Johannes Gutenberg-University Mainz
Bachelor of Science in Wirtschaftswissenschaften

Macroeconomics II: Behavioural Macro

Summer 2024

Prof. Dr. Klaus Wälde (lecture and tutorial)

www.macro.economics.uni-mainz.de
January 15, 2024

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1 The idea of this lecture

1.1 Some background on behavioural macroeconomics

- The state of affairs of behavioural macro
  - Akerlof (2002) "Behavioral Macroeconomics and Macroeconomic Behavior"
  - No textbook on behavioural macro
  - Some articles, getting more
  - It's a growing field
- Why behavioural macro is very important
  - bring more psychology into economics (Rabin, 2013)
  - bring more of economic methods into psychology
  - employ these psychological ideas expressed with economic methods in macroeconomics

1.2 The structure of the lecture

1. Emotional economics
   (a) Introduction and background from psychology and economics
   (b) Schools of thought: Emotions in economic research
      i. Classical economics (historical background)
      ii. Neoclassical economics and decisions
      iii. Behavioural economics
   (c) Modelling emotions in behavioural economics
2. Behavioural economics (beyond emotions)
   (a) Bounded willpower and automatic behaviour
   (b) Time (in)consistency
3. How behavioural macro could look like
   (a) Unemployment and time-inconsistency
   (b) Growth, cues and automatic behaviour
   (c) Business cycles and anxiety

Part I
Emotional Economics

2 Introduction

2.1 Some background from the psychological literature

- Psychological literature: what is an emotion?
  - Kleinginna and Kleinginna (1981) present and discuss a list of 92 definitions of emotions
  - Discrete emotion terms: Shaver et al. (1987), see next figure

Table 1

Mean Prototypicality Ratings and Unfamiliarity Proportions (UP) for 213 Emotion Words

Emotion word	*M*	UP	Emotion word	*M*	UP	Emotion word	*M*	UP
love[a]	3.94	.00	agitation[a]	3.29	.01	triumph[a]	2.95	.00
anger[a]	3.90	.00	outrage[a]	3.28	.00	joviality[a]	2.94	.05
hate[a]	3.84	.00	resentment[a]	3.28	.00	wrath[a]	2.93	.07
depression[a]	3.83	.00	dislike[a]	3.27	.00	arousal[a]	2.92	.03
fear[a]	3.83	.00	glee[a]	3.24	.02	attraction[a]	2.92	.00
jealousy[a]	3.81	.00	alienation[a]	3.23	.01	contentment[a]	2.92	.04
happiness[a]	3.77	.00	distress[a]	3.23	.01	grumpiness[a]	2.92	.00
passion[a]	3.75	.00	enjoyment[a]	3.23	.00	irritation[a]	2.92	.00
affection[a]	3.72	.01	relief[a]	3.23	.00	malevolence	2.92	.32
sadness[a]	3.68	.00	gloom[a]	3.21	.00	ferocity[a]	2.91	.00
grief[a]	3.65	.01	misery[a]	3.20	.02	enthrallment[a]	2.90	.13
rage[a]	3.64	.00	euphoria[a]	3.19	.16	revulsion[a]	2.88	.10
aggravation[a]	3.63	.03	bliss[a]	3.18	.07	alarm[a]	2.87	.00
ecstasy[a]	3.63	.00	gladness[a]	3.17	.00	eagerness[a]	2.87	.00
sorrow[a]	3.62	.00	regret[a]	3.16	.00	hysteria[a]	2.87	.00
joy[a]	3.61	.00	rejection[a]	3.16	.00	liking[a]	2.87	.00
compassion[a]	3.62	.00	pride[a]	3.14	.01	neglect[a]	2.87	.00
envy[a]	3.58	.00	gaiety[a]	3.13	.04	insult[a]	2.86	.00
fright[a]	3.58	.00	homesickness[a]	3.13	.00	mortification[a]	2.85	.04
terror[a]	3.57	.00	jolliness[a]	3.12	.00	tenseness[a]	2.85	.00
elation[a]	3.55	.10	nervousness[a]	3.12	.00	contempt[a]	2.84	.03
guilt[a]	3.53	.00	woe[a]	3.12	.05	amazement[a]	2.83	.00

