Time-Inconsistent Preferences, Borrowing Costs, and Social Security

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Impulsivity from Hyperbolic Discounting

- Hyperbolic discounting engenders time-inconsistent preferences.
  - Divergence between long-run plans and short-run choices.
  - Psychologists: represents **impulsive** decision making.
- Most important economic application of hyperbolic discounting?
  - Insufficient saving for retirement (O'Donoghue & Rabin 2000).
    - Saving plans are formulated, then abandoned and revised.
    - Actual savings is less than the amounts desired when younger.
- Question: Can mandatory saving remedy inadequate saving?

The hyperbolic model explains the uniform popularity of social security, which acts as a precommitment device to redistribute consumption from times when people would be tempted to overspend—during their working lives—to times when they would otherwise be spending too little—in retirement. Even with the distortions entailed in such taxation with hyperbolic discounting... such a transfer is most likely to improve welfare significantly.

George A. Akerlof
Brookings Papers on Economic Activity
(1998, p.187)

Hyperbolic models [also] provide a new framework for analyzing the welfare gains that come from pro-saving policies like social security.

David Laibson
European Economic Review
(1998, p.861)

[H]yperbolic preferences are time-inconsistent...as a consequence, hyperbolic agents report a gap between their long-run goals and their short-run behavior. This has important implications for their economic choices and leads to phenomena like procrastination and undersaving...With hyperbolic preferences individuals will ex post be grateful to the government for having forced them to act according to their long-run concerns.

Helmuth Cremer & Pierre Pestieau
European Economic Review
(2011, p.166)

Yet, a BIG Problem for this Intuition!

- Some recent research findings...
  - İmrohoroğlu et al. (2003, *QJE*); Gul & Pesendorfer (2004, *RED*).
  - Malin (2008, *J PubEcon*); Caliendo (2011, *JEDC*); Caliendo (2014).
  - Guo & Caliendo (2014, *J MathEcon*); Feigenbaum (2014).
- Mandatory saving can improve well-being if...
  - credit markets are completely missing (impossible to borrow).
- Impossible for mandatory saving to improve well-being if...
  - credit markets are "perfect" or "complete".
    - Households borrow and save at same interest rate.
- Difficult to defend these two extreme credit market assumptions.
  - Davis, Kubler, & Willen (2006, *REStat*)
    - True that some households face binding borrowing constraints.
    - But, most can and do borrow; still have unused borrowing capacity.
  - Gap between interest rates on borrowing and saving...
    - averaged 3 percentage-points for loans secured with collateral.
- Literature summary: unwinding forced saving $\Rightarrow$ all or nothing.

Three-Period Example with Perfect Credit Markets

- Age is discrete and indexed by subscript t.
  - Works during Periods 1 and 2, retired during Period 3.
- Constraints on decision making are

$$\begin{aligned} c_1 &= (1-\theta)w_1 - S_1 \\ c_2 &= (1-\theta)w_2 + RS_1 - S_2 \\ c_3 &= RS_2 + b \end{aligned}$$

  - $R = 1 + r$ is gross interest rate; $r \geq 0$ avoids dynamic inefficiency.
  - Fully funded: $b = R^2\theta w_1 + R\theta w_2$; unfunded: $b = \theta w_1 + \theta w_2$.
- Period-1 problem: $\max_{\{c_1,c_2,c_3\}} U_1 = \ln c_1 + \beta\delta \ln c_2 + \beta\delta^2 \ln c_3$

$$\text{subject to} \qquad c_1 + \frac{c_2}{R} + \frac{c_3}{R^2} = \underbrace{(1-\theta)w_1 + \frac{(1-\theta)\,w_2}{R} + \frac{b}{R^2}}_{\equiv \Gamma_1}$$

where Γ_1 is lifetime wealth, and $\beta, \delta \in (0, 1]$ are discount factors.

- Optimal solutions from perspective of Period 1

$$c_1^1 = c_1 = \left(\frac{1}{1+\beta\delta+\beta\delta^2}\right)\Gamma_1,\ c_2^1 = \left(\frac{R\beta\delta}{1+\beta\delta+\beta\delta^2}\right)\Gamma_1,$$
$$c_3^1 = \left(\frac{R^2\beta\delta^2}{1+\beta\delta+\beta\delta^2}\right)\Gamma_1,\ S_1 = (1-\theta)w_1 - \left(\frac{1}{1+\beta\delta+\beta\delta^2}\right)\Gamma_1.$$

- Period-2 problem: $\max_{\{c_2,c_3\}} U_2 = \ln c_2 + \beta\delta \ln c_3$

$$\text{subject to} \qquad c_2 + \frac{c_3}{R} = \underbrace{RS_1 + (1-\theta)\,w_2 + \frac{b}{R}}_{\equiv\ \Gamma_2}$$

where Γ_2 is remaining lifetime wealth measured in Period-2 terms.

- Solutions written in terms of Γ_1,

$$c_2^2 = c_2 = \left(\frac{R(\beta\delta+\beta\delta^2)}{(1+\beta\delta)(1+\beta\delta+\beta\delta^2)}\right)\Gamma_1,$$
$$c_3^2 = c_3 = \left(\frac{R^2\beta\delta(\beta\delta+\beta\delta^2)}{(1+\beta\delta)(1+\beta\delta+\beta\delta^2)}\right)\Gamma_1,$$

- Social security fails again...

$$\frac{\partial c_1}{\partial \theta} = \left(\frac{1}{1+\beta\delta+\beta\delta^2}\right)\frac{\partial \Gamma_1}{\partial \theta},$$

