
Technical note

# Overview of the Agent Based Consumption Model

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NineSquared

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# 1. Introduction

This technical note provides an overview of NineSquared's Agent Based Consumption Model (ABCM) and its underlying synthetic population. It explains our approach to developing agents and compiling them to a synthetic population and presents possible applications.

### The framework: Agent Based modelling

In agent-based modelling (ABM), a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions based on a set of rules. Agents may execute various behaviours appropriate for the system they represent — for example, producing, consuming, or selling. They can act independently or be influenced by each other.

### The basis: A synthetic population

At the heart of every agent-based model is a synthetic population which represents one possible set of best estimates of the actual population. In such a population, agents, and their characteristics (attributes) can be grouped at different geographic levels with localised weights to model the behaviours of people in those areas. For example, the synthetic population used in our model provides the opportunity to allocate data available at a low geographic granularity to small areas and to form robust views of local consumption or other behaviour patterns.

### The application: Consumption modelling

ABM can be particularly useful when there is potential for emergent phenomena, that is, when:

- There is little or no data available on observed behaviour and responses
- Individual behaviour is nonlinear and can be characterised by thresholds, if-then rules, or nonlinear coupling
- Individual behaviour exhibits memory, path-dependence, hysteresis, non-markovian behaviour, or temporal correlations, including learning and adaptation
- Agent interactions are heterogeneous and can generate network effects
- Averages will not work as ABMs tend to be better at depicting fluctuations than aggregate differential equations systems.

In the synthetic population, small geographic areas are populated with agents with assigned consumption patterns that allow us to derive localised expenditure profiles based on a small area's specific mix of agents. Practical applications of the ABCMs include:

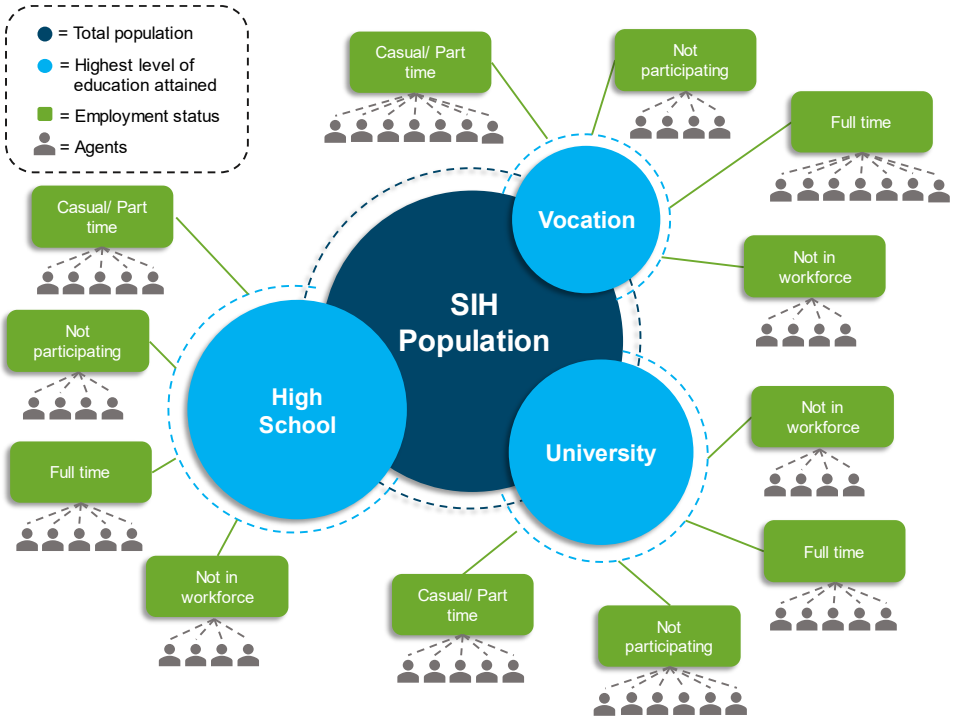
- Introduction of policies providing incentives to adopt emerging technologies
- Impact of urban (transport led) developments on the surrounding community
- Fundamental changes in local economic fabric for example, triggered by the opening or closing of a core industry on the local business landscape
- Diffusion of (new) products including those where reliability (for example, the neighbour's experience with the product such as Electric Vehicles (EVs), solar panels, batteries).

# 2. Agents in the ABCM

The agents in the ABCM are derived from multiple waves of the ABS' Survey of Incomes and Households (SIH). The process applies a hierarchical clustering approach which splits the SIH respondents into groups defined by their education background and employment status. The groups are then clustered into agents based on their key socio-economic attributes including:

- Age
- Income
- Housing cost to income ratio
- Place of residence (urban or regional)
- Dwelling tenure (mortgage, rent, owned outright).

This approach is illustrated below. In the diagram, agents are represented by the small grey icons. Their number differs across the groups defined by employment and education. This reflects that some of these groups are more diverse than others. For example, the smallest group consists of only four agents as persons with low education levels and without employment tend to be more constrained in their means and activities than, for example, persons in this group with employment. In general, groups with more agents tend to be associated with more diverse income and age ranges typically associated with a completed tertiary education and full-time employment.