Figure 1 *Discrete emotion terms (excerpt): Shaver et al. (1987)*

- Psychological literature: what is an emotion? (cont'd)
  - Various surveys by George Loewenstein on emotions and decisions (Rick and Loewenstein, 2008, Loewenstein and Lerner 2003)
  - Wälde and Moors (2017) provide a survey on 'emotion research in economics'
  - Alternative to discrete list of emotions: Quantify emotions by valence, arousal, control or other
    * valence: positive or negative (continuum)
    * arousal: how strong is emotion (continuum)
    * control: "To what extent can you influence the situation (if desired)?" (Sacharin et al., 2012)

- The valence-control view

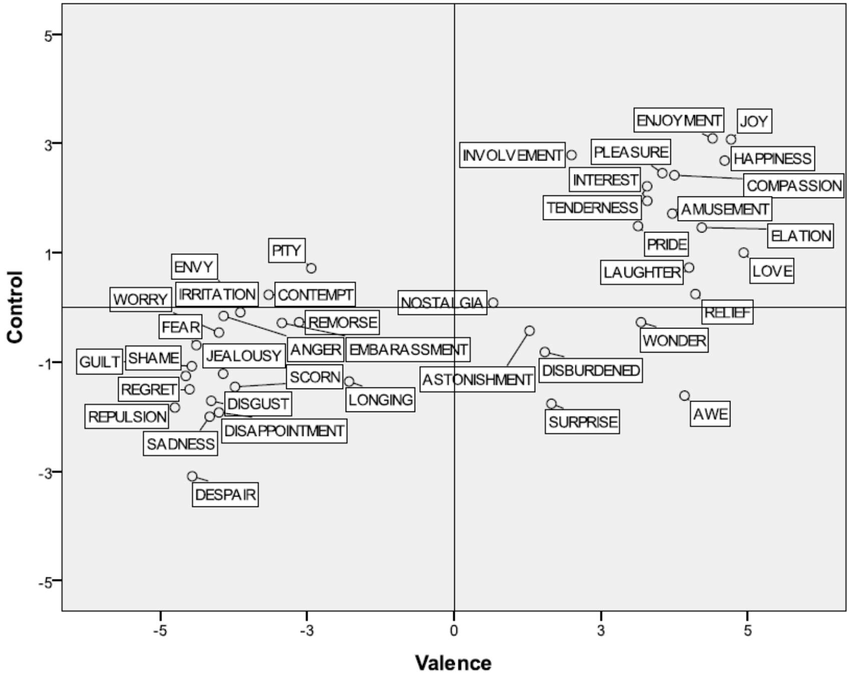


Figure 2 *Valence vs. control of emotions (Sacharin et al. 2012)*

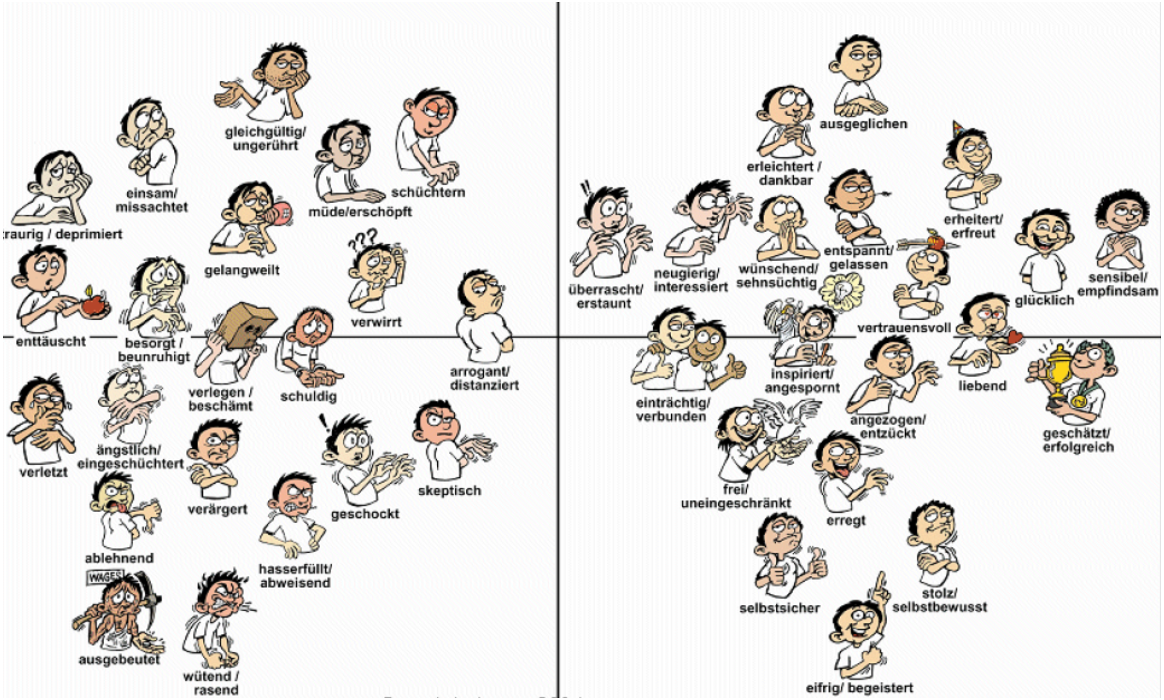


Figure 3 *Valence vs. arousal (http://www.absatzwirtschaft.de/images/emotion.gif)*

2.2 Some background from the economic literature

- Elster (1998 JEL survey, philosopher, political scientist) "Emotions and Economic Theory"
  - "economists mainly try to explain behavior, emotion theorists try to explain emotions" (p. 47)
  - His central question: "How can emotions help us explain behavior for which good explanations seem to be lacking?" (p. 48)
  - ignores specific emotion analyses (Regret theory by Loomes and Sugden, 1982, 1986; disappointment aversion by Gul, 1991) but most emotion papers come after 1998
  - talks a lot about emotions in books by Gary Becker

- Loewenstein (2000) "Emotions in Economic Theory and Economic Behavior"
