Projection and Alignment Methods for Static Microsimulation Models

Association for Public Policy Analysis and Management 2016 Pre-Conference Workshop

Kevin Perese
Tax Analysis Division

As developmental work for analysis for the Congress, the information in this presentation is preliminary and is being circulated to stimulate discussion and critical comment.
### Microsimulation Models

<table>
<thead>
<tr>
<th>Dynamic</th>
<th>Static</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Now</strong></td>
<td><strong>Now</strong></td>
</tr>
<tr>
<td><img src="image1" alt="Dynamic Now" /></td>
<td><img src="image2" alt="Static Now" /></td>
</tr>
<tr>
<td><img src="image3" alt="Dynamic Future" /></td>
<td><img src="image4" alt="Static Future" /></td>
</tr>
<tr>
<td><img src="image5" alt="10% larger" /></td>
<td><img src="image6" alt="10% larger" /></td>
</tr>
</tbody>
</table>

- $n_1 > n_0$
- $n_1 = n_0$
A Quick Outline of This Presentation

1) CBO’s Individual Income Tax Model
   • Overview
   • Current Projection and Alignment Methodology

2) How Other Static Microsimulation Models Project and Align Their Data

3) Criteria for New Projection and Alignment Methodology
1) CBO’s Individual Income Tax Model: Overview

- Began in mid-1980s; models and projects the effects of major tax reforms
- Written in Fortran
- Uses data from the IRS’s Statistics of Income (SOI) and the Census Bureau’s Current Population Survey (CPS)
- Serves as the foundation for multiple CBO products:
  - 10-year baseline projections
  - Distribution of household income and federal taxes (retrospective)
  - Calculation of effective marginal tax rates
  - Analyses of labor supply responses to tax law changes
  - Long-term revenue projections
1) CBO’s Individual Income Tax Model: Overview

- Read In Parameters
- Read In Micro-Data
- Align Micro-Data
- Project Micro-Data
- Calculate Income Tax
- Calculate Payroll Tax
- Print Out Diagnostics
- Print Out Main Outputs
- Write Out Micro-Data
1) CBO’s Individual Income Tax Model: Current Projection and Alignment Approach

Sequential

Population

Targets: Annual population forecasts by age, sex, and marital status from CBO’s long-term analysis model

Application: Multiplicative weight adjustments based on growth in targets

Two Problems:

1) Unit of analysis is tax unit, not individual
   • Married couple gets simple average of two individual growth rates

2) Kids/dependents not explicitly targeted
1) CBO’s Individual Income Tax Model: Current Projection and Alignment Approach

Sequential

1. Population
2. Employment

**Targets:** Annual employment forecasts from CBO’s Macroeconomic Analysis Division

**Application:** Offsetting weight adjustments

\[
adj \_ wgt_{it}^{w} = wgt_{it}^{w} \times \left( \frac{Target_{t}^{w}}{\sum wgt_{it}^{w}} \right) \quad \text{Multiplicative weight adjustment to hit aggregate employment target}
\]

\[
adj \_ wgt_{ijt}^{n} = wgt_{ijt}^{n} \times \left\{ 1 - \left[ \frac{\left( \frac{Target_{t}^{w}}{\sum wgt_{it}^{w}} \right) \times \left( \frac{\sum wgt_{ijt}^{w}}{\sum wgt_{ijt}^{n}} \right)}{\sum wgt_{ijt}^{w}} \right] \right\} \quad \text{Offsetting weight adjustments for nonworkers}
\]

where \( j = 1 \ldots 42 \) cells by marital status (0:1), number of dependents (0:2), and age groups (1:7)
1) CBO’s Individual Income Tax Model: Current Projection and Alignment Approach

**Sequential**

1. Population
2. Employment
3. Private Health Insurance
4. ESI Coverage
5. Random Allocation

**Targets:** Forecasted growth in employer-sponsored health insurance (ESI) coverage from CBO’s health insurance simulation model

**Application:** Simulated coverage, with probabilities scaled by aggregate ESI growth rates

\[
ESI_{cov_{it}} = \begin{cases} 
1, & \text{if } p(ESI_{cov_{jt_0}}) \ast (ESI_t/ESI_{t-1}) > \text{random}_i \\
0, & \text{otherwise}
\end{cases}
\]

where \( j = 1 \ldots 48 \) cells by marital status (0:1), number of dependents (0:1), earnings quartiles (1:4), and age groups (1:3)
1) CBO’s Individual Income Tax Model: Current Projection and Alignment Approach

Sequential

1. Population
2. Employment
3. Private Health Insurance
4. Incomes

**Targets:** Annual income forecasts from CBO’s Macroeconomic Analysis Division

**Application:** Multiplicative scaling of ~100 income sources and tax components by *growth* in 12 projections of income sources from CBO’s Macroeconomic Analysis Division