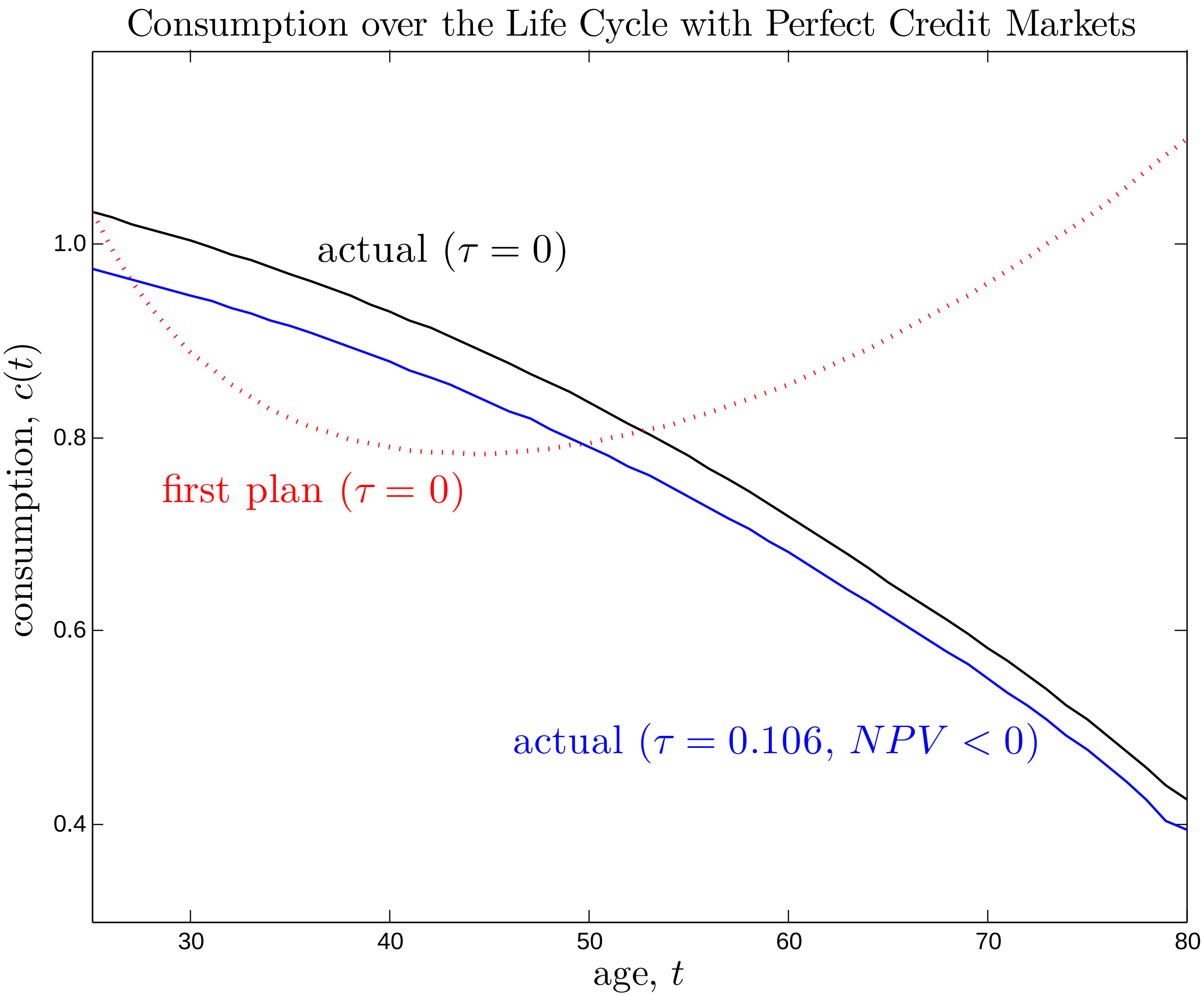
$$\frac{\partial c_2}{\partial \theta} = \left(\frac{R(\beta\delta+\beta\delta^2)}{(1+\beta\delta)(1+\beta\delta+\beta\delta^2)}\right)\frac{\partial \Gamma_1}{\partial \theta},$$

$$\frac{\partial c_2}{\partial \theta} = \left(\frac{R^2\beta\delta(\beta\delta+\beta\delta^2)}{(1+\beta\delta)(1+\beta\delta+\beta\delta^2)}\right)\frac{\partial \Gamma_1}{\partial \theta},$$

- Fully-funded: $b = R^2\theta w_1 + R\theta w_2$

$$\frac{\partial \Gamma_1}{\partial \theta} = 0 \implies \frac{\partial c_1}{\partial \theta} = 0,\ \frac{\partial c_2}{\partial \theta} = 0,\ \text{and}\ \frac{\partial c_3}{\partial \theta} = 0.$$

- Unfunded: $b = \theta(w_1 + w_2)$, $\partial\Gamma_1/\partial\theta = \frac{w_1}{R^2}(1-R^2) + \frac{w_2}{R^2}(1-R)$.
  - For $R = 1$: $$\frac{\partial \Gamma_1}{\partial \theta} = 0 \implies \frac{\partial c_1}{\partial \theta} = 0,\ \frac{\partial c_2}{\partial \theta} = 0,\ \text{and}\ \frac{\partial c_3}{\partial \theta} = 0,$$
  - For $R > 1$: $$\frac{\partial \Gamma_1}{\partial \theta} < 0 \implies \frac{\partial c_1}{\partial \theta} < 0,\ \frac{\partial c_2}{\partial \theta} < 0,\ \text{and}\ \frac{\partial c_3}{\partial \theta} < 0.$$



Parameters: $k(0) = 0$, $r_S = 0.03 = r_B$, $w = 1$, $T = 40$, $\bar{T} = 55$, $\beta = 0.07$, $\sigma = 1$.

