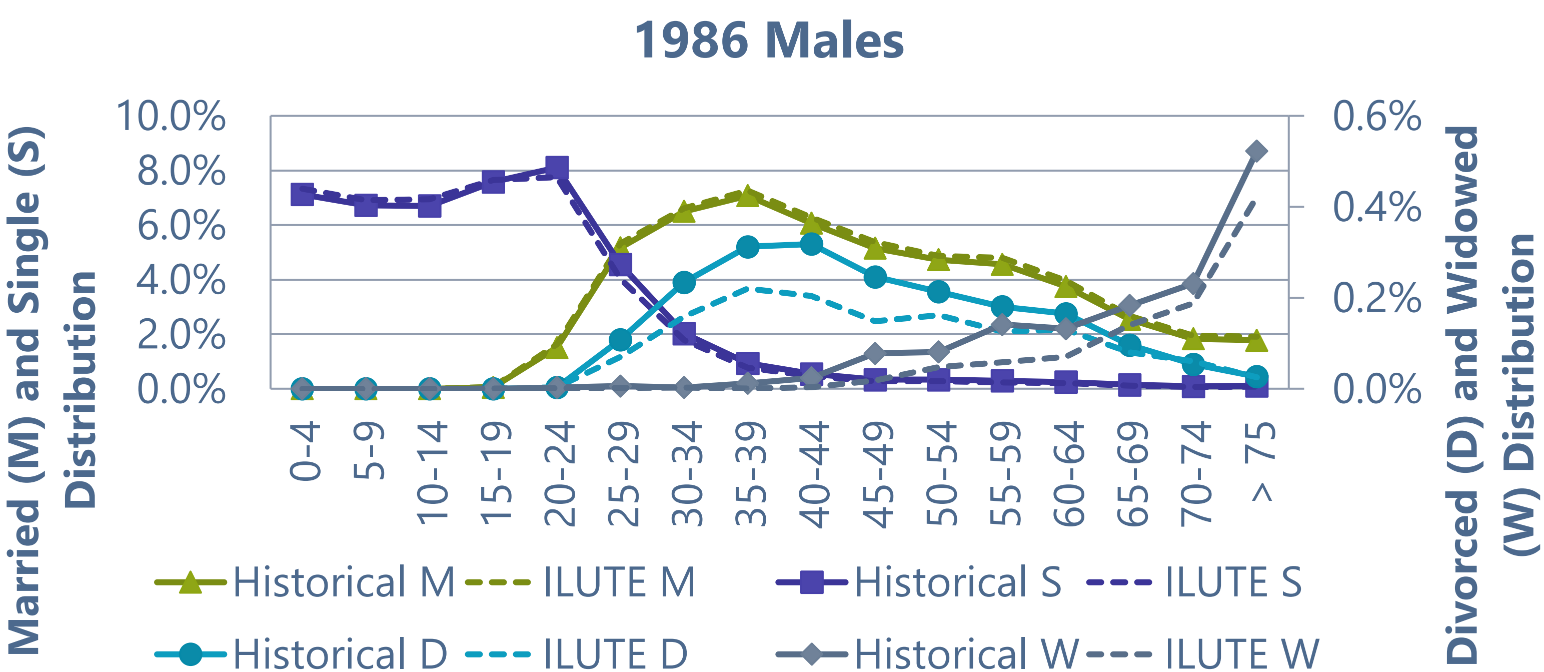
1996 Age Distribution



2006 Age Distribution




1986 Females
8.0%
6.0%
4.0%
2.0%
0.0%
3.0%
2.0%
1.0%
0.0%
Married (M) and Single (S) Distribution
