Penn Wharton Budget Model: Dynamics

July 5, 2016

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

Policy Evaluation

- 75-year CBO debt-to-GDP and government interest rate projections as baseline
- Policy alternatives increase or decrease debt
- Debt-to-GDP stabilized at year 75, government expenditures adjust as closure rule
- Open economy: prices fixed $\Rightarrow$ no debt consequences
- Closed economy: prices affected by debt

Dynamic Scoring

- Process of using dynamic model to measure behavioral and macroeconomic feedback:

1. Generate a *Static Score* using dynamic model: hold prices and behavior (decision rules) constant, apply counter-factual policy variables
2. Evaluate policy using dynamic model as usual
3. Take ratio of dynamic-to-static
4. Multiply ratio and micro-simulation policy projection to generate *Dynamic Score*

Dynamic Model

Households

Labor Productivity (z)

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

Households

Taxes, SS Benefits, and Bequests

- Taxes
  - Federal income tax (Gouveia-Strauss) on total income y:

$$\tau_f(y) = a_0(y - (y^{-a_1} + a_2)^{-\frac{1}{a_1}}) \tag{1}$$

  - Payroll (Social Security) tax on labor income wzn:

$$\tau_{ss} \min\left\{wzn, y_{\text{taxmax}}\right\}, \tag{2}$$

    where y_{taxmax} is maximum labor income subject to payroll tax.
- Social Security benefit
  - Benefit $ss(b)$ depends on average lifetime labor earnings b.
- Accidental bequests are collected by the government and redistributed lump-sum (beq) among all living households.

Households

Working-age household Bellman's equation:

$$V_j(k,z,b) = \max_{k',n} \left\{ \frac{(c^{\gamma}(1-n)^{1-\gamma})^{1-\sigma}}{1-\sigma} + s_{j+1}\beta E_{\{z'|z\}}[V_{j+1}(k',z',b')] \right\} \tag{3}$$

subject to:

$$c = r_p k + wzn - \tau_f(y) - \tau_{ss} \min\{wzn, y_{taxmax}\} - k' + beq \tag{4}$$

$$y = (r_p - 1)k + wzn - d \tag{5}$$

$$b_{j+1} = \frac{1}{j}\left((j-1)b_j + \min\{wzn, y_{\text{taxmax}}\}\right), \tag{6}$$

where (4) is the budget constraint, (5) is income subject to the federal income tax, (6) determines average earnings for SS benefit calculation, s_{j+1} is survival probability, r_p is the return to household portfolios, and d is the federal income tax deduction, which is common to all agents.

Households

Retired household Bellman's equation:

$$V_j(k,b) = \max_{k'} \left\{ \frac{(c^{\gamma}(1)^{1-\gamma})^{1-\sigma}}{1-\sigma} + s_{j+1}\beta V_{j+1}(k',b') \right\} \tag{7}$$

subject to:

$$c = r_p k + ss(b) - \tau_f(y) - k' + beq \tag{8}$$

$$y = (r_p - 1)k + (1 - \phi_{ss})ss(b) - d \tag{9}$$

$$b_{j+1} = b_j, \tag{10}$$

where ϕ_{ss} is the fraction of SS benefits deductible from federal income taxation, common among all retirees.

Production: Closed Economy

- Output:

$$Y = (K - D)^{\alpha} L^{1-\alpha}, \tag{11}$$

where K is aggregate household saving, D is government debt, and L is aggregate efficient labor.

- Firms' problem:

$$\max_{K,L} \left\{ (K - D)^{\alpha} L^{1-\alpha} + (1 - \delta)K - r_f K - wL \right\}, \tag{12}$$

where δ is depreciation and r_f is the rental rate of capital faced by firms.

- Firms' interest rates and wages are determined according to:

$$r_f = 1 + \alpha(K - D)^{\alpha - 1} L^{1-\alpha} - \delta \tag{13}$$

$$w = (1 - \alpha)(K - D)^{\alpha} L^{-\alpha} \tag{14}$$

Production: Open Economy

- Output:

$$Y = \tilde{K}^{\alpha} L^{1-\alpha}, \tag{15}$$

where L is aggregate domestic efficient labor, and $\tilde{K}$ is the aggregate capital determined in international markets.

- Firms' problem:

$$\max_{K,L} \left\{ K^{\alpha} L^{1-\alpha} + (1-\delta)K - r_f^* K - w^* L \right\}, \tag{16}$$

where r_f^* and w^* are the international rental rate of capital and wages, respectively.

- Then $\tilde{K}$ and L are determined according to:

$$r_f^* = 1 + \alpha \tilde{K}^{\alpha-1} L^{1-\alpha} - \delta \tag{17}$$

$$w^* = (1-\alpha)\tilde{K}^{\alpha} L^{-\alpha} \tag{18}$$

- World prices set to initial steady-state value determined in closed economy.

Household Portfolio

- Weighted average of rental rate of capital and government interest rate (r_g):

$$r_p = \frac{r_f K + r_g D}{K + D} \tag{19}$$

- Open economy: portfolio return fixed at initial steady state values of capital and debt.

- Closed economy: determined in general equilibrium throughout transition path.

Government Debt

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

$$D' + R = r_g D + G, \tag{20}$$

where R is government revenue and G is government expenditures.

- R and G have explicit model components. For revenue, federal income taxes (FIT) and payroll taxes (SSREV), and for expenditures, Social Security expenditures (SSEXP).
- We can expand (20) as follows:

$$D' + FIT + SSREV = r_g D + SSEXP + \tilde{G} \tag{21}$$

where $\tilde{G}$ is the non-interest government budget surplus not accounted by the explicit model revenue and expenditure components.

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.

Calibration Overview and Key Parameters

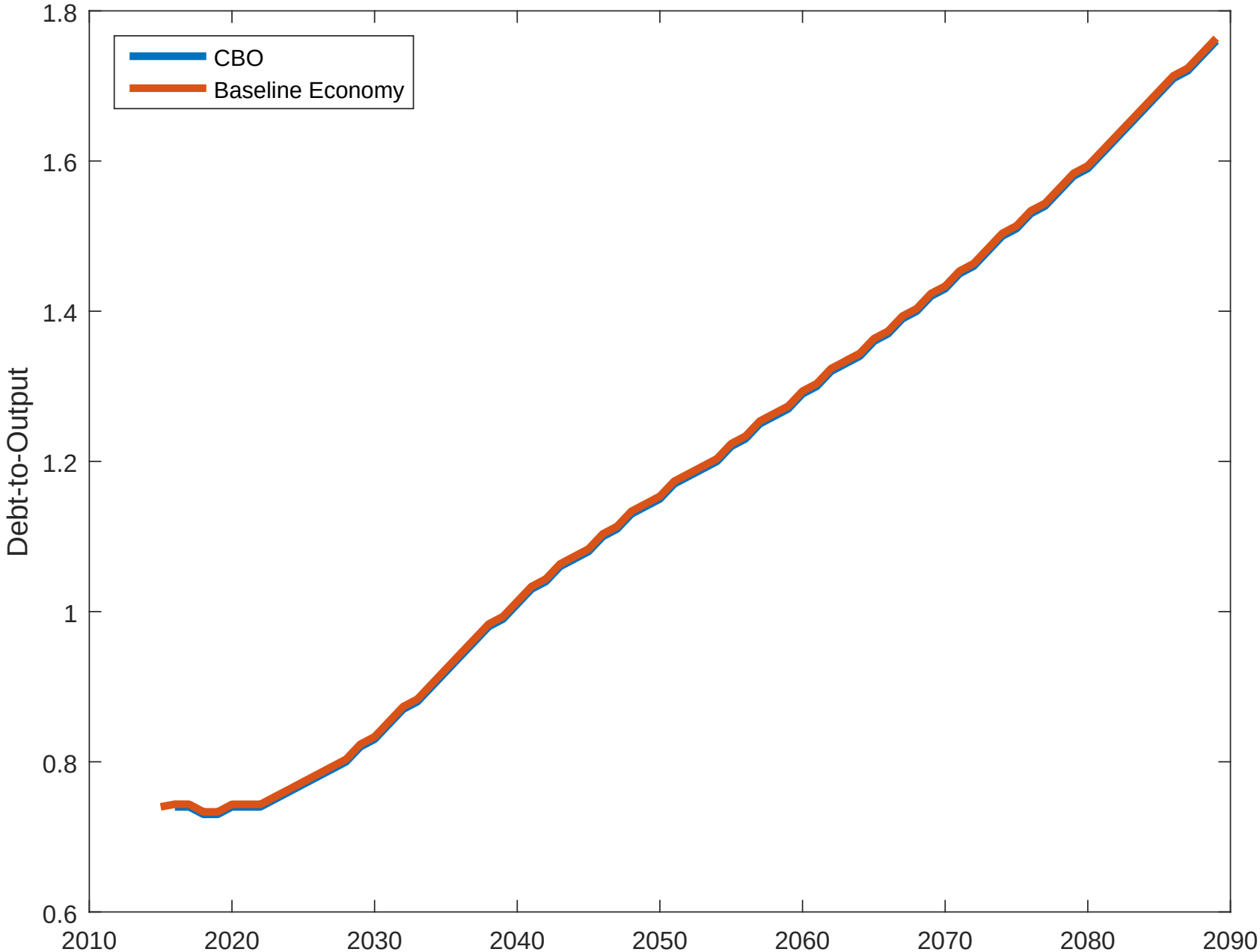
- Frisch Labor Supply Elasticity: 0.5.
- Elasticity of Intertemporal Substitution: 0.5
- Discount factor (β): 0.985 ($\frac{K}{Y} = 3$)
- Depreciation (δ): 0.085 ($\frac{\delta K}{Y} = 25.5\%$)
- Capital share (α): 0.45
- Population growth rate: 1.2%

Key Examples

- Payroll tax increase in 2017: 14.4%, 15.4%, 16.4%
- Benefit change in 2017: 15% $\uparrow$, 15% $\downarrow$, 25% $\downarrow$
- Open economy
  - Behavior driven directly by policy
- Closed economy
  - Short-run: Behavior driven directly by policy
  - Long-run: Behavior dominated by debt's effect on prices

Open Economy

Open Economy Baseline Debt



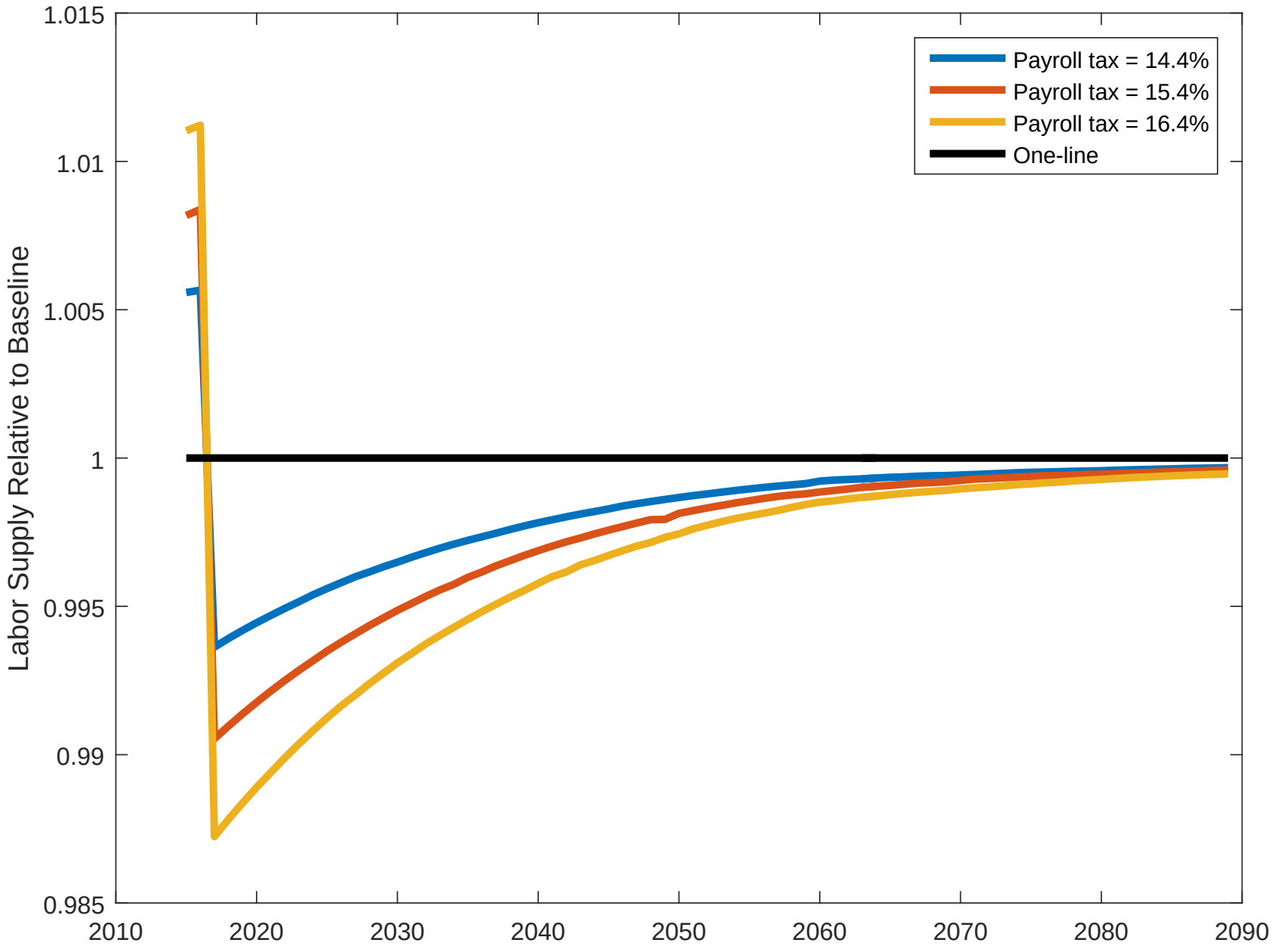
Example: Increasing the payroll tax

Payroll Tax Increase: Solving the Model

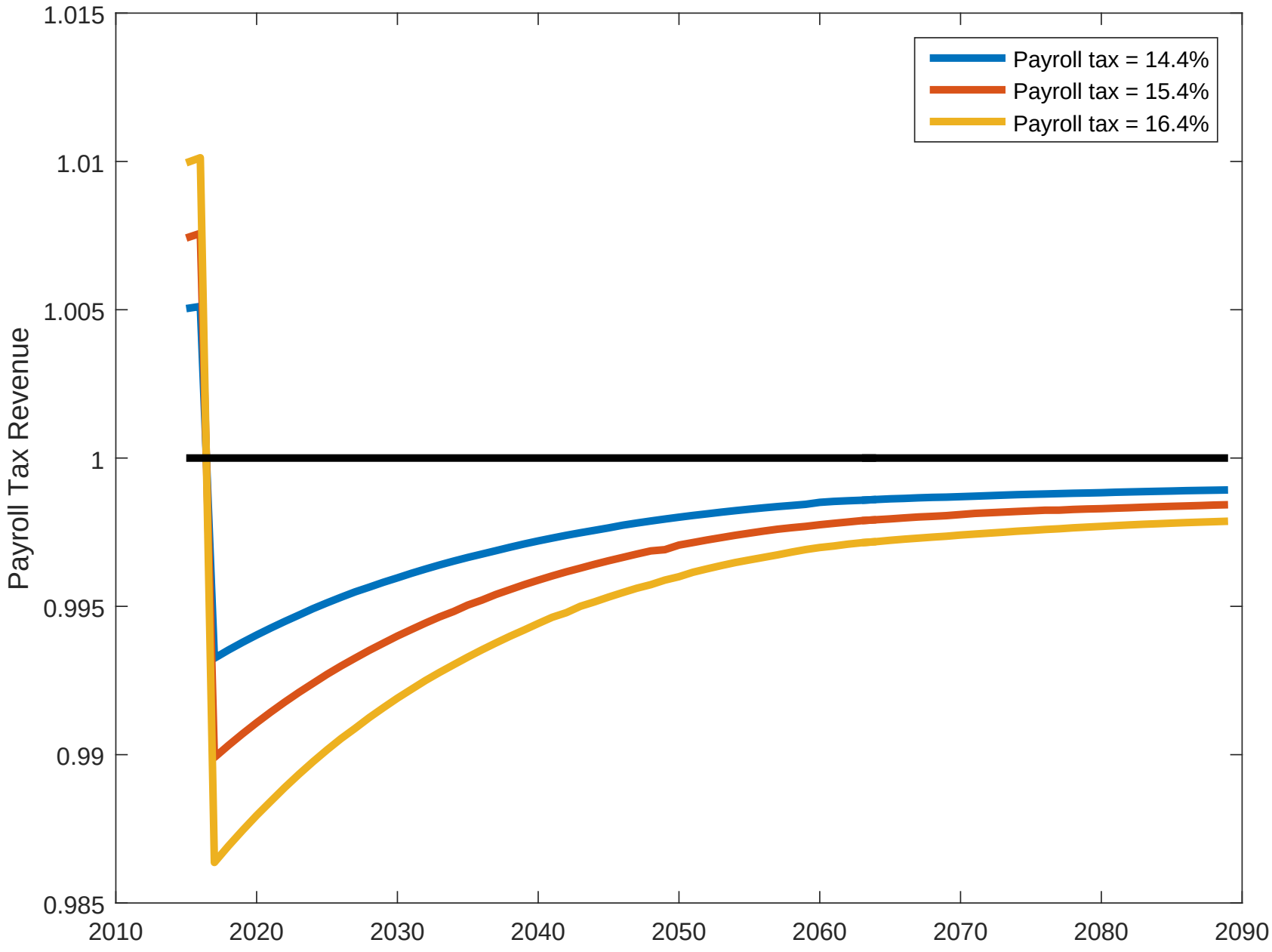
Process:

1. Solve the baseline economy (open economy first for government debt sequence, then closed), store decision rules.
2. Apply higher tax rates to baseline decision rules and prices for static revenue sequence.
3. Aggregate to generate static score over the transition path.
4. Solve equilibrium given higher tax rates to generate optimal responses and macroeconomic feedback.
5. Aggregate to generate dynamic sequence.
6. Take ratio of dynamic-to-static revenue sequence.
7. Multiply this ratio and micro-simulation estimate to generate dynamic score.

