

# OSPC Dynamic Scoring Model: An Open Source Model for Dynamic Revenue Estimates

April 1, 2015

# Overview of the Model

- Households
  - forward looking
  - Live up to 100 periods
  - endogenous labor supply and savings decisions
- Firms
  - fully dynamic
  - endogenous investment and financial policy
- Government
  - taxes, transfers, production of public and private goods, can run deficits
- Rest of world: TBD (currently closed economy)

# What's unique?

- 100-period lived households (80 working periods)
- Rich population dynamics (fertility, mortality, immigration)
- Multiple treatments of bequests
- Large set of production industries
- Multiple assumptions about government budget balance
- Nonlinear solution of steady-state and transition path
- Integration of the microsimulation model
- Open source

# Household Sector

- OLG model with 100-period-lived agents
- Realistic Demographics: Fertility, Immigration, Mortality
- Realistic Earnings Ability Calibration
- Households Leave Intentional and Unintentional Bequests

# Production Sector

- Infinitely lived, representative firms for each production industry
- Firms finance investment with debt, equity, and retained earnings
- Price of capital varies across production industry

# Model Dimensions

- Households:
  - 80 years of economic life
  - 7 lifetime income groups
  - 17 consumption goods
- Firms:
  - 24 production industries
  - Corporate and non-corporate sectors in most industries

# Consumption Goods

	Consumption Good Category
1	Food
2	Alcohol
3	Tobacco
4	Household fuels and utilities
5	Shelter
6	Furnishings
7	Appliances
8	Apparel
9	Public transportation
10	New and used cars, fees, and maintenance
11	Cash contributions and personal care (personal services)
12	Financial services
13	Reading and entertainment (recreation)
14	Household operations (nondurables)
15	Gasoline and motor oil
16	Health care
17	Education

# Production Industries

Industry Number	NAICS Code	Industry
1	11	Agriculture, Forestry, Fishing and Hunting
2	211	Oil and Gas Extraction
3	212 and 213	Mining and Support Activities for Mining
4	22	Utilities
5	23	Construction
6	32411	Petroleum Refineries
7	336	Transportation Equipment Manufacturing
8	3391	Medical Equipment and Supplies Manufacturing
9	Other codes in 31-33	Manufacturing
10	42	Wholesale Trade
11	44-45	Retail Trade
12	48-49	Transportation and Warehousing
13	51	Information
14	52	Finance and Insurance
15	53	Real Estate and Rental and Leasing
16	54	Professional, Scientific, and Technical Services
17	55	Management of Companies and Enterprises
18	56	Administrative and Support
19	61	Educational Services
20	62	Health Care and Social Assistance
21	71	Arts, Entertainment, and Recreation
22	72	Accommodation and Food Services
23	81	Other Services (except Government Enterprise)
24	92	Government Enterprise



# Population Dynamics

New cohort every year.

Becomes economically active at age  $E=20$ .

Immigration and mortality over time.

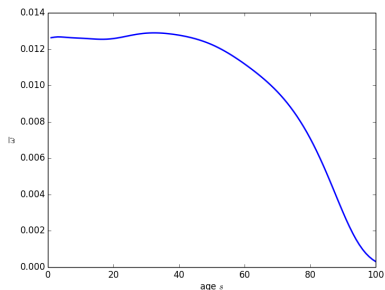
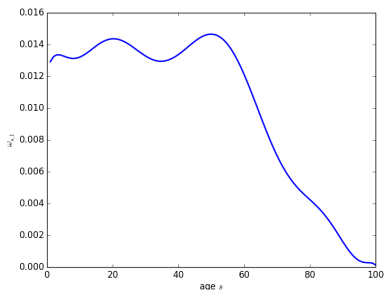
$$\omega_{1,t+1} = \sum_{s=1}^{E+S} f_s \omega_{s,t} \quad \forall t$$

$$\omega_{s+1,t+1} = (1 + i_s - \rho_s) \omega_{s,t} \quad \forall t, 1 \leq s \leq E + S - 1$$

$$N_t \equiv \sum_{s=E}^{E+S} \omega_{s,t} \quad \forall t$$

# Population Dynamics – Population Distribution

## Initial and Steady State Population Distributions by Age



# Households – Utility Function

Utility from Consumption, Leisure and Bequests  
Mortality Risk; Leisure Utility Weights Vary by Age

