Behavioral Macroeconomics:
Part 4 - Hyperbolic Discounting and Savings

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Macroeconomics and Saving

Golden Eggs and Hyperbolic Discounting (Laibson QJE 1997)

- Self-control problems $\rightarrow$ commitment (binding dead-lines, special bank accounts, health-clubs, diet)
- All illiquid assets provide a form of commitment (though there are other reasons to hold them such as diversification, higher expected returns), retirement plans, pension funds

Characterization of Hyperbolic Discounting Functions

- Relatively high discount rate over short horizons
- Relatively low discount rate over long horizons
- Example: from today's perspective, the discount rate between two far-off periods, t and $t + 1$ is the low long-term discount rate, but from time t perspective, the discount rate between t and $t + 1$ is the high short-term discount rate

Summary

Laibson's (1997) conclusions:

- Framework explains high correlation between consumption and income
- Consumers have different propensity to consume out of wealth than labor income
- Ricardian equivalence should not hold
- Financial innovation may have caused savings' decline in the U.S.
- Financial innovations reduce welfare by providing too much liquidity

The Model

- Time-additive utility function:

$$U_t = E_t[u(c_t) + \beta \sum_{\tau=1}^{T-t} \delta^{\tau} u(c_{t+\tau})] \tag{1}$$

- The discount structure is so called "quasi-hyperbolic" - the discount function is a discrete time function with values

$$\{1, \beta\delta, \beta\delta^2, \beta\delta^3, ...\} \tag{2}$$

The Model (continued)

- Preferences given by equation (1) are dynamically inconsistent (preferences at date t are inconsistent with preferences at date $t+1$)

- Marginal rate of substitution between time $t+1$ and $t+2$ at time t is $u'(c_{t+1})/\delta u'(c_{t+2})$

- Marginal rate of substitution at time $t+1$ is $u'(c_{t+1})/\beta\delta u'(c_{t+2})$

- Analyzing equilibrium behavior when preferences are dynamically inconsistent: A T-period consumption problem $\rightarrow$ a T-period game with T players or "selves" $\rightarrow$ subgame perfect equilibrium

The Model (continued)

- Consumer has liquid assets x_{t-1} and nonliquid assets z_{t-1}, both chosen at time period $t-1$. These yield gross return of $R_t = 1 + r_t$.

- Consumption is chosen from deterministic labor income and access to liquid savings $c_t \leq y_t + R_t x_{t-1}$. Note, that in the period of control, self t cannot consume the illiquid asset.

- Thereafter, consumer chooses new asset allocation $y_t + R_t(z_{t-1} + x_{t-1}) - c_t = z_t + x_t$ and $x_t, z_t \geq 0$.

The Model (continued)

- Consumer may borrow against his illiquid assets. Creditor gets contingent control right over some of those assets, consumer receives liquidity that can be consumed.

