Revision Notes by Sally Yang

BEHAVIOURAL ECONOMICS

EC310

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TYING ODYSSEUS TO THE MAST
Ashraf et al.

Measure present bias using a survey

TREATMENT

Group 1: Control
Group 2: Marketing (asked to save more)
Group 3: Marketing + commitment (SEED) account
same interest, cannot freely withdraw

FINDINGS

1. People took up commitment (✓present bias)
2. Present bias predicts higher demand for SEED — but for women only
3. Being offered SEED raised Group 3's savings insignificantly relative to Group 2
   - Largest treatment effects only for the best savers (90% pct of Δsavings)
   - Overall, appear to be driven by marketing

SAVE MORE TOMORROW SMarT
Thaler and Benartzi

PLAN COMPONENTS

1. Default in (status quo/present bias/procrastination — lazy to opt out)
2. Increase saving rate later (present bias — more attractive)
3. Increase saving rate only with pay rise (loss aversion; frame as net gain)

FINDINGS

1. People took up commitment (✓present bias)
2. Welfare improvement based on libertarian paternalism criteria
   - Most participants agreed on higher savings goal but couldn't implement it on their own
   - Improved welfare as they themselves judge, preserving freedom of choice
   - Expected income replacement ratio rose after plan (better prepared for retirement)

401(K) SAVINGS
Madrian and Shea

Effect of defaulting in to participation (3%)

- Participation higher under opt-in
- But too many chose default, including people who would have enrolled anyway into a higher % (better plan)
- Participation effect dampened by lower contributions

REVISION

CONSTANT ABSOLUTE RISK AVERSION (CARA)

$U(x) = B - e^{-\alpha x}$ — α: degree of absolute risk aversion

Risk aversion doesn't change with initial wealth level
If initial wealth level doesn't matter, can 'normalise to 0'

SENSE CHECK

Insurance company must charge more than the buyer's expected loss (actuarial value) to break even
It must charge less than maximum lost value to sell anything at all

ENDOWMENT EFFECT

$$WTA = WTP + \frac{\partial WTP}{\partial y}$$

MP to spend on good
Income effect
should be negligible

BUT in reality WTA > WTP
(WTA: Unwilling to sell; WTP: to buy)

MYTH OF THE SMOOTH U-FUNCTION

Kenneth Arrow (1971)

Given any smooth utility function u,
a better-than-fair lottery D
a riskier lottery L but with better expected returns $E(L) > E(D)$
$\Rightarrow \exists \bar{\alpha} > 0$ s.t. individual would accept gamble αL $\forall \alpha < \bar{\alpha}$ (sufficiently small)
contra-positive $\Rightarrow$ if people don't always accept a sufficiently small αL, then u isn't smooth!

KAHNEMAN & TVERSKY PREFERENCES

REFERENCE DEPENDENCE

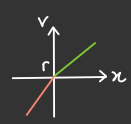
$$U(\underset{1\times k}{\vec{c}}, \underset{1\times k}{\vec{r}}) = U(c_1 - r_1, c_2 - r_2, \dots) = \sum_k v(c_k - r_k)$$

LOSS AVERSION

$$\frac{v'_-(0)}{v'_+(0)} = \frac{\lim_{x\to 0^-} v'(x)}{\lim_{x \to 0^+} v'(x)} \equiv \lambda > 1$$

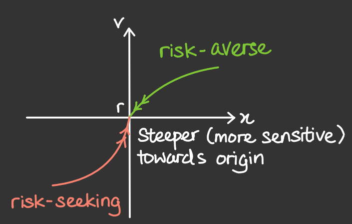
usually $v(x-r) = \begin{cases} x - r & \text{if } x > r \text{ (gains)} \\ \lambda(x-r) & \text{if } x < r \text{ (losses)} \end{cases}$

λ: typically $= 2$, losses hurt more



DIMINISHING SENSITIVITY

$$v''(x) \begin{cases} \leq 0 & \text{for } x > r \\ \geq 0 & \text{for } x < r \end{cases}$$

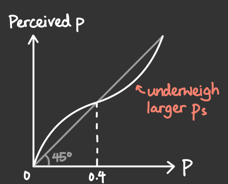


- Marginal sensitivity to changes falls away from reference point
- Can explain risk-aversion for just gains

PROBABILITY WEIGHTING

K-T (1992)

People mentally transform probabilities before applying them
Allais paradox



KÖSZEGI-RABIN PREFERENCES

Proposes recent rational expectations as reference points
Expectations can mean endowment/ status quo, aspirations, norms, social comparisons...

For fixed c, r

$$u(c|r) = \underbrace{m(c)}_{\text{Consumption utility}} + \underbrace{n(c|r)}_{\text{Gain-loss utility}}$$

$$= \sum_{k=1}^{K} \left\{ m_k(c_k) + \mu \left[m_k(c_k) - m_k(r_k) \right] \right\}$$ Equivalent to KT if m is linear

μ: Universal gain-loss function maps consumption utils to gains/losses

often $m_k(c_k) \overset{\text{linear}}{=} c_k$, $\mu = \begin{cases} c_k - r_k & \text{if } c_k \geq r_k \\ \lambda(c_k - r_k) & \text{if } c_k < r_k, \quad \lambda > 1 \end{cases}$

Trick: no need to find μ for $c_i = r_j$.

For random distributions $F(c), G(r)$

$$\underset{\text{cdf}}{U(F(c)} | \underset{\text{cdf}}{G(r)}) = \sum_i f(c_i) \cdot \left\{ m(c_i) + \sum_j g(r_j) \mu \left[m_j(c_i) - m_j(r_j) \right] \right\}$$

Gain-loss utility from c_i compares c_i to each r_j in the reference lottery, weighted by $g(r_j)$

PERSONAL EQUILIBRIUM

The distribution over consumption outcomes $F \in D$ where D is the set of possible distributions is a PE

if $U(F|F) \geq U(F'|F)$ $\forall F' \in D$

violates IIA as new inferior option may change PE

PREFERRED PE

Let $\mathcal{F} \subseteq D$ be the set of PEs.

F is a PPE if F is a PE ($F \in \mathcal{F}$)
and $U(F|F) \geq U(F'|F')$ $\forall F' \in \mathcal{F}$

if F is the only PE, vacuously a PPE

CHOICE-ACCLIMATING PE

$F \in D$ is a CPE if $U(F|F) \geq U(F'|F')$ $\forall F' \in D$

Relevant in scenarios where agents can commit to some F ex ante.
Thus, it doesn't have a no-deviation condition, unlike PE. F doesn't have to be a PE.

If X is a PPE but not CPE: agent knows he will pick X if offered, but would be happier if X is not even available. (Linked to 'uncertainty effect' — prefer the worst outcome to risk)

If X is a CPE but not PE/PPE: Agent likes X ex ante, but knows (sadly) that he'd be 'lured away' by another choice unless he can commit.

