Johannes-Gutenberg University Mainz
Bachelor of Science in Wirtschaftswissenschaften

Macroeconomics II: Behavioural Macro

Summer 2017

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www.macro.economics.uni-mainz.de

February 22, 2017

Part II
Behavioural economics

6 Overview

6.1 General idea

- "Behavioral Economics is the combination of psychology and economics that investigates what happens in markets in which some of the agents display human limitations and complications" (Mullainathan and Thaler, 2001)

- Compared to self-interested homo oeconomicus, human behavior deviates in three dimensions: (i) bounded rationality, (ii) bounded willpower and (iii) bounded self-interest

- Bounded rationality: limited cognitive abilities that constrain human problem solving

- Bounded willpower: people sometimes make choices that are not in their long-run interest

- Bounded self-interest: humans are willing to sacrifice their own interests to help others

6.2 Specific papers in behavioural theory

- Bounded willpower
  - Dual self models: Fudenberg Levine (2006), Krieger and Wälde (2016)
  - Time inconsistency: Strotz (1955), Laibson (1997), O'Donoghue and Rabin (1999), Benhabib Bisin (2005)
  - Automatic behaviour: Bernheim and Rangel (2004), Laibson (2001)
- Bounded self-interest
  - Altruism: Fehr and Schmidt (1999)
  - Superfairness: Baumol (1986)
- Bounded rationality → see the seminar offered by the chair
- Prospect theory
  - Kahneman and Tversky (1979) - see emotion part of lecture
  - Koeszegi and Rabin (2006) – endogenous reference point
  - Foellmi, Rosenblatt-Wisch and Schenk-Hoppe (2011) – allows for savings
- Emotions → see previous part of lecture

6.3 What we do here at JGU

How do we allow modern views to enter traditional economic thinking here at the macro chair?

- Makroökonomik I – nothing so far
- Macro II
  - see slides on emotions for emotional economics
  - Bounded willpower
    - Automatic behaviour: Bernheim and Rangel (2004)
    - Time inconsistency: general ideas (as in Strotz, 1955 and Laibson, 1997) and O'Donoghue and Rabin (1999)
- Advanced Macro (Master in International Economics and Public Policy)
  - Bounded willpower
    - Dual selfs as in Fudenberg and Levine (2006) including game structure
    - Time inconsistency as in Strotz (1955), full analysis à la Krieger (2011)
  - Bounded rationality
    - to be determined

7 Bounded willpower and automatic behaviour

7.1 The plan

We consider the model of addiction by Bernheim and Rangel (2004)

- When thinking about addiction and drug abuse, three observations can be made (p. 1561)
  - there is a pathological divergence between choice and preference – individuals *commit errors*
  - using drugs makes individual sensitive to cues about drug use (think of coffee and the Lavazza bar)
  - addicts understand this and try to manage these processes
- Remarkable feature: allow individuals to *make mistakes*
  - no sense to infer preferences from choice: think about crossing the street in UK (being e.g. a continental European tourist)
  - individuals sometimes are in a "cold" mode where decision making about consumption behaviour is rational. When triggered by some cue (with some probability), individuals are in a "hot" mode and *act against their preferences*

- Nota bene: In revealed preference approach, "*utility maximization and choice are synonymous*" (Gul and Pesendorfer, 2008, S. 6)

7.2 The model

- Basic structure (simplified static version still revealing essential insights)
  - There is a normal consumption good, an addictive substance x and a lifestyle $a \in \{E, A, R\}$
    - The consumption good can be consumed at arbitrary positive amounts c
    - The addictive good is consumed or not, $x \in \{0, 1\}$
    - Lifestyles are Exposure (to cues at, say, a party), Avoidance (stay at home) and Rehabilitation (in a clinical residential center)
  - The individual has a certain income y which is used for normal consumption (whose price is one) and for the addictive good at price q

$$c + qx = y \tag{12}$$

  - The individual has a utility function $u(c, x, a)$ that rises in all three arguments (with a being ordered as above)

- The “modes” of the individual (strength of self-control)
  - The individual can be in a “cold mode” or in a “hot mode”, which is triggered by probabilistic cues
  - The choice of the lifestyle determines the probability p^a of entering the hot mode
  - It is assumed that the probability rises, the “worse” the lifestyle

$$p^E \geq p^A \geq p^R$$

- Sequence of events
  - Wake up in the morning in cold mode
  - Select a “lifestyle” activity $a \in \{E, A, R\}$
  - Observe the cues (when present, given the probabilities p^a)
  - When cue pushes to hot mode, consume addictive substance
  - In the cold mode (in the absence of a cue), allocate resources y rationally between c and x