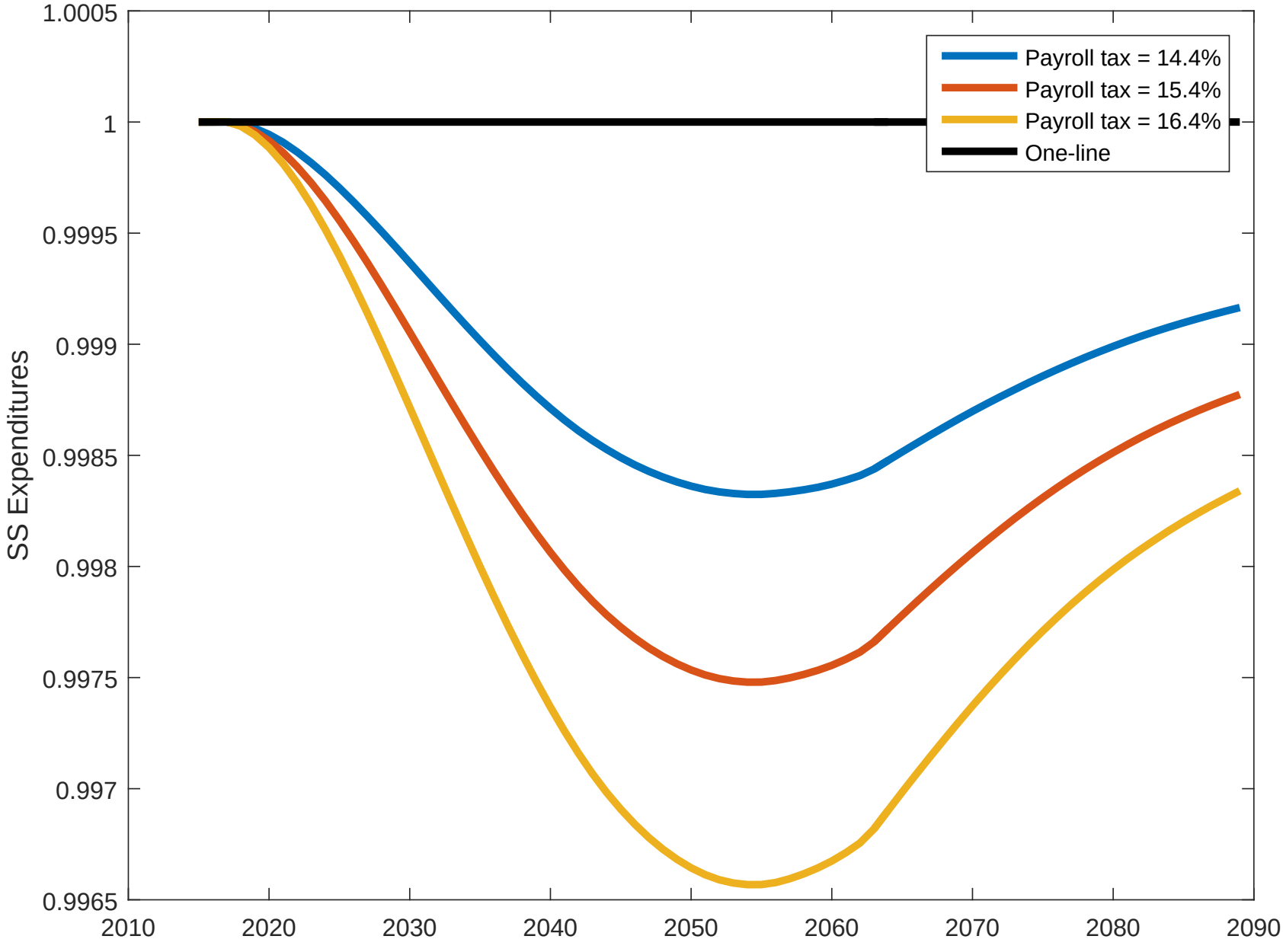
Effect of Tax Increase on Labor Supply



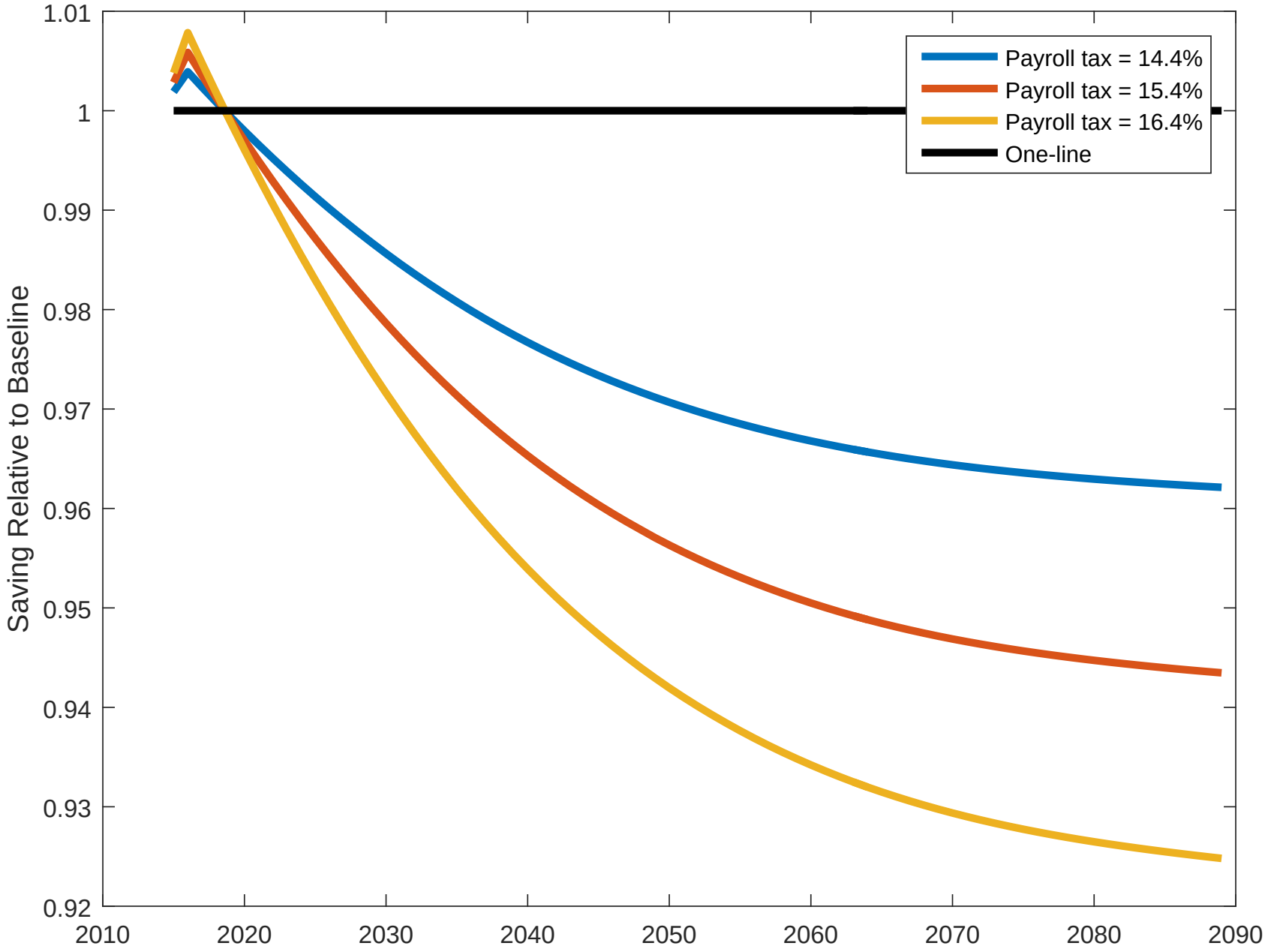
Payroll Tax Revenue Dynamic-to-Static Ratio



