A Model for Dynamic Revenue Estimates: Approaches and Challenges

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Objectives of the model

- Produce year-by-year macro forecasts for current law and policy baselines
- Produce year-by-year dynamic revenue estimates for a wide array of tax policies
- Provide distributional analysis
    - Individuals:
        - Across age and income groups
        - Annual and lifetime incidence
    - Firms:
        - across tax treatment and production industry

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

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 for individual taxes
- 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.

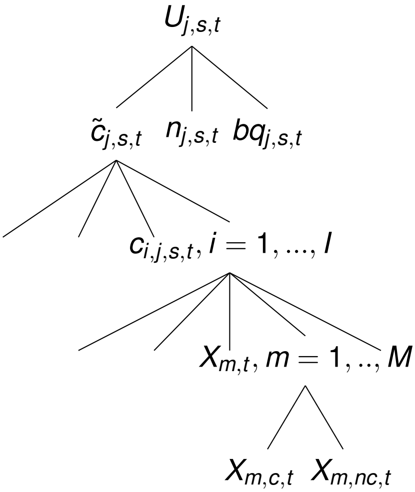
$$\omega_{1,t+1} = \sum_{s=1}^{E+S} f_s \omega_{s,t} \quad \forall t$$

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

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

▸ demographics

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

$$\sum_{i=1}^{I} p_{i,t}\bar{c}_{i,s} + \tilde{p}_{s,t}\tilde{c}_{j,s,t} + b_{j,s+1,t+1} + T_{j,s,t} \leq w_t e_{j,s} n_{j,s,t} + (1 + r_t)\, b_{j,s,t} +$$

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

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

Households – Lifetime Income Groups

Seven lifetime income groups:

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

Households – Tax Structure

Households pay the following taxes:

- Income taxes on capital and labor income
- Payroll taxes on labor income
- Estate taxes on bequests
- (Potentially) a wealth tax on the stock of assets they own
- Ad valorem consumption taxes

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

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

Firm-level taxes allow for changes to:

- Income tax rates
- Property tax rates
- Tax depreciation allowances and expensing
- Investment tax credits
- Interest deductibility
- Pre-pay and post-pay consumption tax systems

Firms – Taxes

Total income taxes on the firms are given by:

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

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

Sources of growth			Not growing[a]
$e^{g_y t}$	$\tilde{N}_t$	$e^{g_y t}\tilde{N}_t$	
$\hat{c}_{j,s,t} \equiv \frac{\tilde{c}_{j,s,t}}{e^{g_y t}}$	$\hat{\omega}_{s,t} \equiv \frac{\omega_{s,t}}{\tilde{N}_t}$	$\hat{X}_t \equiv \frac{X_t}{e^{g_y t}\tilde{N}_t}$	$n_{j,s,t}$
$\hat{b}_{j,s,t} \equiv \frac{b_{j,s,t}}{e^{g_y t}}$	$\hat{EL}_t \equiv \frac{EL_t}{\tilde{N}_t}$	$\hat{K}_t \equiv \frac{K_t}{e^{g_y t}\tilde{N}_t}$	r_t
$\hat{w}_t \equiv \frac{w_t}{e^{g_y t}}$		$\hat{BQ}_{j,t} \equiv \frac{BQ_{j,t}}{e^{g_y t}\tilde{N}_t}$	
$\hat{y}_{j,s,t} \equiv \frac{y_{j,s,t}}{e^{g_y t}}$		$\hat{I}_t \equiv \frac{I_t}{e^{g_y t}\tilde{N}_t}$	
$\hat{T}_{j,s,t} \equiv \frac{T_{j,s,t}}{e^{g_y t}}$			
$\hat{p}_{s,t} \equiv \frac{\tilde{p}_{s,t}}{e^{g_y t}}$			
$\hat{p}_{i,t} \equiv \frac{p_{i,t}}{e^{g_y t}}$			

[a] The interest rate r_t is already stationary because X_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:

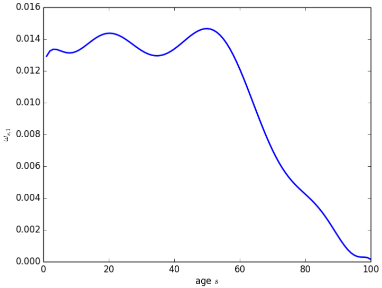
1. households and firms have symmetric beliefs, $\Omega(\cdot)$, about the evolution of the distribution of savings, and those beliefs about the future distribution of savings equal the realized outcome (rational expectations),
2. households J optimize according to $2S$
3. firms $M \times 2$ optimize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

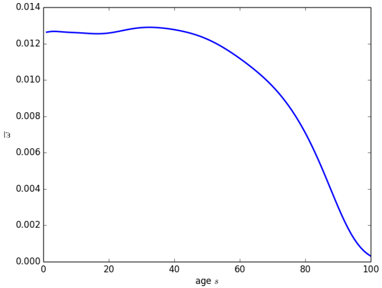
Calibrating population dynamics

- Initial population: Census, 2014
- Fertility rates by age: CDC 2010
- Mortality rates by age: SSA 2010