7.3 Individual behaviour

- Behaviour of the individual in cold mode
  - Optimal choice of c and x
  - Observe that x can not be chosen in continuous amounts (have a drink or not, smoke a cigar or not ...)
  - Choice between ($c = y$ and $x = 0$) or ($c = y - q$ and $x = 1$)
  - To make things precise, assume the utility function reads (this is not from Bernheim and Rangel)

$$u = \chi c^{\gamma} + x + \alpha b \tag{13}$$

where $\chi, \alpha > 0$ and $0 < \gamma < 1$ and

$$b = \left\{ \begin{array}{c} 3 \\ 2 \\ 1 \end{array} \right\} \text{for lifestyle } a = \left\{ \begin{array}{c} E\text{xposure (party)} \\ A\text{voidance (stay at home)} \\ R\text{ehab (clinical center)} \end{array} \right.$$

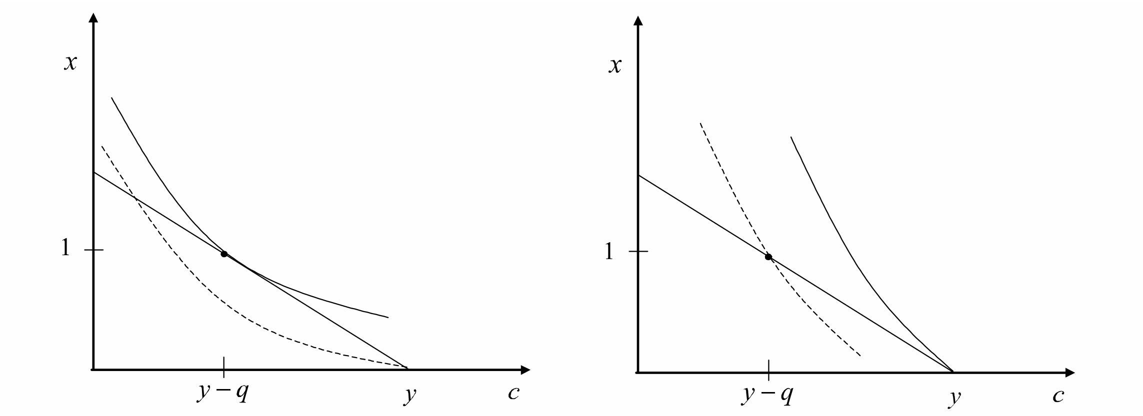

Figure 12 *Budget constraint and pseudo-indifference curves for c and x for a "drug-prone" individual (left panel) and a "drug-resistant" individual (right panel) ('pseudo' as x is indivisible)*

- Drug-resistant and drug-prone individuals
  - We define drug-resistant individuals as those that optimally choose *not* to consume the addictive good x
  - Drug-prone individuals find it optimal to consume the addictive good even in cold mode
  - Drug-resistant individuals have a *higher* χ, i.e. they value normal consumption goods more (relative to the addictive good x) than drug-prone individuals
  - Indifference curves turn clock-wise in the above figure
  - We study a drug-resistant individual in what follows (drug-prone individuals cannot commit any errors)

- (Not necessarily optimal) Behaviour of the individual
  - In cold mode, individual consumes c only
  - Utility is given by the level as shown in the indifference curve in the right panel above
  - Precise utility level in cold mode is, setting $c = y$ and $x = 0$ in (13)

$$u(y, 0, b) = \chi y^{\gamma} + \alpha b \tag{14}$$

    which also depends on the lifestyle a (via b)
  - When a cue occurs, the individual consumes the addictive good and utility falls to

$$u(y - q, 1, b) = \chi [y - q]^{\gamma} + 1 + \alpha b$$

  - To understand that it falls, remember that we look at drug-resistant individual in right panel of above figure (see Exercise 7.5.1)
  - This is an error in behaviour – behaviour does not maximize utility