  - Economists (at that time) looked at anticipated emotions (regret, disappointment) which are *not* felt at the moment of decision making (and are only cognitively perceived)
  - Psychologists focus more on immediate emotions (which are an example of visceral factors) which *are felt* at the moment of decision making (anger, fear, hunger, thirst..)
  - Visceral factors can be dealt with as state-dependent preferences

- DellaVigna (2009, JEL) "Economics and psychology: evidence from the field"
  - looks at emotions in section 4.5: "two examples of emotions, mood and arousal, for which field evidence is available"
  - no conceptual analysis
- Sobel (2005, JEL)
  - inquires into the nature of reciprocal behaviour (intrinsic vs. instrumental)
  - probably strongly related to feelings about another person, but no mention of feelings ...
- Mindless and mindful economics (Gul and Pesendorfer vs. Camerer in Caplin and Schotter, eds., 2008)
  - should we use non-choice data?
  - or should we allow for brain-data (or questionnaire data)?
- Wälde (2016) surveys emotion research in economics (background for this part of the lecture)

2.3 Classification of emotions

- Emotions directed towards oneself or other, towards behaviour, characteristic and possession and positive or negative (2x3x2 structure by Elster)

positive					negative
	oneself	other	oneself	other	
behaviour	*pride*	*admiration*	*guilt*	*anger*	behaviour
characteristic	*pridefulness*	*liking*	*shame*	*hatred*	characteristic
possession	*pridefulness*	*altruism* $u\left(c^A, c^B\right)$	*shame*	*envy* $u\left(c^A, c^B\right)$	possession

