# The Cost of Uncertainty about the Timing of Social Security Reform

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- *Outcome of a future event* is uncertain, and the *timing of that event* is also uncertain.

- Language: "structural uncertainty" and "timing uncertainty."

- Our contribution: new methodology for dynamic problems with timing and structural uncertainty.

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- Feature 3: Developed to evaluate policy questions.

  Study specific examples of policy-induced uncertainty (Baker, Bloom, and Davis (2013) and others).

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- Everyone knows reform is coming, but when? & how?

  "The rational expectations equilibrium concept common to all of our models requires...that an agent living within one of these models would know the monetary and fiscal policies affecting him." —Sargent.

  For example: literature on feasibility/optimality of SS reforms in macro (Kitao (2014), McGrattan and Prescott (2014)).

# Standard (deterministic) regime switching

$$\max_{u(t)_{t\in[0,T]}} : J = \int_0^{t_1} f_1(t, u(t), x(t))dt + \int_{t_1}^{T} f_2(t, u(t), x(t))dt,$$

subject to

$$\frac{dx(t)}{dt} = g_1(t, u(t), x(t)), \text{ for } t \in [0, t_1],$$

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$$t_1 \text{ and } g_2() \text{ are known.}$$

# Our stochastic version

$$\max_{u(t)_{t\in[0,T]}} : J = \mathbb{E}_{t_1,\alpha}\left[\int_0^{t_1} f_1(t,u(t),x(t))dt + \int_{t_1}^{T} f_2(t,u(t),x(t))dt\right],$$

subject to

$$\frac{dx(t)}{dt} = g_1(t,u(t),x(t)), \text{ for } t \in [0,t_1],$$

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$$x(0) = x_0,\ x(T) = x_T,$$

$t_1$ and $\alpha$ are stochastic,

$t_1$ density $\phi(t_1)$ with support $[0,\infty]$,

$\alpha$ density $\theta(\alpha)$ with support $[0,1]$.

**Theorem (Necessary Conditions).** The necessary conditions can be derived recursively in two steps.

**Step 1. Solve the post-switch subproblem $\forall\ (t_1, \alpha)$:**
The program $(u_2^*(t|t_1, x(t_1), \alpha), x_2^*(t|t_1, x(t_1), \alpha))_{t\in[t_1,T]}$ solves a fixed endpoint Pontryagin subproblem

$$\max_{u(t)_{t\in[t_1,T]}} : J_2 = \int_{t_1}^{T} f_2(t, u(t), x(t))dt,$$

subject to

$$\frac{dx(t)}{dt} = g_2(t, u(t), x(t)|\alpha), \text{ for } t \in [t_1, T],$$

$$t_1 \text{ given, } \alpha \text{ given, } x(t_1) \text{ given, } x(T) = x_T.$$

**Step 2. Solve the pre-switch subproblem**:
The program $(u_1^*(t), x_1^*(t))_{t\in[0,T]}$ solves a fixed endpoint Pontryagin subproblem with continuation function $\mathcal{S}(t, x(t), \alpha)$:

$$\max_{u(t)_{t\in[0,T]}} \quad : \quad J_1 = \int_0^T \left[\int_t^\infty \phi(t_1)dt_1\right] f_1(t, u(t), x(t))dt + \int_0^T \int_0^1 \theta(\alpha)\phi(t)\mathcal{S}(t, x(t), \alpha)d\alpha dt,$$

subject to

$$\mathcal{S}(t, x(t), \alpha) = \int_t^T f_2(z, u_2^*(z|t, x(t), \alpha), x_2^*(z|t, x(t), \alpha))dz,$$

$$\frac{dx(t)}{dt} = g_1(t, u(t), x(t)), \text{ for } t \in [0, T],$$

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- Current policy is $(\tau_1, b_1)$ and post-reform policy is $(\tau_2, b_2)$.

$$\max_{c(t)_{t\in[0,T]}} : J = \mathbb{E}\left[\int_0^T e^{-\rho t}\Psi(t)u(c(t))dt\right], \quad \text{subject to:}$$

$$\frac{dk(t)}{dt} = rk(t) + y_1(t) - c(t), \text{ for } t \in [0, t_1],$$

$$\frac{dk(t)}{dt} = rk(t) + y_2(t) - c(t), \text{ for } t \in [t_1, T],$$

$$y_1(t) = \begin{cases} (1-\tau_1)w(t), & \text{for } t \in [0, t_R], \\ b_1, & \text{for } t \in [t_R, T], \end{cases}$$

$$y_2(t) = \begin{cases} (1-\tau_2)w(t), & \text{for } t \in [0, t_R], \\ b_2, & \text{for } t \in [t_R, T], \end{cases}$$

$$k(0) = 0, \; k(T) = 0,$$

$t_1$ random with density $\phi(t_1)$ and sample space $[0, \infty]$.