7.4 Summary

- Many individuals seem to have bounded willpower
- An example of bounded willpower consists in drug use
  - There is a divergence between choice and preference (defined as 'errors')
  - Using drugs makes individuals sensitive to using drugs (not present in our simplified version here)
  - Addicts understand these interactions
- Bounded willpower is captured by exogenous link between cue and consumption of drug x
  - Divergence between choice and preference: see figure on drug-resistant individual and observe that utility falls
  - In model here, probability of a cue depends on lifestyle, $p^E \geq p^A \geq p^R$. Probability could also depend on degree of addiction (how often has drug been used in the passed $\rightarrow$ see paper)
  - Addicts understand all of this and choose lifestyle rationally

- This seems to be (personal opinion) a “no risk no fun” paper
  - The individual enjoys a certain lifestyle – which is the fun part – which however bears a higher risk of an “accident” (drug use)
  - This resembles investment under uncertainty: on average, returns are higher (from lifestyle) but sometimes there are bad realizations (drug use)
- What is the difference to the cue-theory of consumption paper by Laibson (2001)?
  - Laibson studied the effects of cues as well
  - In the presence of a cue, marginal utilities are altered
  - Individuals can still make an optimal choice, however
  - Here, a cue directly leads to behaviour, without any intermediate choice
- Do we have an emotion paper here which we missed in our emotion part of this lecture?
  - The paper does talk about ’cravings’ and ’hedonic payoffs’ or ’hedonic implications’
  - In this sense, yes, it is an emotion paper as well, not just a paper about bounded willpower

7.5 Exercises

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7.5.1 Addiction and Automatic Processes (Bernheim and Rangel, 2004)

Consider an individual who maximises the following objective function in a "cold mode", where she can rationally choose her own consumption, whereas a "hot mode", is where she would have to consume x, is triggered in response to cues:

$$\max_{\{c,x\}} u\left(c,x,b\right) = \chi c^{\gamma} + x^{\gamma} + \alpha b \tag{15}$$

$$s.t.\ c + qx = y \tag{16}$$

Where c is the standard consumption good whose price is normalised to unity, $x \in \{0,1\}$ represents consumption of the addictive good at price q, and b is the activity (or lifestyle) that the individual chooses, with $b \in \{E, A, R\}$ is the state that she can find herself in, with $E \equiv Exposure$, $A \equiv Avoidance$ and $R \equiv Rehab$. Each state carries a certain probability, p^{α}, of being exposed to a cue and thus triggering the "hot mode", which automatically leads to consumption of x, such that $p^{E} > p^{A} > p^{R}$. In other words, E is a more risky state than A which is more risky than R. Each time a cue occurs, x is consumed.

1. Given that we have either $x = 1$ or $x = 0$, and using (16) and (15), what behaviour is optimal for the individual, in the "cold mode"? Do states matter here? In other words, compare the utility from consuming c and x and from consuming only c, and determine which is larger.

2. Derive the ratio of marginal utilities for this problem, using the first-order conditions.

3. What happens to this ratio when q increases? When χ increases?

4. Draw the indifference curves for our problem. First for an addiction-resistant individual (high χ) and then for an addiction-prone individual (low χ). Show graphically what happens to an addiction-resistant individual (high χ) when a cue occurs.

8 Time consistent and time inconsistent behaviour

8.1 Time consistency

To understand time *in*consistency, we first look at what actually time *consistency* is

8.1.1 Two-period utility maximization under certainty

- (Reminder – see 'Makroökonomik I' for certainty, see section 4.1 for uncertainty)
- Setup
  - Agent maximizes
$$U_t = \ln c_t + \delta \ln c_{t+1} \tag{17}$$
  - subject to period 1,
$$w_t = c_t + s_t,$$
  - and period 2 constraint,
$$(1 + r_{t+1}) \, s_t = c_{t+1}.$$
- Optimal behaviour reads
$$c_t = \frac{1}{1+\delta} w_t, \qquad s_t = \frac{\delta}{1+\delta} w_t, \qquad c_{t+1} = \frac{\delta}{1+\delta} (1 + r_{t+1}) \, w_t. \tag{18}$$

8.1.2 Three-period utility maximization under uncertainty

- Setup
  - We now start one period earlier, in period $t-1$. It is called period 0 (such that t remains period 1 and $t+1$ remains period 2)
  - Our individual maximizes

$$U_{t-1} = \ln c_{t-1} + \delta \ln c_t + \delta^2 \ln c_{t+1}$$

  - There are three constraints, one for period 0,

$$w_{t-1} = c_{t-1} + s_{t-1}$$

one for period 1,

$$(1 + r_t)\, s_{t-1} = c_t + s_t \tag{19}$$

and one for period 2

$$(1 + r_{t+1})\, s_t = c_{t+1}$$

- Timing of the models

time index	$t-1$	t	$t+1$
period	0	1	2
two-period model		$1st$ period	$2nd$ period
three-period model	$1st$ period	$2nd$ period	$3rd$ period