Divorced (D) and Widowed (W) Distribution
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
> 75
Historical M
ILUTE M
Historical S
ILUTE S
Historical D
ILUTE D
Historical W
ILUTE W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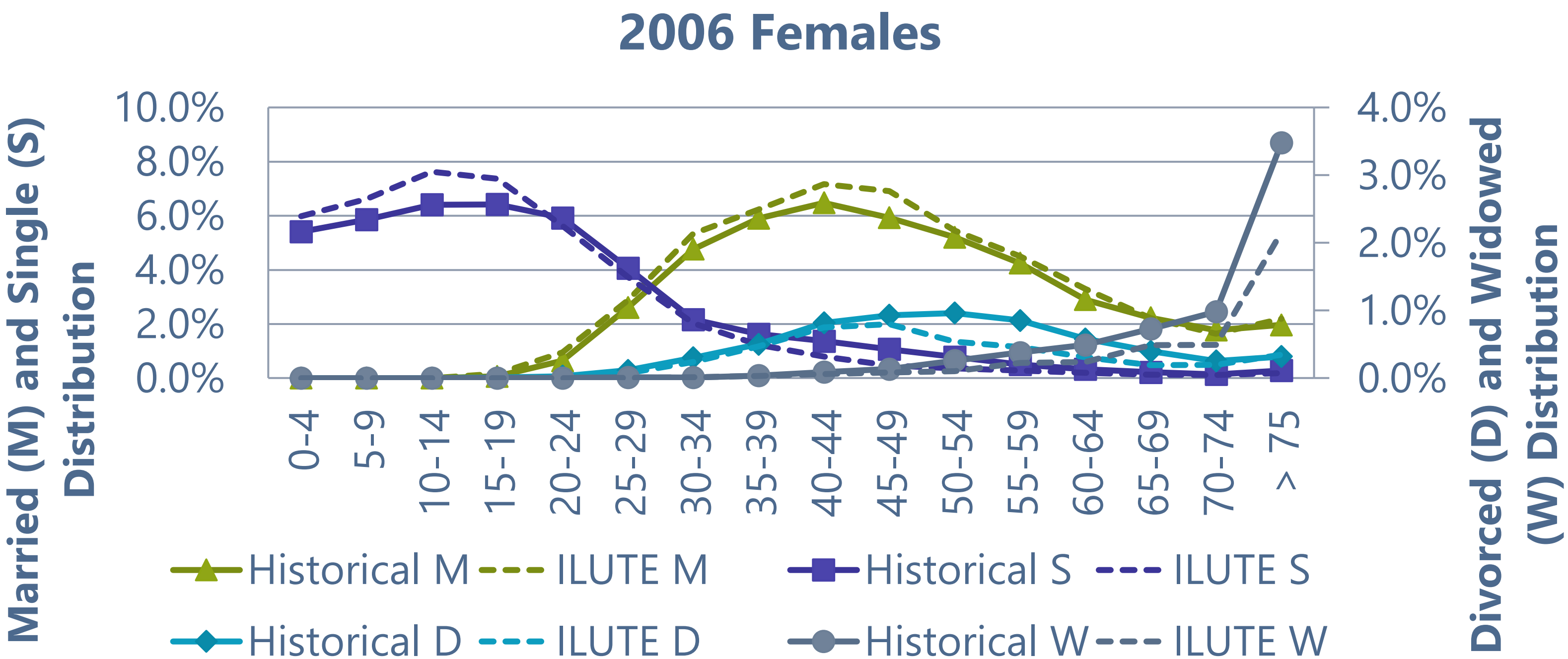
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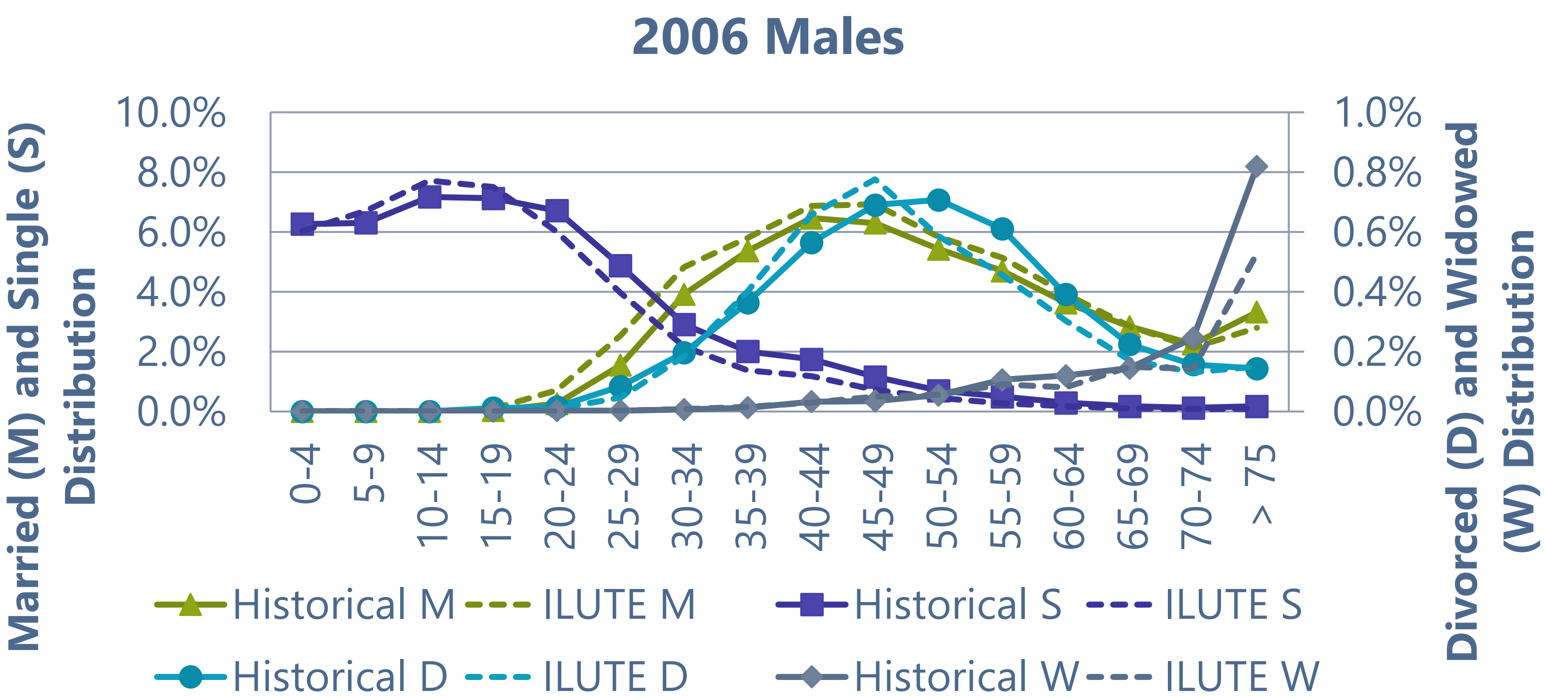