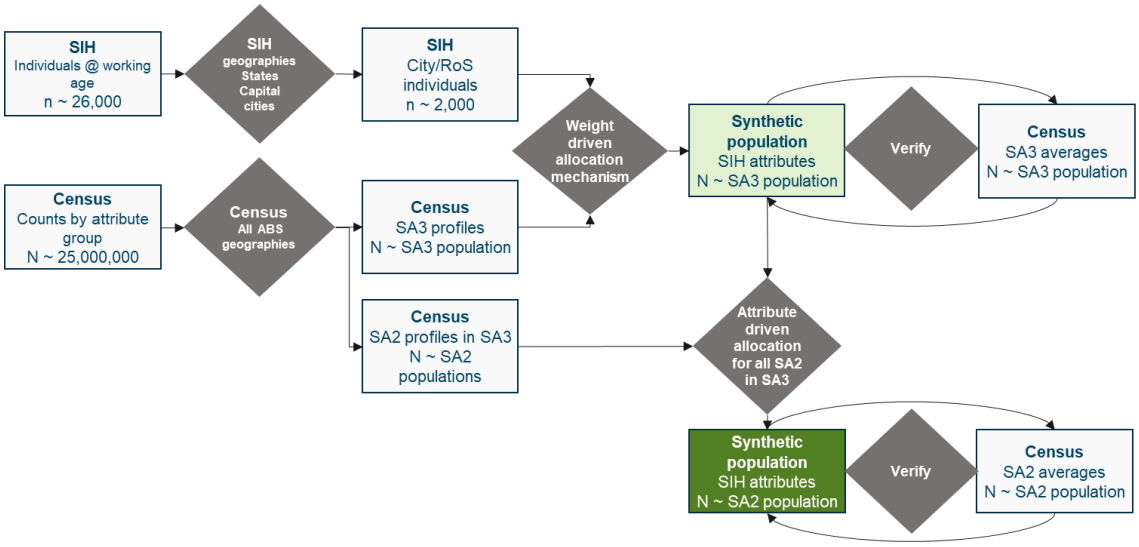


# 3. Synthetic populations

"Population synthesis is concerned with estimating unknown information at fine geographical level based on known aggregate information. A synthetic population basically represents a reconstruction of one possible set of "best estimates" that mirror the distributions of the actual population, where relevant attributes pertaining to every synthetic person and household in the entire study population are fully enumerated at detailed geographical level".[1] Synthetic populations of agents are the foundation of every ABM.

NineSquared's populations are derived by calibrating a population of synthetic persons (agents) defined by the above key relevant attributes taken from the SIH to relevant and observable data that is provided at a more detailed geographical level in the ABS Census. Within the population, agents are 'cloned' such that their composition reproduces a population that mirrors the Census averages for a given detailed geography level. This approach is illustrated below.

As the diagram shows, a key component is the ongoing verification of results by checking if the synthetic population accurately reproduces the relevant aggregate Census data. This ensures geographic allocation is robust and accurate.




# 4. Consumption simulation

The synthetic population developed for our ABCM provides a mechanism to allocate data available at a low geographic granularity (for example, state level) to small areas and form robust views of local consumption or other behaviour patterns. Specifically, behaviour patterns derived from state-level or other surveys can be assigned to the population's representative agents which in turn are defined through a set of core socio-economic attributes. In the synthetic population, small geographic areas are populated with these agents. This allows us to derive localised consumptions patterns based on a small area's specific mix of agents.

[1] Lim, P. P., 2020

The application can span the hundreds of goods included in the ABS' Consumer Price Index (CPI) basket covering the following core groups:

- Current housing costs (selected dwelling)
- Domestic fuel and power
- Food and non-alcoholic beverages
- Alcoholic beverages
- Tobacco products
- Clothing and footwear
- Household furnishings and equipment
- Household services and operation
- Medical care and health expenses
- Transport
- Recreation
- Personal care
- Miscellaneous goods and services
- Income tax
- Mortgage repayments - principal component (selected dwelling)
- Other capital housing costs
- Superannuation and life insurance

For each agent (see section 2 above) and each product class, the ABCM contains consumption distributions representing an agent's range of (weekly) expenditure on a certain good. Local expenditure profiles can be simulated by randomly drawing from these distributions and aggregating results across agents and goods. The simulation thus generates a (mean preserving) estimate of local expenditure for a good or group of goods.

Modelling consumption decisions in this way can provide powerful insights when they drive tailored localised forecasts. For example, recent applications include:

- Modelling localised reactions to payments incentivising households to provide their EVs for vehicle to grid generation based on blended electricity price elasticities derived from longitudinal energy consumption patterns.
- Exploring the spill-over effects urban developments can have on the surrounding community and the viability of new local businesses.
- Tracing population movements triggered by a major (desirable) inner-city redevelopment through a metropolitan area by linking dwelling preferences across agents and assessing the resulting impacts on living affordability across groups.

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