- Comparison to the two-period setup
  - Individual saves in $1st$ *and* in $2nd$ period
  - As before individual works only in $1st$ period
  - This assumptions is made for simplicity and does not affect the result

- Optimal behaviour
  - We can describe optimal behaviour by explicit expressions here as well
  - Labour income in period 0 is split between consumption and saving (see Exercise 8.3.1),

$$\begin{aligned} c_{t-1} &= (1-B)w_{t-1}, \\ s_{t-1} &= Bw_{t-1} \end{aligned} \tag{20}$$

    where the share B is determined by the discount factor, $B \equiv \frac{\delta+\delta^2}{1+\delta+\delta^2}$
  - What is saved in $t-1$ and therefore available in t is again split in t between consumption and savings,

$$\begin{aligned} c_t &= (1-A)(1+r_t)\, s_{t-1}, \\ s_t &= A\,[1+r_t]\, s_{t-1}, \end{aligned} \tag{21}$$

    where the share A amounts to $A \equiv \frac{\delta}{1+\delta}$
  - Finally, in $t+1$, the savings of s_t plus interest are consumed,

$$c_{t+1} = (1+r_{t+1})\, s_t \tag{22}$$

8.1.3 Where can we see that decision making is time consistent?

- General feature
  - Individuals behave the same, independently of *when* the decision (i.e. whether it was made in t or in $t-1$)
  - *The rule is always the same* and does not change when time goes by

- Where do we see this in this example?

  - Consumption in $t+1$ from the perspective of t (see (18) in 2pm)

$$c_{t+1} = \frac{\delta}{1+\delta}\left(1+r_{t+1}\right)w_t$$

  - Consumption in $t+1$ from the perspective of $t-1$ (see (22), (21) and the definition of A in 3pm)

$$\begin{aligned} c_{t+1} &= \left(1+r_{t+1}\right)s_t \\ &= \left(1+r_{t+1}\right)\frac{\delta}{1+\delta}\left[1+r_t\right]s_{t-1} \end{aligned} \tag{23}$$

  - wage in t in two-period model (2pm) corresponds to $\left[1+r_t\right]s_{t-1}$ in three-period model (3pm)
  - individual in 2pm starts in t with wage/ endowment w_t
  - individual in 3pm continues in t with endowment $e_t \equiv \left(1+r_t\right)s_{t-1}$
  - we can write (19) as $e_t = c_t + s_t$ and therefore (23) as

$$c_{t+1} = \frac{\delta}{1+\delta}\left(1+r_{t+1}\right)e_t$$

  - *The rule is always the same:* Consume in $t+1$ a share $\delta/\left(1+\delta\right)$ of endowment in t (e_t or w_t) plus interest paid in $t+1$

8.2 Time inconsistency

- The plan for this section
  - We first look at properties of intertemporal utility functions that imply time consistency and time inconsistency
  - We get to know these specifications for discrete and continuous time setups
  - Then (in section 8.2.4) we look at an example for these general departures
- Teaching background
  - (lecture notes)
  - Prelec (2004) “Decreasing Impatience: A Criterion for Non-stationary Time Preference and ’Hyperbolic’ Discounting”
  - Bryan Karlan Nelson (2010) footnote 6
  - Caplin Leahy (2006) Solution method to be used is dynamic programming, not subgame perfection

8.2.1 Exponential/ geometric discounting

- Standard (Ramsey-Samuelson type) intertemporal utility function in continuous time
  - Intertemporal utility function $U(t)$

$$U(t) = \int_t^{\infty} e^{-\rho[\tau - t]} u(c(\tau)) \, d\tau$$

  - Instantaneous utility function $u(c(\tau))$
  - "Standard" here refers to exponential discounting
  - Discount function is $e^{-\rho[\tau - t]}$ with a constant time-preference rate ρ
  - Important for comparison later
    * This time preference rate is the (negative) growth rate of the discount function
    * This growth rate is constant (the growth rate being another name for instantaneous discount factor)