CHARNESS-RABIN MODEL

distributional social preferences

$$u_1(x_1,x_2) = \begin{cases} (1-\rho)x_1 + \rho x_2 & \text{if } x_1 \geq x_2 \\ (1-\sigma)x_1 + \sigma x_2 & \text{if } x_1 \leq x_2 \end{cases}$$

ρ/σ is placed on other player, ρ if ownself is ahead

Trick: $u = x_1$ if $x_1 = x_2$

~~MBTI!~~

Self-interested: $\rho = \sigma = 0$

Utilitarian: $\rho = \sigma = \frac{1}{2}$

Social Welfare: $1 > \rho \geq \sigma \geq 0$

Difference-averse: $1 \geq \rho \geq 0 > \sigma$

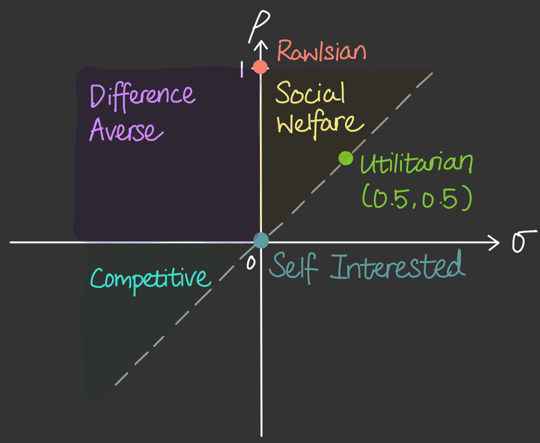
willing to harm player 2 to ↓inequality

Rawlsian: $\rho = 1,\ \sigma = 0$

social welfare = U of worst-off

Envious/Competitive: $0 \geq \rho \geq \sigma$

maximise inequality, win at all costs!



$\rho < 0$ or $\sigma < 0$: willing to engage in Pareto harm, hurt self and/or others

EMPIRICAL RESULTS Average ρ is 0.4. σ varies more ($= 0$ for half of population)

However, CR model doesn't account for endogenous selection into the problem!

DELLAVIGNA-LIST-MALMENDIER MODEL

SECOND PERIOD

$$U(g) = \begin{cases} \underbrace{u(W-g)}_{\text{consumption utility from money}} + \underbrace{av(g)}_{\text{'warm-glow' altruism}} - s(g) & \text{if at home} \\ u(W) & \text{else} \end{cases}$$

$$s(g) = \begin{cases} \underbrace{S}_{\text{social pressure}}(g^S - g) & \text{if } g < g^S \\ 0 & \text{otherwise} \end{cases}$$

g^S ↖ exogenous socially desirable amt

☆ We can model in effective altruism using $v(G+g)$, where G is everyone else's donation (accounts for MB of donating)

FIRST PERIOD Manipulate $\Pr(\text{at home}) := h$ at cost $c(h) = \frac{(h-h_0)^2}{\eta}$

$$h^* = \arg\max_h \ hU(g^*) + (1-h)u(W) - c(h)$$

$h = h_0$ without manipulation

RABIN FAIRNESS MODEL

Intentions based preferences

KINDNESS

Player 1's own kindness of playing a_1 (own intent), given Player 2 is playing b_2

P2's actual payoff

$$f_1(a_1, b_2) = \frac{\pi_2(a_1, b_2) - \pi_2^e(b_2)}{\pi_2^h(b_2) - \pi_2^{min}(b_2)} \in \left[-1, \tfrac{1}{2}\right]$$

Range of possible payoffs to P2

Max possible payoff to P2 from b_2

Min possible payoff to P2 from b_2

"Equitable" payoff to P2,

$$\pi_2^e(b_2) = \frac{\pi_2^h(b_2) + \pi_2^\ell(b_2)}{2}$$

Min possible Pareto efficient payoff to P2 from b_2 (Ignores irrelevant alternatives that both won't play due to common rationality)

PERCEIVED KINDNESS

Player 1's perceived Player 2's kindness (perceived intent) when she thinks P2 is playing b_2 and that P2 thinks P1 is playing c_1 is

$$\tilde{f}_2(c_1, b_2) = \frac{\pi_1(c_1, b_2) - \pi_1^e(c_1)}{\pi_1^h(c_1) - \pi_1^{min}(c_1)} \in \left[-1, \tfrac{1}{2}\right]$$

Trick : $f_2(a_1, b_2) = \tilde{f}_2(c_1, b_2)$ if $a_1 = c_1$

UTILITY

$$u_1(a_1, b_2, c_1) = \pi_1(a_1, b_2) + \tilde{f}_2(c_1, b_2)\left[1 + f_1(a_1, b_2)\right]$$

P1 cannot change $\tilde{f}_2$ but will try to match sign of $\tilde{f}_2$ (reciprocity)

FAIRNESS EQUILIBRIUM

(a_1, a_2) is a FE if $\forall i = 1,2$,

① $a_i = b_i = c_i$

② $a_i = \underset{a}{\operatorname{argmax}}\ u_i(a, b_{-i}, c_i)$ $\Rightarrow a_i = \underset{a}{\operatorname{argmax}}\ u_i(a, a_{-i}, a_i)$

check w Peter

Trick 1: Calculate $\tilde{f}_j(a_j, a_i)$ first. If $\tilde{f}_j(a_j, a_i) = 0$,
i will pick a^* to max her material payoff given a_2
And if $a^* \neq a_i$, (a_i, a_j) can never be an FE
If $a^* = a_i$, repeat for $\tilde{f}_i(a_i, a_j)$

Trick 2: symmetric games will give $f_j(A,B) = f_i(A,B)$

- Strategies are common knowledge
- Rational expectations — no mistaken actions/intents
- But reciprocity can cause mutual scepticism
(I harm you bc I think you think I'll harm you)

THEOREM 1 (a_1, a_2) is an FE if

① (a_1, a_2) is an NE

② (a_1, a_2) is a mutual-max/mutual-min outcome

$$\boxed{a_i \in \underset{a \in S_i}{\operatorname{argmax}}\ \lambda \pi_i(a, a_j) \quad \forall i = 1,2}$$

stake

THEOREM 2 If (a_1, a_2) is a strict NE
then $\exists \bar{\lambda}$ s.t. $\forall \lambda > \bar{\lambda}$, (a_1, a_2) is an FE
For large enough stakes, players no longer willing to deviate from the strict NE (sacrifice material payoff) for fairness

THEOREM 3 If (a_1, a_2) is not an NE
then $\exists \bar{\lambda}$ s.t. $\forall \lambda > \bar{\lambda}$, (a_1, a_2) is not an FE