For example:
- Most income sources and tax components are grown at weighted average of growth in wages, proprietors’ income, dividends, and interest income
- Short-term gain, loss, and carry-over and long-term gain, loss, and carry-over are all grown at single aggregate growth rate in net capital gains
1) CBO’s Individual Income Tax Model: Current Projection and Alignment Approach

**Targets:** None; trend analysis

**Application:** Offsetting adjustments to wage and salary income growth rates

81st to 90th percentiles: Grows at average economywide growth rate

91st percentile and up: Grows faster than average

80th percentile and down: Growth rates adjusted downward to offset faster growth in top decile

(This component of CBO’s projection and alignment method is currently being reviewed and may change.)
2) How Other Static Microsimulation Models Project and Align Their Data

\[ \hat{X}_t = \sum x_{it} w_{it} \]

Most use a two-stage technique:

1. Apply across-the-board multiplicative adjustments to \( x_{it} \) to hit broad aggregate totals
2) How Other Static Microsimulation Models Project and Align Their Data

\[ \hat{X}_t = \sum x_{it} w_{it} \]

Most use a two-stage technique:

1. Apply across-the-board multiplicative adjustments to \( x_{it} \) to hit broad aggregate totals

2. Use a constrained optimization algorithm to adjust weights (\( w_{it} \)) to “fine-tune” / align the projection
2) How Other Static Microsimulation Models Project and Align Their Data

\[ \sum x_{it} w_{it}^* = T_{xt} \]

Most use a two-stage technique:

1. Apply across-the-board multiplicative adjustments to \( x_{it} \) to hit broad aggregate totals
2. Use a constrained optimization algorithm to adjust weights \( (w_{it}) \) to “fine-tune” / align the projection
2) How Other Static Microsimulation Models Project and Align Their Data

<table>
<thead>
<tr>
<th>$w_{it}$</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Smiley faces" /></td>
<td><img src="image2" alt="Smiley faces" /></td>
<td><img src="image3" alt="Smiley faces" /></td>
</tr>
</tbody>
</table>
2) How Other Static Microsimulation Models Project and Align Their Data

One approach:
Minimize the absolute value of the percentage change in weights ($|z_i|$) necessary to hit aggregate targets

$$
\min \sum |z_i| \quad \text{subject to: } \sum x_i w_i z_i = T_x - \sum x_i w_i \quad \text{and} \quad 0 \leq |z_i| \leq \delta
$$

(where $\delta$ is a bounding parameter)

Operationalized by splitting $z_i$ into its positive and negative components:

$$
r_i = \begin{cases} 
    z_i, & \text{if } z_i > 0 \\
    0, & \text{otherwise}
\end{cases}
$$

$$
s_i = \begin{cases} 
    z_i, & \text{if } z_i < 0 \\
    0, & \text{otherwise}
\end{cases}
$$

$$
z_i = (r_i + s_i)
$$

$$
|z_i| = (r_i - s_i)
$$

$$
\min \sum (r_i - s_i) \quad \Rightarrow \quad w_i^* = w_i (1 + r_i + s_i) \quad \text{and} \quad \sum x_i w_i^* = T_x
$$

Because the objective function and the constraints are linear, the problem can be solved with a relatively straightforward linear programming algorithm, such as a simplex algorithm.
2) How Other Static Microsimulation Models Project and Align Their Data

Another approach:
Minimize the “distance” between vector of original weights \( w_i \) and new vector of weights \( w_i^* \) while hitting aggregate targets

\[
\min \sum \varphi(w_i, w_i^*)
\]
subject to:
\[
\sum x_i w_i^* = T_x
\]

(can also add constraint to bound \( w_i^* \))

\( \varphi \) can take many forms:

L1 Norm: \( \varphi(w_i, w_i^*) = |w_i - w_i^*| \)

L2 Norm: \( \varphi(w_i, w_i^*) = (w_i - w_i^*)^2 \)

Treasury and Joint Committee on Taxation use functional form approximately like:

\[
\varphi(w_i, w_i^*) = \left(\frac{w_i^*}{w_i}\right)^4 + \left(\frac{w_i^*}{w_i}\right)^{-4} - 2
\]

If the objective function (\( \varphi \)) is nonlinear, the problem must be solved with a relatively more complex nonlinear programming algorithm.
2) How Other Static Microsimulation Models Project and Align Their Data

Solving 2nd stage optimization with…

…a linear objective function and a linear programming algorithm produces a trimodal distribution of weight changes. …a nonlinear objective function and a quadratic programming algorithm produces a smooth distribution of weight changes.

Note: One is not necessarily better than the other.
3) Criteria for New Projection and Alignment Methodology

- Keep it simple
  - Comprehension is just as important as “precision”

- Minimize aggregate and distributional effects on nontargeted variables

- Integrate with methods used for each alignment component
  - New method of labor force participation in development
  - New method to adjust income distribution under consideration

- Minimize restructuring of current model and workflow
  - Current CBO tax model incorporates projection and alignment in each model run
  - Other models project and align data in a separate module