$$\begin{aligned}
 &U_{j,s,t} \\
 &= \sum_{u=0}^{E+S-s} \beta^u \left[ \prod_{v=s-1}^{s+u-1} (1 - \rho_v) \right] u(c_{j,s+u,t+u}, n_{j,s+u,t+u}, b_{j,s+u+1,t+u+1}) \\
 &\quad u(c_{j,s,t}, n_{j,s,t}, b_{j,s+1,t+1}) = \frac{(c_{j,s,t})^{1-\sigma} - 1}{1 - \sigma} \\
 &\quad + e^{g_y t(1-\sigma)} \chi_s^n \left( b \left[ 1 - \left( \frac{n_{j,s,t}}{\tilde{l}} \right)^v \right]^{\frac{1}{v}} + k \right) \\
 &\quad + \rho_s \chi^b \frac{(b_{j,s+1,t+1})^{1-\xi} - 1}{1 - \xi}
 \end{aligned}$$

# Households – Budget Constraint

Sources: Labor and Capital Income, Bequests

Uses: Consumption, Savings and Taxes

$$c_{j,s,t} + b_{j,s+1,t+1} + T_{j,s,t} \leq w_t e_{j,s} n_{j,s,t} + (1 + r_t) b_{j,s,t} + \frac{BQ_{j,t}}{\lambda_j N_t}$$

$$b_{j,1,t} = 0$$

$$BQ_{j,t+1} = (1 + r_{t+1}) \lambda_j \left( \sum_{s=E+1}^{E+S} \rho_s \omega_{s,t} b_{j,s+1,t+1} \right) \quad \forall j, t$$

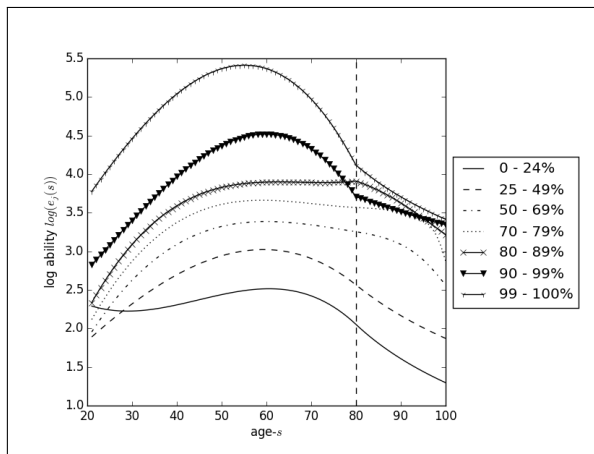
# Households – Earnings Abilities

Seven ability groups:

- Top 1%
- Top 2-10%
- Top 11-20%
- Top 21-30%
- Top 31-50%
- Top 51-75%
- Bottom 25%

# Households – Earnings Abilities

**Figure :** Log of Earnings Abilities by Age and Type



Data: 2013 IRS data fitted

# Households – Tax Structure

$$T_{j,s,t}^I = \tau^I(\hat{a}_{j,s,t})a_{j,s,t}$$

$$\text{where } \hat{a}_{j,s,t} \equiv \frac{a_{j,s,t}}{e g_{y,t}} \quad \text{and} \quad a_{j,s,t} \equiv (r_t b_{j,s,t} + w_t e_{j,s} n_{j,s,t})$$

$$T_{j,s,t}^P = \begin{cases} \tau^P w_t e_{j,s} n_{j,s,t} & \text{if } s < R \\ \tau^P w_t e_{j,s} n_{j,s,t} - \theta_j w_t & \text{if } s \geq R \end{cases}$$

$$T_{j,t}^{BQ} = \tau^{BQ} \frac{BQ_{j,t}}{\lambda_j \tilde{N}_t}$$

$$T_{j,s,t}^W = \tau^W(\hat{b}_{j,s,t})b_{j,s,t}, \quad \text{where } \hat{b}_{j,s,t} \equiv \frac{b_{j,s,t}}{e g_{y,t}}$$

$$T_{j,s,t} = T_{j,s,t}^I + T_{j,s,t}^P + T_{j,t}^{BQ} + T_{j,s,t}^W - T_t^L$$

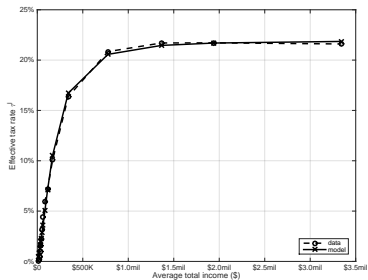
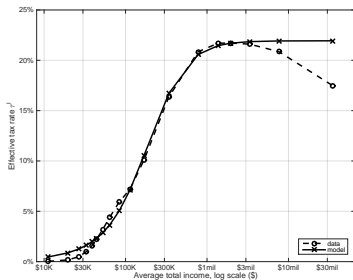
# Households – Tax Structure

Say something about how tax functions estimated from microsimulation output...