LOEWENSTEIN MODEL

Anticipatory utility

Importance of anticipatory utility relative to current consumption (classical: $\alpha=0$)

Ability to 'imagine' future consumption

$$\text{Net utility } U_t = \sum_{\tau=t}^{T} \delta^{\tau-t}\Big[\underbrace{u(x_\tau)}_{\text{current period consumption utility}} + \alpha \underbrace{\sum_{s=\tau+1}^{T} \delta^{s-\tau} u(x_s)}_{\text{anticipation of future utility flows}}\Big]$$

$= \delta u(x_{\tau+1}) + \delta^2 u(x_{\tau+2}) + \ldots + \delta^{T-\tau} u(x_T)$

If self-0 (normalise $t=0$) chooses τ to receive one-off $\underline{u}$ at time τ

additional net utility $\boxed{\Delta U_0 = (1+\tau\alpha)\delta^{\tau}\underline{u}}$

ΔU_0 decrease in τ (dominate in LR)

ΔU_0 increase in τ (dominate in SR)

$$\boxed{\tau^* = -\underbrace{\frac{1}{\ln\delta}}_{<0} - \frac{1}{\alpha}}$$

$\delta \to 1$: $\tau^* \to \infty$ Patience

$\alpha \to \infty$: $\tau^* \to -\frac{1}{\ln\delta}$ >1

$\alpha \to 0$: $\tau^* \to 0$ (Corner)

DYNAMIC INCONSISTENCY

Every future self wants to delay consumption further

NEGATIVE CONSUMPTION

Corner solution!

For negative u shock, will always delay till T if T is s.t. $(1+T\alpha)\delta^T < 1$ (large enough)

if not, $\tau = 0$ (getting over it)

Loewenstein multiplier $(1+\tau\alpha)\delta^{\tau}$ is 'hump-shaped' in τ when $u>0$.

τ_{max} can be anywhere $(u>0)$, while $\tau_{min} = 0$ or T $(u<0)$

CAPLIN-LEAHY MODEL

Informational preferences (+ anticipation)

In period 1, choose current consumption $c_1 \in X_1$ and a lottery $\ell_2 \in \Delta X_2$ determining period 2 consumption: $\ell_2(x_2): X_2 \to \mathbb{R}$

X_2 often contains a "good" and "bad" outcome c_g, c_b

$$\boxed{U_1(c_1, \ell_2) = u_1(c_1, a(\ell_2)) + E_{\ell_2}(u_2(c_2))}$$

Anxiety about the lottery

$a'' < 0$: Info-averse

$a'' > 0$: Info-seeking

SIMPLIFIED CAPLIN-LEAHY MODEL

Informational preferences (+ anticipation)

Utility from not resolving the uncertainty and instead having lottery p :

$$\boxed{u(c_1, m, p) = u(c_1) + a(p) + pu(c_b) + (1-p)u(c_g)}$$

$p := \Pr(c_2 = c_b)$ ℓ_2 now scalar. $X_2 = \{c_g, c_b\}$

Utility from resolving the uncertainty with cost m in period 1 :

$$\boxed{u(c_1, m, p) = u(c_1 - m) + pa(1) + (1-p)a(0) + pu(c_b) + (1-p)u(c_g)}$$

If $m = 0$, will obtain the info iff $pa(1) + (1-p)a(0) \geq a(p)$

$a'' < 0$: Info-averse

$a'' > 0$: Info-seeking

Classical $a(p) = 0$, so will always obtain info if free

If resolving the uncertainty gets me a ρ chance of improving from c_b to c_g :

$$\boxed{u(c_1, m, p) = u(c_1 - m) + \underbrace{p(1-\rho)}_{\text{bad news, not cured}}[a(1) + u(c_b)] + [\underbrace{1 - p + p\rho}_{\text{bad news, but cured}}][a(0) + u(c_g)]}$$

QUASI-HYPERBOLIC ($\beta\delta$) DISCOUNTING

Dynamic inconsistency — disagreement between selves at different times

Self t picks c_t to maximise $U_t(\vec{c}) = u(c_t) + \underset{\uparrow \text{present-bias}}{\beta} \sum_{s=t+1}^{T} \delta^{s-t} u(c_s)$

COMMITMENT — Self-0 puts money in illiquid savings account (no interest)
Pay for commitment (tie self-1's hands to mast)
forgone interest raising effective price of future consumption, but reduces $c_1 - c_2$

NAIVETE ($\beta\hat{\beta}\delta$ DISCOUNTING)

Current self-t always discounts at β still, but may hold incorrect beliefs $\hat{\beta}$ about future selves

$\hat{\beta} \in [\beta, 1]$ weakly overoptimistic

STATEGY — Define Strategy: $S = (a_1(\cdot), a_2(\cdot), \ldots)$ — Strategy picks action functions

$a_t(h_t) : A_{t-1} \to A_t$

history at time t: $h_t \in A_{t-1}$

action at time t: $a_t(h_t) \in A_t$

Self-t's beliefs about future actions: $\hat{S}^t = (\hat{a}_{t+1}(\cdot), \hat{a}_{t+2}(\cdot), \ldots) \neq S$

self-t think self-$(t+1)$ will do this

Self-t will pick: $a_t(h_t) \in \underset{a}{\operatorname{argmax}}\ V^t(a, h_t, \hat{S}^t, \hat{\beta}, \delta)$

DYNAMIC CONSISTENCY — Given $\hat{\beta}$, $\{\hat{S}^1, \hat{S}^2, \ldots\}$ is dynamically consistenct if

1. Internal consistency $\forall \hat{S}^t = \{\hat{a}^t_{t+1}(\cdot), \ldots, \hat{a}^t_\tau(\cdot), \ldots\}$, $\forall \tau, h$,
$\hat{a}^t_\tau \in \underset{a}{\operatorname{argmax}}\ V^\tau(a, h, \hat{S}^t, \hat{\beta}, \delta)$

At each time t, self-t always believes all future selves are BR-ing to any history

2. External consistency $\forall t, t'$ $\hat{a}^t_\tau = \hat{a}^{t'}_\tau$ $\forall \tau > \max\{t, t'\}$
$\Rightarrow$ Can let $\hat{a}_\tau = \hat{a}^t_\tau = \hat{a}^{t'}_\tau$, $\hat{S} = \hat{S}^t = \hat{S}^{t'} = \{\ldots, \hat{a}_\tau(\cdot), \ldots\}$

All selves ($\forall t, t'$) must agree on what they think future selves ($\forall \tau$) will do

PERCEPTION-PERFECT STRATEGY

$s(\beta, \hat{\beta}, \delta) = (\ldots, a_t(\cdot), \ldots)$ is PPS if $\exists\, \hat{s}(\hat{\beta}, \delta)$, $\hat{s}$ dynamically consistent,

s.t. $a_t \in \arg\max V^t(a, h, \hat{s}(\hat{\beta}, \delta), \beta, \delta) \quad \forall t, h$

all future selves, whatever their beliefs, will stick to s in BR to beliefs

$\hat{s} = s$ when $\hat{\beta} = \beta$ (SPNE strategy)