Our Contribution

- Assumptions about access to credit are of first-order importance.
- Design a life-cycle model of consumption and saving.
  - Hyperbolic discounting: time-inconsistent dynamic optimization.
  - Incorporate a "generalized" credit setting with borrowing costs.
    - Credit spread between interest rates on borrowing and saving.
  - Nests extremes of missing credit markets and perfect markets.
    - Missing credit markets (infinite spread).
    - Perfect credit markets (zero spread).
    - Also includes full spectrum of credit spreads in between.
- **Finding:** social security can be easily justified.
  1. Mandatory saving is irrelevant only at knife edge of perfect markets.
  2. SS can improve welfare if there exists a credit spread of *any* size.
  3. Quantitative findings robust to unobservable preference parameters.
  4. Gains generally robust to alternative SS arrangements.
- Findings provide more compelling role for mandatory saving...
  - than what is implied by findings of past studies ⇒ *Lucas Critique*.

Economic Environment

- We abstract from income heterogeneity and income/longevity risk.
  - Avoids confounding welfare effects of mandatory saving...
  - with welfare effects of redistributive and risk-sharing roles of SS.
- Age is continuous and indexed by t.
- Individual starts work at $t = 0$, retires at $t = T$, and dies at $t = \bar{T}$.
- Disposable wages earned at rate $(1 - \tau)w$ for all $t \in [0, T]$.
  - Social security contributions paid at rate τ.
  - Fraction of $(1 - \tau)w$ not consumed flows into asset account, $k(t)$.
    - Private saving assets earn interest at rate r_S.
- Social security benefits are received at rate

$$b = \frac{\int_0^T \tau w \exp[-r_S t]dt}{\int_T^{\bar{T}} \exp[-r_S t]dt} \text{ for all } t \in \left[T, \bar{T}\right]. \tag{7}$$

- $F(x)$ is a discount function in general form, for a delay of x.
- $u[c(t)]$ is a strictly concave utility function; $c(t)$ is consumption.

- Interest rate on assets $r(k(t))$ depends on the sign of assets

$$r(k(t)) = \begin{cases} r_B, & \text{if } k(t) < 0, \\ r_S, & \text{if } k(t) > 0, \end{cases} \tag{1}$$

  where

$$r_B \geq r_S. \tag{2}$$

- We approximate discontinuity with continuous function,

$$r(k(t)) \approx r_S - \frac{r_S - r_B}{1 + \exp[\psi k(t)]}, \text{ where} \tag{3}$$

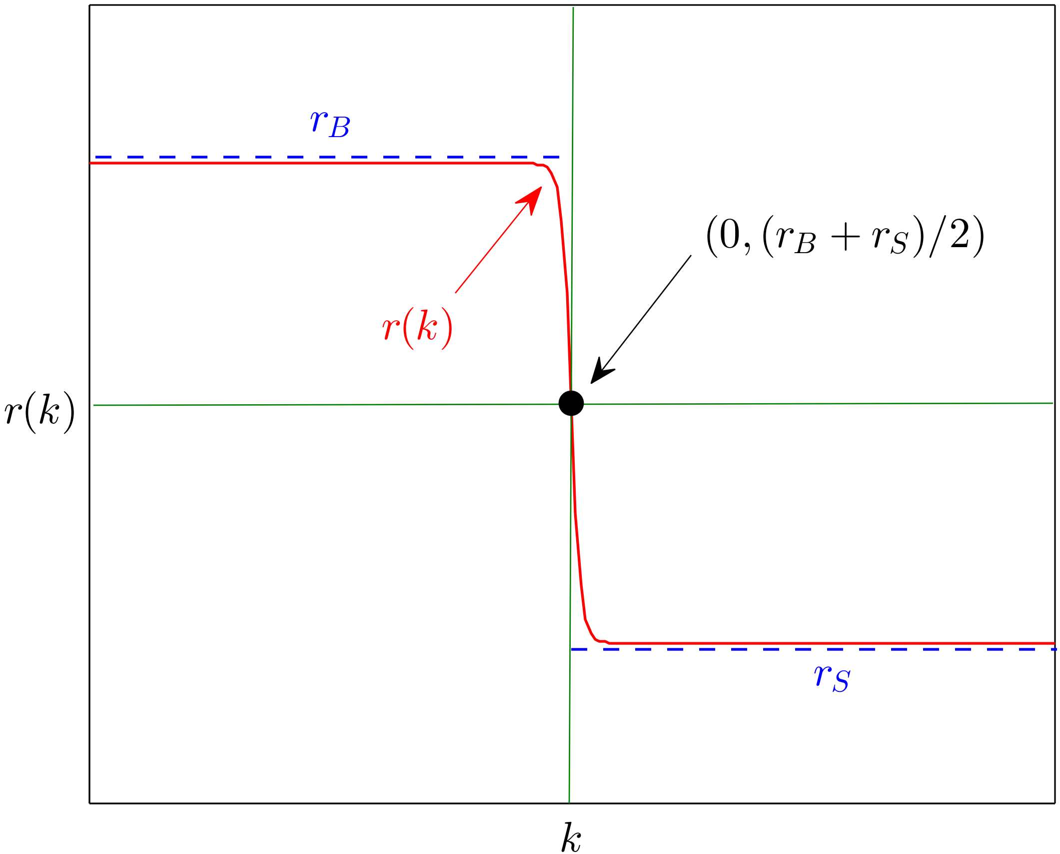
$$\lim_{\psi \longrightarrow \infty} \left[r_S - \frac{r_S - r_B}{1 + \exp[\psi k(t)]} \right] = \begin{cases} r_B, & \text{if } k(t) < 0, \\ r_S, & \text{if } k(t) > 0, \end{cases} \tag{4}$$

$$\lim_{k(t) \longrightarrow -\infty} \left[r_S - \frac{r_S - r_B}{1 + \exp[\psi k(t)]} \right] = r_B, \tag{5}$$

$$\lim_{k(t) \longrightarrow +\infty} \left[r_S - \frac{r_S - r_B}{1 + \exp[\psi k(t)]} \right] = r_S. \tag{6}$$

- Adapts procedure in Caliendo & Guo (2014) to our setting with time-inconsistent preferences.

