The Cost of Uncertainty about the Timing of Social Security Reform

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What we do

Q. How does uncertainty about the timing of the resolution of uncertainty affect economic decision making and welfare?

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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• Language: “structural uncertainty” and “timing uncertainty.”

• *Our contribution:* new methodology for dynamic problems with timing and structural uncertainty.
Our setting has 3 main features:


2. **(Non) stationary distributions of timing risk.** Unlike standard stochastic DP: uncertainty is Markov (stationary).

3. **Developed to evaluate policy questions.** Study specific examples of policy-induced uncertainty (Baker, Bloom, and Davis (2013) and others).
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A prominent example

- What is the cost to households of living with uncertainty about the timing and structure of SS reform?

SS Trust Fund: projected to run out of money by 2033. But "We do not know today...how subsequent political deliberations from shifting majority coalitions will render U.S. …scal policy coherent."— Sargent (2005).

To stay solvent: benefits $21\%$, or taxes $3.1$ points, or...

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 …scal policies a¤ecting him."— Sargent.

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

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

\[
\frac{dx(t)}{dt} = g_2(t, u(t), x(t)), \text{ for } t \in [t_1, T],
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\[x(0) = x_0, \quad x(T) = x_T,\]
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\]

\[
x(0) = x_0, \quad x(T) = x_T,
\]

\(t_1\) and \(g_2()\) 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

\[ \frac{dx(t)}{dt} = g_1(t, u(t), x(t)), \text{ for } t \in [0, t_1], \]
\[ \frac{dx(t)}{dt} = g_2(t, u(t), x(t)|\alpha), \text{ for } t \in [t_1, T], \]
\[ x(0) = x_0, \quad x(T) = x_T, \]
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\max_{u(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

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

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

\[
x(0) = x_0, \quad x(T) = x_T,
\]

\(t_1\) 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 \(S(t, x(t), \alpha)\):

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

subject to

\[
S(t, x(t), \alpha) = \int_t^T f_2(z, u_2^*(z|t, x(t), \alpha), x_2^*(z|t, x(t), \alpha)) dz,
\]

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

\[
x(0) = x_0, \ x(T) = x_T.
\]
Application 1: uncertainty about timing of reform

Households have full information about structure of new reform but not when it kicks in. In other words, households know which of the two worlds they are living in:

— 21% benefit cut.
— 3.1 point tax increase.

Current policy is \((1; b_1)\) and post-reform policy is \((2; b_2)\).
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- In other words, households know which of the two worlds they are living in:
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- Current policy is \((\tau_1, b_1)\) and post-reform policy is \((\tau_2, b_2)\).
\[
\max_{c(t) \in [0, T]} : J = \mathbb{E} \left[ \int_0^T e^{-\rho t} \Psi(t) u(c(t)) dt \right], \quad \text{subject to:}
\]
\[
\frac{dk(t)}{dt} = rk(t) + y_1(t) - c(t), \quad \text{for } t \in [0, t_1],
\]
\[
\frac{dk(t)}{dt} = rk(t) + y_2(t) - c(t), \quad \text{for } t \in [t_1, T],
\]
\[
y_1(t) = \begin{cases} 
(1 - \tau_1)w(t), & \text{for } t \in [0, t_R], \\
b_1, & \text{for } t \in [t_R, T], 
\end{cases}
\]
\[
y_2(t) = \begin{cases} 
(1 - \tau_2)w(t), & \text{for } t \in [0, t_R], \\
b_2, & \text{for } t \in [t_R, T], 
\end{cases}
\]
\[
k(0) = 0, \quad k(T) = 0,
\]
\[t_1 \text{ random with density } \phi(t_1) \text{ and sample space } [0, \infty].\]
Computation
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Solve recursively.
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**Step 1:** for $t \in [t_1, T]$,

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

Solve recursively.

Step 1: for \( t \in [t_1, T] \),

\[
c^*_2(t|t_1, k(t_1)) = \frac{k(t_1) + \int_{t_1}^{T} e^{-r(v-t_1)}y_2(v)dv}{\int_{t_1}^{T} e^{-r(v-t_1)+(r-\rho)v/\sigma}\Psi(v)^{1/\sigma}dv} e^{(r-\rho)t/\sigma} \Psi(t)^{1/\sigma}.
\]

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 \(c(0)\)):

\[
\frac{dc(t)}{dt} = \left( \frac{c(t)}{\Psi(t)} \right)^\sigma \left[ \frac{k(t) + \int_{t}^{T} e^{-r(v-t)}y_2(v)dv}{\int_{t}^{T} e^{-r(v-t)+(r-\rho)v/\sigma}\Psi(v)^{1/\sigma}dv} \right]^{-\sigma} e^{(\rho-r)t - 1}
\]

\[
\times c(t) \left[ \frac{\sigma}{\phi(t)} \int_{t}^{\infty} \phi(t_1)dt_1 \right]^{-1} + \left[ \frac{d\Psi(t)}{dt} \frac{1}{\Psi(t)} + r - \rho \right] \frac{c(t)}{\sigma},
\]