- Standard intertemporal utility function in discrete time
  - Intertemporal utility function U_t

$$U_t = \Sigma_{\tau=t}^{T} \delta^{\tau-t} u\left(c_\tau\right)$$

  - Instantaneous utility function $u\left(c_\tau\right)$
  - Geometric/ exponential discounting at discount factor $\delta < 1$
  - General version of special (3-period) case seen above in ch. 8.1.2
- Common features of continuous and discrete time formulations
  - Instantaneous discount factors are constant over time
  - Time consistent behaviour results

8.2.2 Non-exponential discounting

- Non-exponential discounting a la Strotz (1955) in continuous time
  - Intertemporal utility function $U^{\text{Strotz}}(t)$

$$U^{\text{Strotz}}(t) = \int_t^\infty \lambda(\tau - t)\, u(c(\tau))\, d\tau$$

  - Instantaneous utility function $u(c(\tau))$
  - Discount function $\lambda(\tau - t)$ where discounting depends on length of time $\tau - t$
  - Normalization with $\lambda(0) = 1$
  - Discount function $\lambda(\tau - t)$ can be exponential

$$\lambda_{\text{example 1}}(\tau - t) = b^{-\rho[\tau - t]} \text{ where } b > 1 \text{ (not necessarily } e = 2.7182\text{...)}$$

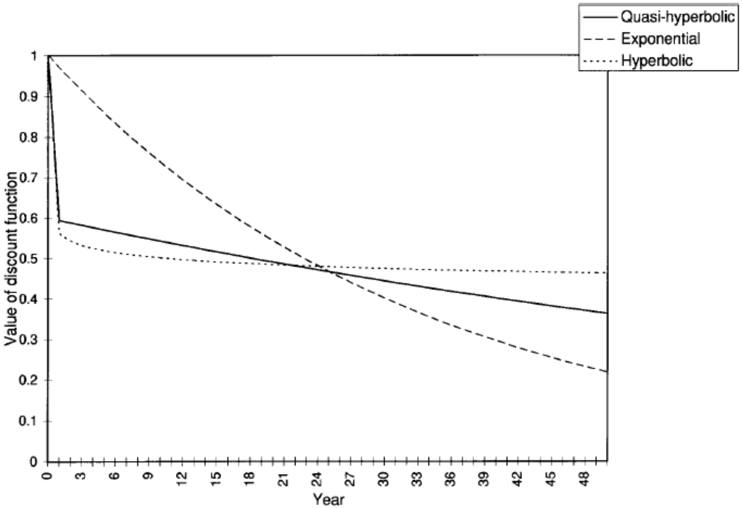
  but also anything else like e.g. hyperbolic

$$\begin{aligned} \lambda_{\text{example 2}}(\tau - t) &= (1 + \alpha[\tau - t])^{-\gamma/\alpha} \text{ where } \alpha, \gamma > 0 \\ &\quad \text{(generalized hyperbolic discount function, Laibson, 1997)} \end{aligned} \tag{24}$$

- Common feature of discount functions
  - Let us define the growth rate of the discount function a.k.a. the instantaneous discount factor as
$$g^{\lambda} \equiv \frac{d\lambda\left(\tau - t\right)/d\left(\tau - t\right)}{\lambda\left(\tau - t\right)}$$
  - For non-exponential discount functions like $\lambda_{\text{example 2}}$, it falls over time
  - As an example, the instantaneous discount factor of (24) is $\gamma/\left(1 + \alpha\tau\right)$ (see Laibson, 1997, or Exercise 8.3.2)
  - Time inconsistent behaviour results

8.2.3 Quasi-hyperbolic discounting

- Quasi-hyperbolic discounting à la Phelps and Pollak (1968) and Laibson (1997) in discrete time
  - Discount factors for t, $t+1$, $t+2$,..., $t+n$ are given by 1, $\beta\delta$, $\beta\delta^2$ ...$\beta\delta^n$
  - Exponential discounting is a special case with $\beta = 1$
  - "Quasi-hyperbolic" (i.e. it mimics (24)) discounting takes place for $\beta < 1$
    * Discounting is exponential for all points in time as of $t+1$ – but not for the time between t and $t+1$
    * Instantaneous discount factor falls in time



$$\text{quasi-hyperbolic} \quad \left\{ \begin{array}{c} 1 \\ \beta\delta^{\tau-t} \end{array} \right\} \text{ for } \left\{ \begin{array}{l} \tau = t \\ \tau > t \end{array} \right.$$

$$\text{exponential} \quad e^{-\rho[\tau-t]}$$

$$\text{hyperbolic} \quad (1+\alpha\,[\tau-t])^{-\gamma/\alpha}$$

Figure 13 *Discount functions and functional forms (figure from Laibson, 1997)*

- Implications of non-exponential discounting
  - time inconsistent behaviour
  - decision made in t implies a behaviour in T that differs from behaviour in T if decision was made at some point after t
  - behaviour depends on *when* an individual makes a decision
  - The rule is *not* always the same