Figure 1. Continuous Approximation (Caliendo and Guo (2014))



Time-Inconsistent Decision Making

- Standing at age $t \in [0, \bar{T})$, the individual solves

$$\max_{\{c(v)\}} : \int_t^{\bar{T}} F(v-t)u[c(v)]dv, \tag{8}$$

- subject to

$$\frac{dk(v)}{dv} = r(k(v))k(v) + y(v) - c(v), \tag{9}$$

$$y(v) = \begin{cases} (1-\tau)w, \text{ for } v \in [t, T], \\ b, \text{ for } v \in [T, \bar{T}], \end{cases} \tag{10}$$

$$r(k(v)) = r_S - \frac{r_S - r_B}{1 + \exp[\psi k(v)]}, \tag{11}$$

$$k(t) \text{ given, } k(\bar{T}) = 0. \tag{12}$$

- The optimality conditions include the Maximum Condition

$$F(v-t)u_c[c(v)] = \lambda(v), \tag{13}$$

and the multiplier equation

$$\frac{d\lambda(v)}{dv} = -\lambda(v)[r'(k(v))k(v) + r(k(v))], \tag{14}$$

which has the particular solution

$$\lambda(v) = \lambda(t)\exp\left[-\int_t^v \{r'(k(z))k(z) + r(k(z))\}dz\right]. \tag{15}$$

- Combine with (13) to get planned consumption for $v \in [t, \bar{T}]$,

$$\begin{aligned} c(v) &= u_c^{-1}\left[\frac{\lambda(t)}{F(v-t)}\exp\left[-\int_t^v \{r'(k(z))k(z) + r(k(z))\}dz\right]\right] \\ &= u_c^{-1}\left[\frac{u_c[c(t)]}{F(v-t)}\exp\left[-\int_t^v \{r'(k(z))k(z) + r(k(z))\}dz\right]\right] \end{aligned} \tag{16}$$

where $c(t)$ is actual consumption at age t.

- Hereafter, we use $(*)$ to distinguish actual from planned quantities.

- Need to identify actual consumption profile, $c^*(t)$, by solving

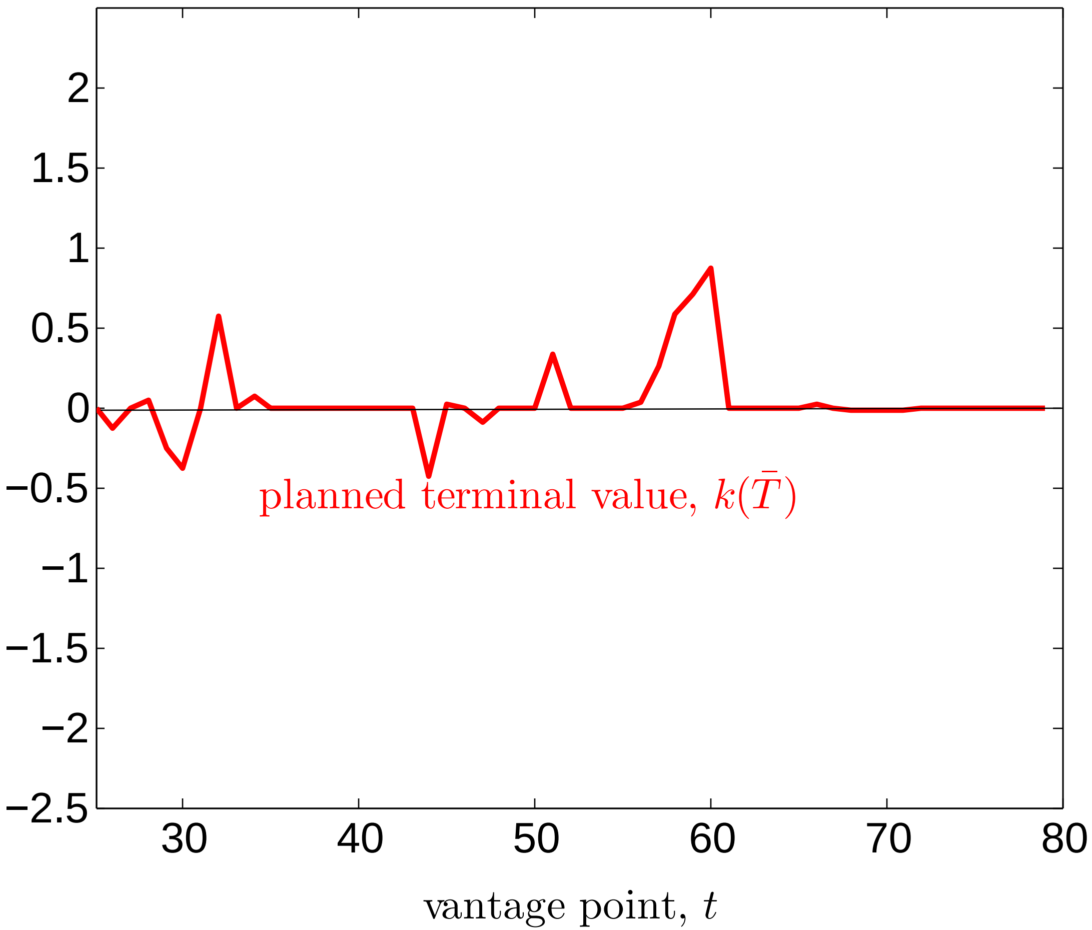
$$\frac{dk(v)}{dv} = r(k(v))k(v) + y(v) - u_c^{-1}\left[\frac{u_c[c^*(t)]}{F(v-t)}\exp\left[-\int_t^v \{r'(k(z))k(z) + r(k(z))\}dz\right]\right] \quad (17)$$

$$k(t) = k^*(t) \text{ given}, \; k(\bar{T}) = 0. \quad (18)$$

for all $t \in [0, \bar{T}]$.