# Computation

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**Step 1**: for $t \in [t_1, T]$,

$$c_2^*(t|t_1, k(t_1)) = \frac{k(t_1) + \int_{t_1}^{T} e^{-r(v-t_1)} y_2(v) dv}{\int_{t_1}^{T} e^{-r(v-t_1)+(r-\rho)v/\sigma} \Psi(v)^{1/\sigma} dv} e^{(r-\rho)t/\sigma} \Psi(t)^{1/\sigma}.$$

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**Step 2**: Using this and working backwards, the pre-reform solution $(c_1^*(t), k_1^*(t))_{t\in[0,T]}$ solves (guess and iterate on $c(0)$):

$$\begin{aligned} \frac{dc(t)}{dt} &= \left( \frac{c(t)^\sigma}{\Psi(t)} \left[ \frac{k(t) + \int_t^T e^{-r(v-t)} y_2(v)dv}{\int_t^T e^{-r(v-t)+(r-\rho)v/\sigma} \Psi(v)^{1/\sigma} dv} \right]^{-\sigma} e^{(\rho-r)t} - 1 \right) \\ &\quad \times c(t) \left[ \frac{\sigma}{\phi(t)} \int_t^\infty \phi(t_1)dt_1 \right]^{-1} + \left[ \frac{d\Psi(t)}{dt} \frac{1}{\Psi(t)} + r - \rho \right] \frac{c(t)}{\sigma}, \end{aligned}$$

$$\frac{dk(t)}{dt} = rk(t) + y_1(t) - c(t),$$

$$k(0) = 0,\ k(T) = 0.$$

# Welfare cost

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Consider a no-risk world where $c^{NR}(t)$ is the solution to

$$\max_{c(t)_{t\in[0,T]}} : \int_0^T e^{-\rho t}\Psi(t)u(c(t))dt, \quad \text{subject to,}$$

$$dk(t)/dt = rk(t) - c(t),$$

$$k(0) = \int_0^T \phi(t_1)Y(t_1)dt_1 + \left[\int_T^\infty \phi(t_1)dt_1\right]\int_0^T e^{-rv}y_1(v)dv, \; k(T) = 0,$$

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$$\int_0^T e^{-\rho t}\Psi(t)u[c^{NR}(t)(1-\Delta)]dt =$$

$$\int_0^T \phi(t_1)\left(\int_0^{t_1} e^{-\rho t}\Psi(t)u[c_1^*(t)]dt + \int_{t_1}^T e^{-\rho t}\Psi(t)u[c_2^*(t|\cdot)]dt\right)dt_1$$

$$+ \left[\int_T^\infty \phi(t_1)dt_1\right]\int_0^T e^{-\rho t}\Psi(t)u[c_1^*(t)]dt.$$

# Parameterization

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- Survival data from SSA's cohort mortality tables, which reflect intermediate projections in the 2013 Trustees Report (male cohort born in 1990—turn 25 and enter labor market in 2015).

- CRRA $u(c(t)) = c(t)^{1-\sigma}/(1-\sigma)$ with $\sigma = 3$, and discount rate $\rho = 0$.

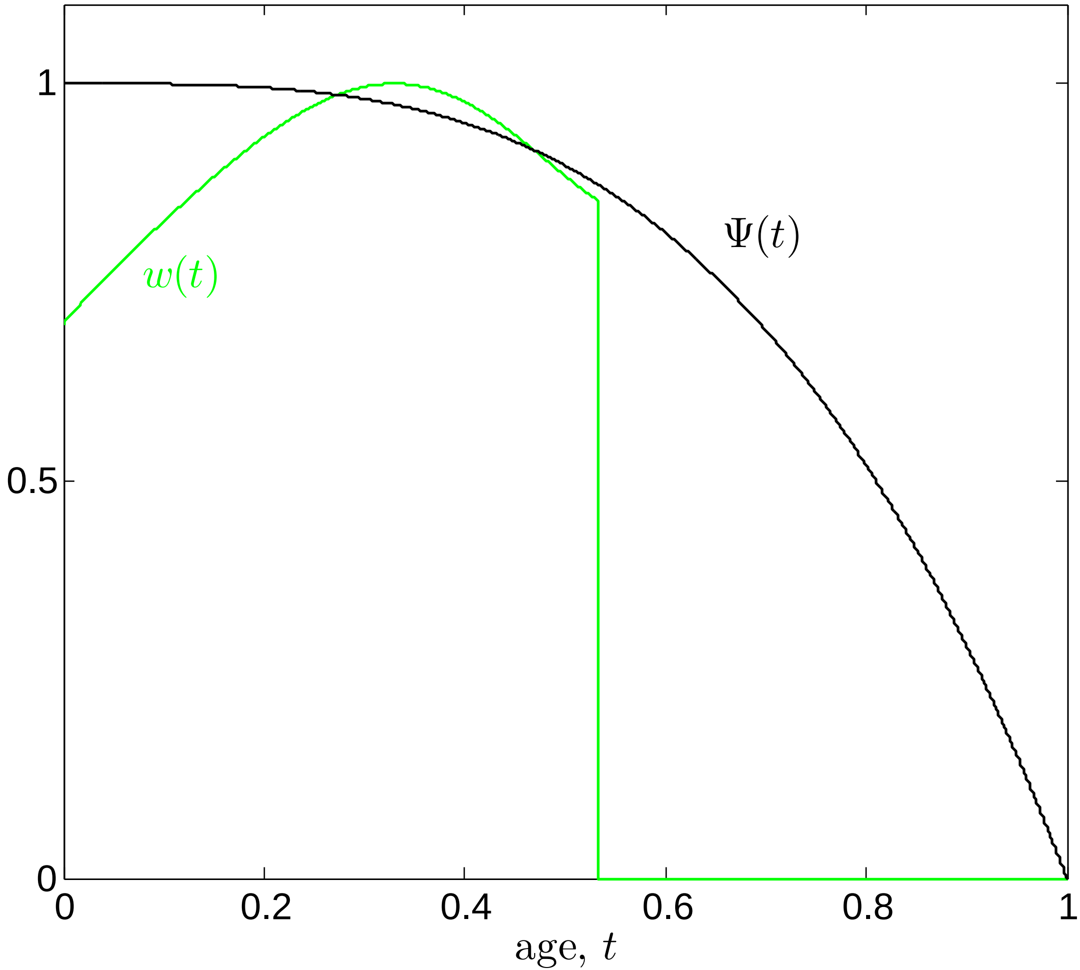
- Life-cycle wages: Gourinchas and Parker (2002, Econometrica). Fit a 5th-order polynomial.