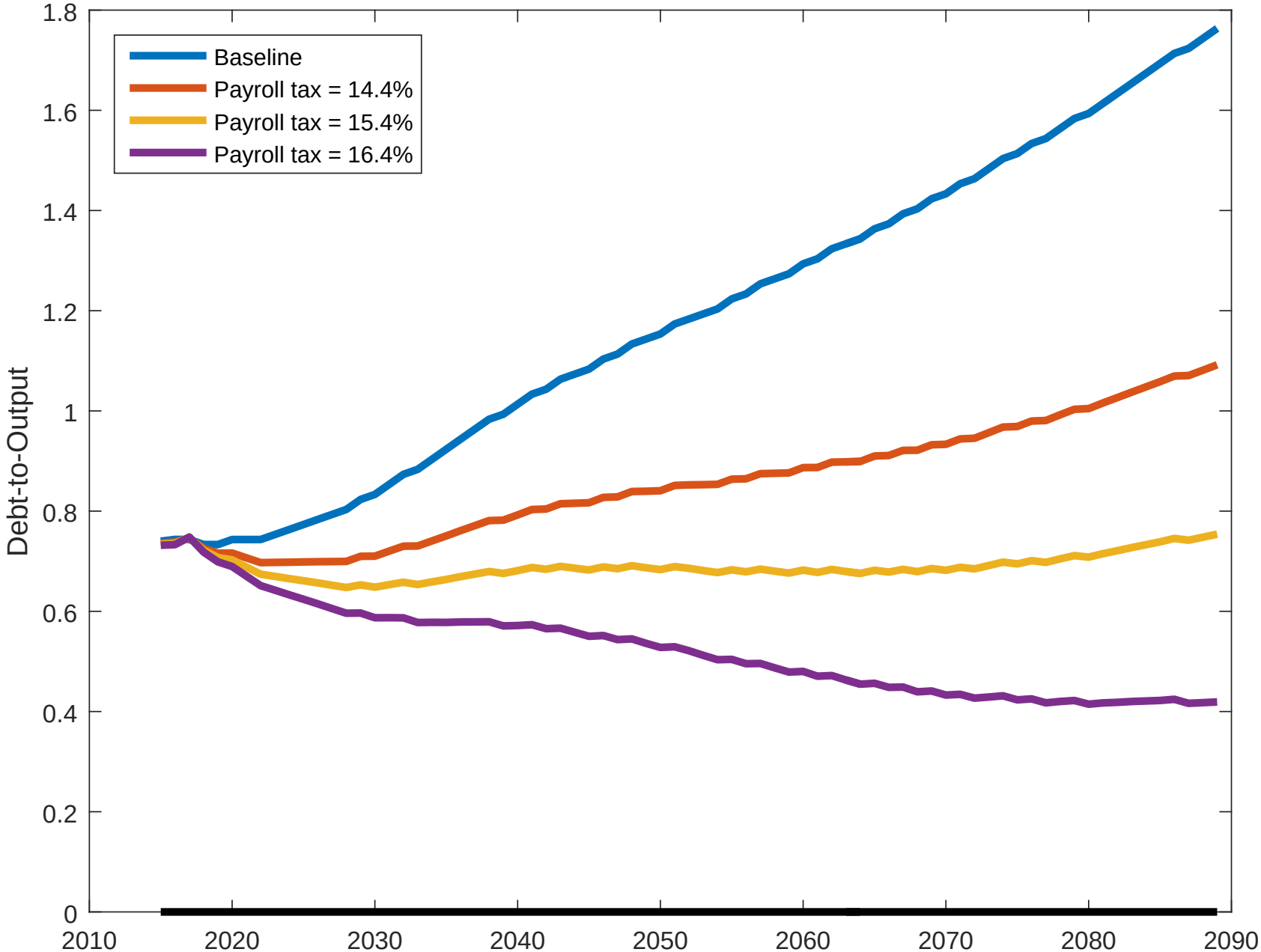
SS Expenditures Dynamic-to-Static Ratio



Effect of Tax Increase on Household Savings

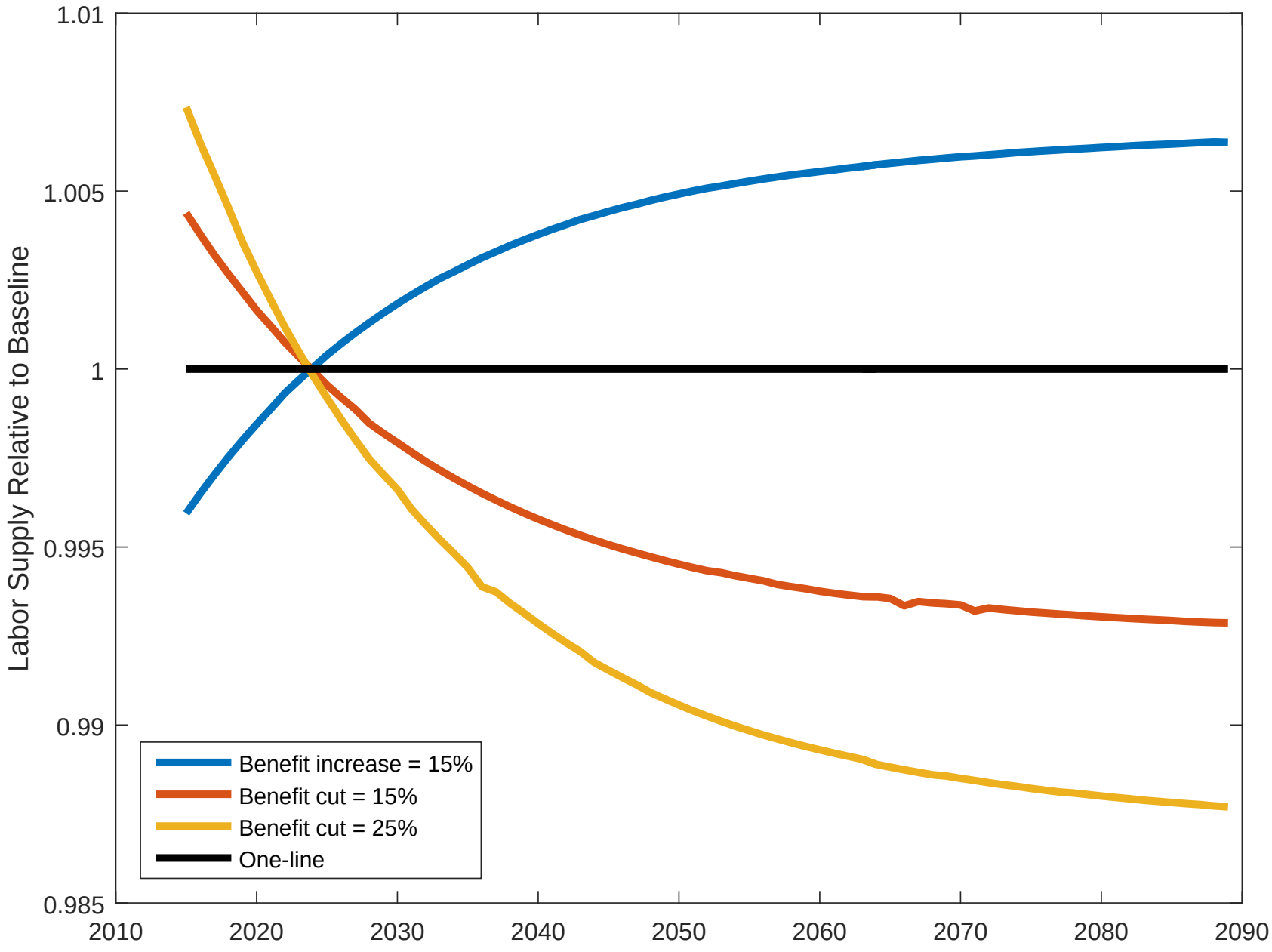


Projected Debt: Payroll Tax Increase

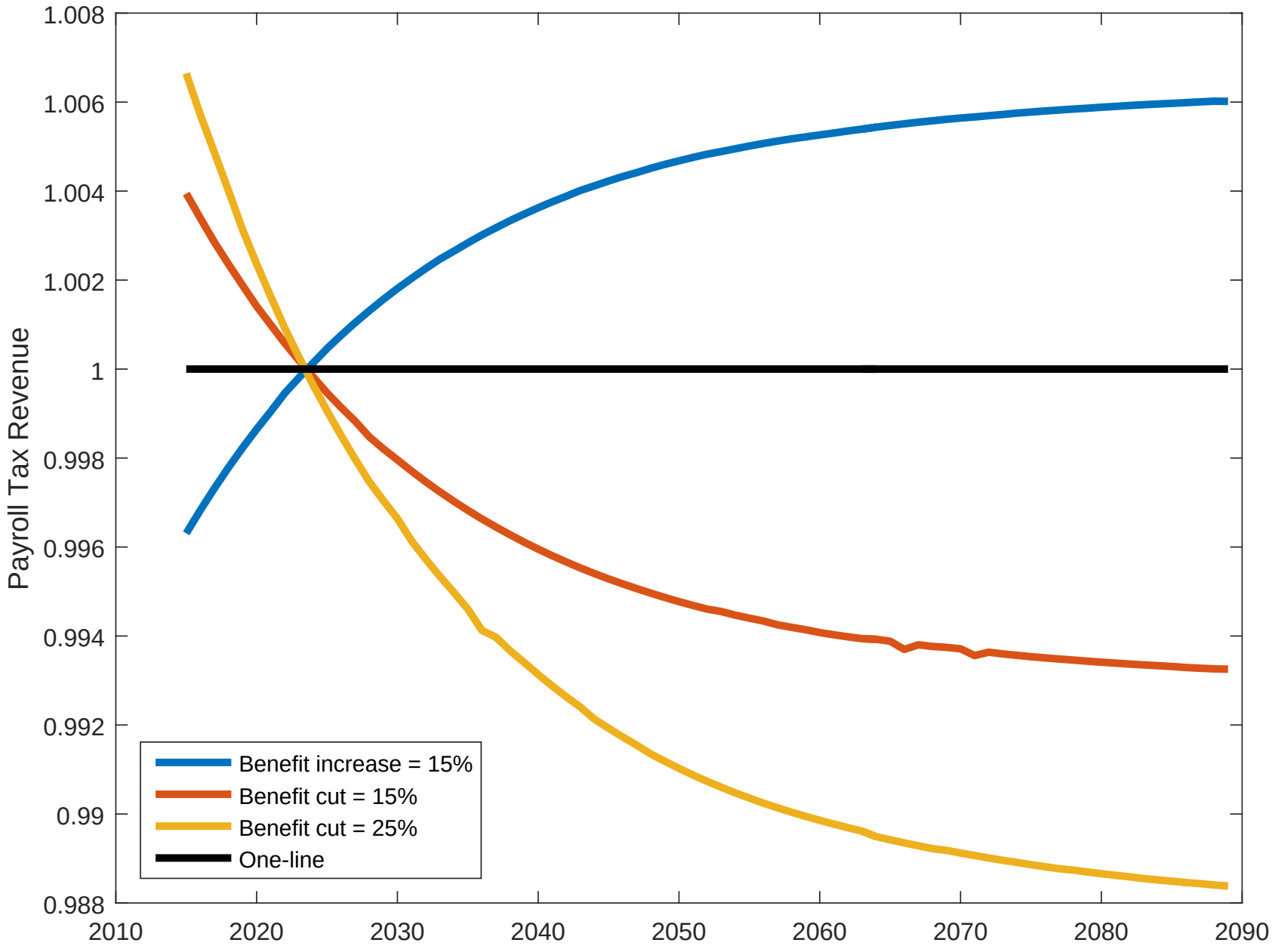


Example: Changing Social Security benefits

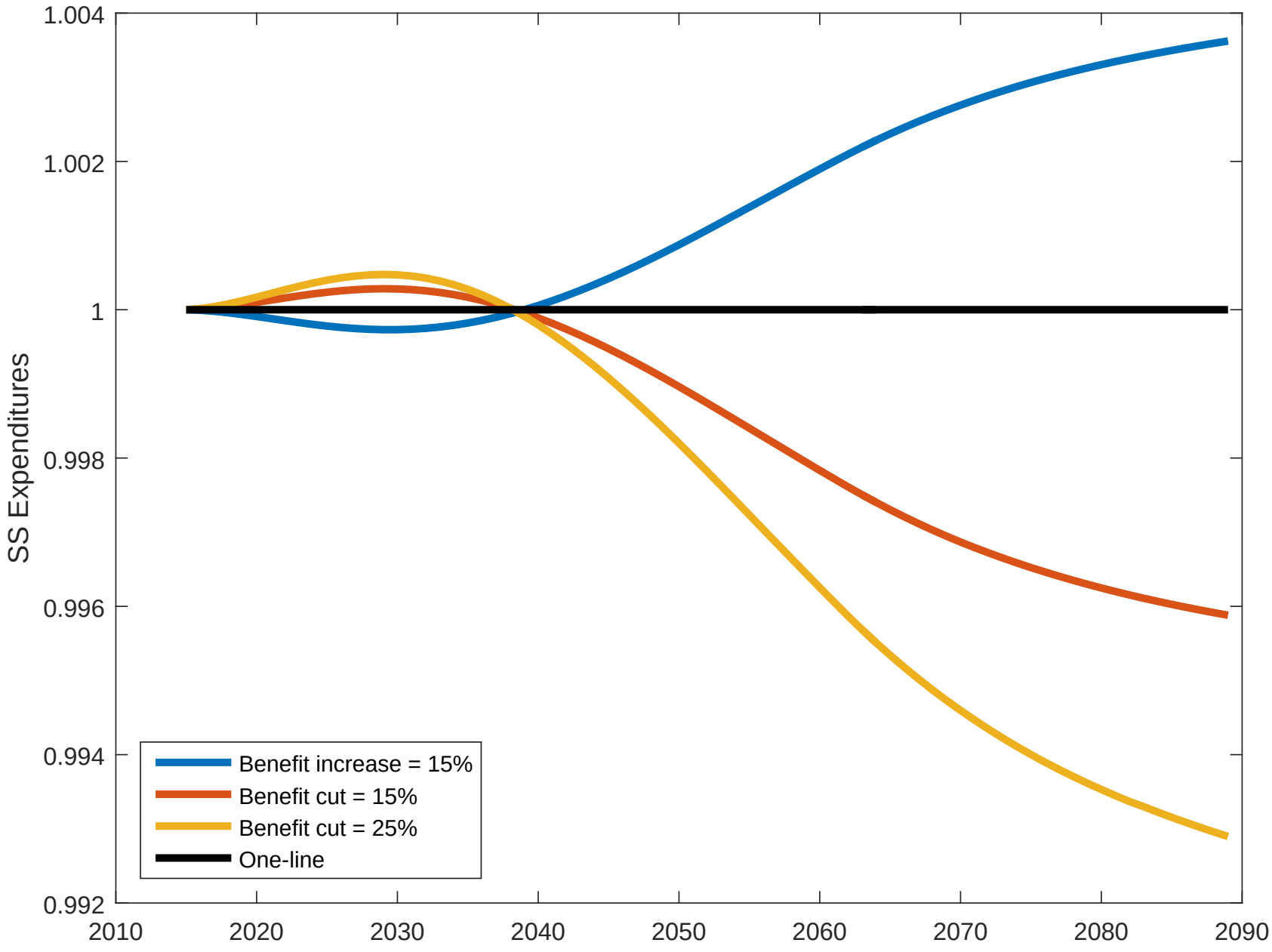
Effect of Benefit Change on Labor Supply



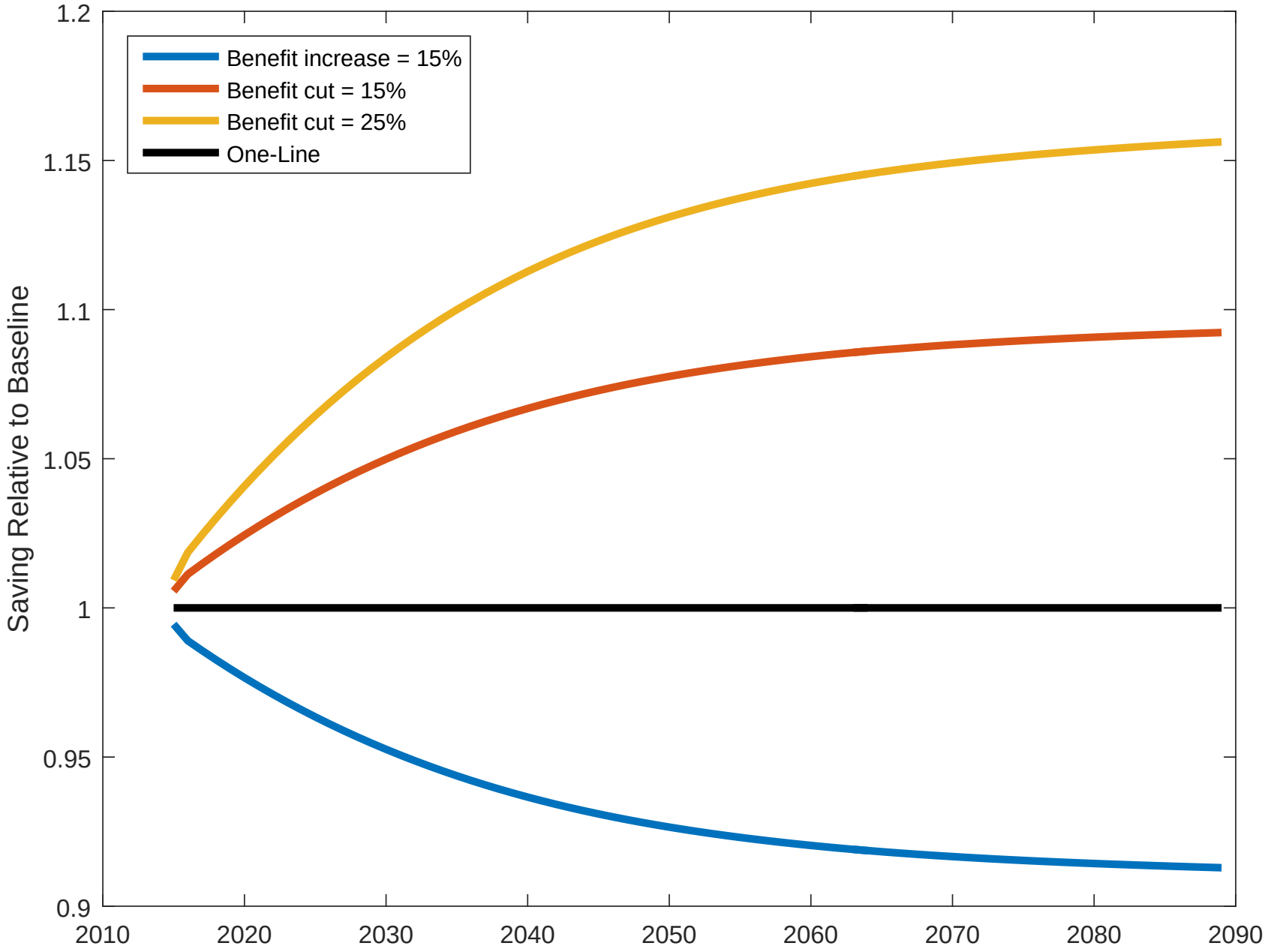
Payroll Tax Revenue Dynamic-to-Static Ratio