- $c^*(t)$ solves a continuum of boundary value problems.
  - Each problem has a Volterra differential equation.
    - Differential equation depends on the complete history of past states.
  - Envelope of initial values from continuum of planned paths.
- We develop computational procedure to solve for $c^*(t)$.

Figure 2. Computational Error



Parameters: $k(0) = 0$, $r_S = 0.01$, $r_B = 0.04$, $\tau = b = 0$, $w = 1$, $\psi = 50$, $T = 40$, $\bar{T} = 55$, $\beta = 0.07$, $\sigma = 1$.

Analytical Results

- **Theorem 1.** *A fully-funded social security arrangement is irrelevant for consumption allocations and welfare if credit markets are perfect* ($r_B = r_S$)*.*
- **Theorem 2.** *Of the full spectrum of credit spreads ranging from zero (perfect credit markets) to infinity (missing credit markets), a fully-funded social security arrangement is irrelevant* ***only*** *at the knife edge of perfect credit markets.*
- **Proofs:** see paper.
- **Remark 1.** *Theorems 1 and 2 hold whether the individual is naive or sophisticated.*
- Results hold for any discount function and concave utility function.
- Magnitude of gains depends on welfare specification.
  - Specifying welfare for time-inconsistent individuals is nebulous.
  - Welfare analysis is just as nebulous for exponential discounters.
    - Caplin & Leahy (2004, *JPE*).

Metric 1: Mean-Variance Welfare

- Let $c^*(t|\tau)$ be actual consumption path conditional on τ, and let

$$C(\tau) \equiv \bar{T}^{-1} \int_0^{\bar{T}} c^*(t|\tau) dt, \quad (29)$$

$$VAR(\tau) \equiv \int_0^{\bar{T}} [c^*(t|\tau) - C(\tau)]^2 dt. \quad (30)$$

- Welfare is

$$S(\tau) \equiv C(\tau) - \phi VAR(\tau), \quad (31)$$

where ϕ is penalty for inequality (non-smoothness) among selves.

Metric 2: First Plan is the Policy Target

- Treats original, optimal plan as the relevant goal.
  - Laibson (1998), O'Donoghue & Rabin (1999), Gruber & Kőszegi (2001), Rubinstein (2006), Cremer & Pestieau (2011).
  - First plan *Multi-Self Pareto Dominates* the equilibrium allocation.
    - Caliendo & Findley (2015).
- Let $c^*(t|\tau)$ be actual consumption path conditional on τ.
- Let $c_0(t)$ be the first plan for the specific case of $\tau = 0$.
- Euclidean distance (gap) between planned and actual profiles is

$$g(\tau) \equiv \sqrt{\int_0^{\bar{T}} [c^*(t|\tau) - c_0(t)]^2 dt}. \quad (32)$$

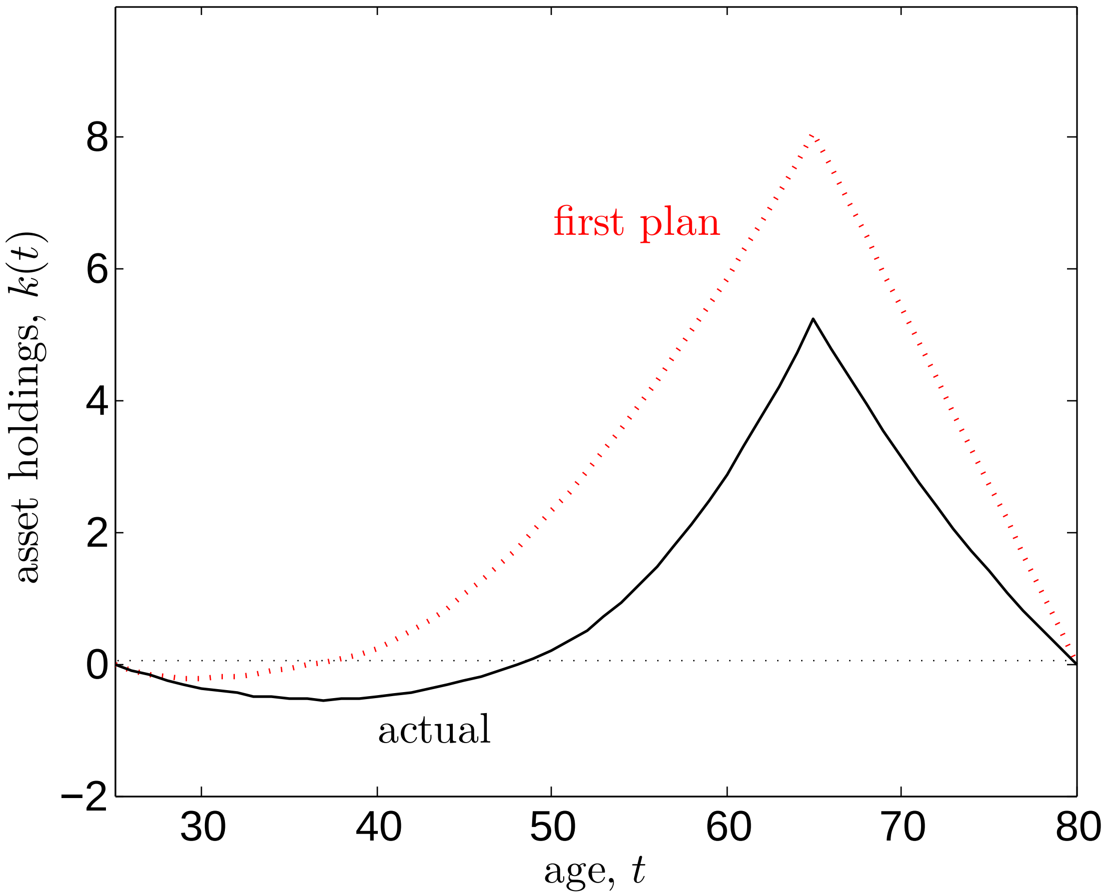
- Fraction of gap closed by social security is the welfare statistic,