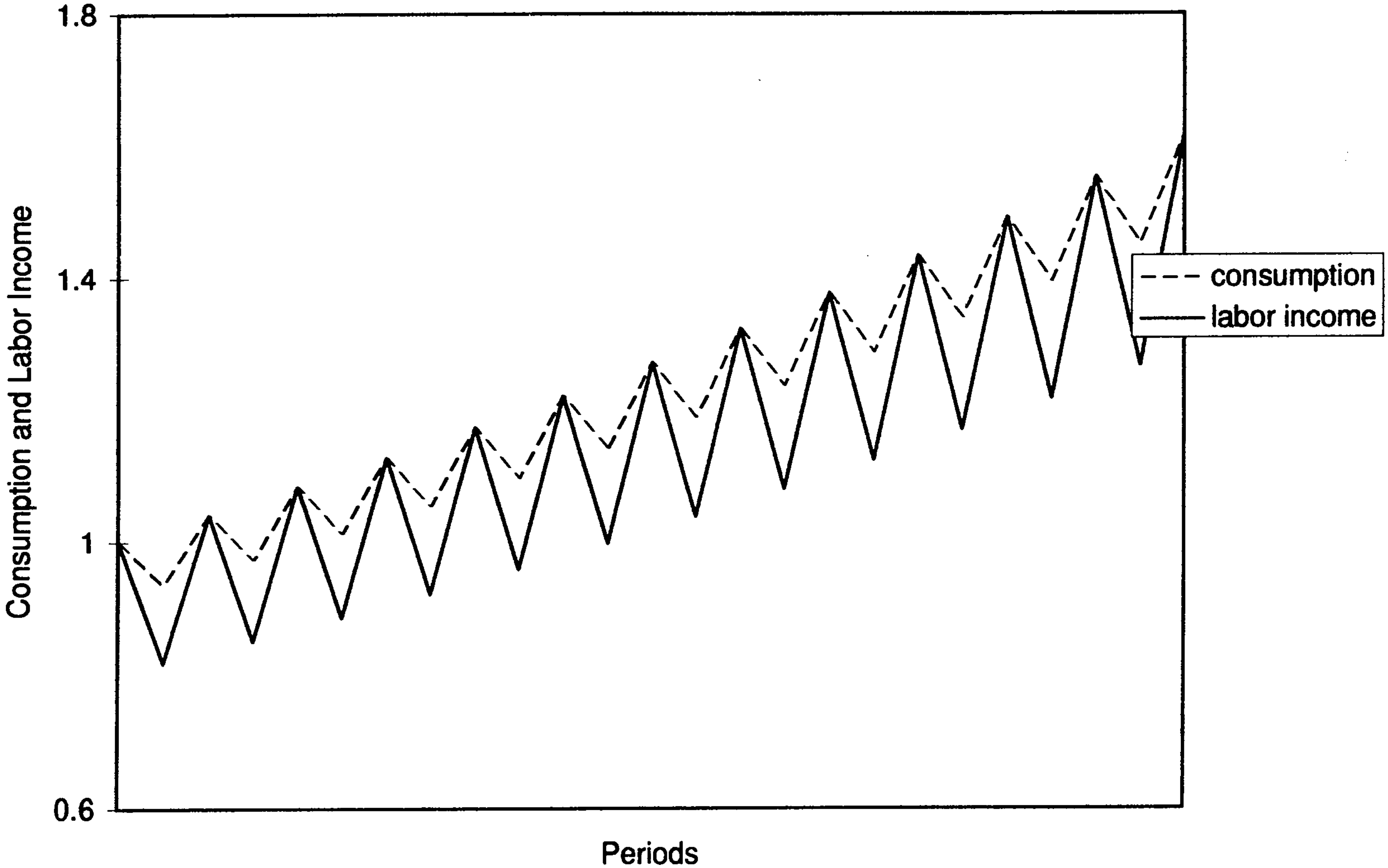
Co-Movement in Consumption and Income

- In the model, self $t-1$ chooses x_{t-1} to constrain the consumption of self t. As such, manipulation of cash flow process by keeping most assets in the illiquid instrument
- Self-imposed liquidity constraint
- In equilibrium consumption equals current level of cash flow:

$$c_t = y_t + R_t x_{t-1} \tag{3}$$

- When y_t is large, self $t-1$ will make x_{t-1} small to prevent self t from overconsuming.
- Self $t-1$ can only deny self t access to assets that have been accumulated in the past, cannot deny access to y_t, labor income at time t

Co-Movement in Consumption and Income (continued)



Aggregate Savings

- Classical: High discount rates necessary condition for consumption-income co-movement. This implies low level of capital accumulation.

- Golden eggs model: Consumption-income co-movement even when actors are wealthy, since in equilibrium decision to dissave out of the illiquid asset stock is not dependent on β.

- Why? Self t is not able to consume from illiquid assets, so does not consider trade-off between consumption today and consumption tomorrow when dissaving from illiquid assets.

Asset-Specific MPCs

- Thaler (1990): people have mental accounts, different marginal propensities to consume (MPCs) for different categories of assets

- Thaler: 3 categories: current income (MPC ~ 1), net assets (MPC $0 < x < 1$), future income (MPC ~ 0)

- In golden eggs model current self is liquidity constrained on equilibrium path $\rightarrow$ MPC out of current cash flow is 1 ($\frac{\partial c_t}{\partial (R_t x_{t-1})} = 1$)

- On equilibrium path self-imposed liquidity constraint $\rightarrow$ MPC out of illiquid assets is 0 ($\frac{\partial c_t}{\partial (R_t z_{t-1})} = 0$)

Ricardian Equivalence

- Here, sequence of exogenous cash flows matters, independent of present value scheme. Taxation schemes affect these exogenous cash flows, so Ricardian equivalence is violated.

