Penn Wharton Budget Model: Dynamics

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Dynamic Model Overview

- Dynamic general equilibrium OLG model with heterogeneity
- Idiosyncratic productivity risk $\Rightarrow$ distribution of earnings histories
- Detailed Social Security system, progressive taxes, immigration
- Evaluates unbalanced fiscal reform over long time horizons
- Considers open and closed economy frameworks

Household Labor Productivity(z)

- Deterministic dependence on age j
- Permanent shock drawn at birth
- Transitory and persistent (AR1) shocks
- Initial distribution of non-permanent shocks

Household Social Security and Bequests

- Social Security benefit $ss(b)$ depends on average lifetime labor earnings b, issuance during retirement ages: $j > Tr$.

- Accidental bequests are collected by the government and redistributed evenly in lump-sum (beq) among all living households

Investment Expensing

- Let $q = (1 - e\tau_{cap})$, where e is the rate of investment expensing.

- Following Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001), a no-arbitrage condition on old capital relative to new capital implies the net return to capital is $\frac{r_K - 1}{q}$, where r_K will be the gross rental rate of capital.

Personal Income Tax

$$y_{pit} = wzn1_{\{j \leq Tr\}} + (1-\phi_{ss})ss(b)1_{\{j>Tr\}} + \left(\phi_K \frac{r_K - 1}{q}(1-\theta) + (1-\phi_K)(r_G - 1)\right)a \quad (1)$$

where wzn is labor income, $(1-\phi_{ss})$ is the taxable share of Social Security benefits, ϕ_K is the portfolio weight on physical capital, r_G is the return on government debt, θ is the share of capital income subjected to the capital tax rate, and a is asset holdings.

$$\tau_{pit}\left(y_{pit}\right) = \int_0^{y_{pit}} \xi\left(y\right)dy \quad (2)$$

Tax function $\tau_{pit}\left(y_{pit}\right)$ is cumulative tax liability from marginal tax rate function $\xi\left(y\right)$. The function $\xi\left(y\right)$ is a step-function (from TPC) which accounts for deductions and credits.

Capital Tax

$$y_{cap} = \phi_K \frac{r_K - 1}{q} \theta a \tag{3}$$

$$\tau_{cap}(y_{cap}) = \tau_{cap} y_{cap} \tag{4}$$

Payroll Tax

$$y_{ss} = \min\{wzn, y_{\text{taxmax}}\} \tag{5}$$

$$\tau_{ss}(y_{ss}) = \tau_{ss} y_{ss} \tag{6}$$

Household Optimization: Working age

Working-age household Bellman's equation:

$$V_j(a,z,b) = \max_{a',n} \left\{ \frac{(c^\gamma (1-n)^{1-\gamma})^{1-\sigma}}{1-\sigma} + s_{j+1} \beta E_{\{z'|z\}}[V_{j+1}(a',z',b')] \right\} \quad (7)$$

subject to:

$$c = wzn + \left[\phi_K \left(1 + \frac{r_K - 1}{q} + \frac{q'-q}{q} \right) + (1-\phi_k) r_G \right] a - \tau_{pit}(y_{pit}) - \tau_{cap}(y_{cap}) - \tau_{ss}(y_{ss}) - a' + beq \quad (8)$$

$$b_{j+1} = \frac{1}{j} \Big((j-1) b_j + \min\{wzn, y_{\text{taxmax}}\} \Big), \quad (9)$$

where s_{j+1} is survival probability, (8) is the budget constraint, and (9) determines average earnings for SS benefit calculation. Households take ϕ_K as exogenous.

Household Optimization: Retiree

Retired household Bellman's equation:

$$V_j(a,b) = \max_{a'} \left\{ \frac{(c^{\gamma}(1)^{1-\gamma})^{1-\sigma}}{1-\sigma} + s_{j+1}\beta V_{j+1}(a',b') \right\} \tag{10}$$

subject to:

$$\begin{aligned} c = ss(b) + \left[\phi_K\left(1 + \frac{r_K - 1}{q} + \frac{q' - q}{q}\right) + (1-\phi_k)r_G\right] a \\ - \tau_{pit}(y_{pit}) - \tau_{cap}(y_{cap}) - a' + beq \end{aligned} \tag{11}$$

$$b_{j+1} = b_j. \tag{12}$$

Production: Closed Economy

- Capital K equals aggregate savings A less government debt D in capital terms: $K = \frac{A-D}{q}$.
- Output:

$$Y = K^{\alpha} L^{1-\alpha}, \tag{13}$$

  where L is aggregate efficient labor.
- Firms' problem:

$$\max_{K,L} \left\{ K^{\alpha} L^{1-\alpha} + (1-\delta)K - r_K K - wL \right\}, \tag{14}$$

  where δ is depreciation and r_K is the rental rate of capital faced by firms.
- Firms' gross interest rates and wages are determined according to:

$$r_K = 1 + \alpha K^{\alpha-1} L^{1-\alpha} - \delta \tag{15}$$

$$w = (1-\alpha) K^{\alpha} L^{-\alpha} \tag{16}$$

Production: Open Economy

- International capital flows in and out of the economy, but labor is immobile.
- Let constant:

$$\lambda \equiv \left(\frac{r_K^{ss} - 1}{q^{ss}}\right)(1 - \tau_{cap}^{ss}), \tag{17}$$

  denote the after-tax net capital return in the initial steady-state closed economy. We set λ as the international after-tax net capital return for the small open-economy.
- After change in policy, territorial capital tax $\Rightarrow$ capital flows until r_K clears international capital markets by matching the international after-tax net return on capital:

$$\left(\frac{r_K - 1}{q}\right)(1 - \tau_{cap}) = \lambda, \tag{18}$$

  where q and τ_{cap} represent the new transition path values.