- Emotion directed towards possession of others: envy (also: malice, indignation, jealousy) requires $\frac{\partial u\left(c^A, c^B\right)}{\partial c^B} < 0$, altruism requires $\frac{\partial u\left(c^A, c^B\right)}{\partial c^B} > 0$
- More or less unclear cases: contempt, disgust, romantic love, boredom/stress, interest, sexual desire

- Classification of emotions by time structure
  - Anticipatory emotions: fear, hope, suspense
  - Ex post emotion
    * General: joy and grief
    * Counterfactual emotions (relative to expectation): regret, rejoicing, disappointment, elation
  - Immediate emotions and visceral factors: excitement, arousal, hunger, thirst, tiredness, pain

3 Which role do emotions play in economic research?

We look at the following economic fields

- Classical economics
- Neoclassical economics
- The current view/ behavioural economics

3.1 Emotions in classical economics

- The natural place to look for emotions in economic thinking is the field of 'utility theory'
- Adam Smith in his "The Wealth of Nations" (1776) used the term 'utility' to denote the "value in use" of a certain good (as opposed to the "value in exchange" (Stigler, 1950, p. 307))
- The hedonic concept of utility was then made popular by Jeremy Bentham in 1789 with his "Introduction to the Principles of Morals and Legislation"
  - He suggested to measure utility by measuring "pleasure and pain"
  - He also talked about "happiness" when discussing the effect of wealth on a person
- Jevons strongly denied that utility could be measured stating that
  - "we can hardly form the conception of a unit of pleasure or pain"
  - the idea of "quantities of feelings" is out of the question (Stigler, 1950a, p. 317)
  - Yet, he clearly perceived utility resulting from an object as a feeling
- Utility theory in economics, initially, was all about feelings

3.2 Absence of emotions in neoclassical decision making?

- Two approaches in economics to decision making (see Mas-Colell et al., 1995, ch. 1)
  - Preference-based approach
  - Choice-based approach
- In both cases, an individual chooses among a set X of alternatives
- Examples include
  - different professions (X_1)
  - different ways to allocate time between studying and seeing a friend (X_2)
  - $X_1 = \{$become an economist, engineer, philosopher$\}$
  - $X_2 = \{(4,1), (1,4), (2,3)\}$, where the first pair stands for (study $4h$, see friends for $1h$)

- Preference-based approach
  - Traditional approach in economics
  - The fundamentals (“below which” there is no theory) of this approach are preferences of a decision maker
  - These preferences represent the decision maker’s tastes
  - Rationality axioms are imposed on these preferences and the implied choice behaviour is then studied
- Choice-based approach
  - Primitives of decision making is the choice behaviour
  - Consistency axioms are imposed on these decisions and the implied decision process is studied

3.2.1 Preference-based approach

- Starting point is the set X of alternatives with an element x and another element y
- Tastes of decision maker are described by "preference relationships"
- Preference relationships are denoted by the symbol $\succsim$
- $x \succsim y$ means "x is at least as good as y"
  - becoming an economist (x) is at least as good as becoming a philosopher (y)
  - (study $4h,$ see friends for $1h$) is at least as good as (study $3h,$ see friends for $2h$)

- Definition of rationality of a preference relationship (see Exercise 3.4.1)
  - A preference relationship $\succsim$ is rational if it possesses the following two properties:
    (a) Completeness: for any x and y, either $x \succsim y$ or $y \succsim x$ or both hold
    (b) Transitivity: for any x, y and z, if $x \succsim y$ and $y \succsim z$ then $x \succsim z$
  - (Compare this to "rational" in everyday language)
- Completeness sounds obvious but not so clear in practice
  - Think of any tough choice with lots of trade-offs (similar to a dilemma)
  - become an economist (x) or become a philosopher (y)?
  - Have children or not? Have 1, 2 or 3?
  - Go on wonderful sunny-beach holiday in winter but pollute the environment?