Declining U.S. Saving Rates in the 1980s

- Large proportion of national income realized as cash flow during that time period

- Special developments in consumer credit market $\rightarrow$ expansion in U.S. consumer credit market $\rightarrow$ commitment devices such as illiquid assets loose effectiveness, since one can generate credit loans on these illiquid assets

- Original model:

$$c_t \leq y_t + R_t x_{t-1} \tag{4}$$

- Now:

$$c_t \leq y_t + R_t x_{t-1} + R_t z_{t-1} \tag{5}$$

with instantaneous access to credit

What about Welfare?

- Instantaneous credit increases consumers' choice set,
- though eliminates possibility for partial commitment.
- Current self no longer liquidity constrained, can consume more in period of control, though can also consume more out of wealth stock
- First effect positive, second one is negative and usually dominant $\rightarrow$ people would not save enough

Evaluation

Problems with the model:

- How are assets accumulated in the first place
- Usually consumers do not consume all their liquid assets, but do hold some liquidity
- Some agents do have internal self-control and do not need commitment devices
- There may be social commitment devices (marriage, work, friendship etc.)

Hyperbolic Discounting and Savings

We discuss paper by O'Donoghue and Rabin (1999): "Procrastination in Preparing for Retirement" (see also O'Donoghue and Rabin: "Doing it Now or Later", AER, 1999)

- Hyperbolic discounting and self-control problems may cause undersaving
- A taste for immediate gratification can lead a person to sacrifice too much future consumption for the sake of current consumption → people end up with too little retirement savings
- People sophisticated and foresee that they will have self-control problems or rather naive and do not foresee the self-control problems? Or rational without any self-control problems?

The Model

- Intertemporal preferences:

$$U^t(u_t, u_{t+1}, ..., u_T) = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau, \qquad (6)$$

  where $\delta \leq 1$ is the time-consistent discount factor and $\beta \leq 1$ is the bias for the presence.

- Sophisticates: are aware of their future self-control problems

- Naifs: are fully unaware of their future self-control problems

- The rational investor: no time-inconsistency (TCs)

Loss from a τ-Delay

- $$L(\tau) = P[(1 + \frac{r_B}{365})^T - (1 + \frac{r_A}{365})^\tau (1 + \frac{r_B}{365})^{T-\tau}] \qquad (7)$$

  where $r_B > r_A$ (rates of return on saving plan A, respectively B), $C > 0$ (transaction costs), P principal

- Hence, if in period t the person expects to incur transfer cost C in period $\tau \geq t$ and expects to retire in period $T + 1 \geq \tau$ with retirement savings S, then his period-t intertemporal utility is given by

$$U^t = \begin{cases} -C + \beta\delta^{T+1-t}S & \text{if } \tau = t \\ -\beta\delta^{\tau-t}C + \beta\delta^{T+1-t}S & \text{if } \tau > t \end{cases} \qquad (8)$$

Lost Retirement Savings from Delay

Table 1: Lost Retirement Savings from Delay
(Principal = \$10,000, Horizon = 30 years)

r_A	r_B	Lost Retirement Savings from One-Day Delay ($L(1)$)	Lost Retirement Savings if Never Transfer ($L(T)$)
0%	1%	\$0.37	\$3,499
5%	6%	\$1.66	\$15,675
10%	11%	\$7	\$70,219
0%	5%	\$6	\$34,812
5%	10%	\$28	\$155,961
10%	15%	\$123	\$698,567
0%	10%	\$55	\$190,773
5%	15%	\$246	\$854,527
10%	20%	\$1,103	\$3,826,891

Now or Never

- More realistic: Plan B is more attractive the further one is from retirement, $\delta(1 + \frac{r_B}{365}) > 1$
- In this case, TCs and Naifs either transfer immediately or never.