- Interest rate $r = 2.9\%$ (long-run real interest rate assumed in the 2013 Trustees Report).

- We assume that reform is a Weibull random variable,

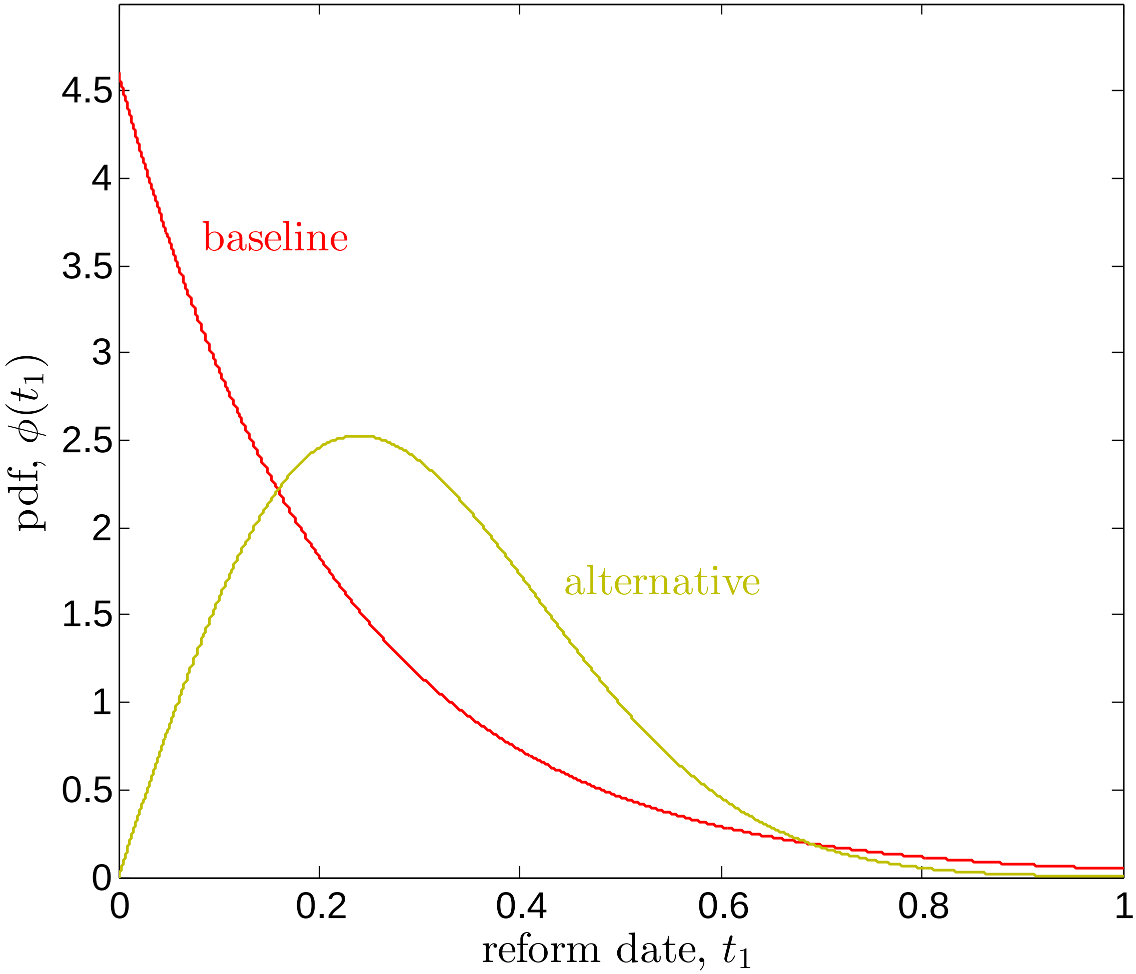
$$\phi(t_1) = \frac{\mu}{\gamma}\left(\frac{t_1}{\gamma}\right)^{\mu-1} e^{-(t_1/\gamma)^{\mu}}, \text{ for } t_1 \in [0, \infty].$$