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

\( k(0) = 0, \ k(T) = 0. \)
Welfare cost

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

$$\max_{c(t)} c(t)\quad t \in [0;T]$$

subject to,

$$dk(t) = dt = rk(t)c(t)$$

$$k(0) = \int_0^T e(t_1)Y(t_1)dt_1 + \int_0^T e(t_1)rv_1\left(v_1\right)dv_1$$

$$k(T) = 0$$

$$Y(t_1) = \int_0^{t_1} e(t)u[c_{NR}(t)(1)]dt = \int_0^{t_1} e(t)u[c_1(t)]dt + \int_{t_1}^T e(t)u[c_2(t)]dt$$
Welfare cost

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

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

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

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

$$Y(t_1) \equiv \int_0^{t_1} e^{-rv} y_1(v) dv + \int_{t_1}^T e^{-rv} y_2(v) dv.$$
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$$Y(t_1) \equiv \int_0^{t_1} e^{-rv} y_1(v) dv + \int_{t_1}^T e^{-rv} y_2(v) dv.$$
Parameterization


\[ \text{CRRA}_u(c(t)) = c(t)^{1 \beta} \]

with \( \beta = 3 \), and discount rate \( r = 3.9\% \) (long-run real interest rate assumed in the 2013 Trustees Report).

We assume that reform is a Weibull random variable,

\[ \text{Weibull}(t_1, \lambda) = \frac{1}{\lambda} t_1^{\lambda-1} e^{-t_1^\lambda}, \quad \text{for } t_1 \in [0, 1] \]
Parameterization


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


- 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

Figure 2. Weibull Density Functions over Random Timing of Reform
Parameterization: structure of reform

Currently, all workers pay tax rate $\bar{1} = 10\%$, and retirees collect benefits $b_{1} = \text{AIME}$ replacement rate income class income replacement rate (if claimed at 65) very low $w_{67} = 0\% $ low $w_{49} = 0\% $ average $w_{36} = 4\% $ high $w_{30} = 1\% $ max $w_{24} = 0\% $

Full benefit cut: across-the-board reduction for all current and future retirees, $b_{2} = (1 - 21\%)$.

Full tax increase: across-the-board increase for all taxpayers, $b_{2} = (1 + 3\%)$. 
Parameterization: structure of reform

- Currently, all workers pay tax rate $\tau_1 = 10.6\%$, and retirees collect benefits $b_1 = AIME \times \text{replacement rate}$
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- **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: \( \tau_1 = 0.106, \tau_2 = 0.137, b_1 = 0.322, b_2 = 0.322. \)
Welfare calculations

For an average earner with constant hazard rate of reform, the welfare loss from uncertainty about the timing of benefit reform is 0.01% of lifetime consumption.

Table 1. Welfare Loss from Timing Uncertainty:

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<th>Panel A</th>
<th>Full Benefit Reform</th>
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<tr>
<td>Income Level</td>
<td>(21% benefit cut)</td>
<td>(3.1 ppt increase)</td>
</tr>
<tr>
<td>very low</td>
<td>2.39</td>
<td>1.70</td>
</tr>
<tr>
<td>low</td>
<td>1.51</td>
<td>1.91</td>
</tr>
<tr>
<td>average</td>
<td>1.00</td>
<td>2.07</td>
</tr>
<tr>
<td>high</td>
<td>0.78</td>
<td>2.16</td>
</tr>
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<td>max</td>
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Panel B. Alternative Density with Mode at 2033

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<td>1.35</td>
</tr>
<tr>
<td>low</td>
<td>0.75</td>
<td>1.52</td>
</tr>
<tr>
<td>average</td>
<td>0.58</td>
<td>1.66</td>
</tr>
<tr>
<td>high</td>
<td>0.51</td>
<td>1.74</td>
</tr>
<tr>
<td>max</td>
<td>0.46</td>
<td>1.81</td>
</tr>
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Application 2: double uncertainty

Households don't know timing or structure of reform. New policy depends on random variable:

\[ b_2(t) = b_1(t) \left( 1 + \text{~} b_2 \right) \]

After solving for \( c_{NR} \) and \( c_1 \) and \( c_2 \), compute:

\[ \int_{T}^{Z} D(t) u[c_{NR}(t)] dt = \int_{0}^{T} \left( \int_{t_1}^{T} D(t) u[c_1(t)] dt + \int_{t_1}^{T} D(t) u[c_2(t)] dt \right) dt \]

where \( D(t) e^t \).
Application 2: double uncertainty

- Households don’t know **timing** or **structure** of reform.
Application 2: double uncertainty

- Households don’t know **timing** or **structure** of reform.