Open Economy (cont.)

- Rearranging terms in (18) gives:

$$\frac{r_K - 1}{q} = \frac{\lambda}{(1 - \tau_{cap})} \tag{19}$$

- Equation (15) implies a unique capital-to-labor ratio $\kappa = \frac{K}{L}$ given in the firm's FOC:

$$r_K = 1 + \alpha\kappa^{\alpha-1} - \delta, \tag{20}$$

or equivalently:

$$\frac{r_K - 1}{q} = \frac{\alpha\kappa^{\alpha-1} - \delta}{q} \tag{21}$$

- (19) and (21) give:

$$\kappa = \left[\frac{1}{\alpha}\left(\frac{q \times \lambda}{1 - \tau_{cap}} + \delta\right)\right]^{\frac{1}{\alpha-1}} \tag{22}$$

Open Economy (cont.)

- κ in (22) then gives wages:

$$w = (1-\alpha)\kappa^{\alpha} \tag{23}$$

- Agents optimize over the transition path given (20) and (23), which results in an aggregate efficient labor sequence, $\mathbf{L}$.

- Then, the corresponding capital sequence is given by the product:

$$\mathbf{K} = \kappa\mathbf{L} \tag{24}$$

Open Economy (cont.)

- Since the closed economy steady-state provides initial conditions for the open economy, we assume that initial foreign capital is zero.

- Define $\mathbf{K}_{domestic}$ to be the aggregate capital holdings of households in the economy. Then, foreign capital is

$$\mathbf{K}_{foreign} = \mathbf{K} - \mathbf{K}_{domestic} \tag{25}$$

Capital Tax Revenue

- Because of territorial capital tax, must account for taxation of foreign capital.
- By assumption, capital tax share θ also applies to foreign capital. In other words, $1 - \theta$ of foreign capital income is not taxed in the US.
- Capital tax revenue from foreign capital is then: $\theta \frac{r_K - 1}{q} K_f$.

Household Portfolio

- Weighted average of return on capital and government interest rate:

$$\phi_K = \frac{K}{K + D} \tag{26}$$

- Open economy: portfolio allocation fixed at initial steady state shares of capital and debt.

- Closed economy: portfolio allocation determined in general equilibrium throughout transition path $\Rightarrow$ all debt is held by households.

Government Debt

- Sequence of government interest rates r_g is exogenous.
- Government debt evolves according to:

$$D' + R = r_g D + G, \quad (27)$$

  where R is government revenue and G is government expenditures.
- R and G have explicit model components. For revenue, personal income taxes (PIT), capital taxes (CT) and payroll taxes (SSREV), and for expenditures, Social Security expenditures (SSEXP).
- We can expand (27) as follows:

$$D' + FIT + SSREV + CT + \tilde{T} = r_g D + SSEXP + \tilde{G} \quad (28)$$

  where $\tilde{G}$ is the non-interest government budget surplus not accounted by the explicit model revenue and expenditure components and $\tilde{T}$ is non-explicit tax revenue introduced only in counter-factual experiments (e.g., estate taxes, tariffs).

Simulating Debt Over the Transition Path

- Process of matching CBO debt projection:
  1. Choose $\tilde{G}$ to match CBO non-interest surplus in each year in the open economy.
  2. Use CBO government interest rates to generate debt sequence (generates exactly the CBO debt projection).
  3. Use resulting $\tilde{G}$ from open economy (no macroeconomic feedback from debt) to construct government budget in closed economy.
- Key intuition: CBO debt projections correspond to our open economy (no feedback effects of debt).
- Baseline closed economy accounts for macroeconomic feedback from this debt sequence.

Reported Tax Revenue Aggregates

- Personal Income Tax is assessed on wage income and a portion of capital income:

$$PIT_{BASE} = wL + (1-\theta)\frac{r_K - 1}{q}K_{domestic}, \qquad (29)$$

where L is aggregate efficient labor.

- Capital Income is $\frac{r_K - 1}{q}K$
  - Portion taxed at PIT is $(1-\theta)\frac{r_K - 1}{q}K$.
  - Portion taxed at the single capital tax rate is $\theta\frac{r_K - 1}{q}K$.
  - Capital tax is from corporate tax, tax on dividends, tax on capital gains, etc.
    - Complex tax structure
    - Simplified into the PIT and single rate structure as above.
    - PIT $\Rightarrow$ residential, single rate τ_{cap} $\Rightarrow$ territorial

Reported Tax Revenue Aggregates (cont.)

- Since PIT is non-linear, it is not clear how to assign tax dollars from capital income portion:

$$PIT_{REVENUE} = \tau_{pit}(PIT_{BASE}) \tag{30}$$

- We say taxes assigned by percent of income

$$PIT_{CAP\_REV} = \frac{(1-\theta)\frac{r_K - 1}{q} K_{domestic}}{PIT_{BASE}} PIT_{REVENUE} \tag{31}$$

- So CT is

$$CT_{REVENUE} = \tau_{cap}\theta \frac{r_K - 1}{q} K + PIT_{CAP\_REV} \tag{32}$$