Behavior of TCs

- Transfer funds immediately iff $C \leq \delta^T L(T)$
- Present discounted value of the extra interest is bigger than immediate cost of transferring the funds
- Never transfer funds iff $C > \delta^T L(T)$

Behavior of Naifs

- Unlike TCs, they do not compare transferring the funds now or never
- They constantly believe if they do not transfer the money today they will do so tomorrow.
- They only make the transfer iff doing so is preferred to a one-day delay.
- Thus, they prefer delaying iff $C > \beta\delta C + \beta\delta^T L(1)$
- i.e Transfer funds immediately iff $C \leq \frac{\beta}{1-\beta\delta}\delta^T L(1)$ or never transfer funds vice versa

Naifs' Procrastination on Daily Basis

Table 2: When Naifs Procrastinate: Single Alternative, Daily Decisions
(Principal = $10,000, Horizon = 30 years)

			TCs never	Naifs	never	transfer	funds	if
r_A	r_B	δ^{365}	transfer funds if	$\beta = .99$	$\beta = .98$	$\beta = .95$	$\beta = .90$	$\beta = .80$
0%	1%	.99	$C >$2,588	$C >$27	$C >$13	$C >$5	$C >$2	$C >$1
5%	6%	.99	$C >$11,595	$C >$121	$C >$60	$C >$23	$C >$11	$C >$5
		.96	$C >$4,606	$C >$48	$C >$24	$C >$9	$C >$4	$C >$2
		.99	$C >$51,941	$C >$542	$C >$269	$C >$104	$C >$49	$C >$22
10%	11%	.96	$C >$20,634	$C >$214	$C >$106	$C >$41	$C >$20	$C >$9
		.91	$C >$4,147	$C >$42	$C >$21	$C >$8	$C >$4	$C >$2
0%	5%	.99	$C >$25,751	$C >$448	$C >$222	$C >$86	$C >$41	$C >$18
		.96	$C >$10,230	$C >$177	$C >$88	$C >$34	$C >$16	$C >$7
		.99	$C >$115,364	$C >$2,008	$C >$995	$C >$386	$C >$183	$C >$81
5%	10%	.96	$C >$45,830	$C >$791	$C >$394	$C >$153	$C >$73	$C >$32
		.91	$C >$9,210	$C >$157	$C >$79	$C >$31	$C >$15	$C >$6
		.99	$C >$516,730	$C >$8,994	$C >$4,457	$C >$1,730	$C >$820	$C >$364
10%	15%	.96	$C >$205,279	$C >$3,543	$C >$1,764	$C >$686	$C >$325	$C >$145
		.91	$C >$41,252	$C >$702	$C >$352	$C >$137	$C >$65	$C >$29

Naifs' Procrastination on Weekly Basis

Table 3: When Naifs Procrastinate: Single Alternative, Weekly Decisions
(Principal = $10,000, Horizon = 30 years)

			TCs never	Naifs	never	transfer	funds	if
r_A	r_B	δ^{365}	transfer funds if	$\beta = .99$	$\beta = .98$	$\beta = .95$	$\beta = .90$	$\beta = .80$
0%	1%	.99	$C >$2,588	$C >$186	$C >$93	$C >$36	$C >$17	$C >$8
5%	6%	.99	$C >$11,595	$C >$833	$C >$416	$C >$162	$C >$77	$C >$34
		.96	$C >$4,606	$C >$313	$C >$161	$C >$64	$C >$30	$C >$14
10%	11%	.99	$C >$51,941	$C >$3,733	$C >$1,865	$C >$727	$C >$345	$C >$154
		.96	$C >$20,634	$C >$1,403	$C >$720	$C >$286	$C >$136	$C >$61
		.91	$C >$4,147	$C >$258	$C >$138	$C >$56	$C >$27	$C >$12
0%	5%	.99	$C >$25,751	$C >$3,086	$C >$1,542	$C >$601	$C >$285	$C >$127
		.96	$C >$10,230	$C >$1,160	$C >$596	$C >$236	$C >$113	$C >$50
5%	10%	.99	$C >$115,364	$C >$13,825	$C >$6,908	$C >$2,694	$C >$1,279	$C >$569
		.96	$C >$45,830	$C >$5,195	$C >$2,668	$C >$1,058	$C >$505	$C >$225
		.91	$C >$9,210	$C >$954	$C >$511	$C >$209	$C >$101	$C >$45
10%	15%	.99	$C >$516,730	$C >$61,919	$C >$30,939	$C >$12,066	$C >$5,726	$C >$2,548
		.96	$C >$205,279	$C >$23,265	$C >$11,949	$C >$4,740	$C >$2,263	$C >$1,010
		.91	$C >$41,252	$C >$4,273	$C >$2,291	$C >$935	$C >$451	$C >$202
0%	10%	.99	$C >$141,115	$C >$27,639	$C >$13,810	$C >$5,386	$C >$2,556	$C >$1,137
		.96	$C >$56,060	$C >$10,385	$C >$5,334	$C >$2,116	$C >$1,010	$C >$451
		.91	$C >$11,266	$C >$1,907	$C >$1,022	$C >$417	$C >$201	$C >$90
5%	15%	.99	$C >$632,094	$C >$123,787	$C >$61,853	$C >$24,122	$C >$11,448	$C >$5,093
		.96	$C >$251,109	$C >$46,511	$C >$23,888	$C >$9,477	$C >$4,524	$C >$2,019
		.91	$C >$50,462	$C >$8,543	$C >$4,579	$C >$1,869	$C >$901	$C >$404
10%	20%	.99	$C >$2,830,753	$C >$554,302	$C >$276,971	$C >$108,015	$C >$51,264	$C >$22,806
		.96	$C >$1,124,561	$C >$208,271	$C >$106,968	$C >$42,437	$C >$20,258	$C >$9,039
		.91	$C >$225,989	$C >$38,253	$C >$20,505	$C >$8,368	$C >$4,034	$C >$1,809