- New policy depends on random variable $\alpha$:

  \[
  \tau_2(\alpha) = \tau_1 + \alpha(\tilde{\tau}_2 - \tau_1),
  \]
  \[
  b_2(\alpha) = b_1 - (1 - \alpha)(b_1 - \tilde{b}_2).
  \]
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- New policy depends on random variable $\alpha$:

\[
\tau_2(\alpha) = \tau_1 + \alpha(\tilde{\tau}_2 - \tau_1),
\]
\[
b_2(\alpha) = b_1 - (1 - \alpha)(b_1 - \tilde{b}_2).
\]

After solving for $c^{NR}$ and $c_1^*$ and $c_2^*$, compute $\Delta$. 
Application 2: double uncertainty

- Households don’t know **timing** or **structure** of reform.

- New policy depends on random variable $\alpha$:

\[
\tau_2(\alpha) = \tau_1 + \alpha(\tilde{\tau}_2 - \tau_1), \\
b_2(\alpha) = b_1 - (1 - \alpha)(b_1 - \tilde{b}_2).
\]

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

\[
\int_0^T D(t)u[c^{NR}(t)(1 - \Delta)]dt
\]

\[
= \int_0^1 \int_0^T \theta(\alpha)\phi(t_1) \left( \int_0^{t_1} D(t)u[c_1^*(t)]dt + \int_{t_1}^T D(t)u[c_2^*(t|\cdot)]dt \right) dt_1 d\alpha
\]

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

where $D(t) \equiv e^{-\rho t}\Psi(t)$.
The share of the budget crisis resolved through extra taxation is $\alpha$, and the share resolved through benefit adjustments is $1 - \alpha$.  

---

**Figure 5. Double Uncertainty: Timing and Structural Uncertainty**
Figure 6. **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 7. **Double Uncertainty**: Timing and Structural Uncertainty

$t_R = 0.53$
Table 2. Welfare Loss: Timing & Structural Uncertainty

Panel A. Constant Hazard Rate of Reform

<table>
<thead>
<tr>
<th></th>
<th>Benefit Reform Tax Reform Double</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
<td></td>
</tr>
<tr>
<td>Very low</td>
<td>2.39 1.70 3.09</td>
</tr>
<tr>
<td>Low</td>
<td>1.51 1.91 1.96</td>
</tr>
<tr>
<td>Average</td>
<td>1.00* 2.07 1.45</td>
</tr>
<tr>
<td>High</td>
<td>0.78 2.16 1.27</td>
</tr>
<tr>
<td>Max</td>
<td>0.60 2.25 1.19</td>
</tr>
</tbody>
</table>
• Let $\theta(\alpha)$ be uniform.
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### Table 2. Welfare Loss: Timing & Structural Uncertainty

*Panel A. Constant Hazard Rate of Reform*

<table>
<thead>
<tr>
<th>Income</th>
<th>Benefit Reform (21% benefit cut)</th>
<th>Tax Reform (3.1 ppt increase)</th>
<th>Double Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low</td>
<td>2.39</td>
<td>1.70</td>
<td>3.09</td>
</tr>
<tr>
<td>low</td>
<td>1.51</td>
<td>1.91</td>
<td>1.96</td>
</tr>
<tr>
<td>average</td>
<td><strong>1.00</strong>*</td>
<td>2.07</td>
<td>1.45</td>
</tr>
<tr>
<td>high</td>
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</tr>
<tr>
<td>max</td>
<td>0.60</td>
<td>2.25</td>
<td>1.19</td>
</tr>
</tbody>
</table>
Table 2. Welfare Loss: Timing & Structural Uncertainty

Panel B. Alternative Density with Mode at 2033

<table>
<thead>
<tr>
<th>Income</th>
<th>Benefit Reform (21% benefit cut)</th>
<th>Full Tax Reform (3.1 ppt increase)</th>
<th>Double Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low</td>
<td>1.04</td>
<td>1.35</td>
<td>3.60</td>
</tr>
<tr>
<td>low</td>
<td>0.75</td>
<td>1.52</td>
<td>2.17</td>
</tr>
<tr>
<td>average</td>
<td>0.58</td>
<td>1.66</td>
<td>1.47</td>
</tr>
<tr>
<td>high</td>
<td>0.51</td>
<td>1.74</td>
<td>1.22</td>
</tr>
<tr>
<td>max</td>
<td>0.46</td>
<td>1.81</td>
<td>1.06</td>
</tr>
</tbody>
</table>
Robustness

Preference parameters: welfare costs when or .

Uniform reform dates: welfare costs and regressivity when reform shock is distributed uniformly over lifetime.

Extreme political risks: welfare costs and regressivity 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.
Robustness

- Preference parameters: welfare costs ↑ when ↑ σ or ↑ ρ.
Robustness

- **Preference parameters**: welfare costs $\uparrow$ when $\uparrow \sigma$ or $\uparrow \rho$.

- **Uniform reform dates**: welfare costs $\uparrow$ and regressivity $\uparrow$ when reform shock is distributed uniformly over lifetime.
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Methodology to study how timing and structural uncertainty jointly affect economic decision making and welfare.

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 the government simply announces when and how SS will be reformed.
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