Calibrated Population Dynamics

Initial and Steady State Population Distributions by Age





Calibrating individual subutility

Stone-Geary preferences $\implies$ linear expenditure system

- Estimate min consumption and share parameters
- Consumer Expenditure Survey, 2012-2013

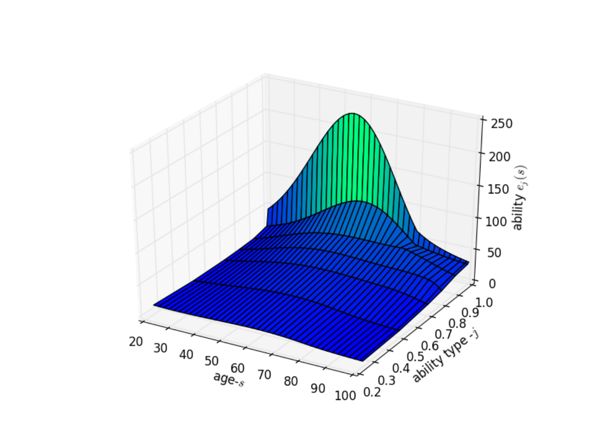
Calibrating life-cycle profiles

Need hourly earnings rates in panel data:

- Estimate wage profiles by lifetime income group
- Define lifetime income group by value of labor endowment (not income!)
- Data: 2013 IRS full sample

Earnings Abilities

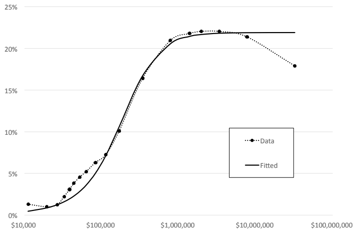
Figure: Earnings Abilities by Age and Type

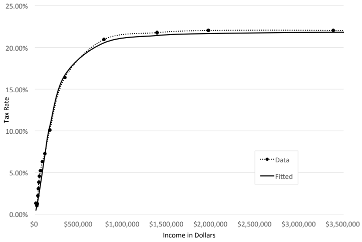


Data: 2013 IRS data fitted

Calibrating Income Taxes

Log scale versus normal scale





Calibrating economic depreciation rates

Rates vary by industry and sector

- Rates represent weighted average of economic depreciation rates
- BEA data on capital stock by asset type and industry (2012)
- IRS data on capital stock by industry and tax treatment (2012)

Calibrating inputs and outputs

Relation between production goods, consumption goods, and capital

- BEA PCE Bridge Table 2007 relates consumption and production goods
- BEA Input-Output Table 2007 relates production goods and capital by industry

Other calibration

- Firm financial policy parameters: Fed Flow of Funds
- Production function: BEA NIPA accounts, by industry
- Utility weights:
  - Disutility of labor: PSID hours worked by age
  - Utility of bequests: Estate tax return data (?)

Income Inequality and Taxes

"The Distributional Effects of Redistributional Tax Policy"
Using a simplier version of the model with only the household richness, we contrast two taxes and their effects on inequality.