Behavior of Sophisticates

- A sophisticate correctly predicts behavior, thus, he will never make transfer iff on day 1 he prefers never making the transfer to making it immediately, thus $C > \beta\delta^T L(T)$

Sophisticates' Procrastination

Table 4: When Sophisticates Procrastinate Forever: Single Alternative, Daily Decisions
(Principal = \$10,000, Horizon = 30 years)

r_A	r_B	δ^{365}	TCs never transfer if	Sophisticates never transfer funds if			
				$\beta = .98$	$\beta = .95$	$\beta = .9$	$\beta = .8$
0%	1%	.99	C >2,588	C >2,536	C >2,458	C >2,329	C >2,070
5%	6%	.99	C >11,595	C >11,363	C >11,015	C >10,435	C >9,276
		.96	C >4,606	C >4,514	C >4,376	C >4,146	C >3,685
		.99	C >51,941	C >50,902	C >49,344	C >46,747	C >41,553
10%	11%	.96	C >20,634	C >20,222	C >19,603	C >18,571	C >16,507
		.91	C >4,147	C >4,064	C >3,939	C >3,732	C >3,317
0%	5%	.99	C >25,751	C >25,236	C >24,463	C >23,176	C >20,601
		.96	C >10,230	C >10,025	C >9,718	C >9,207	C >8,184
		.99	C >115,364	C >113,057	C >109,596	C >103,828	C >92,291
5%	10%	.96	C >45,830	C >44,914	C >43,539	C >41,247	C >36,664
		.91	C >9,210	C >9,026	C >8,749	C >8,289	C >7,368
		.99	C >516,730	C >506,395	C >490,894	C >465,057	C >413,384
10%	15%	.96	C >205,279	C >201,174	C >195,015	C >184,751	C >164,223
		.91	C >41,252	C >40,427	C >39,190	C >37,127	C >33,002
		.99	C >141,115	C >138,292	C >134,059	C >127,003	C >112,892
0%	10%	.96	C >56,060	C >54,939	C >53,257	C >50,454	C >44,848
		.91	C >11,266	C >11,040	C >10,702	C >10,139	C >9,013
		.99	C >632,094	C >619,452	C >600,489	C >568,885	C >505,675
5%	15%	.96	C >251,109	C >246,087	C >238,554	C >225,998	C >200,888
		.91	C >50,462	C >49,453	C >47,939	C >45,416	C >40,370
		.99	C >2,830,753	C >2,774,138	C >2,689,215	C >2,547,678	C >2,264,602
10%	20%	.96	C >1,124,561	C >1,102,070	C >1,068,333	C >1,012,105	C >899,649
		.91	C >225,989	C >221,470	C >214,690	C >203,390	C >180,791

Alternative Investments

- Costless transfer from plan A to plan B with $r_B > r_A$, or transfer from plan A to plan C with cost C and $r_C > r_B$
- Again $\delta(1 + \frac{r_B}{365}) > 1$

Behavior of TCs

- Transfer to plan C at $\tau = 1$ iff
  $\delta^T P[(1 + \frac{r_C}{365})^T - (1 + \frac{r_B}{365})^T] \geq C$
- Transfer to plan B at $\tau = 1$ iff
  $\delta^T P[(1 + \frac{r_C}{365})^T - (1 + \frac{r_B}{365})^T] < C$