Figure 1. Baseline Wage Profile and Survival Uncertainty




Survival data: SSA 1990 cohort. Wage data: Gourinchas and Parker (2002).

Figure 2. Weibull Density Functions over Random Timing of Reform



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| income class | income | replacement rate (if claimed at 65) |
|---|---|---|
| very low | $0.25\bar{w}$ | 67.5% |
| low | $0.45\bar{w}$ | 49.0% |
| average | $\bar{w}$ | 36.4% |
| high | $1.6\bar{w}$ | 30.1% |
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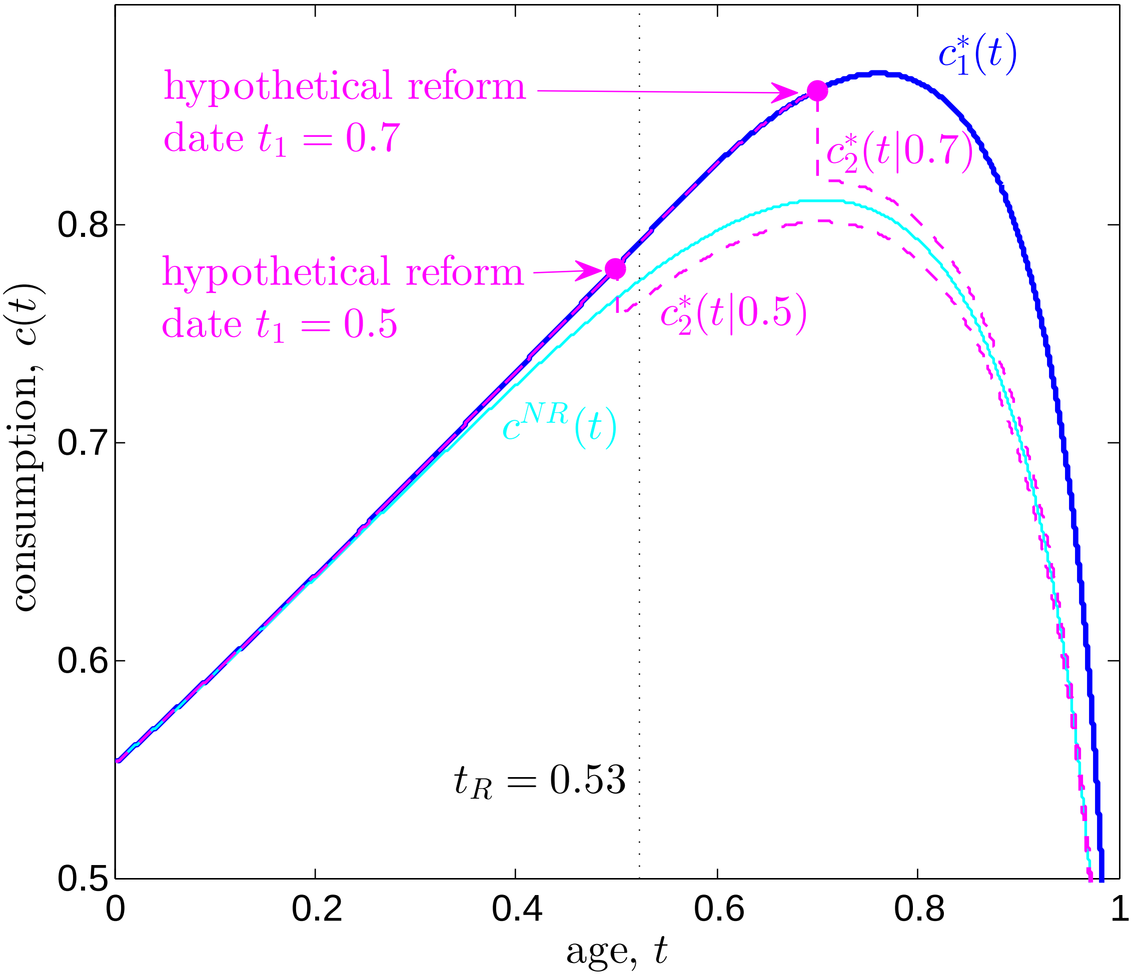
- **Full benefit cut**: across-the-board reduction for all current and future retirees, $(\tau_2, b_2) = (\tau_1, b_1 \times (1 - 21\%))$.