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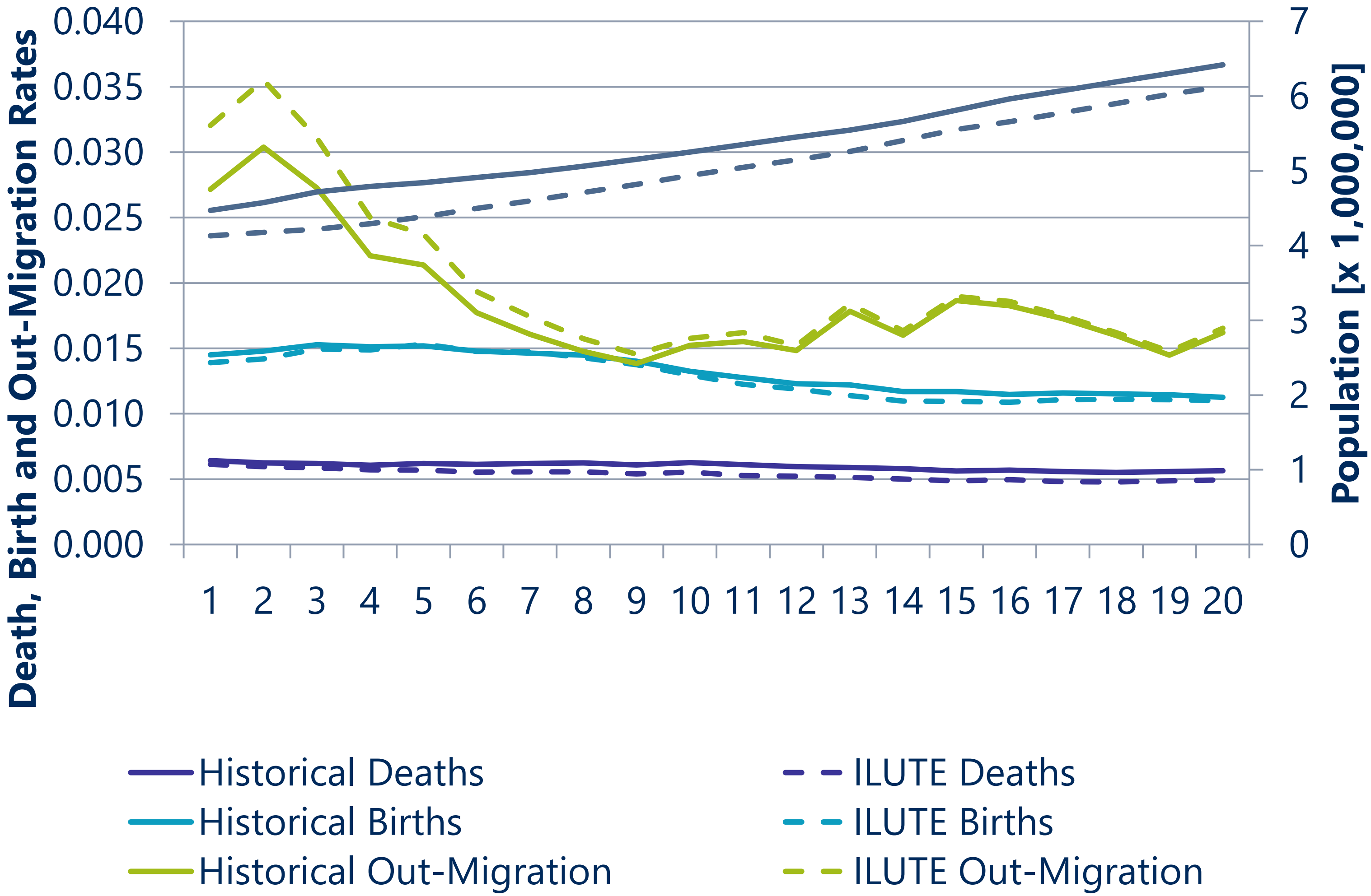
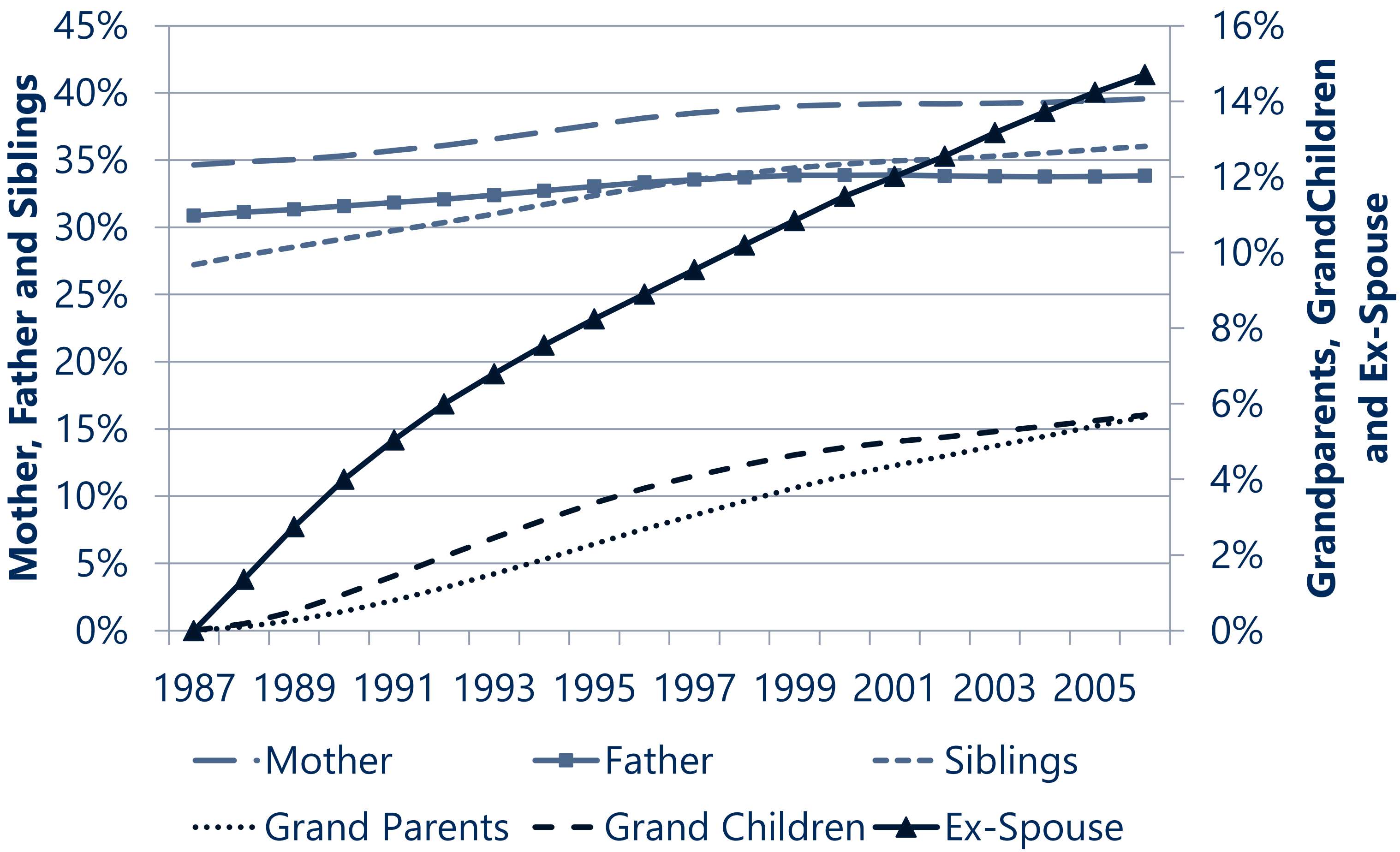
ILUTE vs. historical household type distributions