Behavior of Naifs

Three options: choose plan B today, choose plan C today, plan to choose plan C tomorrow (plan B today dominates plan B tomorrow since no costs apply). These plans yield utility of:

- Plan B today: $\beta\delta^{T+1-\tau}P(1+\frac{r_A}{365})^{\tau-1}(1+\frac{r_B}{365})^{T+1-\tau}-0$
- Plan C today: $\beta\delta^{T+1-\tau}P(1+\frac{r_A}{365})^{\tau-1}(1+\frac{r_C}{365})^{T+1-\tau}-C$
- Plan C tomorrow: $\beta\delta^{T+1-\tau}P(1+\frac{r_A}{365})^{\tau}(1+\frac{r_C}{365})^{T-\tau}-\beta\delta C$

TCs and Naifs

- If TCs prefer plan B and think that plan C requires too much effort - so will Naifs, and since plan B is costless, if Naifs plan to choose B, they will do so immediately.
- What if TCs choose plan C? Assume Naifs prefer plan C to plan B today, then plan B irrelevant for Naifs' decision $\rightarrow$ relevant is only plan C today or plan C tomorrow.
- This means we are back at same problem as before - the best action is the unique action.
- Introducing a costless option does not necessarily overturn procrastination.
- But not forever - as time goes by, benefit of plan C compared to plan B decreases $\rightarrow$ eventually investment in plan B (since it is costless).

Transfer of Funds - Alternatives

Table 7: When People Transfer Funds: Choice of Alternatives
(Principal = $10,000, Horizon = 30 years)

r_A	r_B	r_C	C	δ^{365}	TCs	β^c	Naifs If $\beta > \beta^c$	If $\beta < \beta^c$
			500	.99	Plan C on day 1	.986	Plan C on day 1	Plan B at 25.8 yrs
0%	5%	6%	500	.96	Plan C on day 1	.994	Plan C on day 1	Plan B at 25.3 yrs
			2000	.96	Plan C on day 1	.999	Plan C on day 1	Plan B at 14.0 yrs
			500	.99	Plan C on day 1	.966	Plan C on day 1	Plan B at 26.1 yrs
0%	7%	8%	500	.96	Plan C on day 1	.986	Plan C on day 1	Plan B at 25.7 yrs
			2000	.96	Plan C on day 1	.997	Plan C on day 1	Plan B at 17.1 yrs
			500	.99	Plan C on day 1	.892	Plan C on day 1	Plan B at 26.4 yrs
0%	10%	11%	500	.96	Plan C on day 1	.954	Plan C on day 1	Plan B at 26.1 yrs
			500	.91	Plan C on day 1	.991	Plan C on day 1	Plan B at 25.2 yrs
			2000	.96	Plan C on day 1	.988	Plan C on day 1	Plan B at 19.7 yrs

Implications for Policy

- Status-quo bias
- Thus firms may choose default investment
- High sensitivity to short-run incentives
- Tax incentives
- Impose dead-lines - for example less frequent transaction dates
- Improve information

Example: Save More Tomorrow

Thaler and Benartzi: Save More Tomorrow: Using Behavioral Economics to Increase Employee Saving

- Design of pension plans
- Save More Tomorrow (SMT) program - workers are given the option to commit future raises in salary to savings
- If workers are already choosing their life-cycle savings rate optimally, they have no incentive to join a program that will commit them to periodic changes.

Example: Save More Tomorrow (continued)

- Lag between sign-up and start-up date should be as long as feasible.

- If employees join, their contribution to the plan is increased beginning with the first paycheck after a raise. This feature mitigates the perceived loss aversion of a cut in take-home pay.

- Contribution rate continues to increase on each scheduled raise until the contribution rate reaches a preset maximum. In this way, inertia and status quo bias work towards keeping people in the plan.

- Employee can opt out of the plan at any time.

References

[1] **Laibson, David (1997):** "Golden Eggs and Hyperbolic Discounting," *Quarterly Journal of Economics*, 112, 443-477.

[2] **O'Donoghue, Ted and Rabin, Matthew (1999):** "Procrastination in Preparing for Retirement,"in: Behavioral Dimensions of Retirement Economics, Brookings Institution Press & Russell Sage Foundation.

[3] **Thaler, Richard H. and Benartzi, Shlomo (2004):** "Save More Tomorrow: Using Behavioral Economics to Increase Employee Saving," *Journal of Political Economy*, 112, S164-S187.