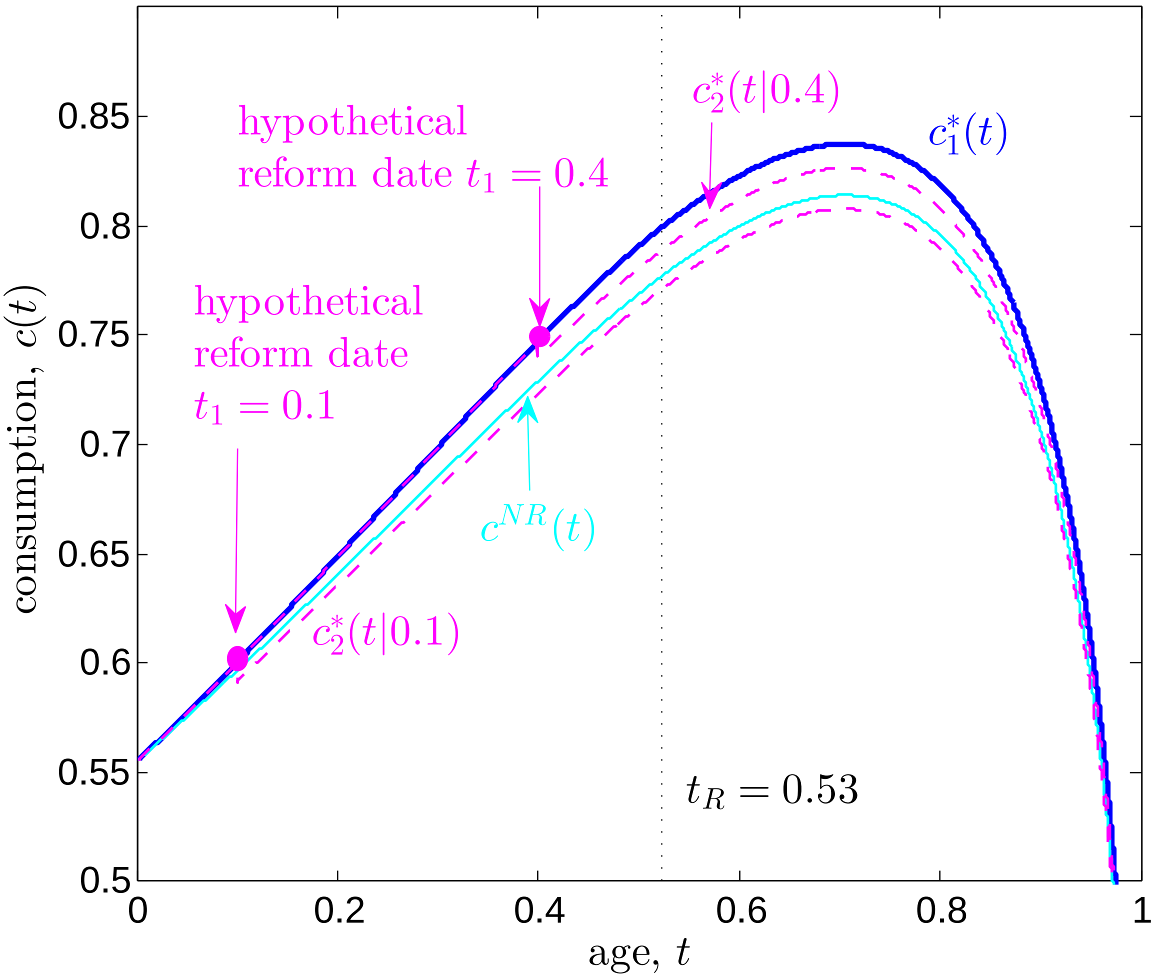
- **Full tax increase**: across-the-board increase for all taxpayers, $(\tau_2, b_2) = (\tau_1 + 3.1\%, b_1)$.

Figure 3. The Case of **Benefit Reform** with Stochastic Reform Date




Social security parameters: $\tau_1 = 0.106$, $\tau_2 = 0.106$, $b_1 = 0.322$, $b_2 = 0.254$.

Figure 4. The Case of **Tax Reform** with Stochastic Reform Date




Social security parameters: $\tau_1 = 0.106$, $\tau_2 = 0.137$, $b_1 = 0.322$, $b_2 = 0.322$.