1. Find dynamically consistent $\hat{s}(\hat{\beta}, \delta)$
   - $\longrightarrow$ Find $\hat{a}_\tau \in \arg\max_a V^\tau(a, h, \hat{s}^t, \hat{\beta}, \delta) \quad \forall \tau$
   - $\longrightarrow$ Check if $\hat{a}^t_\tau = \hat{a}^{t'}_\tau \quad \forall t, t'$
2. Find if a PPS $s(\beta, \hat{\beta}, \delta)$ exists (can be supported by) for this $\hat{s}(\hat{\beta}, \delta)$

PRESENT-BIASED EFFECT: Naifs consume temptation goods earlier than TCs,
immediate benefit
delayed cost
investment goods later than TCs
immediate cost
delayed benefit

SOPHISTICATION EFFECT: Sophisticates consume all types of goods earlier than naifs

Sophisticate is (correctly) pessimistic about future self's succumbing to temptation

Preproperation: "Might as well succumb now!"

Gets lower utility than a (partial naif) who at least resisted a little

Both naifs and sophisticates may commit, but

A (constant) failure to stick to commitment necessarily implies (partial) naivete

CUTOFF (OPTIMAL STOPPING) STRATEGIES

Sophistication effect applied example

Choose between known payoff and stochastic process

e.g. Daily temptation $a_t \overset{i.i.d}{\sim} U[0,1]$, consume only once
Problem: pick cutoff a s.t. consume iff $a > a_t$. Let $\delta = 1$

$$V(a) = \Pr(a \leq a_t) E(a_t \mid a \leq a_t) + \Pr(a > a_t) V(a) \Rightarrow V(a) = \frac{1+a}{2}$$

Current self-t expects self-$(t+1)$ to pick $\hat{a}$ that makes self-$(t+2)$ indifferent between acting (pickin $\hat{a}$) and waiting (get $\hat{\beta} V(\hat{a})$)

$$\hat{a} = \hat{\beta} V(\hat{a}) \quad \Rightarrow \hat{a} = \frac{\hat{\beta}}{2-\hat{\beta}} \leq 1 \Rightarrow \hat{S} = \text{all future selves consume iff } a > \hat{a} = \frac{\hat{\beta}}{2-\hat{\beta}}$$

$\hat{\beta} = 1 \Rightarrow \hat{a}$ reaches maximum
(expecting higher threshold)

Current self's cutoff: $a = \beta V(a) = \beta\left(\frac{1+\hat{a}}{2}\right) = \frac{\beta}{2-\hat{\beta}}$ is increasing in β and $\hat{\beta}$!

PAYING NOT TO GO TO THE GYM

SETUP Contract $= (T, L, p)$

periods | flat fee in $t=1$ NOT $t=0$ | pay in period t when she goes

In every period t, going to the gym costs $c \sim F(c)$ now and benefit b in $t+1$

Conditional on having accepted contract (paid L),
I think future self will go if $\hat{\beta}\delta b - c - p \geq 0$

EXPECTED UTILITY Expected benefit from day $t > 1$

$$E_c\left[\mathbb{1}(\hat{\beta}\delta b - p \geq c)\beta(\delta^{t+1}b - \delta^t c - \delta^t p)\right] = \beta\delta^t\left(\int_{-\infty}^{\hat{\beta}\delta b - p}(\delta b - c - p) f(c)dc + \int_{-\infty}^{\hat{\beta}\delta b - p} 0\, f(c)dc\right)$$

EXPECTED UTILITY (SELF-0) Assume $T=1$

Self-0's expected utility from contract: $\beta\delta\left[-L + \int_{-\infty}^{\hat{\beta}\delta b - p}(\delta b - c - p) f(c)dc\right]$

FLAT RATE VS PAY-PER-USE Prefer flat rate $(T, L, 0)$ to pay-per-use $(T, 0, p)$ if

$$-L + \int_{-\infty}^{\hat{\beta}\delta b}(\delta b - c) f(c)dc \geq \int_{-\infty}^{\hat{\beta}\delta b - p}(\delta b - c - p) f(c)dc$$

$$L \leq \underbrace{\int_{-\infty}^{\hat{\beta}\delta b - p} p f(c)dc}_{\text{Low-cost days}} + \underbrace{\int_{\hat{\beta}\delta b - p}^{\hat{\beta}\delta b} (\delta b - c) f(c)dc}_{\text{Intermediate-cost days (Go iff had flat rate)}}$$

$$= p F(\beta\delta b) + p\left[F(\beta\delta b) - F(\beta\delta b)\right] + \delta b\left[F(\hat{\beta}\delta b) - F(\hat{\beta}\delta b - p)\right] - \int_{\hat{\beta}\delta b - p}^{\beta\delta b} c f(c)dc$$

Assuming $c \leq \hat{\beta}\delta b$

$$\leq \underbrace{p F(\beta\delta b)}_{\text{face value always} \neq 0} + \underbrace{p\left[F(\hat{\beta}\delta b) - F(\beta\delta b)\right]}_{\text{overoptimism } =0 \text{ if } \hat{\beta}=\beta \text{ (sophisticate)}} + \underbrace{\delta b(1-\hat{\beta})\left[F(\hat{\beta}\delta b) - F(\hat{\beta}\delta b - p)\right]}_{\text{Commitment value } =0 \text{ if } \hat{\beta}=1 \text{ (naive)}}$$

cost of correcting future misbehaviour

FIRM'S PROBLEM

$$\max_p \; L + (p - MC) F(\beta\delta b - p) - \text{Fixed Cost}$$

NOT $\hat{\beta}$

IR: $\int_{-\infty}^{\hat{\beta}\delta b - p}(\delta b - c - p) f(c)dc = L$ binds, can sub in, take FOCs

If agents are time consistent, $p^* = a$
sophisticated, $p^* = a - (1-\beta)\delta b$
naive, $p^* = a - \dfrac{F(\beta b - p) - F(\beta\delta b - p)}{f(\beta\delta b - p)}$

Below MC pricing happens with any present bias $\beta < 1$, regardless of $\hat{\beta}$!

PROCRASTINATION ON CANCELLATION

Pay $c_t \sim F(c_t)$ now to cancel next period. If not, keep paying f in next periods

Find a PP cutoff $\tilde{c}$, and actual cutoff strategy c^*

① Conditional on having followed a cutoff strategy of c, today's EU:

$$V(c_t, c) = -f - E(c_t \mid c_t < c)\Pr(c_t < c) + \delta E(V(c_{t+1}, c))\Pr(c_t \geq c)$$

$V(c_t, c) = V(c_{t+1}, c) = V(c)$ by stationarity. Solve by recursion.