		Single Indiv	Multi Indiv	Single Fam	Single Fam Indivs	Multi Fam
StatsCan	1986	20.8%	2.8%	74.0%	2.2%	0.1%
	1991	21.4%	3.7%	71.6%	3.1%	0.2%
	1996	22.0%	3.0%	72.5%	2.2%	0.2%
	2001	22.2%	2.9%	72.6%	2.1%	0.2%
ILUTE	1986	21.1%	3.3%	74.1%	1.0%	0.5%
	1991	23.3%	2.8%	71.9%	1.8%	0.4%
	1996	25.3%	2.4%	70.4%	1.7%	0.3%
	2001	27.3%	2.2%	68.7%	1.5%	0.3%

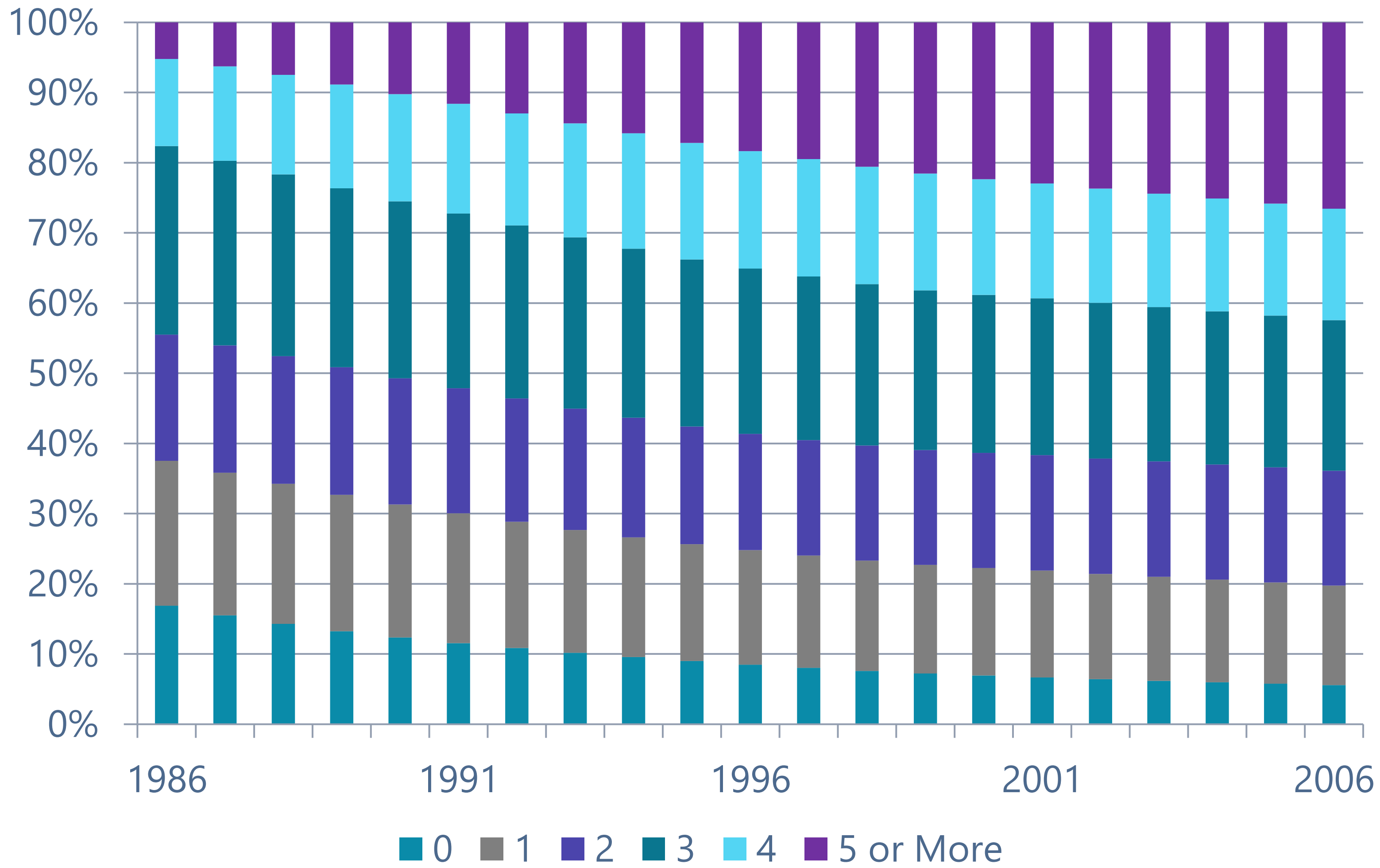
Source of Population Changes



Percent of ILUTE population with a particular relationship over time



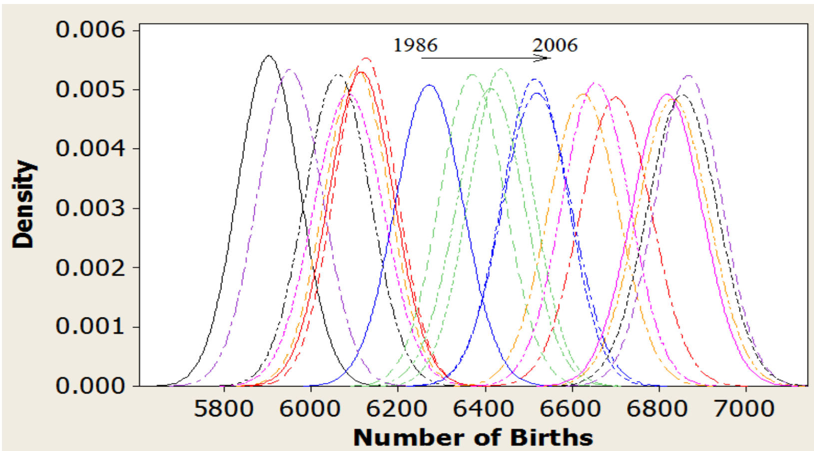
"Social Connections"