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**Table 1. Welfare Loss from Timing Uncertainty:**

*Panel A. Constant Hazard Rate of Reform*

| Income Level | Full Benefit Reform (21% benefit cut) | Full Tax Reform (3.1 ppt increase) |
|---|---|---|
| very low | 2.39 | 1.70 |
| low | 1.51 | 1.91 |
| average | **1.00*** | 2.07 |
| high | 0.78 | 2.16 |
| max | 0.60 | 2.25 |

**Table 1. Welfare Loss from Timing Uncertainty:**

*Panel B. Alternative Density with Mode at 2033*

| Income Level | Full Benefit Reform (21% benefit cut) | Full Tax Reform (3.1 ppt increase) |
|---|---|---|
| very low | 1.04 | 1.35 |
| low | 0.75 | 1.52 |
| average | 0.58 | 1.66 |
| high | 0.51 | 1.74 |
| max | 0.46 | 1.81 |

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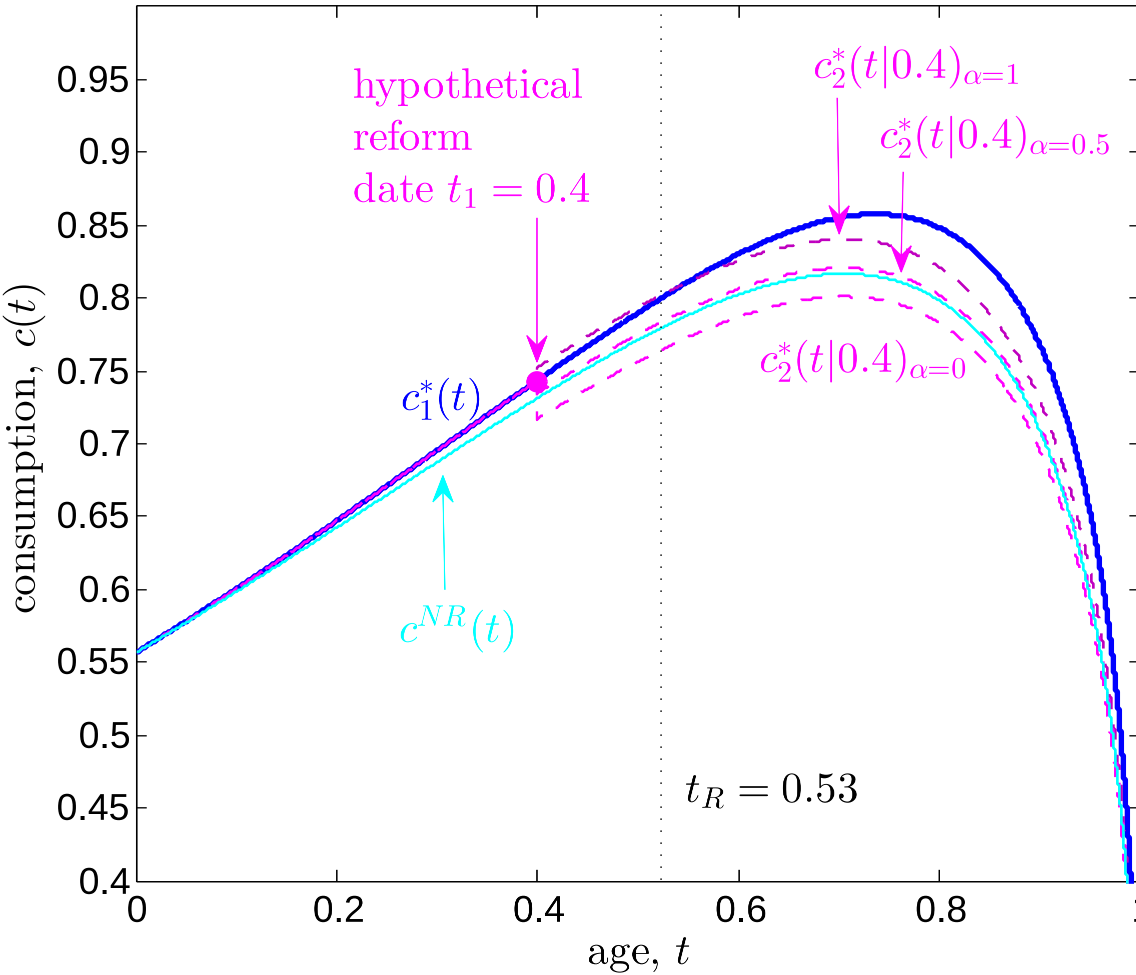
After solving for $c^{NR}$ and $c_1^*$ and $c_2^*$, compute $\Delta$

$$\begin{aligned} &\int_0^T D(t)u[c^{NR}(t)(1-\Delta)]dt \\ = &\int_0^1 \int_0^T \theta(\alpha)\phi(t_1)\left(\int_0^{t_1} D(t)u[c_1^*(t)]dt + \int_{t_1}^T D(t)u[c_2^*(t|\cdot)]dt\right) dt_1 d\alpha \\ &+ \left[\int_T^\infty \phi(t_1)dt_1\right] \int_0^T e^{-\rho t}\Psi(t)u[c_1^*(t)]dt. \end{aligned}$$

where $D(t) \equiv e^{-\rho t}\Psi(t)$.

