Demographic Microsimulator for Integrated Urban Systems: Adapting Panel Survey of Income Dynamics to Capture the Continuum of Life

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ABSTRACT

Most of the **synthetic population generators** are cross sectional in nature and do not account for households' and individuals' life progression **which has been proved to have impact on short- and long-term transportation decisions**

This paper proposes a **demographic microsimulator (DEMOS)** to capture the *'continuum of life'* by accounting for lifecycle events

Panel Study of Income Dynamics (PSID) Survey – one of the world's longest running longitudinal surveys – is leveraged to develop DEMOS sub-models

DEMOS considers **key lifecycle events** which are influenced by host of demographic variables. The framework is applied to evolve the synthetic population of **San Francisco (SF) Bay Area** over a **9-year horizon**

Findings show DEMOS can effectively capture the linkage between household-level and individual-level evolution, highlighting the importance of a **structural evolution framework** to capture population trends accurately

RESEARCH MOTIVATION

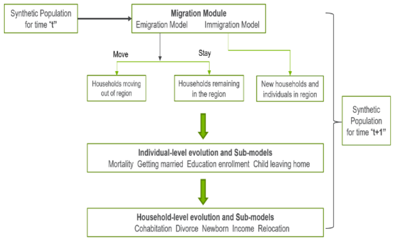
Activity-based models (ABMs) usually require a region's population and its composition as a key input. Such models often rely on **cross-sectional** synthetic population data to forecast travel demand and evaluate transportation policies

Using cross sectional information limits the ability of ABMs to capture people's travel related decisions impacted by lifecycle events (e.g., a newborn event influences household vehicle purchasing decisions and utilization)

While some **demographic evolution models** were proposed in the past few years, most of them **rely on cross-sectional survey data** which do not capture household dynamics (i.e., timing and sequence of important lifecycle events)

DEMOS models **key lifecycle events** using PSID data and evolves the demographic characteristics by capturing the **interdependencies between short and long-term lifecycle events**

DEMOS FRAMEWORK



Initiate with a **base-year (t)** synthetic population which is advanced through a host of key lifecycle events

Households and individual-level characteristics are updated and provided as inputs to subsequent year's (t+1) population evolution

This process is repeated to **evolve the population** of a study region over a span of 10-30 years

Each module in the DEMOS framework comprises a series of sub-models to **predict the changes in demographic characteristics** of synthetic households and individuals

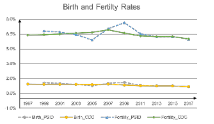
PANEL STUDY OF INCOME DYNAMICS

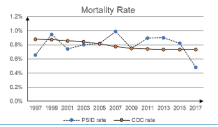
PSID is one of the **world's longest-running national representative longitudinal surveys**, collecting longitudinal data from 1968 - current on a wide range of socioeconomic, demographic, health, and attitudinal characteristics

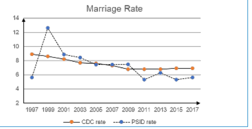
In PSID, household- and individual-level information is recorded **annually or once every two years**

The dataset used for this study is from the years 1997-2017, which had information from 13,900 households and 41,506 individuals

The PSID data show consistent trend for **Birth and Fertility**, **Mortality, and Marriage rates** as data from **Center for Disease Control and Prevention (CDC)**, which gives confidence in using the PSID data for Demographic evolution modeling







DEMOS MICROSIMULATION PROCESS

The demographic evolution process starts with the **ageing model** and updates the age of all agents in the base-year synthetic population

Out-migration, in-migration, and mortality models determine the agent population that needs to progress to the next simulation time-step

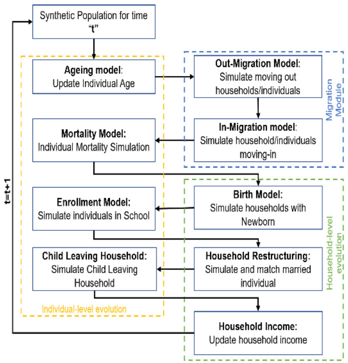
Birth event is considered as a household-level decision, and females aged 14-45 years are considered likely to give birth

Education enrollment model is applied to individuals above 16 years to predict whether (or not) they would continue to receive education

Household restructuring module considers single-to-X model, cohabitation-to-X model, and married to-X model to capture marital status change

Leaving parental home covers the situation of adult children (a) continuing to stay at parental home or (b) moving out to be a household head and/or to form a cohabitation or marriage relationship

Most of the models are estimated using the logit structure while a few are implemented using a rate-based approach



CASE STUDY IN SAN FRANCISCO BAY AREA

To **test the DEMOS framework**, a case study was carried out using data from the San Francisco (SF) Bay Area, California

The 2010 base-year synthetic population for SF Bay Area used in this study comprises ≈**7M** individuals residing in ≈ **2.6M** households

The **DEMOS sub-models** detailed in the previous section are **applied to the synthetic population** in order to simulate the combined effect of the interactions among all lifecycle events

The synthetic population was evolved over a **9-year** timespan with **2010** as **year 't'**

It can be observed that **evolution of total number of households in the region** (across the simulation time horizon) is captured well

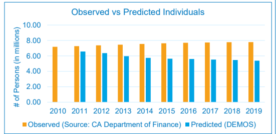
However,

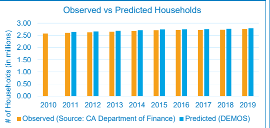
DEMOS is seen to systematically **underpredict** the number of **synthetic individuals** in the study region. This results from:

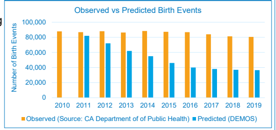
(a) The single-to-X sub-model predicting a higher proportion of individuals staying single, compared to those who chose to get married

(b) Increase in single person households creating a cascading impact on childbirth

The **lessons learned** from this exercise can inform ways to better implement and interact household- and individual-level evolution mechanisms







CONLUSIONS AND IMPLICATIONS

The demographic simulator (DEMOS) proposed in this paper covers the **entire spectrum of household- and individual-level lifecycle events** and is powered, by data from the **Panel Survey of Income Dynamics (PSID),** which is one of the **world's longest running longitudinal household surveys**

DEMOS captures a **host of lifecycle events** including migration, individual-level events (e.g., education attainment, marriage, mortality), and household-level events (e.g., childbirth, family formation/dissolution)

Model results indicate that **gender, age, education attainment, household size, and income** influence key lifecycle events such as cohabitation, marriage, childbirth, and adult children moving out

The DEMOS framework was tested by applying its sub-models to evolve a synthetic SF Bay Area population from 2010-2019; this initial test captured **household evolution trends well**, but underestimated evolution of the total number of people in the SF Bay Area

Lessons learned from this effort underscore the importance of **household restructuring** in the evolution process and led to re-evaluation of the **model sequencing** in DEMOS as an alternate to model **causal structure** may impact population evolution trends

DEMOS enables **travel demand models** to evaluation the impact of different demographically sensitive policy and technology evolution scenarios, such as adoption and utilization of automated vehicles, electric vehicles, micromobility trends, and shared mobility services

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