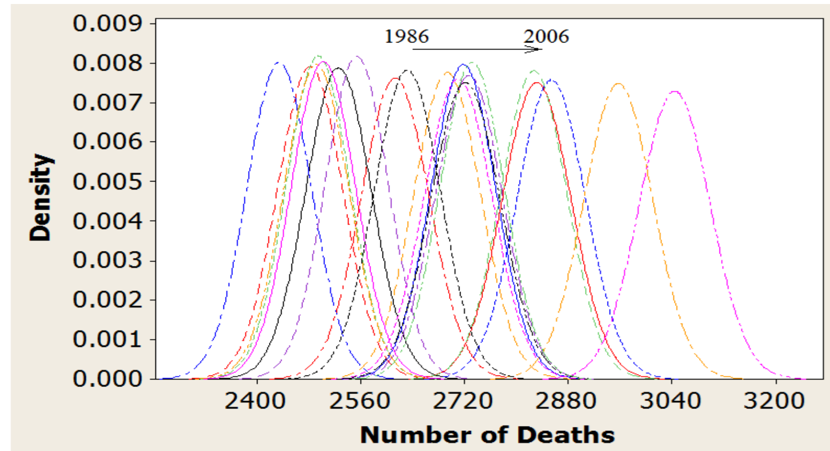
Statistical Tests

- 1000 replications.
- Different starting seeds for each replication.
- 10% sample to speed up run times.

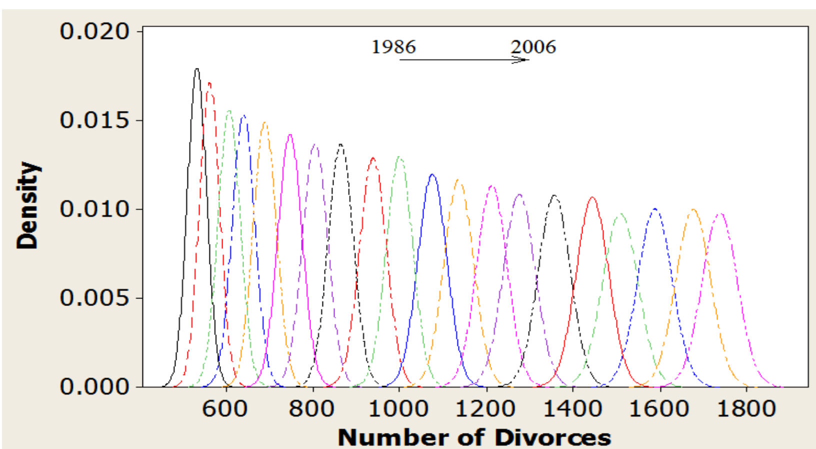
Births, Deaths, Marriages and Divorces



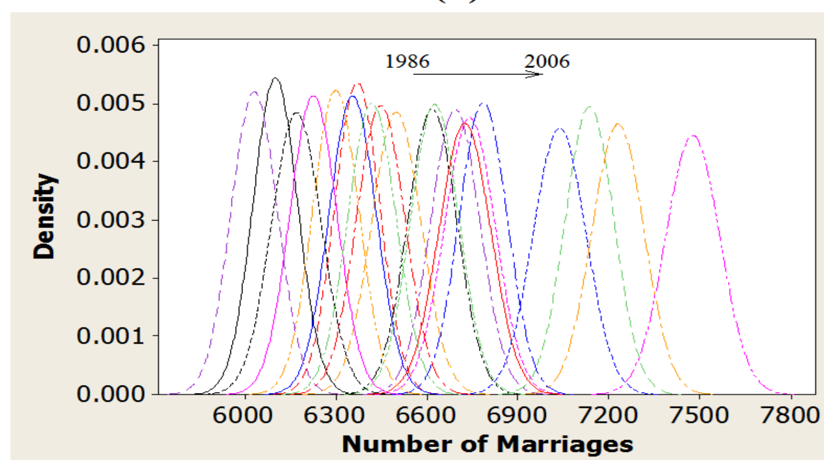
(a)



(b)