Figure 5. **Double Uncertainty**: Timing and Structural Uncertainty




The share of the budget crisis resolved through extra taxation is $\alpha$, and the share resolved through benefit adjustments is $1-\alpha$.

Figure 6. **Double Uncertainty**: Timing and Structural Uncertainty

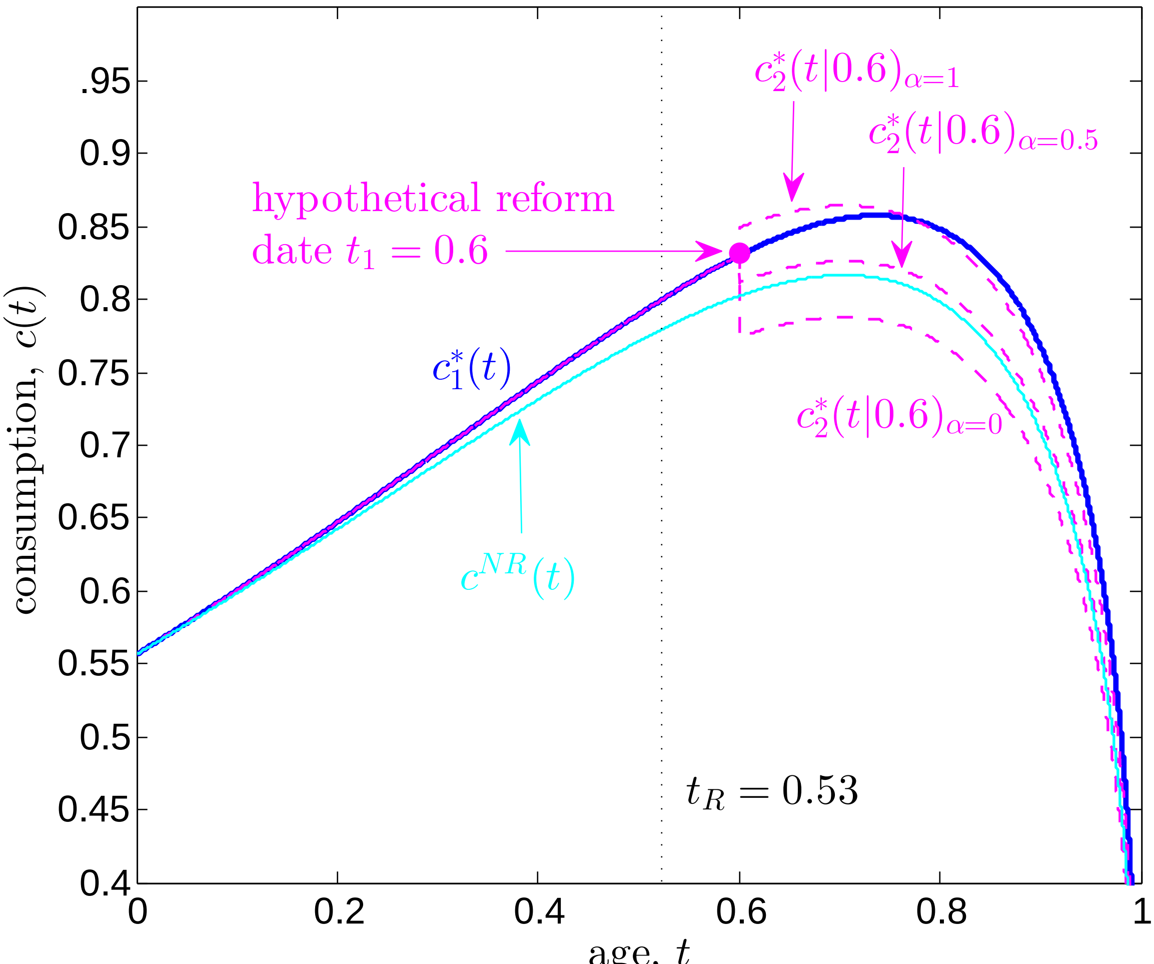



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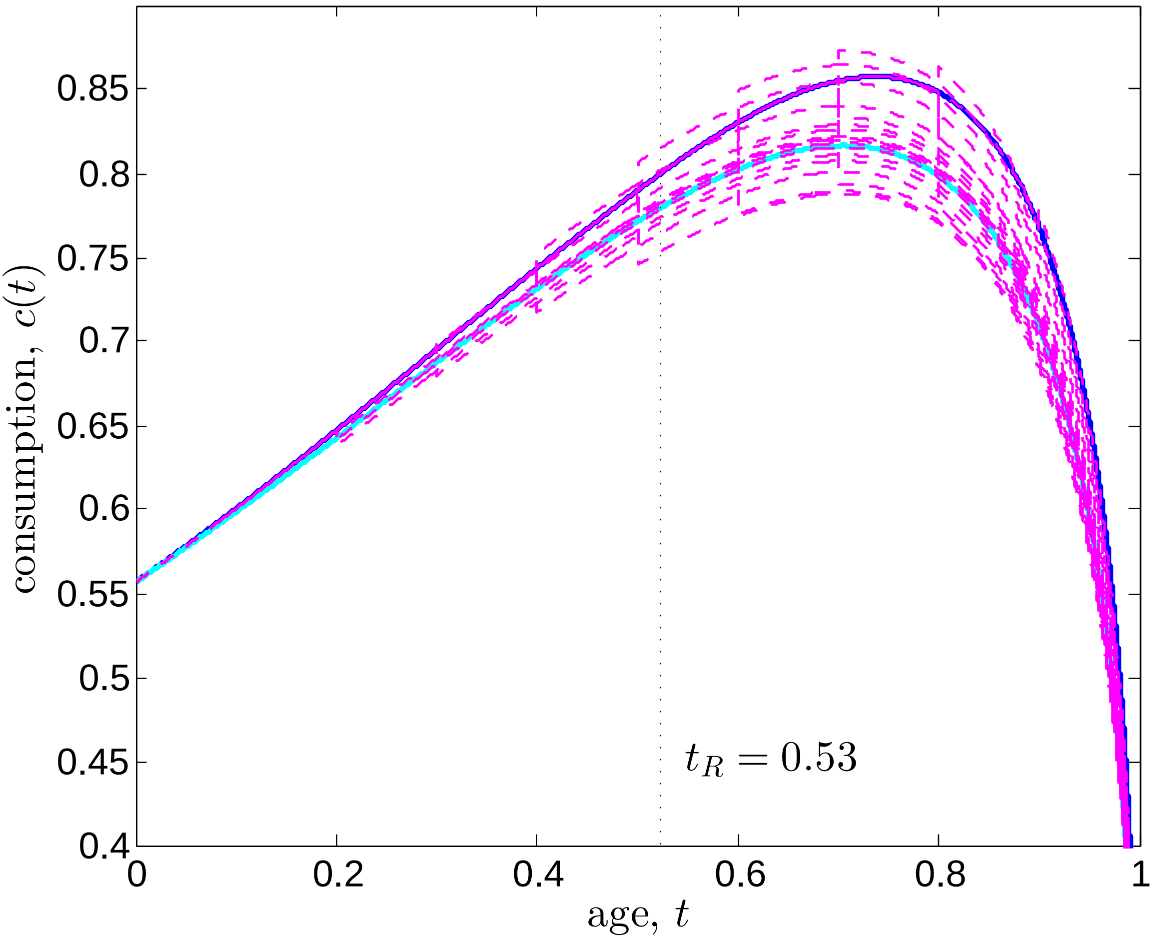
Figure 7. **Double Uncertainty**: Timing and Structural Uncertainty



- Let $\theta(\alpha)$ be uniform.

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**Table 2. Welfare Loss: Timing & Structural Uncertainty**

*Panel A. Constant Hazard Rate of Reform*

| Income | Benefit Reform (21% benefit cut) | Tax Reform (3.1 ppt increase) | Double Uncertainty |
|---|---|---|---|
| very low | 2.39 | 1.70 | 3.09 |
| low | 1.51 | 1.91 | 1.96 |
| average | **1.00*** | 2.07 | 1.45 |
| high | 0.78 | 2.16 | 1.27 |
| max | 0.60 | 2.25 | 1.19 |

## Table 2. Welfare Loss: Timing & Structural Uncertainty

*Panel B. Alternative Density with Mode at 2033*

| Income | Benefit Reform (21% benefit cut) | Full Tax Reform (3.1 ppt increase) | Double Uncertainty |
|---|---|---|---|
| very low | 1.04 | 1.35 | 3.60 |
| low | 0.75 | 1.52 | 2.17 |
| average | 0.58 | 1.66 | 1.47 |
| high | 0.51 | 1.74 | 1.22 |
| max | 0.46 | 1.81 | 1.06 |

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- Uniform reform dates: welfare costs $\uparrow$ and regressivity $\uparrow$ when reform shock is distributed uniformly over lifetime.
- Extreme political risks: welfare costs $\uparrow$ and regressivity $\uparrow$ when either D's or R's win the tug-of-war with no chance for compromise.
- Differential mortality: welfare costs essentially same under differential mortality by income type.

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- Micro welfare effects of uncertainty over the timing and structure of SS reform.

- Consistent theme: reform uncertainty hits low-income groups especially hard.

- All of the costs that we report in this paper disappear if gov't simply announces when and how SS will be reformed.