$$\Delta g \equiv \frac{g(0) - g(\tau)}{g(0)}. \quad (33)$$

Numerical Examples

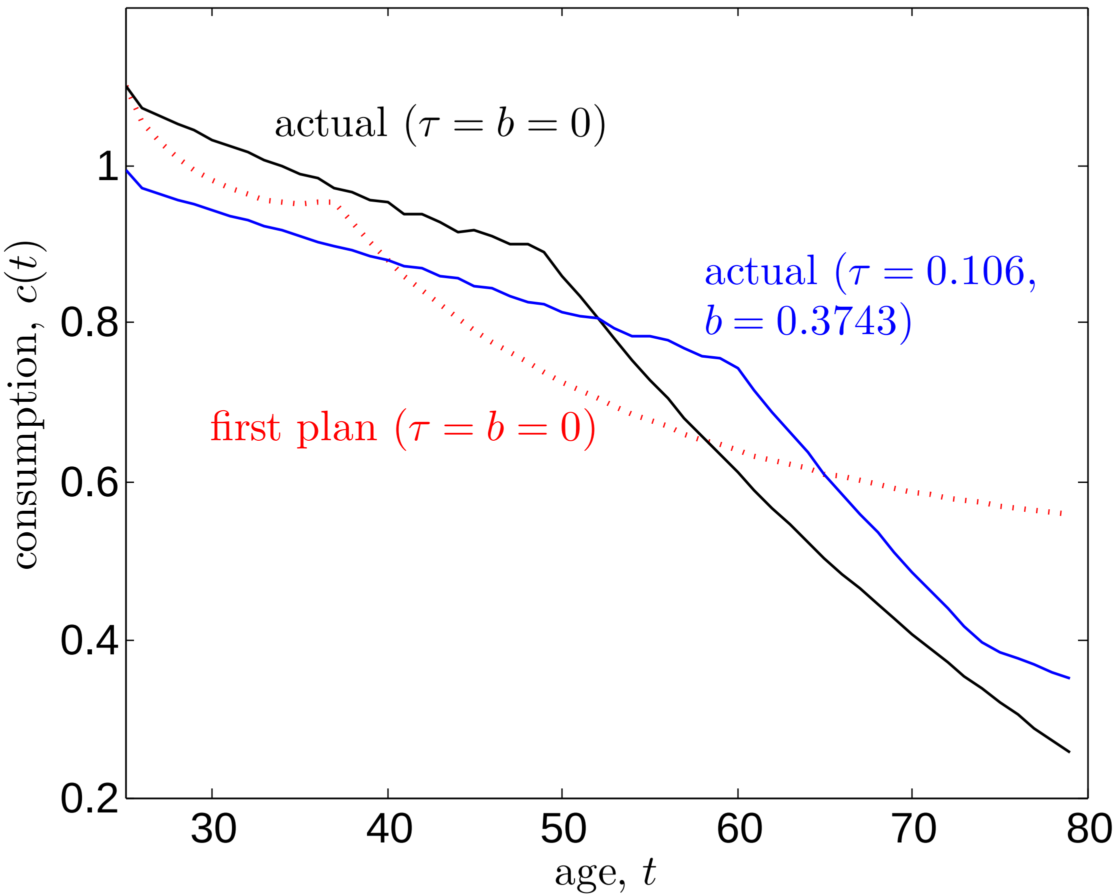
- $T = 40$ and $\bar{T} = 55$.
  - Work starts at age 25, retirement at 65, death at age 80.
- $r_S = 1\%$, $r_B = 4\%$, and $k(0) = 0$.
  - 3-point spread matches average during Greenspan-Bernanke era.
- Normalize $w = 1$, and we examine $\tau = 0$ and $\tau = 10.6\%$.
  - Means that $b = 0$ and $b = 0.3743$ respectively.
- Isoelastic utility
  - $u[c(t)] = c(t)^{1-\sigma}/(1-\sigma)$ for $\sigma \neq 1$.
  - $u[c(t)] = \ln c(t)$ as $\sigma = 1$, which is used at baseline.
- Hyperbolic discount function: $F(x) = [1 + \beta x]^{-1}$, $\beta = 7\%$.
- $\psi = 50$ from the logistic function.
- Discrete-time simulation with a time grid size of one year.
  - Also used finer time grid (e.g., one-tenth of a year).