# Households – Income Tax

## Log scale versus normal scale



# Firms – Solutions

Perfectly Competitive CRS Firms  
Labor-augmenting Technology

$$Y_t = AK_t^\alpha (e^{g_y t} L_t)^{1-\alpha} \quad \forall t$$

$$w_t = (1 - \alpha) \frac{Y_t}{L_t} \quad \forall t$$

$$r_t = \alpha \frac{Y_t}{K_t} - \delta \quad \forall t$$

# Government

Government collects income, payroll, bequest and wealth taxes and refunds them lump-sum.

$$T_t^L = \frac{1}{\tilde{N}_t} \sum_s \sum_j \left( T_{j,s,t}^I + T_{j,s,t}^P + T_{j,s,t}^{BQ} + T_{j,s,t}^W \right)$$

# Stationarizing the Model

**Table : Stationary variable definitions**

Sources of growth			Not growing <sup>a</sup>
$e^{g_y t}$	$\tilde{N}_t$	$e^{g_y t} \tilde{N}_t$	
$\hat{c}_{j,s,t} \equiv \frac{c_{j,s,t}}{e^{g_y t}}$	$\hat{\omega}_{s,t} \equiv \frac{\omega_{s,t}}{\tilde{N}_t}$	$\hat{Y}_t \equiv \frac{Y_t}{e^{g_y t} \tilde{N}_t}$	$n_{j,s,t}$
$\hat{b}_{j,s,t} \equiv \frac{b_{j,s,t}}{e^{g_y t}}$	$\hat{L}_t \equiv \frac{L_t}{\tilde{N}_t}$	$\hat{K}_t \equiv \frac{K_t}{e^{g_y t} \tilde{N}_t}$	$r_t$
$\hat{b}q_{j,s,t} \equiv \frac{bq_{j,s,t}}{e^{g_y t}}$		$\hat{B}Q_{j,t} \equiv \frac{BQ_{j,t}}{e^{g_y t} \tilde{N}_t}$	
$\hat{w}_t \equiv \frac{w_t}{e^{g_y t}}$			
$\hat{y}_{j,s,t} \equiv \frac{y_{j,s,t}}{e^{g_y t}}$			

<sup>a</sup> The interest rate  $r_t$  is already stationary because  $Y_t$  and  $K_t$  grow at the same rate. Individual labor supply  $n_{j,s,t}$  is stationary.

# Steady-State: 2JS equations

## Definition (Stationary steady-state equilibrium)

A non-autarkic stationary steady-state equilibrium in the overlapping generations model with  $S$ -period lived agents and heterogeneous ability  $e_{j,s}$  is defined as constant allocations  $\hat{n}_{j,s,t} = \bar{n}_{j,s}$ ,  $\hat{b}_{j,s+1,t+1} = \bar{b}_{j,s+1}$ , and  $\hat{b}q_{j,E+S+1,t+1} = \bar{b}q_{j,E+S+1}$  and constant prices  $\hat{w}_t = \bar{w}$  and  $\hat{r}_t = \bar{r}$  for all  $j$ ,  $s$ , and  $t$  such that the following conditions hold:

- ① households  $J$  optimize according to 2S Euler equations,
- ② firms optimize according to 2 FOCs,
- ③ markets clear according to 2 market clearing conditions, and
- ④ the population has reached its stationary steady state distribution  $\bar{\omega}_s$  for all ages  $s$ .

# Stationary non-steady-state equilibrium

## Definition (Stationary non-steady-state equilibrium)

A non-autarkic stationary non-steady-state equilibrium in the overlapping generations model with  $S$ -period lived agents and heterogeneous ability  $e_{j,s}$  is defined as allocations  $n_{j,s,t}$ ,  $\hat{b}_{j,s+1,t+1}$ , and  $\hat{b}q_{j,E+S+1,t+1}$  and prices  $\hat{w}_t$  and  $r_t$  for all  $j$ ,  $s$ , and  $t$  such that the following conditions hold:

- 1 households have symmetric beliefs  $\Omega(\cdot)$  about the evolution of the distribution of savings, and those beliefs about the future distribution of savings equal the realized outcome (rational expectations),
- 2 households  $j$  optimize according to 2S
- 3 firms optimize according to 2 FOCs, and
- 4 markets clear according to 2 market clearing conditions.

# Summary

- Big model
- Efficient code
- Year by year effects
- Integration with micro model