② Perceived cost function for future selves

$$W(c_t, c) = \begin{cases} -f - c_t & \text{if procrastinate} \\ -f + \hat{\beta}\delta E(V(c_{t+1}, c)) & \text{if cancel} \end{cases}$$

Dynamically consistent cutoff $\tilde{c}$ that current self-0 believes will be chosen by self-t such that all future selves are indifferent between cancelling and procrastinating, using cutoff $\tilde{c}$, when $c_t = \tilde{c}$: $-f - \tilde{c} = -f + \hat{\beta}\delta V(\tilde{c})$

③ Given $\tilde{c}$, find actual cutoff c^* that self-t uses to make future self $(t+1)$ indifferent when $c_t = c^*$: $-f - c^* = -f + \beta\delta V(\tilde{c})$

$\uparrow \beta \Rightarrow \uparrow c^*$ more willing to cancel

$\uparrow \hat{\beta} \Rightarrow \downarrow c^*$ less willing to cancel

④ Expected number of periods till enrolment $= \dfrac{1}{c^*}$

Sophisticates cancel much earlier than naifs at all β values (with assumptions on $F(c_t)$ and δ)
Cancellation lag can be used to tell sophisticates and naifs apart empirically

LOEWENSTEIN - O'DONOGHUE - RABIN

Projection bias + State-dependent preferences (Stigler-Becker)

STIGLER-BECKER STATE-DEPENDENT PREFERENCES

$u_t = u(c_t, s_t)$

Human capital / underlying "state variable", s_t

can be defined as $s_t := f(c_{t-1}, c_{t-2}, \ldots)$ (addiction)

$s_t := f(a_t)$ (advertising) etc.

$s_t := \gamma(c_{t-1} + s_{t-1}),\ \gamma \in (0,1)$

PROJECTION BIAS

Self-t's predicted utility of future self-τ:

Current state 'leaks' into prediction

$$\tilde{u}(c_\tau, s_\tau | s_t) = (1-\alpha)\underbrace{u(c_\tau, s_\tau)}_{\substack{\text{correct utility prediction} \\ \text{(time consistent)}}} + \alpha u(c_\tau, s_t)$$

α: Misperception that future state = current state

Trick: no bias when $s_t = s_\tau$.

Self-t thus maximises $\sum_{\tau=t}^{T} \delta^{\tau-t} \tilde{u}(c_\tau, s_\tau | s_t)$

DURABLE GOOD

Buy once, get utility for all future periods (e.g. mug)

WTP increases with α

- Think future selves will fail to get used to mug, always happily surprised

BUT WTA increases with α too

- Think future selves will fail to get used to losing mug, ask for more ££ to compensate for expected 'lingering effect' of loss
- In reality, there's no lingering effect and future selves adapt swiftly to new reality

Consequence: Both $Q_D(P)$ and $Q_S(P)$ ↑, price ↑↑

LOR DURABLE GOOD

Durable good, once purchased, gives per-period utility $s_t \overset{iid}{\sim} g(s)$, $E(s_t) = \bar{s}$

Rational agent buys iff $T\bar{s} \geq p$

Projection-biased agent buys too often. As $Var(s) \to \infty$, $Pr(buy) \to 1$

HABIT-FORMATION

REINFORCEMENT

$$\frac{\partial^2 u}{\partial c_t \partial c_{t-1}} \text{ or } \frac{\partial^2 u}{\partial s_t \partial c_t} > 0$$

Positive feedback loop: MU of today's consumption increases in my state (which partly depends on yesterday's consumption)

TOLERANCE

$$\frac{\partial u}{\partial s_t} < 0$$

Prefer to be less addicted

BECKER & MURPHY

Agent's instantaneous utility

$$u(x_t, a_t, s_t) = \underbrace{x_t}_{\text{numeraire}} + \gamma_a \underbrace{a_t}_{\text{addictive good } \{0,1\}} + \underbrace{\gamma_{as}}_{\text{reinforcement}} a_t s_t - \underbrace{\gamma_s}_{\text{tolerance } \gamma_{as} \geq \gamma_s} s_t, \quad s_t = \gamma(a_{t-1} + s_{t-1})$$

Price of addictive good $= \bar{p} \ \forall t$

CUTOFF STRATEGY

Under stationarity of prices, income, etc, agent either hit forever or refrain forever!

① Find $s^*(\bar{p})$ s.t. always hit if $s_0 \geq s^*(\bar{p})$, never hit if $s_0 \leq s^*(\bar{p})$.

Consume forever if $p \leq p^* = EU(\text{always hit}|s_0) - EU(\text{always refrain}|s_0)$

$$= \ldots = \frac{\gamma_{as} s_0}{1-\delta\gamma} + \frac{\gamma_a}{1-\delta} - \sum_{j=1}^{\infty} \delta^j p_j + \xi$$

$\frac{\partial p^*}{\partial s_0} > 0$ Higher addiction $\Rightarrow$ higher cutoff

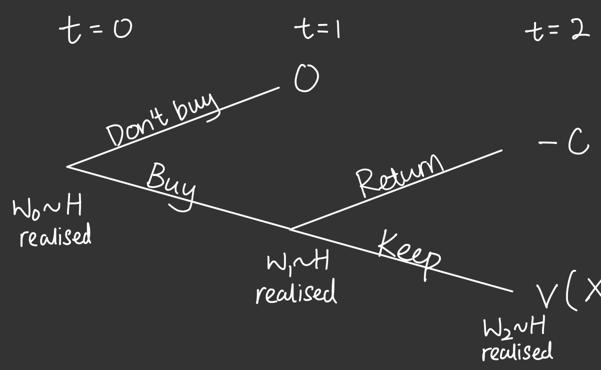
$\frac{\partial}{\partial \delta} \frac{\partial p^*}{\partial s_0} < 0$ Less sensitive to current state

$\frac{\partial p^*}{\partial p_t} = -\delta^t$ Forward-lookingness. Current WTP falls as future price rises

Can get $\hat{\delta}$ or $\widehat{\beta\delta}$ by dividing future-price elasticity $\frac{\partial p^*}{\partial p_{t+1}}$ by current-price elasticity $\frac{\partial p^*}{\partial p_t}$

② Invert to find initial demand if we know $F(s_0)$: $D(\bar{p}) = 1 - F_{s_0}(s^*(\bar{p}))$