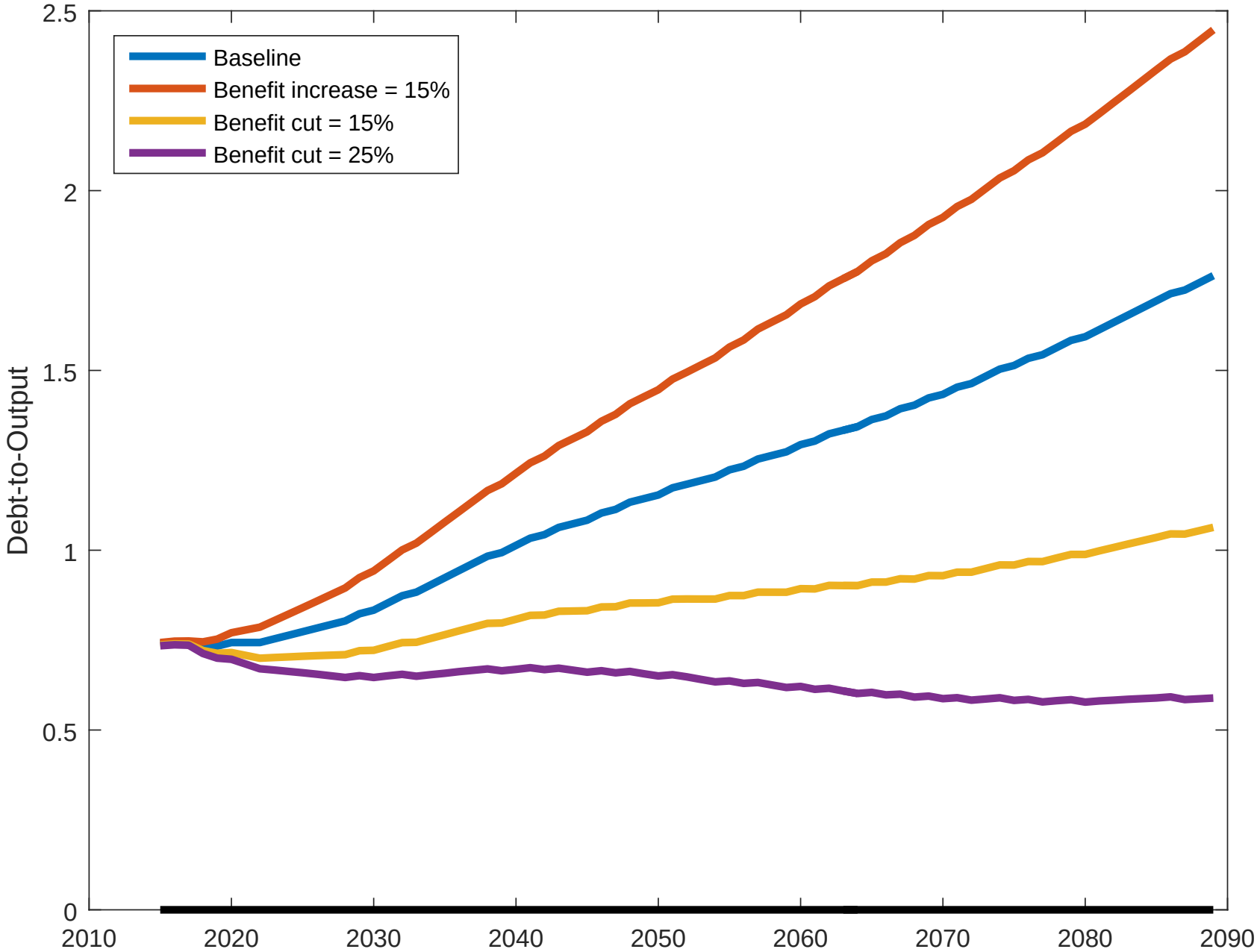
SS Expenditures Dynamic-to-Static Ratio



Effect of Benefit Change on Household Savings



Projected Debt: Benefit Change

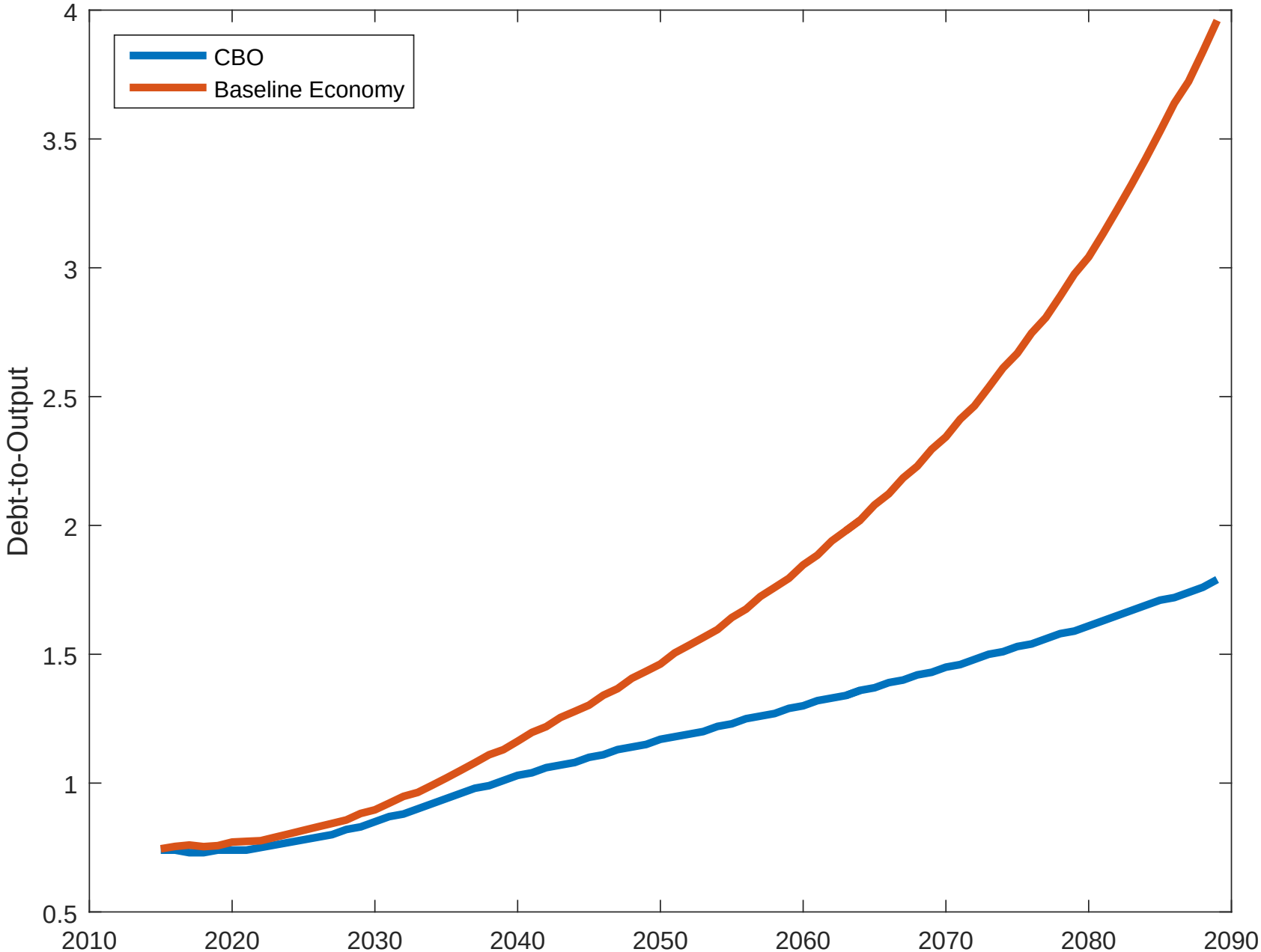


Effects of Debt

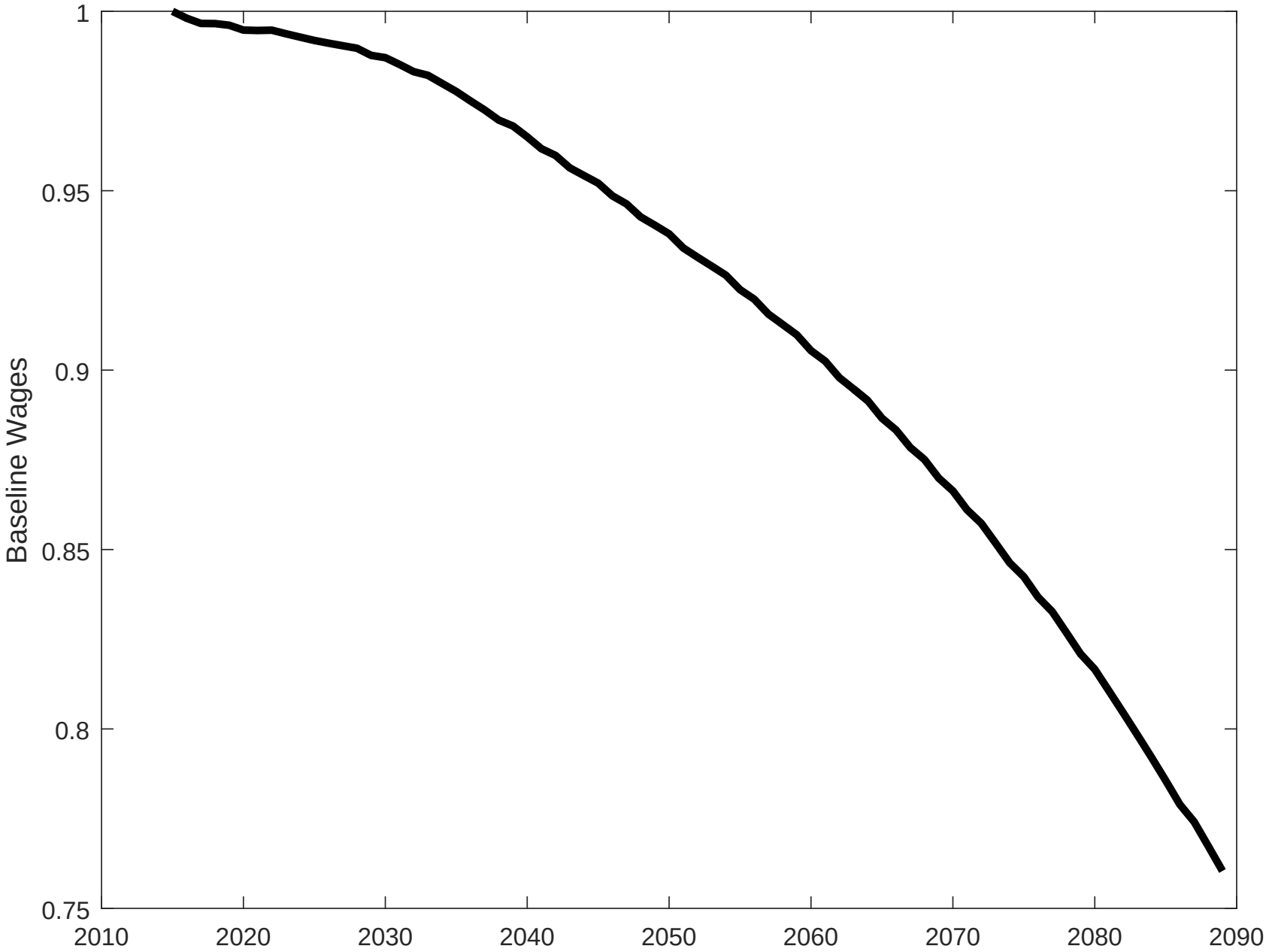
- Open economy: baseline prices and other variables unaffected by debt
- Closed economy: baseline prices significantly affected by growing debt
  - Rising debt reduces total capital $\Rightarrow$ interest rates increase
  - Wages driven down $\Rightarrow$ labor supply declines
  - Decline in capital and labor $\Rightarrow$ decline in output