8.2.4 O'Donoghue and Rabin (1999)

- Let us now look at an explicit example for time-inconsistent behaviour due to quasi-hyperbolic discounting
- We will find that people make plans and then do not stick to them – despite the absence of any new information
- The analysis is taken from O'Donoghue and Rabin (1999)

- Preferences
  - Time-consistent preferences (TC)

$$U_t^{TC} = \Sigma_{\tau=t}^{T} \delta^{\tau-t} u_\tau \quad (25)$$

    where t is today and $T > t$ is the end of the planning horizon, $0 < \delta \leq 1$ is the discount factor and u_τ is instantaneous utility in τ
  - We can write these preferences as

$$U_t^{TC} = u_t + \Sigma_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau$$

    and see the discounting to amount to $1 = \delta^0$, δ, δ^2 and so on
  - Intertemporal preferences that imply time-inconsistencies are "present-biased preferences" (O'Donoghue and Rabin, 1999)

$$U_t = u_t + \beta \Sigma_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau, \quad \beta < 1 \quad (26)$$

    where the new crucial parameter is $\beta < 1$.
  - Discount factors here are 1, $\beta\delta$, $\beta\delta^2$, $\beta\delta^3$ ...

- The decision problem
  - We assume that there is only *one* decision to be made
  - The decision implies an activity which can be performed at any point in time $\tau \geq t$
  - Costs of the activity in τ are given by c_τ, benefits v always accrue at T
  - We set the usual discount factor equal to one, $\delta = 1$
  - Intertemporal preferences therefore read

$$U_t = u_t + \beta \Sigma_{\tau=t+1}^{T} u_\tau, \quad \beta < 1$$

  - Then, the gain (relative to the status quo) from performing this activity is given by (see Exercise 8.3.2)

$$\left\{ \begin{array}{c} V_t(t) = \beta v - c_t \\ V_t(\tau) = \beta v - \beta c_\tau \end{array} \right\} \text{if the activity is undertaken in} \left\{ \begin{array}{c} t \\ \tau > t \end{array} \right\} \quad (27)$$

- Sophistication of individuals
- We would like to understand optimal behaviour for three types of individuals
  - TCs: time consistent individuals with $\beta = 1$
  - naifs: time inconsistent with $\beta < 1$
  - sophisticated: time inconsistent with $\beta < 1$
- Definition of optimal behaviour as "perception-perfect strategy"
  - TCs: choose point in time for action such that present value gain V_t is highest
  - naifs: do the same, _ignoring_ that they have a present bias also in the future
  - sophisticated: do the same thing, taking into account that they have a present bias also in the future
- Example for benefits and costs
  - Individual needs to write a (seminar/ research/ professional) paper
  - There are four evenings left
  - As an alternative, the individual can enjoy a movie
  - The reward is v, the costs are 1, 2, 3, and 11 on evenings 1 to 4 (e.g. because quality of movie rises)

- Optimal behaviour of TCs

  – By (27), the TCs compute

$$\left\{ \begin{array}{c} V_1\left(1\right) = v - c_1 \\ V_1\left(\tau\right) = v - c_\tau \end{array} \right\} \Rightarrow V_1\left(1\right) > V_1\left(\tau\right) \Leftrightarrow c_\tau > c_1$$

  – TCs write paper in period 1

- Optimal behaviour of naifs
  - From (27), naifs compute

$$\left\{ \begin{array}{c} V_1(1) = \beta v - c_1 \\ V_1(\tau) = \beta v - \beta c_\tau \end{array} \right\} \Rightarrow V_1(1) > V_1(\tau) \Leftrightarrow \beta c_\tau > c_1$$