CATALOG SALES - PROJECTION BIAS



$$v(X, \varepsilon, w_2) - p = (X\beta + \varepsilon)u(w_2) - p$$

this is a constant

$w_t \sim H$ i.i.d

NON-BIASED

t = 1 Keep if $EU(\text{return}|\text{buy}) < EU(\text{keep}|\text{buy})$

$$\iff -c < E_H[(X\beta+\varepsilon)u(w_2) - p]$$

$$\iff -c < (X\beta+\varepsilon)E_H[u(w_2)] - p$$

$$\iff \varepsilon > \frac{p-c}{E_H[u(w_2)]} - X\beta = A(w_2)$$

t = 0 Buy if $0 < EU(\text{buy})$

$$= EU(\text{keep}|\text{buy})Pr(\text{keep}|\text{buy}) + EU(\text{return}|\text{buy})Pr(\text{return}|\text{buy})$$

$$= E\{[(X\beta + E(\varepsilon|\varepsilon > A(w_2))]u(w_2) - p\}\ Pr[\varepsilon > A(w_2)]$$

$$+ (-c)Pr[\varepsilon < A(w_2)]$$

PROJECTION BIASED

t = 1 Will actually keep if $EU(\text{return}|\text{buy}, w_1) < EU(\text{keep}|\text{buy}, w_1)$

$$\iff -c < E\{(X\beta+\varepsilon)[(1-\alpha)u(w_2) + \alpha u(w_1)] - p\}$$

$$\iff -c < (X\beta+\varepsilon)\{(1-\alpha)E_H[u(w_2)] + \alpha \underbrace{u(w_1)}_{\text{known at } t=1}\} - p$$

$$\iff \varepsilon > \frac{p-c}{(1-\alpha)E_H[u(w_2)] + \alpha u(w_1)} - X\beta = \tilde{A}(w_1)$$

t = 0 Self-0 thinks self-1 will keep if

$$\varepsilon > \frac{p-c}{(1-\alpha)E_H[u(w_2)] + \alpha u(w_0)} - X\beta = \tilde{A}(w_0)$$

dynamic consistency: naive self-0 expects self-2 to get $u(w_0)$ so expects self-1 to be similarly projection-biased about self-2

Will buy if $0 < EU(\text{buy})$

$$= EU(\text{keep}|\text{buy})\ Pr(\text{keep}|\text{buy}) + EU(\text{return}|\text{buy})\ Pr(\text{return}|\text{buy})$$

$$= E\{[X\beta + E(\varepsilon|\varepsilon > \tilde{A}(w_0))][(1-\alpha)u(w_2) + \alpha u(w_0)] - p\}\ Pr[\varepsilon > \tilde{A}(w_0)]$$

$$+ (-c)Pr[\varepsilon < \tilde{A}(w_0)]$$

Buy if $X\beta > g(w_0, \alpha)$ individual characteristics exceed some threshold that increases in degree of projection bias and initial weather (which is projected onto future states)

- Will be too inclined to buy warm clothes for future if today is cold
- Also, $Pr(\text{return}|\text{order})\downarrow$ with $g(w_0, \alpha)$, $\uparrow$ with $\tilde{A}(w_1, \alpha)$

SALLY YANG 2022

AVAILABILITY HEURISTIC

- Ease of imaginability
- Ease of Search
- Ease of recall
- Egocentrism (overestimate own contribution)
- Salience (past disaster)

ANCHORING-ADJUSTMENT HEURISTIC

Initial anchor affects judgement due to partial adjustment

- Anchor may be informative (guesstimates) or uninformative
- Related to incomplete debiasing

MISC. BIASES

- Hindsight bias
- Curse of knowledge (e.g. Dr Levy's 'a bit of algebra')
- Confirmation bias

BASE-RATE NEGLECT

$$\Pr(B|A) = \frac{\Pr(A|B)\Pr(B)}{\Pr(A|B)\Pr(B) + \Pr(B|A)\Pr(A)}$$

forgets about these prior probabilities!

REPRESENTATIVENESS

Gennaioli-Shleifer Model

HYPOTHESIS

Given a set of states $\Omega = \{w_k\}_k$ and prior beliefs $\pi(w_k) = \Pr(w = w_k)$

A hypothesis is $h_r \subseteq \Omega$, $\Pr(h_r) = \sum_{w_k \in h_r} \pi(w_k)$

FREE DIMENSION F_r is the dimension that h_r doesn't specify

SCENARIO $s = \{\omega \in \Omega \mid \omega_j = \omega'_j \ \forall j \in F_r\}$

e.g. $h = B$ (pins down B/NB)

$F_r = F/NF$

$$\begin{cases} S_F = \{\langle F, B\rangle, \langle F, NB\rangle\} \\ S_{NF} = \{\langle NF, B\rangle, \langle NF, NB\rangle\} \end{cases}$$

Compare $\underset{\Pr(h|s_{NF})}{\Pr(B|NF)}$ and $\underset{\Pr(h|s_F)}{\Pr(B|F)}$. If $\Pr(B|NF) \geq \Pr(B|F)$,

NF becomes the stereotype (most representative scenario) for h

Then $$\tilde{\Pr}(h) = \frac{\Pr(\langle B, NF\rangle)}{\Pr(\langle B, NF\rangle) + \Pr(\langle NB, F\rangle)}$$

Stereotypes for all hypotheses $h_1 = B$, $h_2 = NB$ (normalisation)

CONJUNCTION FALLACY When $\tilde{\Pr}(h_1 \cap h_2) \geq \tilde{\Pr}(h_1)$ weak

or $\tilde{\Pr}(h_1 \cap h_2) > \tilde{\Pr}(h_1)$ strong

$\tilde{\Pr}(h_1 \cap h_2) \geq \tilde{\Pr}(h_1)$ only when the s_1 chosen to represent h_1 is not the most likely, conditional on h_1. If F represents B, then $\frac{\Pr(B)}{\Pr(B \cap F)} = 1$

REPRESENTATIVENESS IN SEQUENCES

Gambler's fallacy: Think independent sequences are negatively autocorrelated when DGP is known

Hot-hand fallacy: Think independent sequences are positively autocorrelated when DGP is unknown

LAW OF SMALL NUMBERS

True rate of the world (e.g. coin type) $\theta \in [0,1]$
Given an infinite sequence of signals $s_t = \{a, b\}$, agent observes finite subset

$$Pr(s_t = a) = \theta \quad , \quad s_t \text{ is i.i.d}$$

Agent beliefs about true rate: $\pi(\theta_j) = Pr(\theta = \theta_j)$

THREE LAYERS OF BELIEFS

① Prediction (Gambler's fallacy): $Pr(s_t = a \mid \vec{s}_{t-1}, \theta)$
② Type Inference (Hot-hand): $Pr(\theta = \theta_t \mid \vec{s}_{t-1}, \pi)$
③ Population Inference $Pr(\pi = \pi_j \mid \vec{s}_{t-1})$

If θ isn't known, do 2 first
If even π isn't known, do 3 first

1. PREDICTION

An N-Freddy thinks, given known θ (i.e. $\pi(\theta) = 1$), that signal is drawn without replacement from urn with θN a signals, $(1-\theta)N$ b signals

assume it's a whole no.