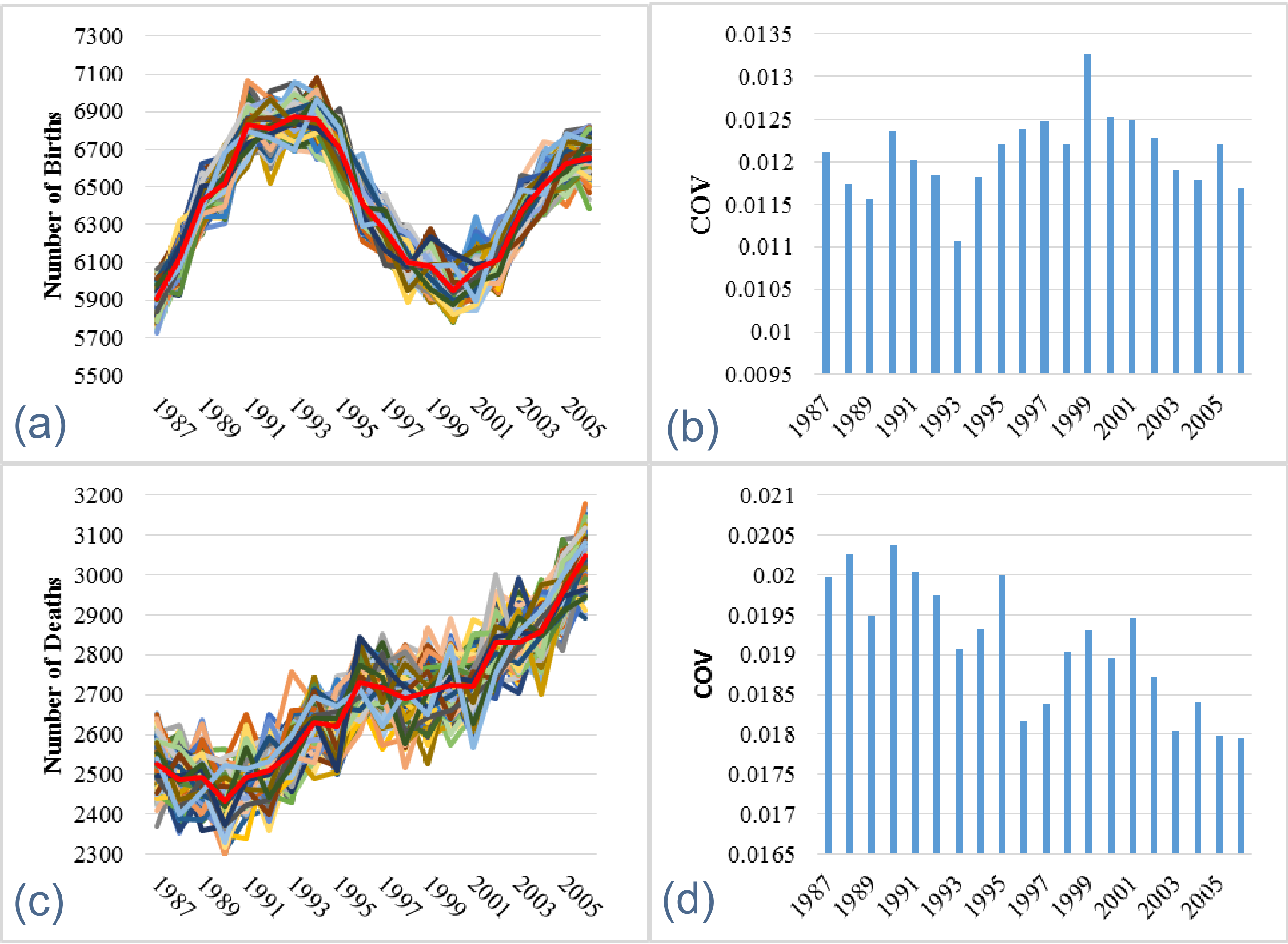


(c)