- Transitivity is at least as strong an axiom as completeness
  - If you prefer macro to micro and micro to econometrics, do you still prefer macro to econometrics?
  - If you prefer Italian to Indian food and Indian food to French food, do you still prefer Italian to French food?
  - What if you already had 10 pizzas in a row?
- General problem for both completeness and transitivity
  - Multi-dimensionality of x and y such that preference depends on weight attached to components of x and y
  - Some components are more present (salient) than others

- What is a utility function?
  - A utility function $u(x)$ that represents a preference relation $\succsim$ is a function for which

$$x \succsim y \Leftrightarrow u(x) \geq u(y)$$

- A first result
  - Given a choice set X, a preference relationship $\succsim$ and a definition of rationality, we find:
  - A preference relationship can be represented by a utility function only if it is rational
- In other words
  - When we work with a utility function that represents a preference relationship, then the latter must be rational
  - We assume completeness and transitivity in all of our economic models as soon as we write down a utility function

3.2.2 Choice-based approach

- Starting point (here as well) is the set X of alternatives
- Budget set $\mathcal{B}$ is a set of subsets of X – in words: Budget set is exhaustive list of feasible choices
- As an example, consider a consumption-leisure choice

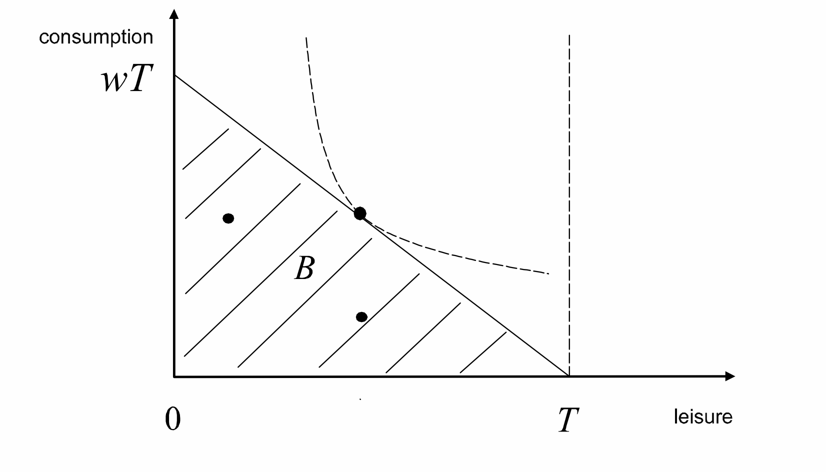


Figure 4 *Consumption-leisure choice (see next slide for background)*

- The consumption-leisure choice (formal description)
  - Budget constraint
    $$c = w\,[T - l] \tag{3.1}$$
    where c is consumption, w is the real wage, T is time endowment and l is leisure
  - Budget set $\mathcal{B}$ is the shaded area including the budget constraint
  - subsets of X are e.g. the three dots (can be on the budget line or below)
- Choice rule $C\,(\mathcal{B})$
  - assigns a set of chosen elements for the budget set $\mathcal{B}$
  - (example from Micro I: tangency point between indifference curve and budget line)
  - note that we have not yet introduced any notion of utility function or other

- Now impose some "reasonable" restrictions on budget set $\mathcal{B}$ and choice rule $C(\mathcal{B})$
  - originally proposed by Samuelson (1947, Foundations of Economic Analysis)
  - Weak axiom of revealed preferences implies:
    if $C(\{x, y\}) = x$, then $C(\{x, y, z\}) = y$ is excluded (see Exercise 3.4.1)
- Definition of "revealed preference relation $\succsim^*$"
  - Formal statement
$$x \succsim^* y \Leftrightarrow \text{if } x, y \in \mathcal{B} \text{ then } x \in C(\mathcal{B})$$
  - In words: x is revealed preferred to y if x is chosen whenever both x and y are feasible (i.e. are in the budget set, i.e. can be afforded)
- Interesting feature of this approach
  - Individual choice is analyzed with fundamentals that can be observed
  - We do not need unobservable "preference relationships" but we can work with observable "revealed preference relations"