Figure 3. Asset Holdings over the Life Cycle: No Social Security



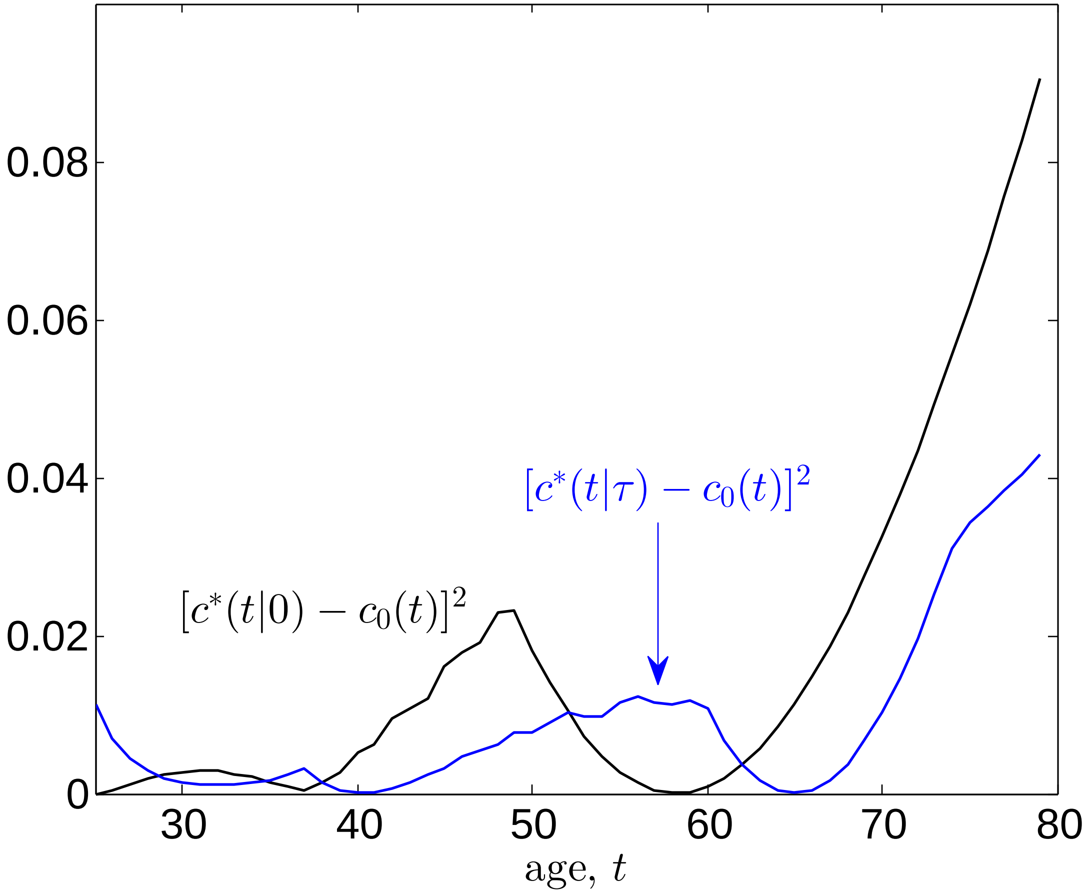
Parameters: $k(0) = 0$, $r_S = 0.01$, $r_B = 0.04$, $\tau = b = 0$, $w = 1$, $\psi = 50$, $T = 40$, $\bar{T} = 55$, $\beta = 0.07$, $\sigma = 1$.

Figure 4. Consumption over the Life Cycle



Parameters: $k(0) = 0$, $r_S = 0.01$, $r_B = 0.04$, $w = 1$, $\psi = 50$, $T = 40$, $\bar{T} = 55$, $\beta = 0.07$, $\sigma = 1$.

Figure 5. Squared Distance from First Plan



Parameters: $k(0) = 0$, $r_S = 0.01$, $r_B = 0.04$, $w = 1$, $\psi = 50$, $T = 40$, $\bar{T} = 55$, $\beta = 0.07$, $\sigma = 1$.

Table 1. Robustness to Unobservables: Welfare Metric 1 under US Tax

Panel A. Change in mean consumption, $[C(\tau) - C(0)]/C(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%
$\beta = 4\%$	1.99%	1.15%	0.16%	0.01%	0.01%	0.01%	0.01%
$\beta = 7\%$	0.56%	0.66%	0.65%	0.27%	0.06%	0.02%	0.01%
$\beta = 10\%$	-2.24%	-1.17%	-0.08%	0.28%	0.20%	0.08%	0.02%

Panel B. Change in variance, $[VAR(\tau) - VAR(0)]/VAR(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.01%	-0.06%	-0.16%	-0.22%	-0.26%	-0.28%	-0.30%
$\beta = 4\%$	-49.21%	-40.08%	-10.06%	0.43%	0.25%	0.17%	0.13%
$\beta = 7\%$	-50.17%	-45.98%	-36.59%	-17.52%	-3.51%	0.16%	0.20%
$\beta = 10\%$	-28.19%	-38.13%	-38.04%	-30.49%	-16.28%	-5.31%	-0.43%

Table 2. Robustness to Unobservables: Welfare Metric 2 under US Tax

Panel A. Euclidean gap between planned and actual consumption, $g(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.23	0.11	0.06	0.04	0.03	0.02	0.02
$\beta = 4\%$	1.00	0.69	0.38	0.26	0.20	0.16	0.14
$\beta = 7\%$	1.14	0.97	0.68	0.48	0.37	0.30	0.26
$\beta = 10\%$	1.71	1.15	0.88	0.67	0.52	0.43	0.36

Panel B. Fraction of the gap closed by social security, Δg

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.05%	0.10%	0.18%	0.26%	0.33%	0.40%	0.46%
$\beta = 4\%$	5.62%	2.18%	0.58%	-0.12%	-0.01%	0.02%	0.04%
$\beta = 7\%$	52.05%	26.54%	12.15%	3.45%	0.49%	-0.07%	-0.01%
$\beta = 10\%$	18.92%	35.82%	23.87%	13.44%	5.09%	1.17%	0.004%

Table 3. Robustness to Unobservables: Welfare Metric 1 under OECD Tax

Panel A. Change in mean consumption, $[C(\tau) - C(0)]/C(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.03%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%
$\beta = 4\%$	***	3.72%	1.90%	1.16%	0.80%	0.58%	0.44%
$\beta = 7\%$	***	0.88%	1.27%	1.04%	0.83%	0.68%	0.56%
$\beta = 10\%$	-5.65%	-4.01%	-1.99%	-0.97%	-0.59%	-0.39%	-0.26%