Closed Economy

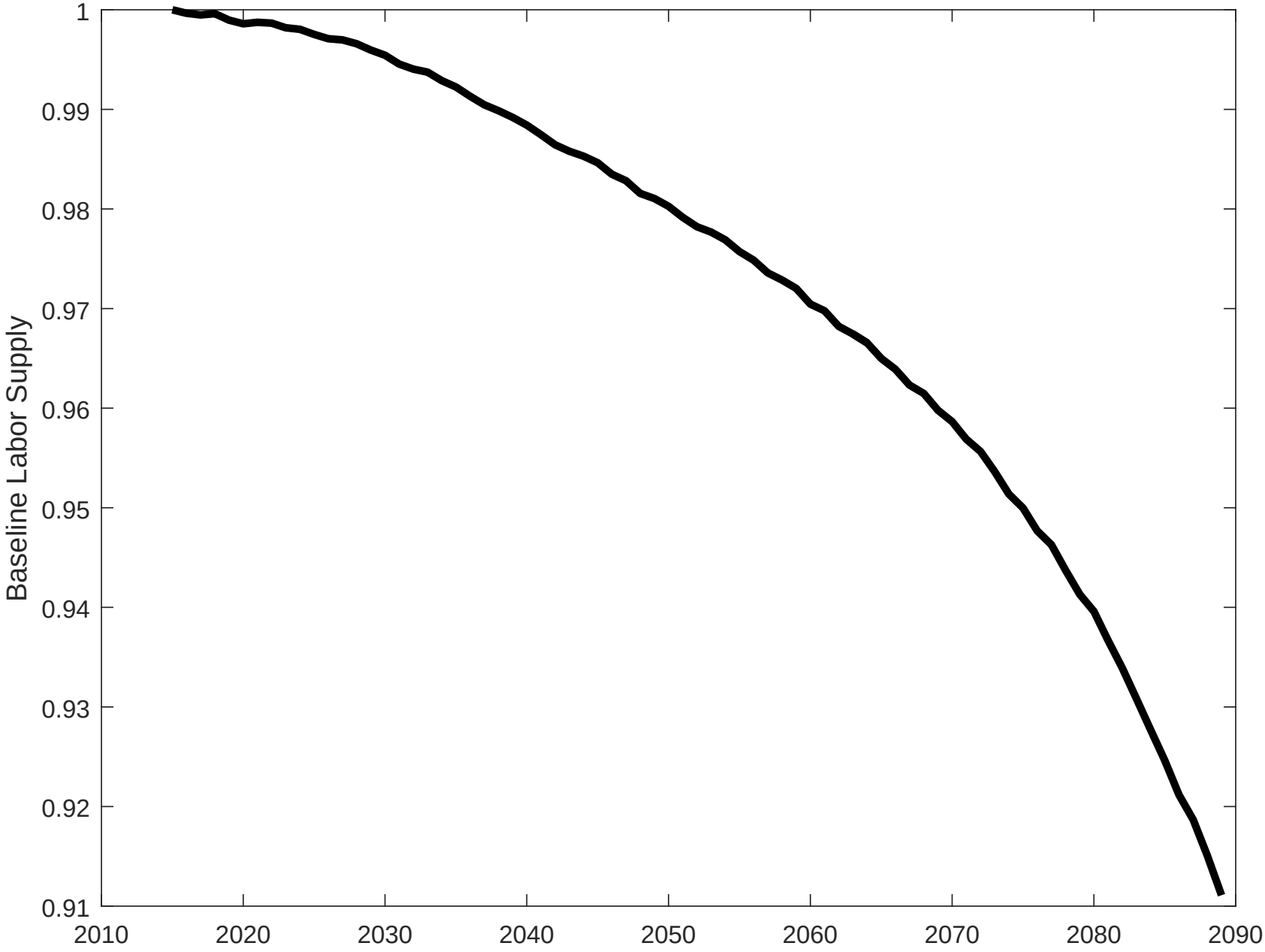
Closed Economy Baseline Debt



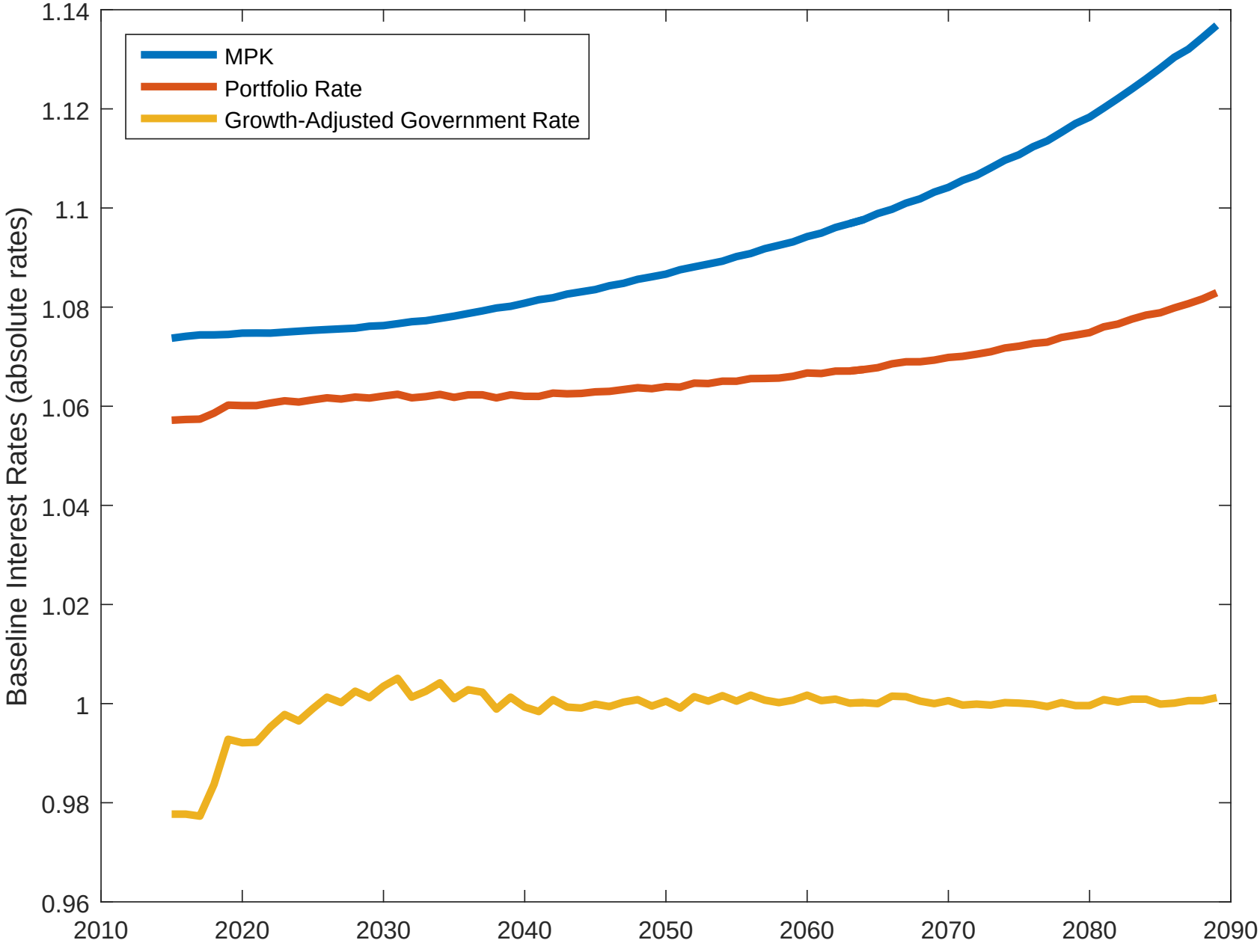
Baseline Wage



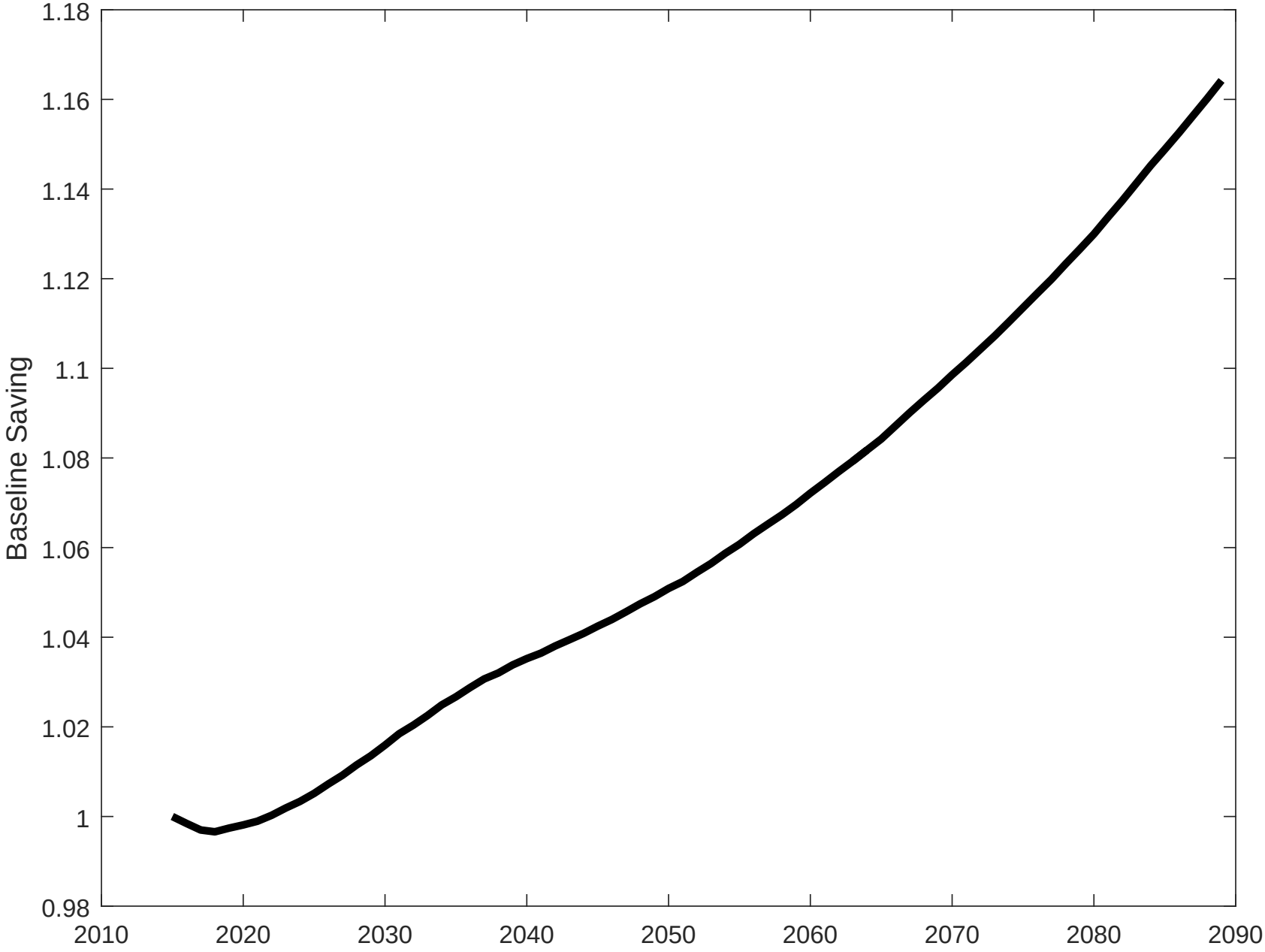
Baseline Labor Supply



Baseline Interest Rates

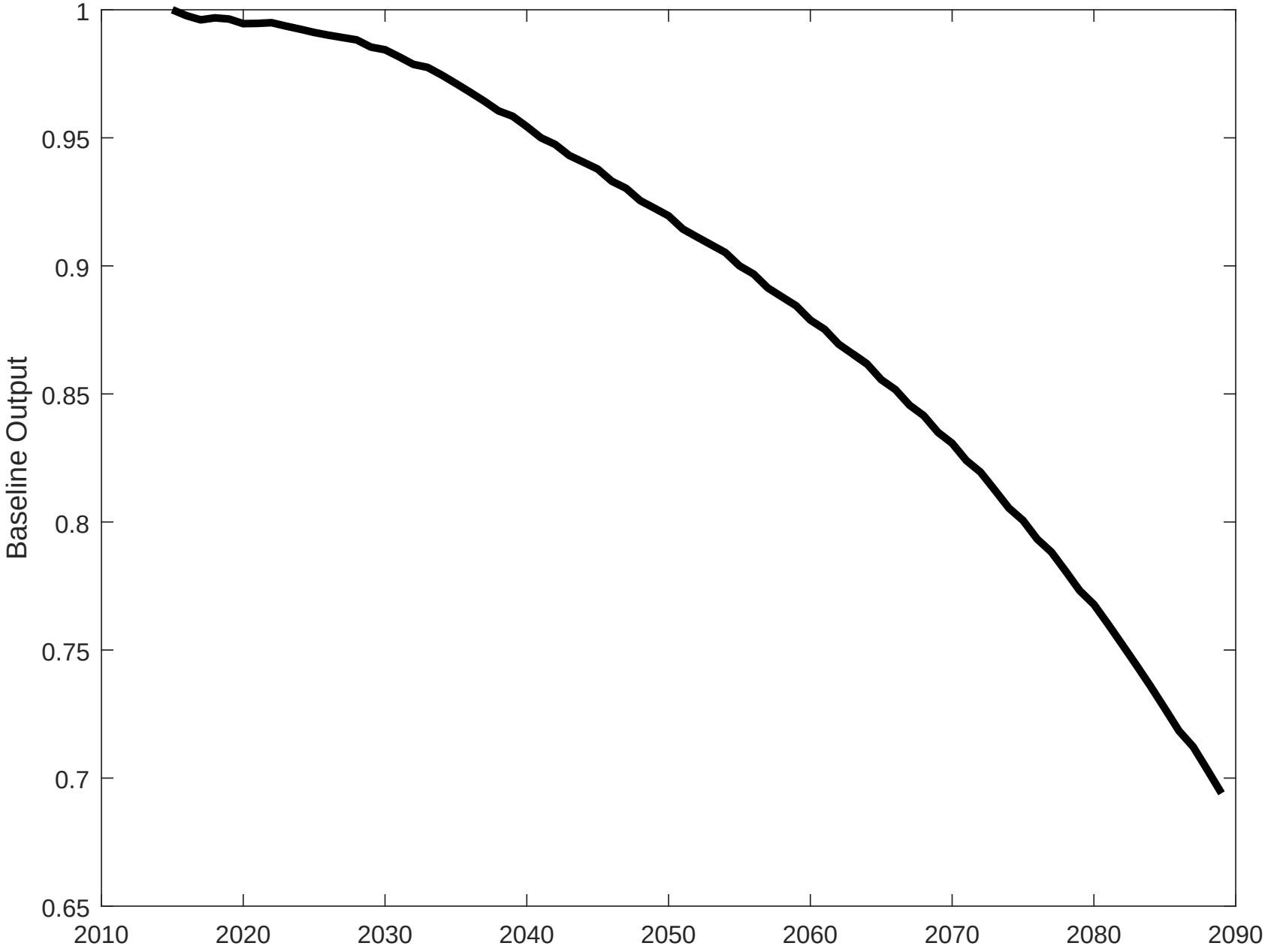


Baseline Saving



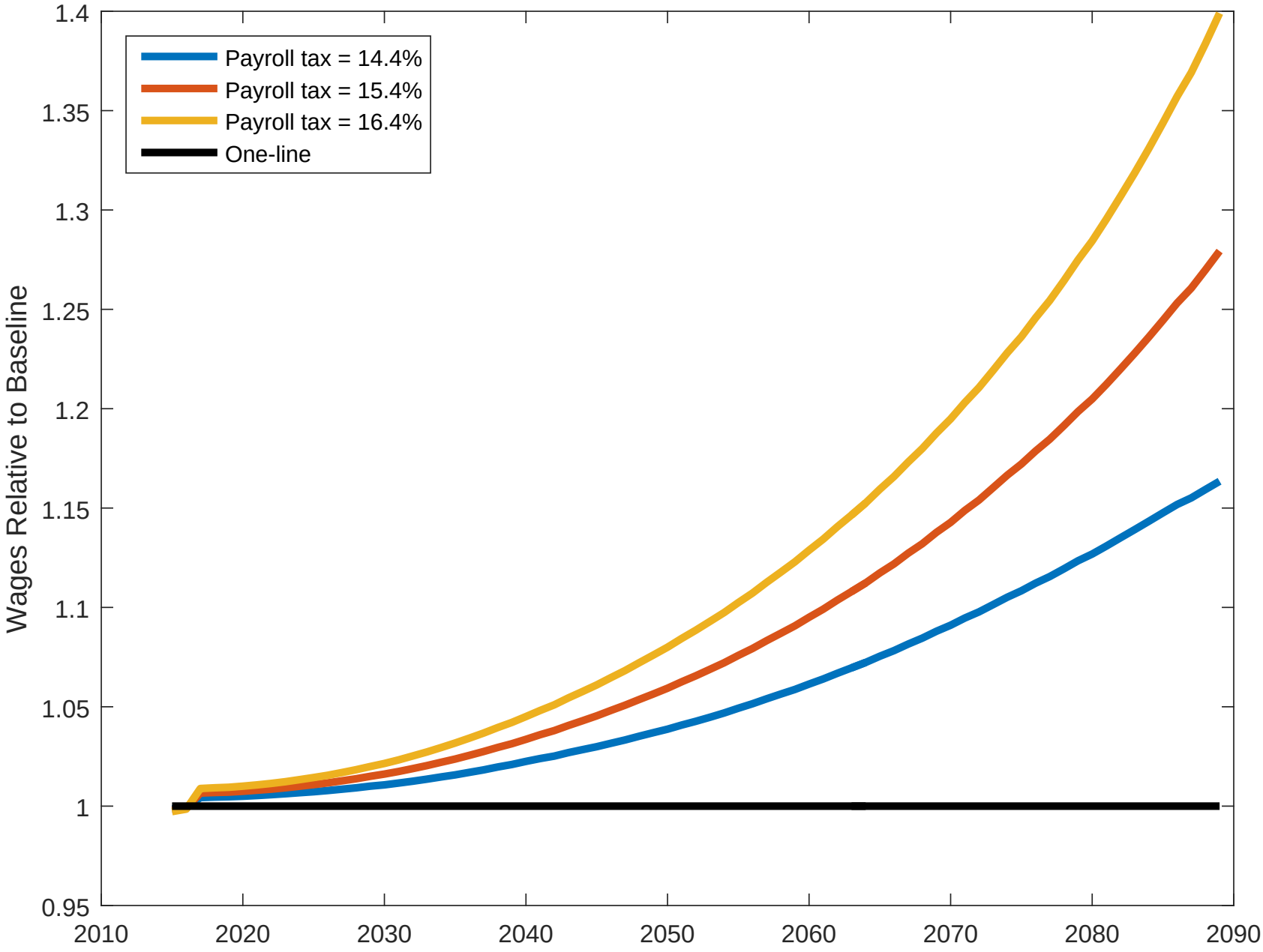
Baseline Total Capital

Baseline Output

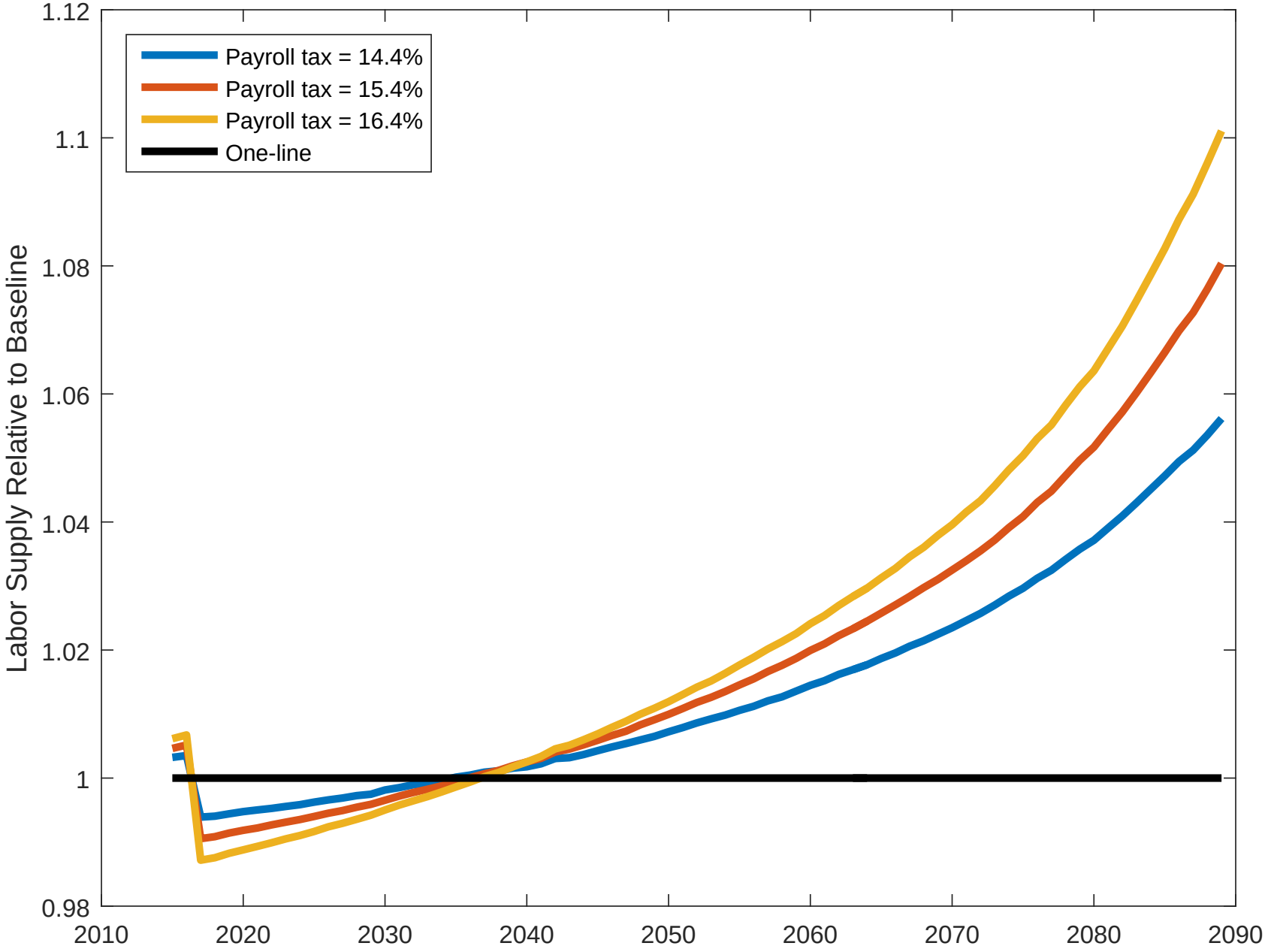