- What do these approaches share?
  - In both cases, the objective is to understand decision *making*
  - This suggests that this is a process that requires some e.g. thinking
  - Approaches might also allow to capture automatisms
- What is the difference between these two approaches?
  - Preference-based approach works with objects (preferences) which *cannot* be observed (in some objective sense)
  - Choice-based approach works with objects (choices) which *can* be observed
  - A theory of decision making (even though decisions take place in some "black box") can be built on observables only
- Choice-based approach very much in line with "positivism"
  - Philosophy of science (Carnap, Schlick, Wittgenstein) which states that
  - all knowledge either comes from logical derivations (like in mathematics) or is based on objective observations
  - Introspection (pleasure and pain, questionnaire answers) and intuitive knowledge are rejected

3.2.3 Emotions in neoclassical decision making or not?

- Mainstream view
  - Emotions do not play a role in preference-based or choice-based approach to decision making
  - Mas-Colell et al. (1995) write (about the choice-based approach) "theory of individual decision making need not be based on a process of introspection but can be given an entirely behavioral foundation"
  - Varian (1992) writes (about preference-based approach) "A utility function is often a very convenient way to describe preferences, but it should not be given any psychological interpretation"

- My reading of the choice-based approach
  - clearly "observation-only" structure
  - behaviouristic approach (in the psychological sense), positivists (in philosophical sense) should be happy
  - no emotions around, simply not needed, all based on objectively observable quantities

- My reading of the preference-based approach
  - As always with economic methods: open for any extension, extremely flexible setup
  - What are preference relationships? Tastes! (Mas-Colell et al., 1995)
  - I prefer x to y means (can be understood as) I have a more positive feeling when I own x as compared to y
  - Preference-based approach is perfect to put emotions into economic model building
  - Economics is open for a "cognitive revolution" (cmp. Brandstätter et al., 2010) as it took place in psychology

- Are there emotions in neoclassical decision making or not?
  - There are not, at least in standard interpretation of textbook decision models
  - There are alternative interpretations (preference relationships describe feelings)
  - There is room for allowing for emotions in textbook setups
- We can use economic tools
  - to understand emotions
  - to understand the effect of emotions on decisions
- (This could even be ‘standard economics’ as defined by Gul and Pesendorfer, 2008, see also Camerer, 2008)

3.3 Emotions in behavioural economics – the current view

- Behavioural economics goes further than state-dependent preferences
- Among the many departures, one big departure consists in making a distinction between
  - decision utility and
  - experienced (or true) utility
- People phrase this distinction in different ways
  - "What makes individuals happy ('true utility') differs from what they choose. Economic welfare analysis should use true utility rather than the utilities governing choice ('choice utility')" (Gul and Pesendorfer, 2008)
  - An example (from Kahneman et al., 1997): A person suffering from amnesia has two toasters in their kitchen. The toaster on the right functions normally. The toaster on the left delivers a painful electric shock when the toast is removed. Because of the amnesia, the person is always indifferent between the toasters, their decision utility for using the two toasters is equal. Experienced utilities are quite different
  - Maximizing decision utility will not maximize experienced utility
  - This example raises "doubts about a methodology in which observed choices provide the only measure of the utility of outcomes" (Kahneman et al., 1997, p. 376)

3.3.1 Back to Bentham

- Building blocks of Kahneman, Wakker and Sarin (1997): four building blocks
  - two notions of experienced utility
    * instant utility as "a measure of hedonic and affective experience" based on immediate subjective reports
    * remembered utility is based on subjective "reports of the total pleasure or displeasure associated with past outcomes"
  - total utility: normative concept based on instant utility "according to a set of normative rules"
  - decision utility: inferred from choices

- Basic idea
  - instant utility is how the individual feels at a certain moment
  - remembered utility is a biased account of instant utility
  - decisions are biased and do not maximize instant (or total) utility

- Character of this paper
  - suggests a research programme – does not answer all questions that are raised
  - "The relations among the various utility concepts define a complex agenda for research"
- Can we measure all of this?
  - instant utility: Experience sampling (instantaneous report at random point in time of various preprogrammed questions)
  - remembered utility: questionnaires
  - decision utility: observe choices