  - If β is only small enough, action is postponed to the future
    * Imagine $\beta = .1$
    * then $\beta c_2 = .2 < c_1 = 1$ and they therefore
    * postpone to evening 2
  - When do they plan to write the paper?
    * From the perspective of evening 1, they believe that the paper will be written on evening 2
    * From the perspective of evening 1, $c_3 > c_2$ and therefore
    * It is better to write on evening 2 rather than on evening 3
  - Let us now go "into the future", i.e. we make this decision again in period 2
    * Naifs compare $\beta c_3 = .3$ to $c_2 = 2$
    * They again postpone (in contrast to what they believed in period 1) and so on
    * They therefore write the paper on the last evening with the highest costs

- Optimal behaviour of sophisticated
  - The sophisticated know that they have a present-bias in each period
  - They know that they will postpone (procrastinate) in each period
  - They know that not writing the paper in 1 means writing the paper in period 4
  - The value of doing it in period 4 is

$$V_1(4) = \beta v - \beta c_4$$

  - Now comes the smart move (this is why they are called "sophisticated"): They can compare value in period 4 to the cost of writing the paper today. This implies

$$V_1(1) > V_1(4) \Leftrightarrow \beta v - c_1 > \beta v - \beta c_4 \Leftrightarrow \beta c_4 > c_1 \Leftrightarrow 1.1 > 1$$

  - Hence, they write the paper immediately in period 1 (just as time-consistent individuals)

- Conclusion
  - Why do people make plans and do not stick to them?
  - They have a present-bias and they act naively
  - TCs make plans and each time they revisit the plan, they confirm it
  - Present-biased individuals that are sophisticated might postpone, but they stick to their plan
  - Naive individuals do not stick to their plans

8.3 Exercises

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8.3.1 Three-period savings problem

Consider the following three-period setup, where the individual maximises the following objective function, dependent on consumption in $t-1$, t and $t+1$:

$$U\left(c_{t-1}, c_t, c_{t+1}\right) = \ln\left(c_{t-1}\right) + \delta \ln\left(c_t\right) + \delta^2 \ln\left(c_{t+1}\right) \tag{28}$$

Subject to the following constraints:

$$w_{t-1} = c_{t-1} + s_{t-1} \tag{29}$$

$$\left(1 + r_t\right) s_{t-1} = c_t + s_t \tag{30}$$

$$\left(1 + r_{t+1}\right) s_t = c_{t+1} \tag{31}$$

where w_{t-1} is labour income in $t-1$, s_{t-1} are savings in $t-1$, s_t are savings in t, and the interest rate is r_t in t and r_{t+1} in $t+1$.

1. Find optimal savings s_{t-1} and s_t as functions of the wage, w_{t-1}.

2. Determine optimal consumption c_{t-1}, c_t and c_{t+1}.

8.3.2 Time (in)consistency (Laibson, 1997; O'Donoghue and Rabin, 1999)

Consider the three main types of discount functions listed below:

$$\begin{array}{ll} \text{exponential:} & e^{-\rho(\tau-t)} \\ \text{hyperbolic:} & (1+\alpha\,[\tau-t])^{-\frac{\gamma}{\alpha}} \\ \text{quasi-hyperbolic:} & \beta\delta^{\tau-t} \end{array}$$

where $\rho, \alpha, \gamma > 0$, and $\beta, \delta \in (0,1)$, $\tau \in [t, \infty)$ and e is the Euler number.

Also note that a discount function is considered consistent if its growth rate does *not* depend on the time distance being evaluated.

1. Compute the growth rate of each discount function with respect to the time distance $\tau - t$.

2. Which discount functions are consistent/inconsistent over time?

9 Conclusion

- Behaviour economics studies
  - bounded rationality
  - bounded willpower
  - bounded self-interest
- Bounded rationality
  - see Bachelor seminar at chair
  - or wait for Master studies
- Bounded willpower
  - We studied time-inconsistent behaviour (O'Donoghue and Rabin, 1999)
  - General principles of utility functions (Strotz, 1955, Laibson, 1997)
  - Automatic behaviour (Bernheim and Rangel, 2004)

- Bounded self-interest
  - see Sobel (2005) or
  - use a utility function for an individual A that reads $u\left(c^A, c^B\right)$ and that takes utility of individual B into account
- These departures from neoclassical economics allow us to
  - better understand human behaviour per se
  - better understand human behaviour in economic situations
  - better develop models applied to understand economic issues ...
  - ... such as macro – to which we now turn