Example: Increasing the payroll tax

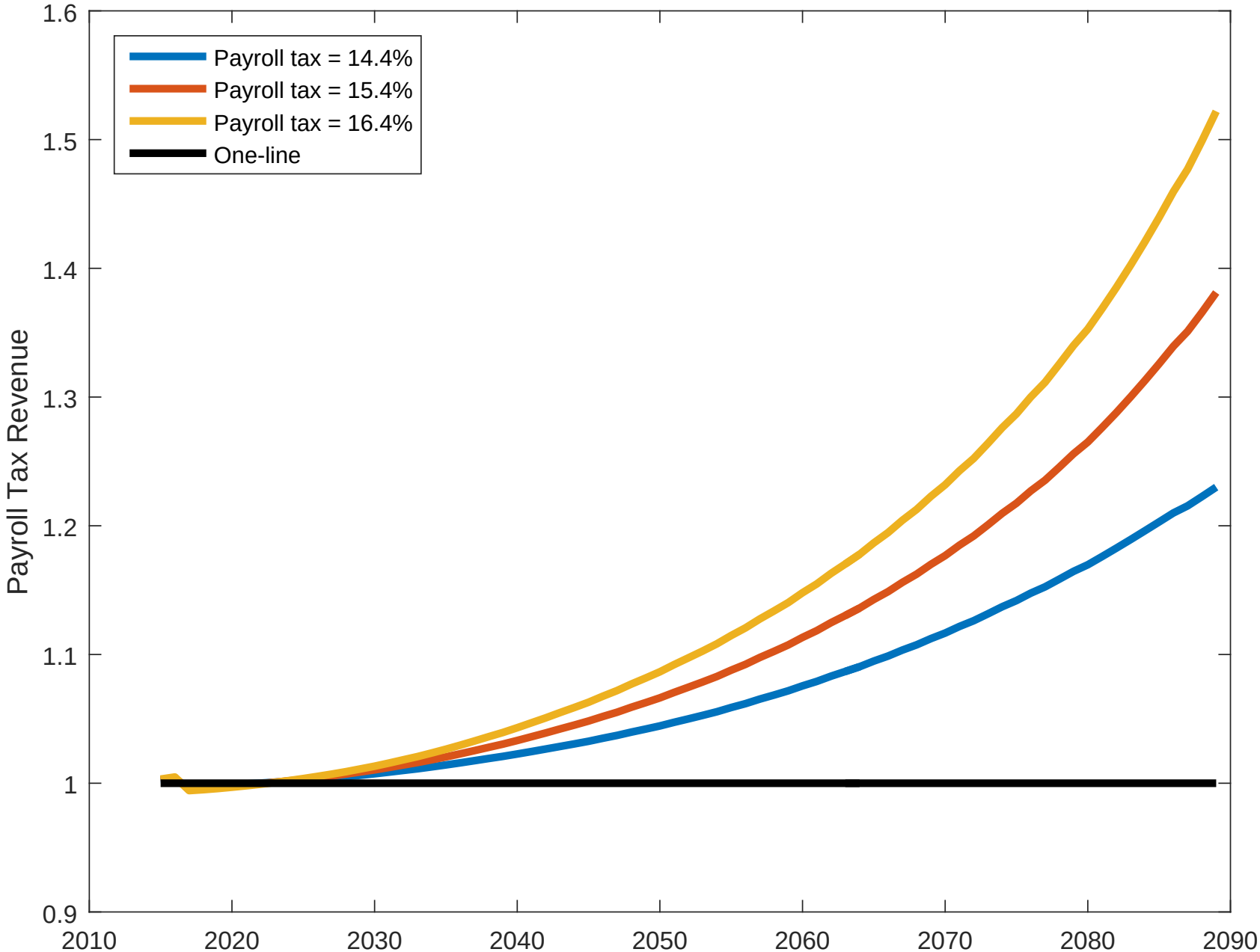
Effect of Tax Increase on Wages



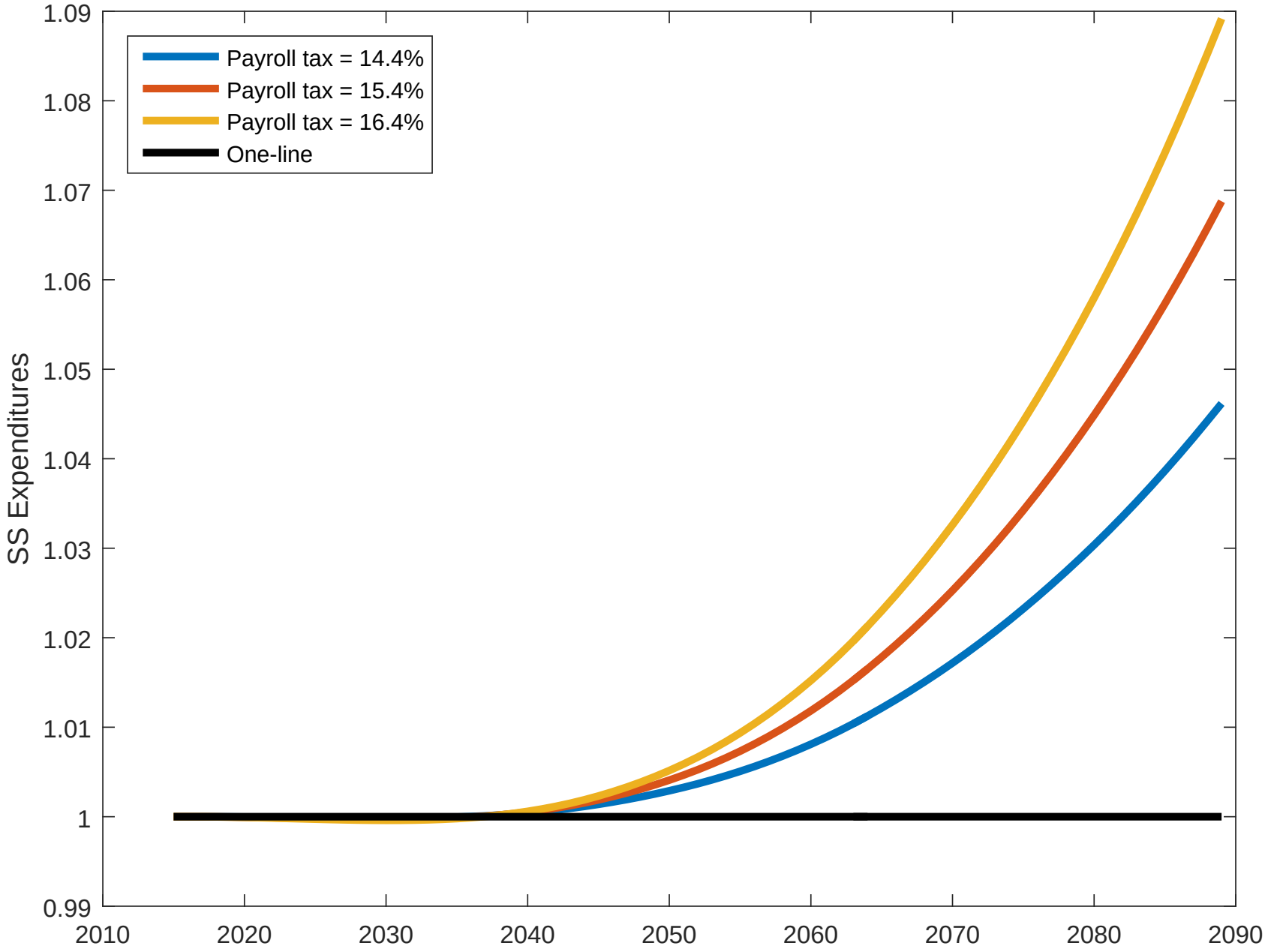
Effect of Tax Increase on Labor Supply



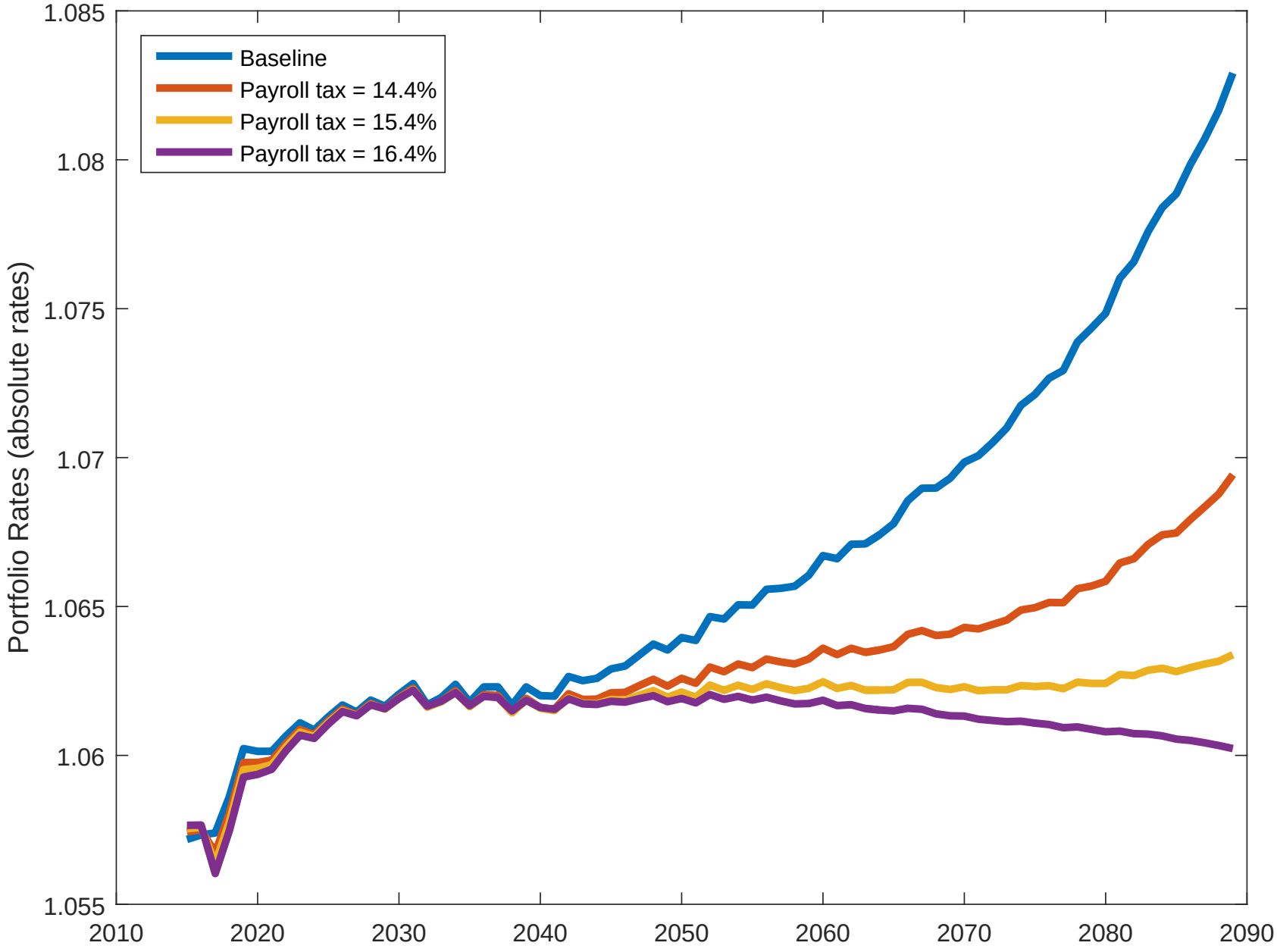
Payroll Tax Revenue Dynamic-to-Static Ratio



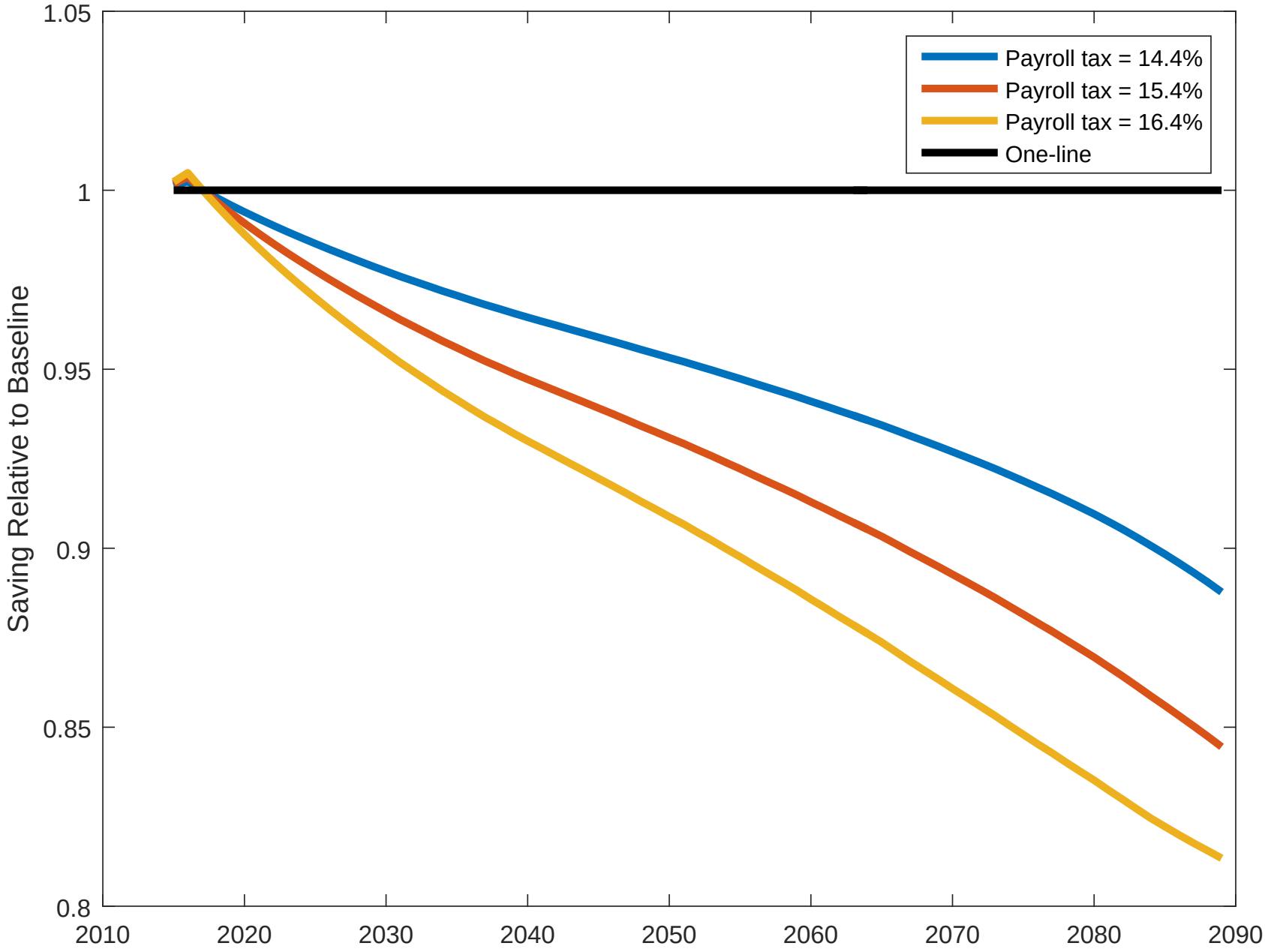
SS Expenditures Dynamic-to-Static Ratio



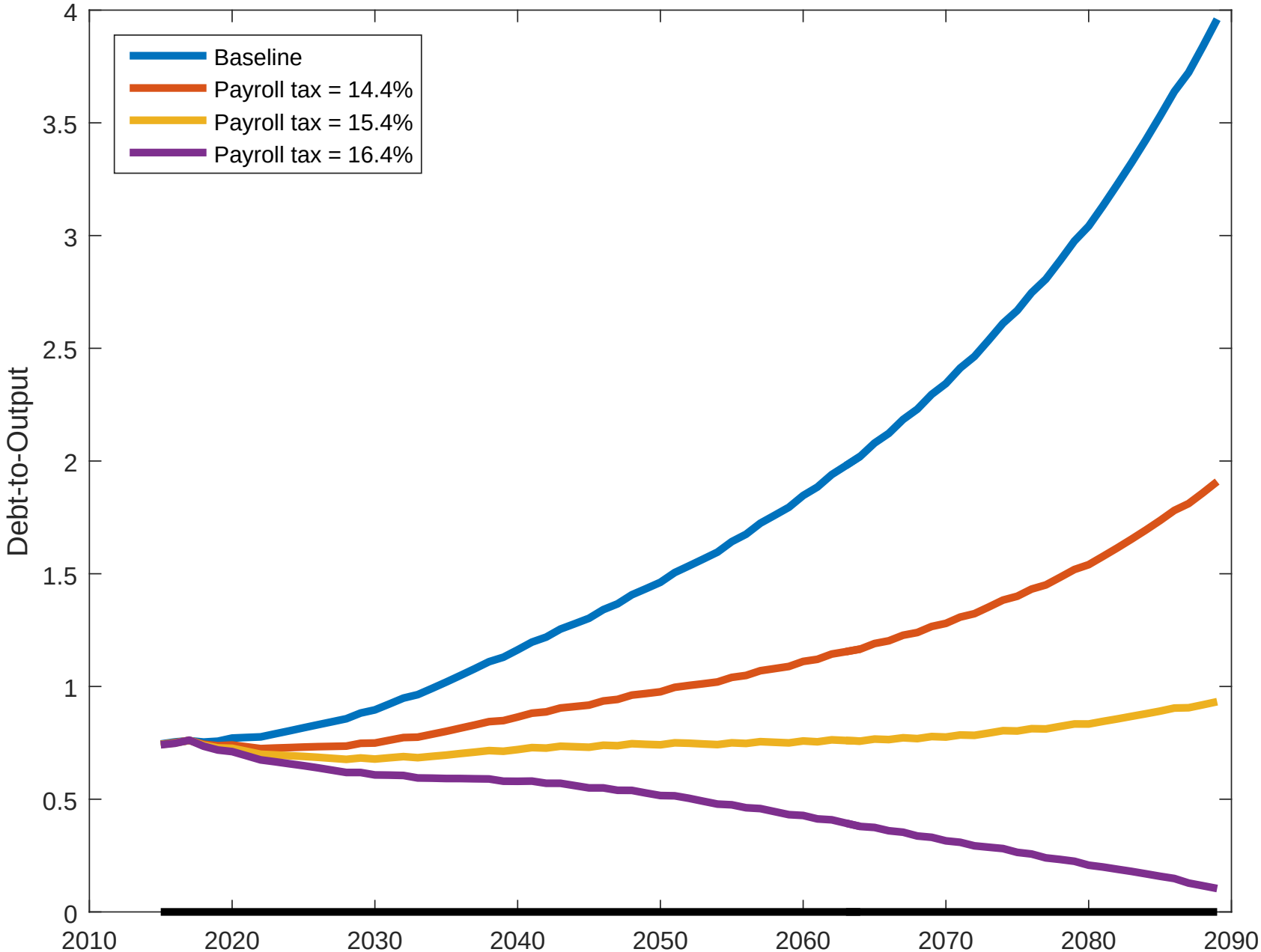
Effect of Tax Increase on Portfolio Rates