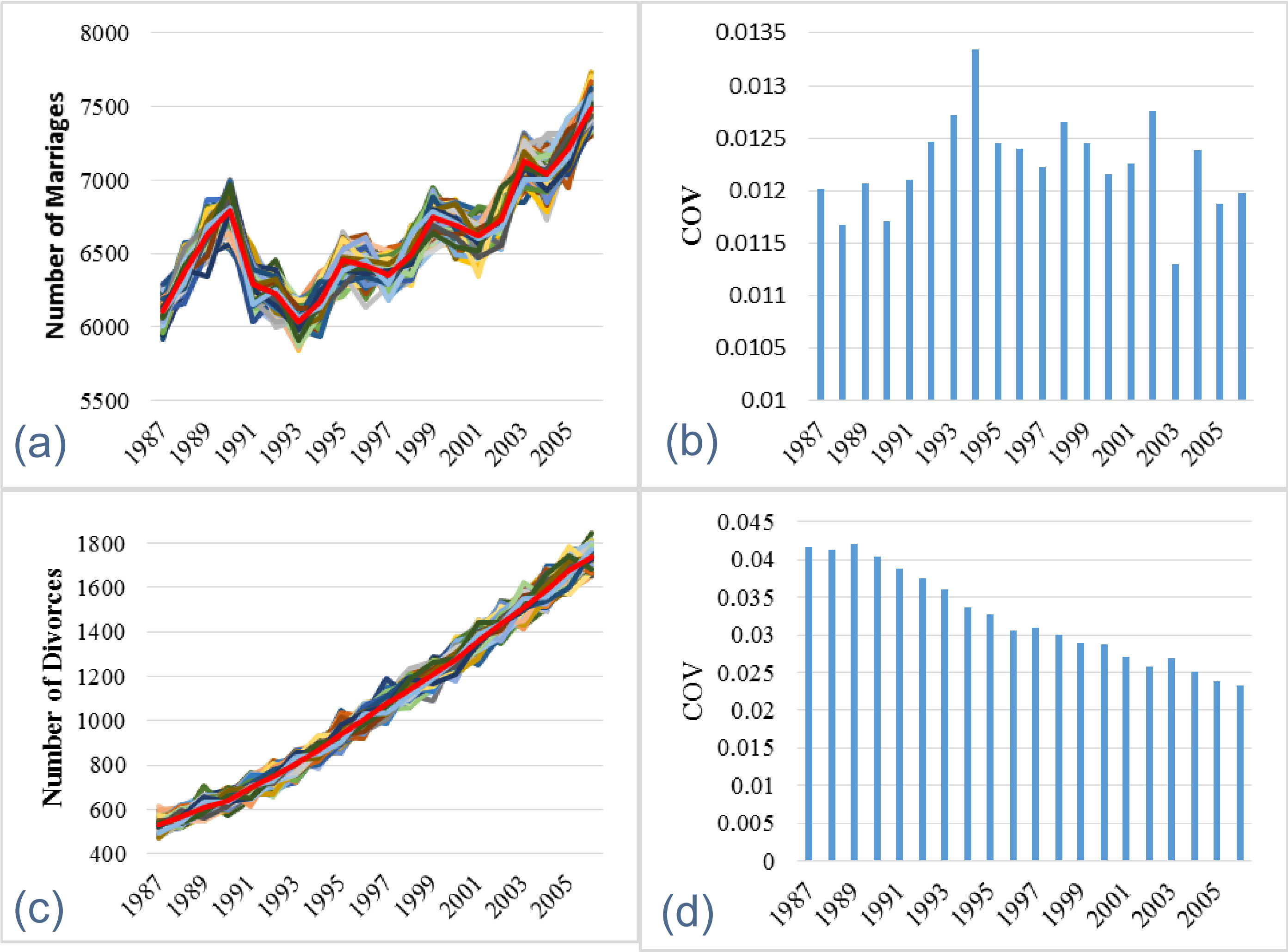


(d)

Spread in Number of Births and Deaths

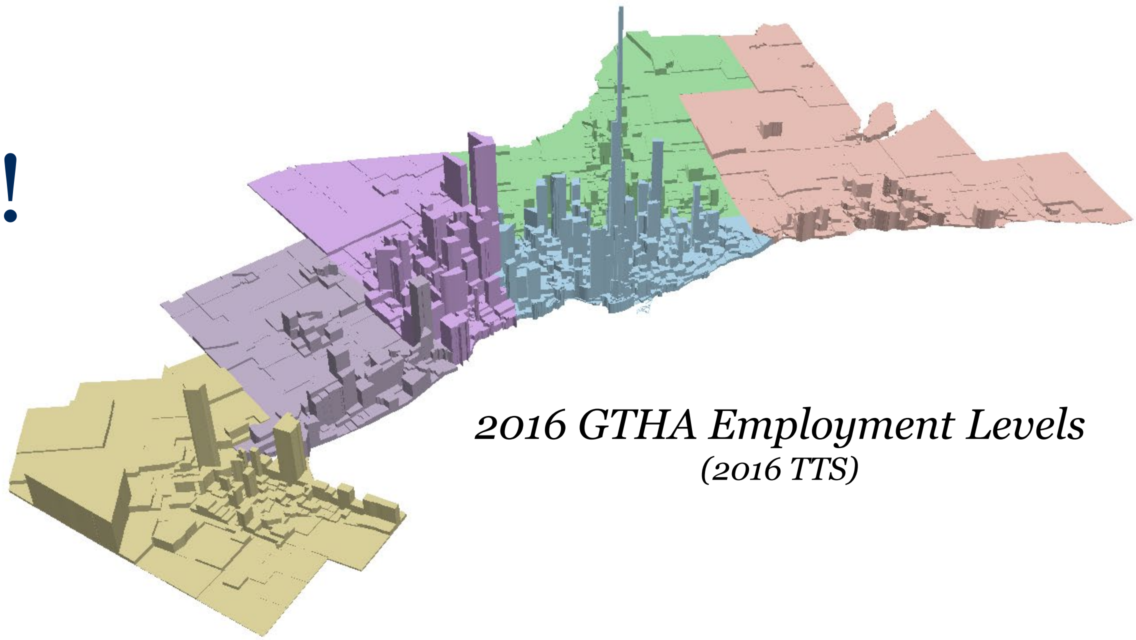


Spread in Number of Marriages and Divorces



Thank you.

Let's discuss!



2016 GTHA Employment Levels
(2016 TTS)

A few references

Chingcuanco, F. and E.J. Miller, "The ILUTE Demographic Microsimulation Model for the Greater Toronto-Hamilton Area: Current Operational Status and Historical Validation", GeoComputational Analysis and Modeling of Regional Systems , J.C. Thill and S. Dragicevic (eds), Springer, 2018, pp. 139-162.

Beykaei, S.A. and E.J. Miller, "Testing Uncertainty in ILUTE - An Integrated Land Use-Transportation Microsimulation Model of Demographic Updating", *Journal of Civil and Environmental Engineering*, 7:1, 2017, 1-9. DOI: 10.4172/2165-784X.1000264.

Chingcuanco, F. and E.J. Miller, "A Demographic Microsimulation Model for the Integrated Land Use, Transportation, Environment (ILUTE) Model System", pre-print CD 92nd Annual Meeting of the Transportation Research Board, Washington, D.C., January, 2013.

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Miller, E.J., F. Chingcuanco, B. Farooq, K.M.N. Habib and M.A. Habib, *Development of an Operational Integrated Urban Model System, Volume IV: Demographic & Labour Market*, Toronto: Urban Transportation Research & Advancement Centre, University of Toronto, December, 2008, 42 pages.

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