① Will still correctly predict averages (θN)
② Prediction of next signal is correct when urn is new

2. TYPE INFERENCE

An N-Freddy thinks, given known π ($Pr(\pi) = 1$), that

$$\pi_t^N(\theta^* \mid \vec{s}_t) = \frac{\pi_t^N(\vec{s}_t \mid \theta^*)\,\pi(\theta^*)}{\sum_{\theta \in \Theta} \pi_t^N(\vec{s}_t \mid \theta)\,\pi(\theta)}$$

← weighted by different ways you might observe s_t

exogenous prior beliefs

exogenous set of possible θs

APPLICATION: CALIBRATION

When beliefs are symmetric or true $\theta = \frac{1}{2}$

e.g. $\pi(A) = \pi(B) = q$, $\pi(C) = 1 - 2q$

Freddy thinks $\pi(\theta_j) = q$, doesn't know q
By LLN, in a large sample he'll observe signal $s = a$ half the time if $\theta = \frac{1}{2}$

Calibrate $\pi(\theta)$ using $\frac{1}{2} = \tilde{Pr}(s_t = a \mid \pi) = \sum_{\theta \in \Theta} \underbrace{\tilde{Pr}(s_t = a \mid \theta)}_{\text{numbers (can be calculated)}} \underbrace{\pi(\theta)}_{\text{variables}}$

General Approach: MLE Observe a K times, b M times

$$\theta^* \in \underset{\theta}{\operatorname{argmax}}\ \tilde{Pr}(s_t = a \mid \theta)^K\, \tilde{Pr}(s_t = b \mid \theta)^M$$

OVERINFERENCE

Hot-hand fallacy

Fictitious variation: Believe there's more variation in θ than there really is!
If true π is symmetric and $\pi(\theta = 1) < \frac{1}{2}$, then N-Freddy will exaggerate the probability of extreme types.

LEVEL-K THINKING

Level-0 : randomise (assume uniform)
Level - k : think all others are level k-1 and BR

COMPARISON TO PSNE

- If level-k players ever choose a PSNE, all higher level players play it too
- If there is a unique rationalisable (=dominant, in 2-player games) strategy players will converge to it as k grows
- If IDSDS takes k rounds to find unique strategy, level-k and up will end up playing it
- Level-k thinkers may outperform Nash in many games
  - Their presence may significantly change NE

INCOMPLETE IDSDS

Level-0 (D0): assume others play randomly and BR (= level-1)
D1 : Eliminate strictly dominated strategies, assume others play conditionally randomly
D2 : Iterate deletion, assume others play conditionally randomly

- Distinguish this from level-k model through asymmetric beauty contest

COGNITIVE HIERARCHY

Given priors $Pr(L0), Pr(L1), \ldots$

L0 : Randomise
L1 : $Pr(L0) = 1$ still.
L2 : At every subgame, conditional on having reached node a

Updates beliefs. $Pr(L1|a) = \dfrac{Pr(a|L1)Pr(L1)}{Pr(a|L1)Pr(L1) + Pr(a|L2)Pr(L2)}$

probability of reaching a if all L1

SHROUDING

$\boxed{\text{MARKET POWER}}$ Given demand for firm i's good $D_i(\underset{\substack{\uparrow \\ \text{eqm price (assume symmetric)}}}{p^*} - \underset{\text{own price}}{p_i})$

$$\mu := p - c = \frac{D(0)}{D'(0)} \xrightarrow{N \to \infty} 0$$

	True	Perceived (Sophisticates)
Equilibrium prices at other firms (primary good)	p^*	p^*
Own firm price (primary good)	p_i	p_i
Equilibrium prices at other firms (add-on)	$\hat{p}^*$	$\tilde{\hat{p}}^*$
Own firm price (add-on)	$\hat{p}_i$	$\tilde{\hat{p}}_i$

$$\hat{p}_i \leq \bar{p} \text{ (legal limit) } \forall i$$

α are naifs (don't know add-on) : $D_i^N(p_i, p^*) = -p_i + p^*$

$(1-\alpha)$ are sophisticates : $D_i^S(p_i, p^*, \tilde{\hat{p}}_i, \tilde{\hat{p}}_i^*) = -p_i + p^* - \min\{\tilde{\hat{p}}_i, e\} + \min\{\tilde{\hat{p}}_i^*, e\}$

either pay what I think is the add-on price

or avoid using costly effort

If unshroud, $\lambda \in (0,1]$ of naifs become sophisticated

$(1-\lambda)\alpha$ "uninformed naifs"

SHROUND $\hat{p}^* = \hat{\hat{p}}^* = \hat{\hat{p}} = \bar{p}$ in shrouded equilibrium $\forall i$

- Since consumers don't know, might as well charge max possible
- Then all sophisticates avoid; only naifs buy add-on

$$\text{Profit}: \pi(p) = (p + \alpha\bar{p}) D(p^* - p)$$

$$\text{FOC}: p = \frac{D(p^*-p)}{D'(p^*-p)} - \alpha\bar{p}$$

$$\text{Since } p = p^*, \quad p^* = \mu - \alpha\bar{p}$$

UNSHROUD $\tilde{\hat{p}} = \hat{p}$, $\tilde{\hat{p}}^* = \hat{p}^*$ when unshrouded. Can show $\hat{p}^* = e$.

<u>Case 1</u> $\hat{p} > e$. Still, only uninformed naifs buy.

Profit: $(p + (1-\lambda)\alpha\bar{p}) D(p^* - p)$ strictly smaller than shroud.

<u>Case 2</u> $\hat{p} \leq e$. Sophisticates buy. Constraint binds: $p^* = e$.

If not, can $\uparrow\hat{p}$ and $\downarrow p$ to attract naifs (sophs indiff).

$$\text{Profit}: (p + \hat{p}) \left[(1 - (1-\lambda)\alpha) D_i(p - p^* - \hat{p} + e) + (1-\lambda)\alpha\, D_i(p - p^*) \right]$$

$$= (p + e) D_i(p - p^*) \quad \text{as } \hat{p} = e$$

$$\text{FOC}: p^* = \mu - e$$

NAIF % From above, if shrouded eqm exists, then

$$\max_p (p - c + \alpha\bar{p}) D(p - p^*) = \max_p (p - c - e) D(p - p^*) \Rightarrow \alpha\bar{p} \geq e$$

Minimum threshold for shrouding, $\underline{\alpha} = \frac{e}{\bar{p}}$

$e\uparrow \Rightarrow$ Even if unshroud, sophs may buy add-on anyway $\Rightarrow$ less shrouding $\uparrow\underline{\alpha}$

WELFARE Under perfect competition ($\mu = 0$)