Effect of Tax Increase on Household Savings

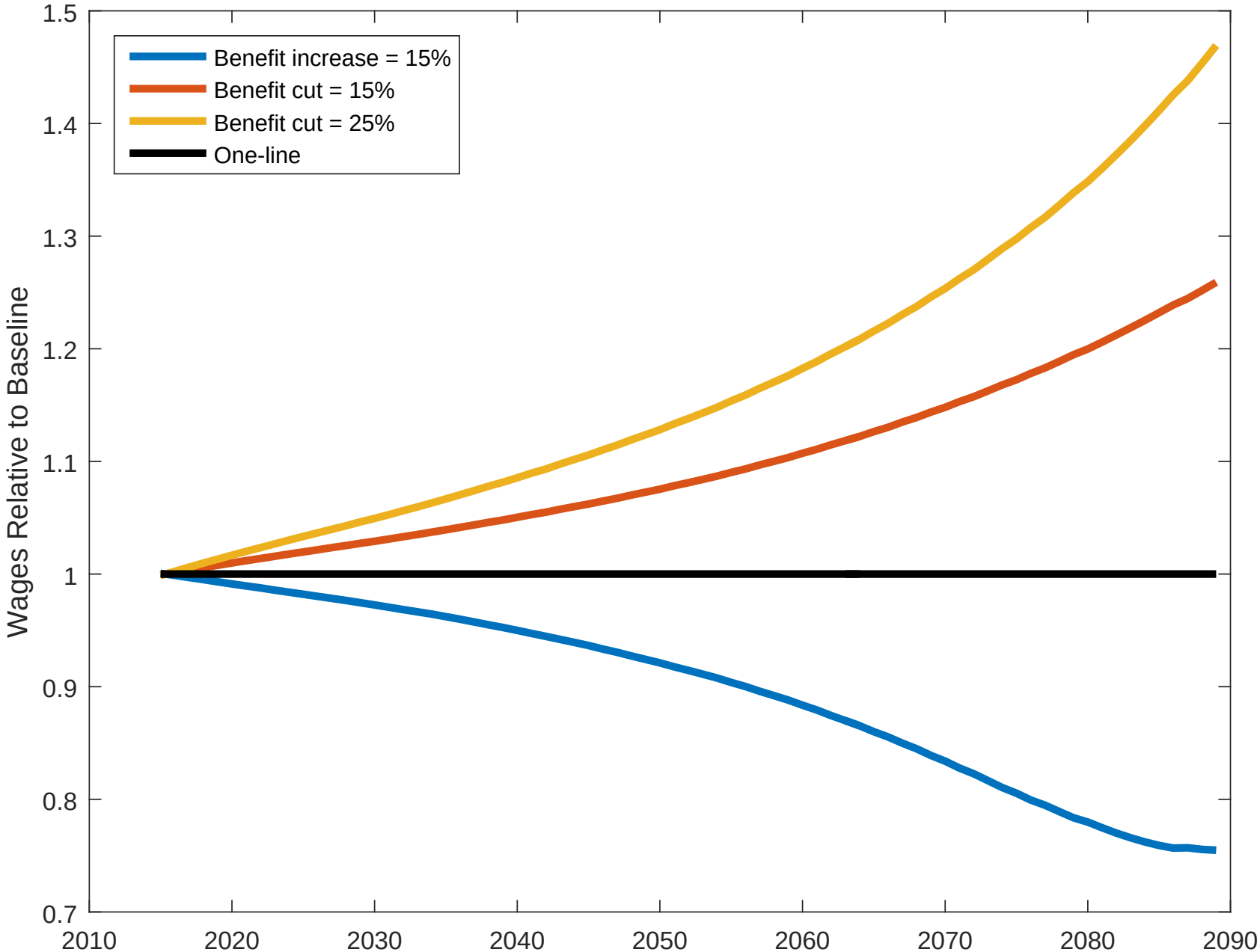


Projected Debt: Payroll Tax Increase

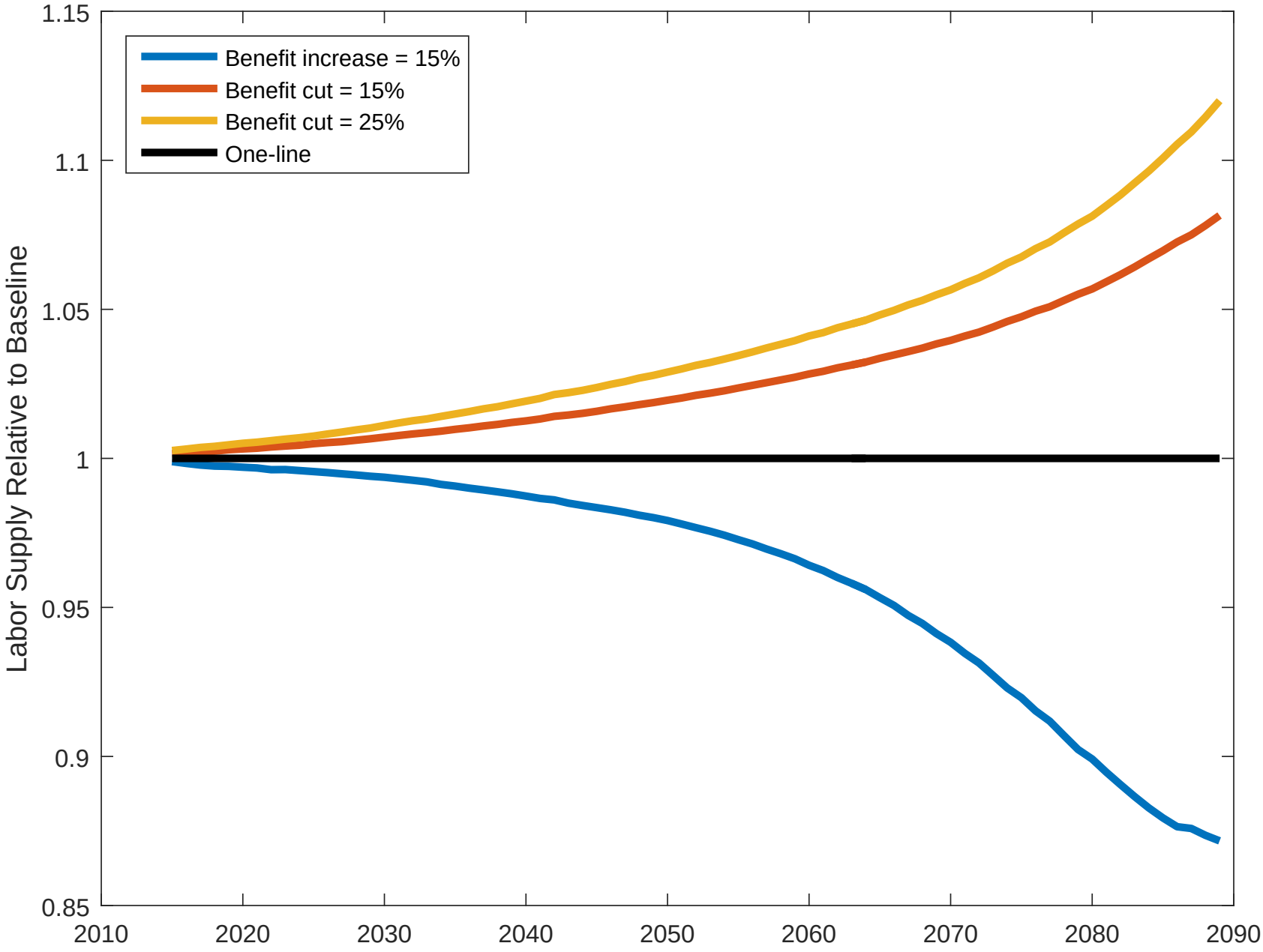


Example: Changing Social Security benefits

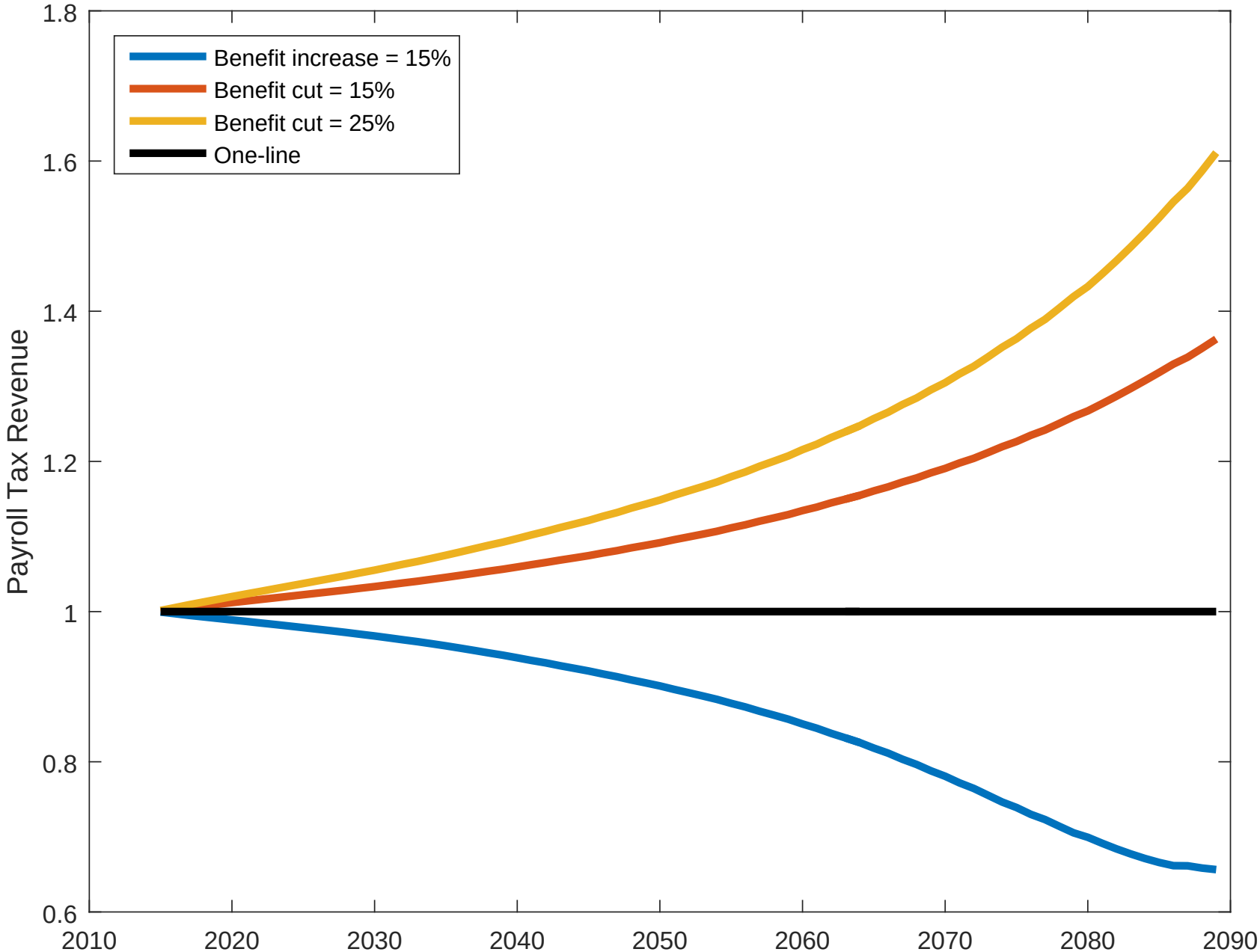
Effect of Benefit Change on Wages



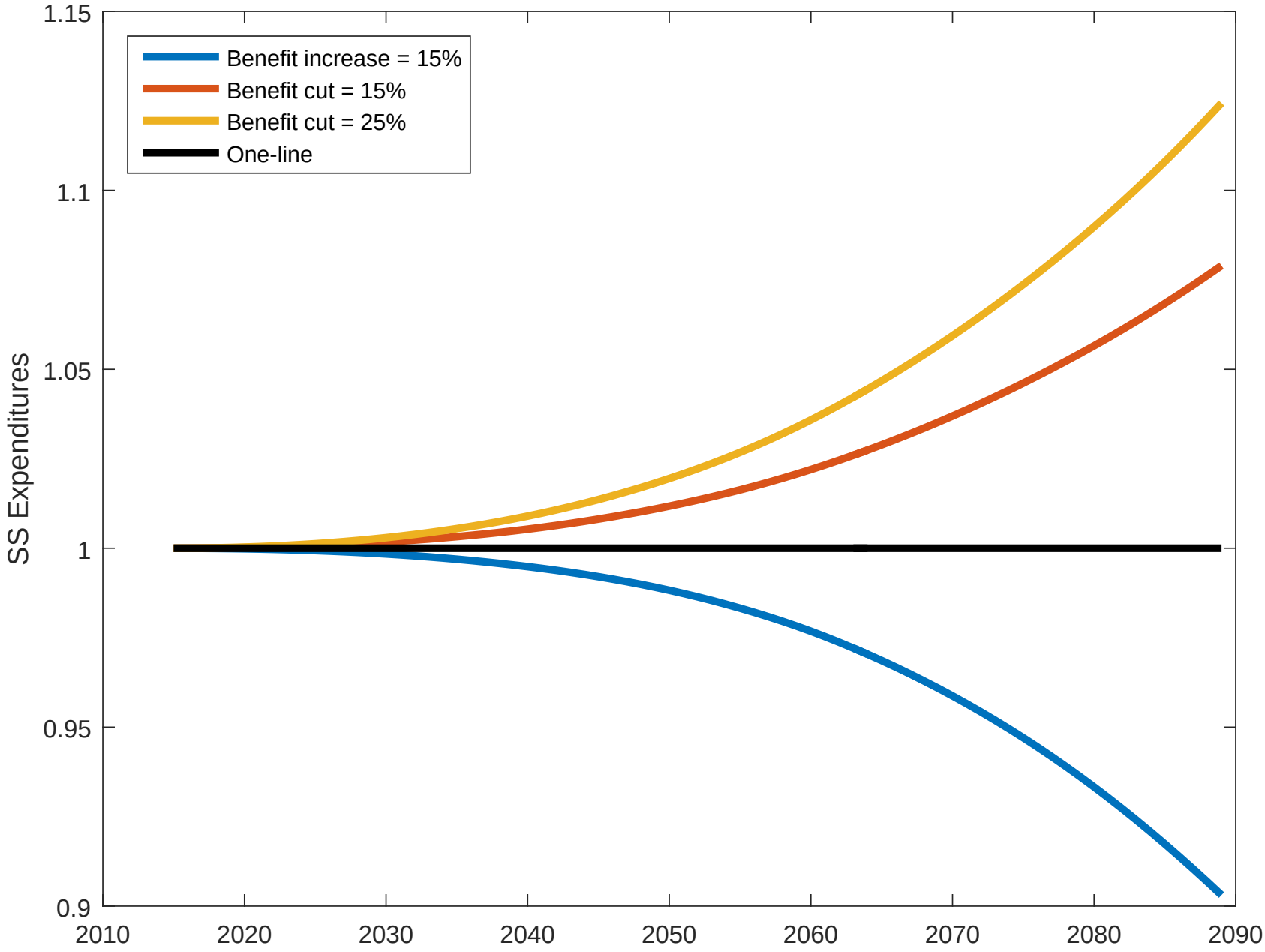
Effect of Benefit Change on Labor Supply