Panel B. Change in variance, $[VAR(\tau) - VAR(0)]/VAR(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	-1.38%	-5.62%	-10.93%	-14.14%	-16.24%	-17.68%	-18.72%
$\beta = 4\%$	***	-98.82%	-96.39%	-92.39%	-87.24%	-81.22%	-74.68%
$\beta = 7\%$	***	-89.98%	-93.53%	-93.12%	-92.04%	-90.38%	-87.98%
$\beta = 10\%$	-46.82%	-63.91%	-77.89%	-81.45%	-81.15%	-80.40%	-79.61%

Table 4. Robustness to Unobservables: Welfare Metric 2 under OECD Tax

Panel A. Euclidean gap between planned and actual consumption, $g(0)$

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.23	0.11	0.06	0.04	0.03	0.02	0.02
$\beta = 4\%$	***	0.69	0.38	0.26	0.20	0.16	0.14
$\beta = 7\%$	***	0.97	0.68	0.48	0.37	0.30	0.26
$\beta = 10\%$	1.71	1.15	0.88	0.67	0.52	0.43	0.36

Panel B. Fraction of the gap closed by social security, Δg

	$\sigma = 0.5$	$\sigma = 1.0$	$\sigma = 2.0$	$\sigma = 3.0$	$\sigma = 4.0$	$\sigma = 5.0$	$\sigma = 6.0$
$\beta = 1\%$	0.01%	-0.36%	-1.16%	-1.78%	-2.25%	-2.60%	-2.87%
$\beta = 4\%$	***	-23.48%	-10.64%	1.59%	8.52%	12.07%	13.23%
$\beta = 7\%$	***	28.12%	21.51%	24.48%	30.25%	34.26%	36.62%
$\beta = 10\%$	26.39%	41.56%	45.05%	43.43%	45.58%	48.19%	50.03%

Table 5. Robustness to Credit Spread: Welfare Metric 1 under US Tax

Panel A. Change in mean consumption, $[C(\tau) - C(0)]/C(0)$

	$r_B = 2.0\%$	$r_B = 3.0\%$	$r_B = 4.0\%$	$r_B = 5.0\%$	$r_B = 6.0\%$	$r_B = 7.0\%$
$r_S = 0.0\%$	-1.88%	-1.53%	-0.87%	-0.27%	-0.03%	-0.02%
$r_S = 0.5\%$	-1.31%	-0.90%	-0.13%	0.57%	0.86%	0.88%
$r_S = 1.0\%$	-0.74%	-0.27%	0.66%	1.47%	1.83%	1.84%
$r_S = 1.5\%$	-0.25%	0.32%	1.46%	2.41%	2.85%	2.87%

Panel B. Change in variance, $[VAR(\tau) - VAR(0)]/VAR(0)$

	$r_B = 2.0\%$	$r_B = 3.0\%$	$r_B = 4.0\%$	$r_B = 5.0\%$	$r_B = 6.0\%$	$r_B = 7.0\%$
$r_S = 0.0\%$	-23.02%	-34.27%	-40.56%	-41.67%	-41.19%	-41.17%
$r_S = 0.5\%$	-21.43%	-35.46%	-43.04%	-44.54%	-43.96%	-43.95%
$r_S = 1.0\%$	-18.59%	-36.19%	-45.98%	-47.99%	-47.30%	-47.29%
$r_S = 1.5\%$	-12.47%	-36.28%	-49.27%	-52.17%	-51.39%	-51.38%

Table 6. Robustness to Credit Spread: Welfare Metric 2 under US Tax

Panel A. Euclidean gap between planned and actual consumption, $g(0)$

	$r_B = 2.0\%$	$r_B = 3.0\%$	$r_B = 4.0\%$	$r_B = 5.0\%$	$r_B = 6.0\%$	$r_B = 7.0\%$
$r_S = 0.0\%$	0.80	0.74	0.75	0.81	0.84	0.85
$r_S = 0.5\%$	0.90	0.84	0.85	0.90	0.93	0.93
$r_S = 1.0\%$	1.04	0.97	0.97	1.01	1.03	1.04
$r_S = 1.5\%$	1.21	1.13	1.13	1.16	1.17	1.18

Panel B. Fraction of the gap closed by social security, Δg

	$r_B = 2.0\%$	$r_B = 3.0\%$	$r_B = 4.0\%$	$r_B = 5.0\%$	$r_B = 6.0\%$	$r_B = 7.0\%$
$r_S = 0.0\%$	29.04%	30.44%	13.55%	-0.84%	-6.11%	-6.29%
$r_S = 0.5\%$	24.52%	32.36%	20.74%	7.36%	1.70%	1.48%
$r_S = 1.0\%$	18.68%	31.53%	26.54%	15.41%	9.80%	9.56%
$r_S = 1.5\%$	10.40%	28.31%	30.06%	22.60%	17.63%	17.40%

Summary

- Conventional intuition suggests that innovation in credit markets...
  - "eliminates the commitment properties of illiquid assets [like social security]" (Laibson 1998, p.869).
- We find that social security can still provide partial commitment as long as there are borrowing costs (credit spread) of **any** size.
  - Even in settings where people can borrow as much as they want.
    - No capacity constraint on borrowing.
- Future Work
  - Build in margins of choice over (time-inconsistent) labor supply.
  - GE extension for fully-funded SS program:
    - Will reinforce PE welfare gains from SS since $K \uparrow$.
  - GE extension for case of unfunded program:
    - Inefficiencies with financing the program $\Rightarrow K \downarrow$.
    - Welfare effects are ambiguous *a priori*.