	Shroud	Unshroud	Surplus
Sophs welfare	$-p^* - e = \alpha\bar{p} - e$	$-p^* - e = -(-e) - e = 0$	$\alpha\bar{p} - e$
Naif welfare	$-p^* - \hat{p} = -(1-\alpha)\bar{p}$	$-p^* - [(1-\lambda)\hat{p} + \lambda e]$ $= -(-e) - e = 0$	$-(1-\alpha)\bar{p}$

Overall consumer surplus from shrouding:

$$(1-\alpha)[\alpha\bar{p} - e] + \alpha[-(1-\alpha)\bar{p}] = -(1-\alpha)e$$

add-on can be produced at no cost
socially efficient for it to be consumed

Transfer (cross-subsidy) from naif to soph

- $\uparrow\bar{p}$ increases inequality, doesn't change consumer surplus

EMH VIOLATIONS

1. Equity returns are too high: Investors loss averse, narrowly bracket portfolio risk
2. Volatility too high
3. Excess returns sometimes predictable: mkt do not fully incorporate all info

DISPOSITION EFFECT

Behavioural finance — explaining the presence of excess returns

- Reference point: Purchase price
- Gains and losses only over realised transactions
  Under K-T loss aversion, more likely to sell gain-making ("up") asset over loss-making ("down") as derive more utility from selling the former
- "Sell gains, hold on to losses": % of gains realised > % of losses realised

$$\frac{\text{Realised gains}}{\text{Realised gains} + \text{Paper (unrealised) gains}}$$

ALT EXPLANATIONS

✗ Portfolio rebalancing — effect persists when liquidating entire portfolio/ no new purchases afterwards

✗ Taxes — would've favoured losses over gains

✗ Irrational belief in mean reversion (due to gambler's fallacy)
- Note: winners aren't actually more likely to underperform next
- Test for evidence of LSN
  - Effect persists even if people are hot-handing (should've held on to gains)

OVERCONFIDENCE

DEFINITION Moore and Healy says it's a combination of 3 phenomena

1. Overestimation Overestimate own absolute ability
2. Overplacement Overestimate own relative ability
3. Overprecision Overestimate accuracy of own beliefs

A student's mark on an exam

$$X_i = S + L_i$$

Exam-specific component $S \sim N(m_S, v_S)$
Student ability $L_i \overset{iid}{\sim} N(0, v_L)$

A student's "gut feeling" (imperfect signal) on exam score

$$Y_i = X_i + E_i, \quad E_i \sim N(0, v_E)$$

$$E(X_i | Y_i) = \frac{v_L + v_E}{v_L + v_E + v_S} m_S + \frac{v_S}{v_L + v_E + v_S} Y_i$$

weighted average of prior m_S and signal Y_i

WELFARE

WELFARE CRITERION

① x is a multiself Pareto improvement over y if
$x \succsim y$ $\forall$selves, $x \succ y$ for at least one self

- e.g. picking a consumption path to improve utility of all self-ts

  Too weak — cannot "sacrifice" any self to improve all others

② Use long-run preference (O'Donoghue and Rabin)

- Self-t-1's preferred consumption path (not a function of β or $\hat{\beta}$)
- Treats all selves equally, and doesn't respect agent's actual choices

GENERALISED MODEL

$\mathbb{X}$ set of all possible choice objects

$X \subseteq \mathbb{X}$ be a constraint set (set of feasible alternatives)
e.g. possible consumption bundles/paths/lotteries

d be an ancillary condition that may affect choice
e.g. full/no commitment, when X is intertemporal budget constraint

- Cannot be a characteristic of object, cannot change X
- May affect chooser's behaviour, but not the social planner's evaluation

$(X,d) \in G$ be a generalised choice situation
$c: G \to 2^{\mathbb{X}}$ be the agent's choice: $c(X,d) \subseteq X \quad \forall (X,d) \in G$

MAXIMAL ELEMENT

of X, under relation Q, are

$$m_Q(X) = \{x \in X \mid \nexists y \in X \text{ s.t. } yQx\}$$

e.g. Most preferred alternative $(Q = \succ)$
Largest number $(Q = >)$

LIBERTARIAN RELATION

Social planner chooses Q (welfare condition)

Q is a "libertarian" relation if anything an agent ever chooses is welfare-optimal

$$\bigcup_{d \mid (X,d) \in G} c(X,d) \subseteq m_Q(X)$$

The null criterion (nothing is better than anything) is vacuously libertarian

$\boxed{\text{WARP}}$ often used for $R = \succsim$

$aRb \Leftrightarrow \forall X$ s.t. $a, b \in X$, $b \in c(X) \Rightarrow a \in c(X)$

- If $a \succsim b$, then for all sets containing both a and b, if b is chosen, then a is chosen too
- But b is not ruled out

(STRICT) UNAMBIGUOUS CHOICE P^*

$$aP^*b \Leftrightarrow \forall (X,d) \in \mathcal{G} \text{ s.t. } a, b \in X, \quad b \notin c(X,d)$$

- b is never chosen over a regardless of other alternatives (X), in any situation (d)
- Rules out b — not indifferent between a and b
- If b is not in some $c(X,d)$ and in some $c(X,d)$ i.e. sometimes chosen over a and sometimes not, we can only conclude $\neg(aP^*b)$ and $\neg(bP^*a)$

$\boxed{\text{ACYCLIC}}$ P^* is acyclic if

(A1) $\forall$ finite nonempty $X \subseteq \mathbb{X}$, $\exists d_X$ s.t. $(X, d_X) \in \mathcal{G}$ i.e. we observe choices

(A2) $\forall (X,d) \in \mathcal{G}$, $c(X,d) \neq \emptyset$

- If $x_1 P^* x_2 P^* \ldots P^* x_N$, then $\neg(x_N P^* x_1)$
- Weaker than transitivity as $\neg(x_N P^* x_1)$ doesn't imply $x_1 P^* x_N$

$\boxed{\text{THEOREM}}$ $m_{P^*}(X) \subseteq m_Q(X)$ $\forall$ libertarian Q

- P^* is the finest libertarian relation
- $m_{P^*}(X)$: set of all elements in X that aren't unambiguously dominated chosen over by another in X
- $a \in m_{P^*}(X)$ is a weak welfare optimum in X

APPLICATION: PRESENT BIAS

$$\vec{x} P^* \vec{y} \Leftrightarrow \underbrace{\sum_{k=0}^{T-1} (\beta\delta)^k u(x_k)}_{\text{Utility of an exponential discounter who uses } \beta\delta} > \underbrace{u(y_0) + \beta \sum_{k=0}^{T-1} \delta^k u(y_k)}_{\text{Normal self-0 utility}}$$

Guarantees that letting any future self decide any future self decide any future period won't overturn $\vec{x}$ for $\vec{y}$