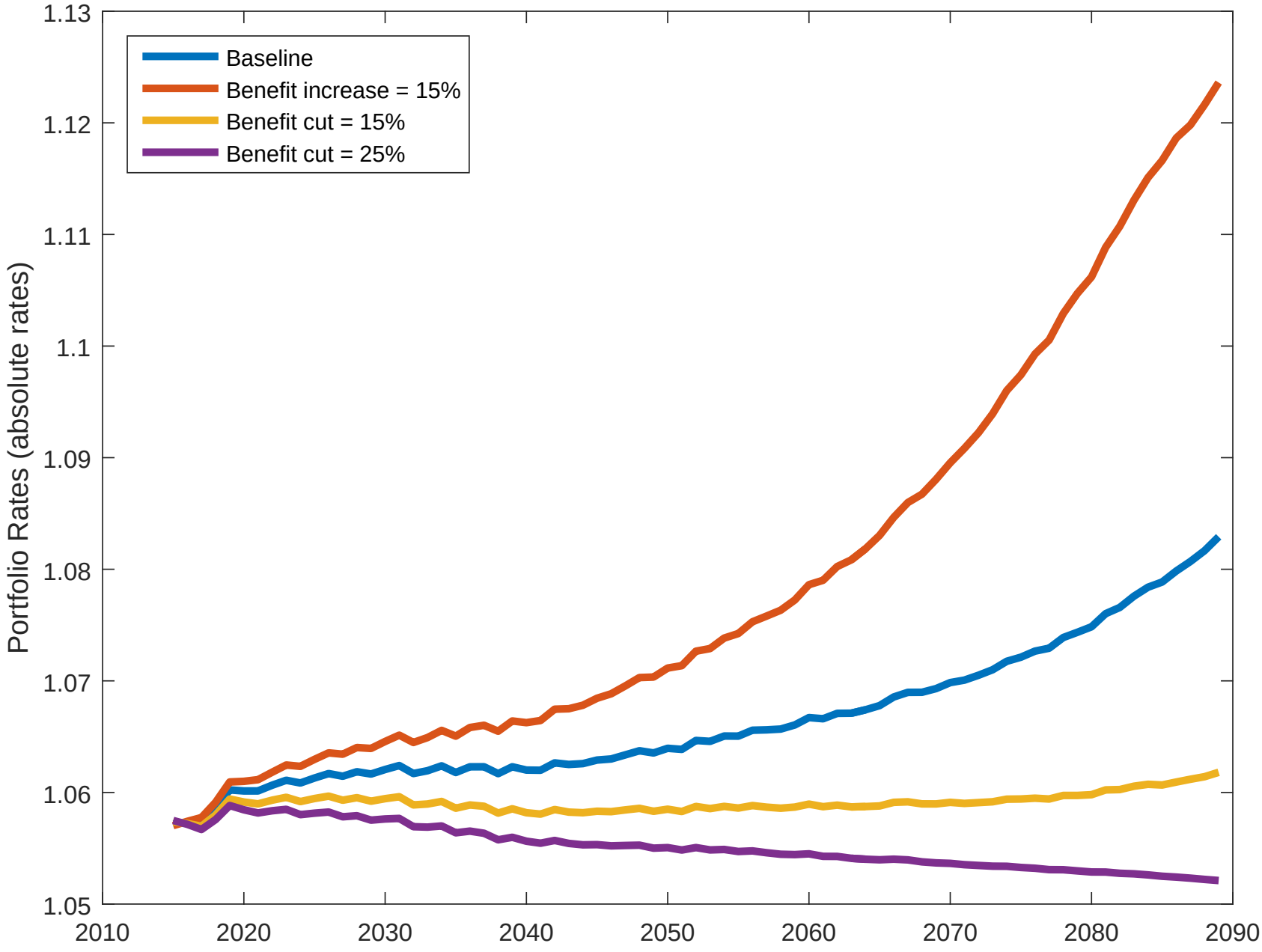
Payroll Tax Revenue Dynamic-to-Static Ratio



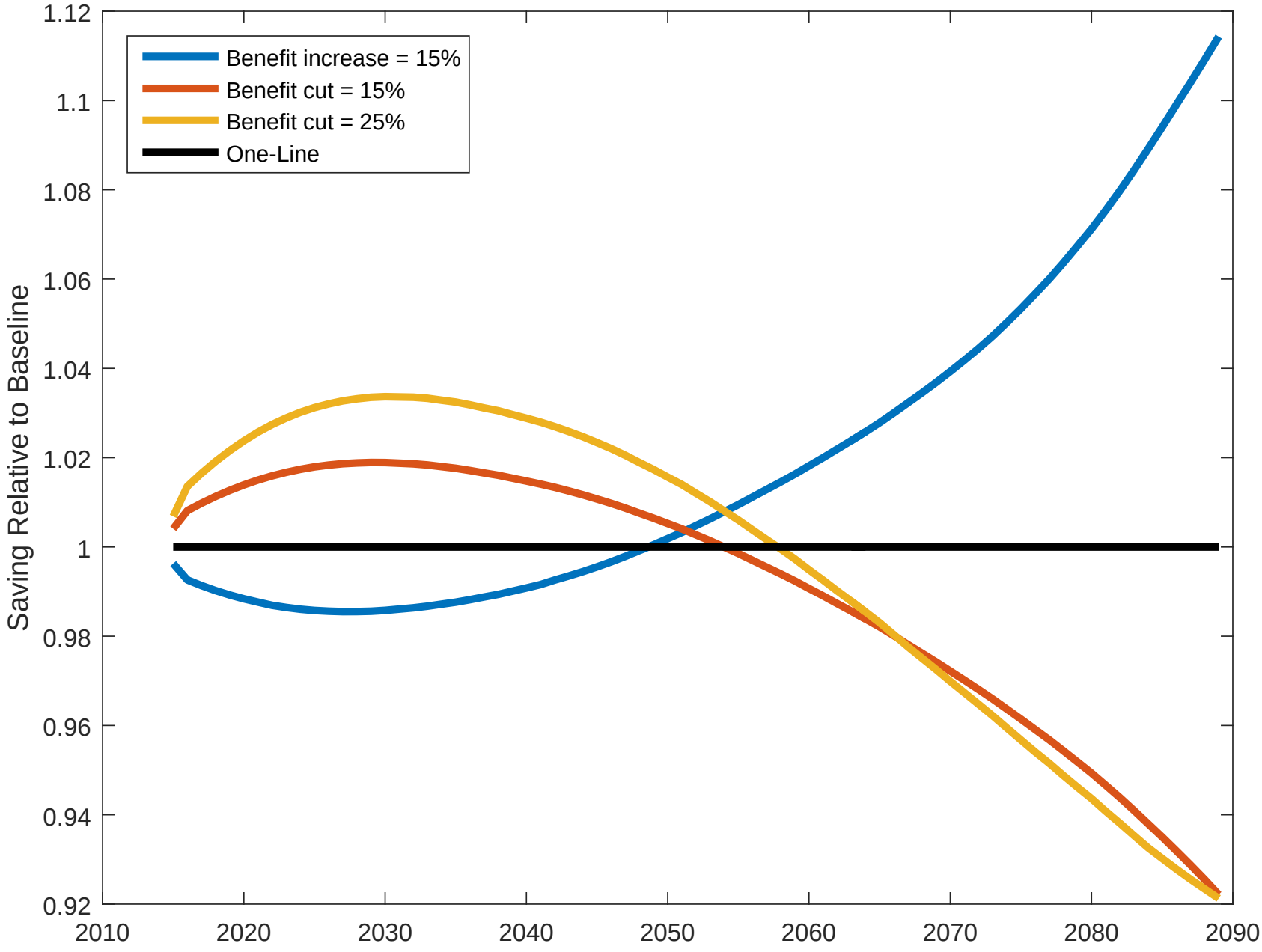
SS Expenditures Dynamic-to-Static Ratio



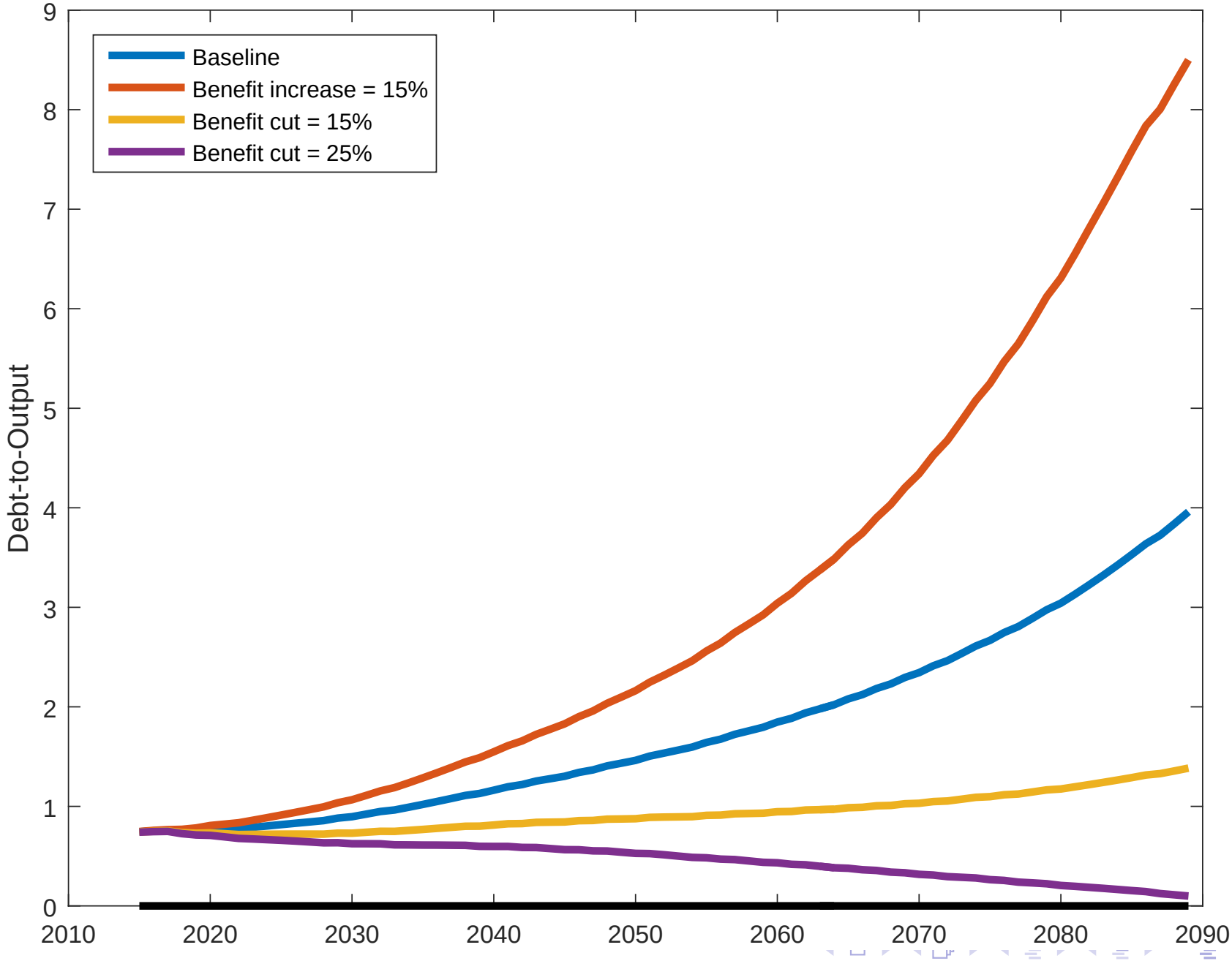
Effect of Benefit Change on Portfolio Rates



Policy Effect on Household Savings: Benefit Change



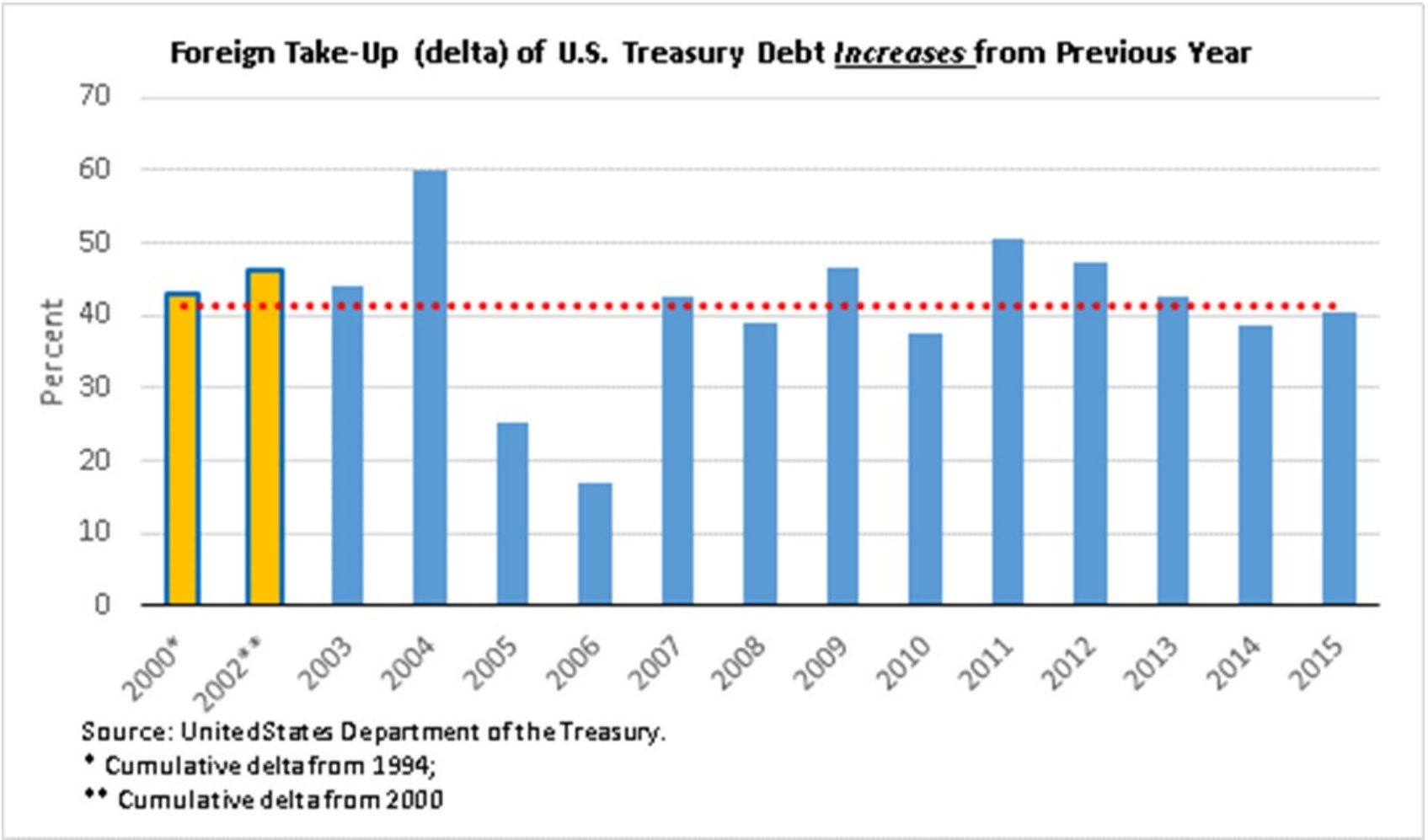
Projected Debt: Benefit Change



Open or Closed Economy?

- To generate a single dynamic score, we take a convex combination of open and closed economy dynamic score.
- Weight: 40% open, 60% closed.
- Motivated by foreign accumulation of U.S. Treasury Debt.

U.S. Treasury Debt Holdings



Penn Wharton Budget Model Dynamic Scoring

- Dynamic models can evaluate behavioral responses and macroeconomic feedback, but they lack richness because of extreme computational demands.
- Micro-simulation models have detailed demographics and extensive heterogeneity, but they lack rigorous behavioral and feedback measurements.
- Our approach combines the strengths of both models to evaluate policy.