- Summary
  - Feelings are at the center of understanding human behaviour
  - Decision does not necessarily maximize well-being
  - Individuals do not necessarily do what is best for them ("therapeutic approach" of behavioural economics)
  - BIG difference to neoclassical approach: utility maximization and decision are the same (by construction)

3.3.2 Happiness literature

- A by now well-established (empirical) literature studies the determinants of "happiness"
  - Happiness is measured by self-reports of subjective well-being
  - Typical question read (from Benjamin et al., 2012, p. 2083)
    - "All things considered, how satisfied are you with your life as a whole these days?"
    - "Taken all together, how would you say things are these days—would you say that you are very happy, pretty happy, or not too happy?"

- A short history of happiness research (see Frey and Stutzer, 2002, p. 403 onwards)
  - Easterlin (1974) – does happiness rise when countries become richer over time?
  - Clark and Oswald (1994), Di Tella, MacCulloch, and Oswald (2001), Ohtake (2012)
    - unemployed workers are less happy than employed workers (at otherwise identical characteristics - see Exercise 3.4.2)
    - but see Gielen and van Ours (2014): activation policies still needed despite unhappy unemployed workers
  - argue that self-reports of subjective well-being are a good measure of utility of an individual

- The link between happiness research/ subjective well-being and (utility) theory
  - There is no link between choice-based approach ("objective well-being", Frey and Stutzer, 2002) and measures of subjective well-being ("subjective well-being")
  - Frey and Stutzer (2002) see measures of subjective well-being as "complementary path to study the world"
  - Aghion et al. (2016) undertake a remarkable (empirical and theoretical) study of the effect of turnover on life-satisfaction
    - In this paper, "(l)ife satisfaction is captured by the average present value of an individual employee" (p. 3874), i.e. by the value function from dynamic programming (intertemporal utility under optimal behaviour)
    - This is the return of Bentham again, the utility function is seen as representing *experienced* utility

- Conclusion
  - Happiness research in economics is all about emotions
  - Integration into theoretical structures of economics still needed (beyond Aghion et al., 2016)
  - Some interesting empirical questionnaire findings come from Benjamin et al. (2012)
    $\rightarrow$ choices are determined by their effect on (expected) subjective well-being
    $\rightarrow$ choices are also influenced by "sense of purpose", "control over life", "family happiness" and "social status"
  - Many ideas and "stylized facts" for explanations available, explanations (theory) still missing

3.3.3 Experienced utility vs. decision utility in theory

- Regret theory
  - Loomes and Sugden (1982) explicitly put themselves in the tradition of Bernoulli and Marshall
  - They understand the choiceless utility function they employ as “the psychological experience of pleasure that is associated with the satisfaction of desire”
  - They write about “the utility being experienced” in choiceless situations
- Disappointment (vs. elation) theory
  - Loomes and Sugden (1986) follow the same approach
  - Experienced utility depends on utility from outcome and on some reference point
  - Reference point is prior expectation (see below for details)

- Evolutionary efficiency and happiness
  - Rayo and Becker (2007) model happiness as a tool to rank alternatives
  - Happiness is a decision making device
  - Explains why measures of happiness return to their mean in the long run (see Easterlin paradox)
  - Another example of hedonic view of utility

3.4 Exercises

3.4.1 Decision-making: preference- and choice-based approaches

1. *Weak axiom of revealed preferences* – Imagine you discuss with your friend what to do on the weekend. The choice is between *cinema* and *theatre*. You leave the choice to your friend and s/he chooses *theatre*. Next weekend comes and a big *pop concert* takes place. You leave the choice again to your friend and s/he chooses *cinema* this time. You recall the weak axiom of revealed preferences and you feel puzzled. Why?

2. *Rationality* – Given that the choices of your friend puzzled you, you now say, next weekend I decide. You tell your friend I always prefer *cinema* to *theatre* and I always prefer *theatre* to *pop concert*. Next weekend, you have the choice between *cinema* and *pop concert* and you suggest to go to the *pop concert*. Now your friend tells you that you are not rational. You recall the definition of rationality, What do you reply to your friend?