- Progressive Wealth Tax
- Increase in Income Tax

Figure: Wealth Tax

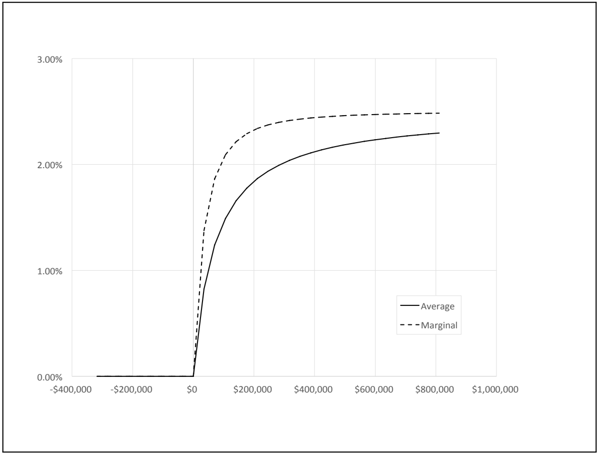


Figure: Income Tax

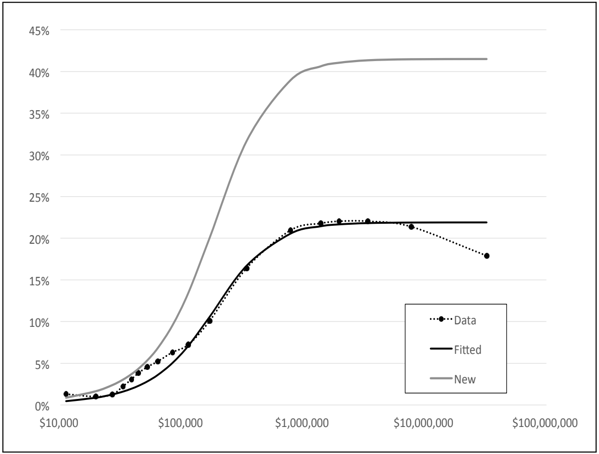


Table: Comparison of changes in steady-state Gini coefficients

Steady-state variable	Gini type	Baseline	Wealth tax Treatment	Wealth tax % Chg.	Income tax Treatment	Income tax % Chg.
$\bar{b}_{j,s}$ Wealth	Total	0.943	0.929	-1.48%	0.939	-0.42%
	Ability *j*	0.954	0.942	-1.26%	0.950	-0.42%
	Age *s*	0.606	0.565	-6.77%	0.613	1.16%
$\bar{y}_{j,s}$ Income	Total	0.775	0.733	-5.42%	0.757	-2.32%
	Ability *j*	0.811	0.774	-4.56%	0.794	-2.10%
	Age *s*	0.425	0.377	-11.29%	0.423	-0.47%
$\bar{c}_{j,s}$ Cons-umption	Total	0.664	0.621	-6.48%	0.644	-3.01%
	Ability *j*	0.716	0.679	-5.17%	0.697	-2.65%
	Age *s*	0.305	0.272	-10.82%	0.305	0.00%
$\bar{n}_{j,s}$ Labor supply	Total	0.240	0.258	7.50%	0.236	-1.67%
	Ability *j*	0.324	0.349	7.72%	0.321	-0.93%
	Age *s*	0.145	0.145	0.00%	0.142	-2.07%

Note: Under Gini type, *Total* refers to the Gini coefficient calculated from all the steady-state data, *Ability j* refers to the Gini coefficient calculated by averaging the data over the ages so we are measuring only inequality across lifetime income groups (ability), and *Age s* refers to the Gini coefficient calculated by averaging the data over the life cycle income groups so we are measuring only inequality across ages.

Table: Comparison of changes in steady-state aggregate variables from wealth tax versus income tax

Steady-state		Wealth tax		Income tax	
aggregate variable	Baseline	Treatment	% Chg.	Treatment	% Chg.
Income (GDP) $\bar{Y}$	0.503	0.489	-2.78%	0.474	-5.77%
Capital stock $\bar{K}$	1.777	1.612	-9.29%	1.577	-11.25%
Labor $\bar{L}$	0.299	0.299	0.00%	0.289	-3.34%
Consumption $\bar{C}^{*}$	0.414	0.408	-1.45%	0.396	-4.35%
Total utility $\bar{U}^{*}$	6185.054	6234.131	0.79%	6225.937	0.66%

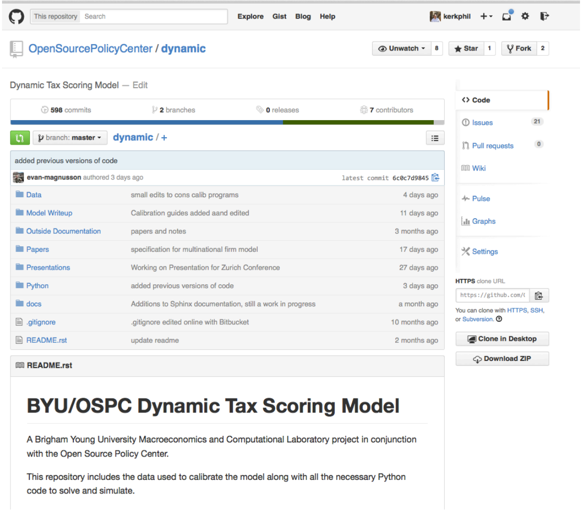
* Steady-state consumption $\bar{C}$ and total utility $\bar{U}$ are calculated as the population-weighted sum of steady-state individual consumptions and utilities for each individual of type j and age s.

The GitHub Repo

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

https://github.com/OpenSourcePolicyCenter/dynamic

The GitHub Repo



Summary of Model

- Detailed macro model
- Efficient code
- Year by year effects

Going forward

- Where we are:
    - Closed economy model specified
    - Solution in place for households and firms
    - Calibration in process

Going forward

- What needs to be done:
  - International sector
- Computational Challenges
  - Integration with Microsimulation Tax Model
  - Incorporate Stochastic Switching of Earnings Abilities
- Approximation about the Current State

Approximation about the Current State

- Introduces additional approximation error
- Minimizes error due to distance from approximation point

Approximation about the Current State

Comparison of solution methods for standard infinite horizon growth

		Value function iteration	1st order approx. (Dynare)	2nd Order approx. (Dynare)	Current state linearization
IRF 1	RMSEE	$2.868e-06$	$1.933e-04$	$9.876e-01$	$1.078e-05$
	MAEE	$8.948e-06$	$2.119e-04$	$9.876e-01$	$1.787e-05$
	RMSD	0	$2.954e-03$	$4.820e-05$	$2.889e-03$
IRF 2	RMSEE	$3.742e-06$	$2.356e-04$	$9.822e-01$	$7.254e-05$
	MAEE	$1.415e-05$	$7.589e-04$	$9.889e-01$	$1.568e-04$
	RMSD	0	$3.707e-03$	$8.473e-05$	$7.011e-03$
Sim	RMSEE	$6.888e-04$	$4.417e-04$	$1.965e-04$	$9.578e-04$
	MAEE	$2.022e-02$	$5.225e-03$	$5.611e-03$	$2.150e-02$
	RMSD	0	$1.820e-00$	$1.788e-00$	$1.795e-00$