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	Applicances
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 entertrainment (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.

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

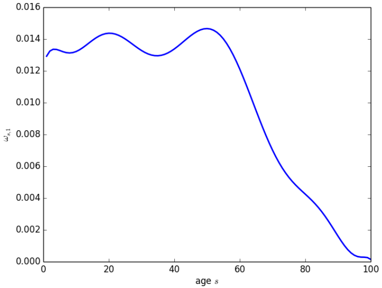
$$\omega_{s+1,t+1} = (1 + i_s - \rho_s)\omega_{s,t} \quad \forall t, 1 \leq s \leq E + S - 1$$

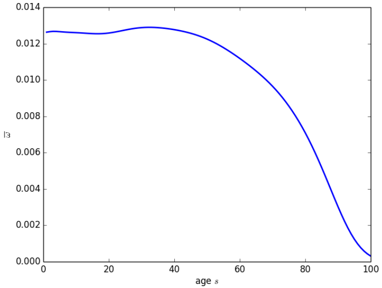
$$N_t \equiv \sum_{s=E}^{E+S} \omega_{s,t} \quad \forall t$$

demographics

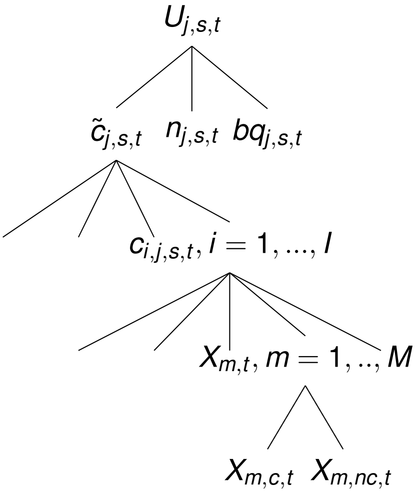
Population Dynamics – Population Distribution

Initial and Steady State Population Distributions by Age





Summary of the Consumer's Problem



U, is a CRRA function

$\tilde{c}_{j,s,t}$ is a Stone-Geary function

$c_{i,j,s,t}$, determined by a fixed coefficient function

$X_{m,t}$, are determined by a CES function

Households – Utility Function

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

$$U_{j,s,t} = \sum_{u=0}^{E+S-s} \beta^u \left[\prod_{v=s-1}^{s+u-1} (1-\rho_v)\right] u\left(c_{j,s+u,t+u}, n_{j,s+u,t+u}, b_{j,s+u+1,t+u+1}\right)$$

$$u\left(c_{j,s,t}, n_{j,s,t}, b_{j,s+1,t+1}\right) = \frac{\left(c_{j,s,t}\right)^{1-\sigma} - 1}{1-\sigma}$$
$$+e^{g_y t(1-\sigma)} \chi^n_s \left(b\left[1 - \left(\frac{n_{j,s,t}}{\tilde{l}}\right)^{\upsilon}\right]^{\frac{1}{\upsilon}} + k\right)$$
$$+\rho_s \chi^b \frac{\left(b_{j,s+1,t+1}\right)^{1-\sigma} - 1}{1-\sigma}$$

▸ elliptic

Households – Budget Constraint

Sources: Labor and Capital Income, Bequests
Uses: Consumption, Savings and Taxes

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

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

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

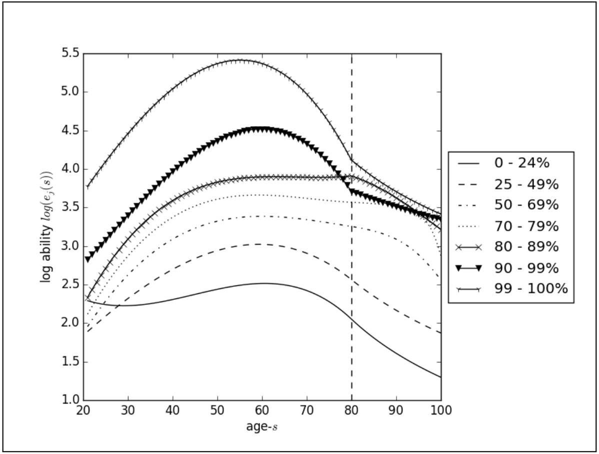
Households – Earnings Abilities

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

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

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

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

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

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

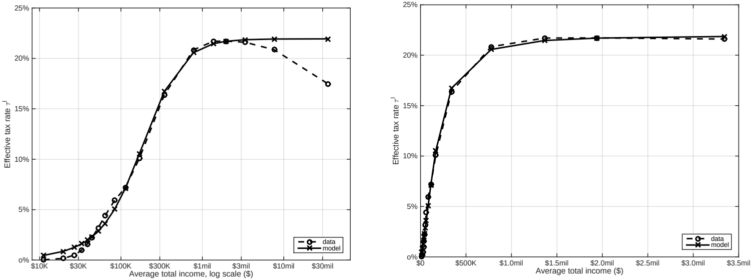
$$T_{j,s,t} = T^I_{j,s,t} + T^P_{j,s,t} + T^{BQ}_{j,t} + T^W_{j,s,t} - T^L_t$$

Households – Tax Structure

- These functions are fit using micro data on tax burden
- Micro data come from the OSPC microsimulation model
- We integrate the two
  - Micro output results of macro forecast
  - The macro forecast a result of tax functions
  - Tax functions estimated from micro output
  - A fixed point

Households – Income Tax

Log scale versus normal scale



Firms – Objective

Maximize Firm Value:

$$V_t = \max_{\{I_u, EL_u\}_{u=t}^{\infty}} \sum_{u=t}^{\infty} \prod_{\nu=t}^{u} \left(\frac{1}{1+\theta_\nu} \right) \left[\left(\frac{1-\tau_u^d}{1-\tau_u^g} \right) DIV_u - VN_u \right] \quad (1)$$

Firms – Taxes

$$TE_t = \tau_t^b \Big[p_t X_t - w_t EL_t - f_e p_t^K I_t - \Phi_t I_t - f_i i_t B_t - f_p \delta b K_t + \ldots \\ f_b b p_t^K I_t - f_d \delta^\tau K_t^\tau - \tau_t^p K_t \Big] + \tau_t^{ic} p_t^K I_t \tag{2}$$

Government Budget:

$$D_{t+1} + T_t^{\tau} = (1 + r_t)D_t + T_t^H + G_t^{subs} + G_t^{emp} + I_t^G \qquad (3)$$

Stationarizing the Model

Table: Stationary variable definitions

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

[a] 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 $\hat{bq}_{j,E+S+1,t+1} = \bar{bq}_{j,E+S+1}$ 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 $M \times 2$ optimize according to 2 FOCs,
3. markets clear according to 3 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 $\hat{bq}_{j,E+S+1,t+1}$ and prices $\hat{w}_t$ and r_t for all j, s, and t such that the following conditions hold:

1. households and firms 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 $M \times 2$ optimize according to 2 FOCs, and
4. markets clear according to 3 market clearing conditions.

The GitHub Repo

The open, online repository houses all model code, data, and documentation:

https://github.com/OpenSourcePolicyCenter/dynamic

Summary

- Detailed macro model
- Efficient code
- Year by year effects
- Integration with microsimulation model