3.4.2 Happiness and unemployment (Clark & Oswald, 1994)

1. Looking at the standard consumption-leisure choice shown in Figure 4, what would the optimal solution be for consumption and leisure? We assume that the individual utility function rises in consumption $c > 0$, and in leisure $0 < l < T$, where T is the total time endowment of the individual,
$$u(c, l) = \ln c + \alpha l,$$
with $\alpha > 0$. Use the budget constraint from equation 3.1, given by
$$c = w[T - l].$$

2. Labelling your answers above as c^* and l^*, what would happen to the individual's optimal utility, $u^* := u(c^*, l^*)$, if α increased?

3. Would utility be higher if we had $l = T$, i.e. if the individual were to be unemployed? Is it even possible?

4. Now assume that consumption can be financed entirely by unemployment benefits, such that optimal consumption c^* is still feasible. Would the individual prefer to have $l = T$ now?

5. Why are the findings by Clark & Oswald (1994) so surprising to economists compared to the standard consumption-leisure model above?

4 How do economists model emotions?

4.1 Background: Expected utility maximization

- Before we go deeper into models of emotions, we need some background related to uncertainty
  - How does homo oeconomicus treat risk?
  - Answer: they maximize expected utility
- We take a standard example from business cycle analysis as motivation
  - This extends business cycle analysis from Makroökonomik I to allow for uncertainty
  - Will be used later in this lecture when looking at business cycles and anxiety
  - A textbook treatment is in Wälde (2012, ch. 8.1.4)

- Budget constraints
  - An individual lives for two periods
  - [We could allow for uncertainty in one-period setup or in many periods as well]
  - Budget constraint in the first period (period t)

    $$w_t = c_t + s_t$$

    where w_t is the wage, c_t consumption and s_t stands for savings in t
  - Budget constraint in the second period (imagine individual is retired) reads

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

    where left-hand side is income in period $t+1$ (savings plus interest r_{t+1} on savings) and right-hand side is consumption expenditure
  - [Identical to setup in Makroökonomik I]
  - Now assume that the interest rate r_{t+1} is uncertain, i.e. its value is not known in the first period t

- Describing uncertainty
  - How do we model this uncertainty technically? We make r_{t+1} a random variable
  - We assume that r_{t+1} is a *discrete* random variable with realizations $r_{i,t+1}$ and probabilities p_i with $i = 1, ..., n$ such that $\sum_{i=1}^{n} p_i = 1$
  - As a consequence, the individual in period t does not know the consumption level c_{t+1}
  - A random variable is an example of what decision theorists call a lottery: A collection of outcomes and their probabilities
  - For our example, the lottery (without the time index) is $(r_1, p_1, r_2, p_2, ..., r_n, p_n)$
  - Some authors define a lottery as the collection of probabilities only $(p_1, p_2, ..., p_n)$

- Preferences
  - Individual consumes in both periods
  - Instead of the "Makroökonomik I" utility function $U_t = \gamma \ln c_t^y + (1-\gamma) \ln c_{t+1}^o$, we write
$$U_t = u(c_t) + \beta u(c_{t+1})$$
(i.e. we generalize the utility function from ln to some concave $u(.)$, with $0 < \beta < 1$)
  - We also need to take uncertainty into account: the individual needs to form expectations as consumption c_{t+1} is uncertain
$$U_t = u(c_t) + \beta \mathbb{E}_t u(c_{t+1})$$
  - $\mathbb{E}_t$ is the expectations operator saying that individual forms expectations in t and takes all knowledge up to and including t into account
  - We talk about an *expected utility maximizer*, when the utility function is of the von Neumann-Morgenstern form, i.e. when we write
$$\mathbb{E}_t u(c_{t+1}) = \sum_{i=1}^{n} p_i u(c_{i,t+1})$$
  - In words: there are utility levels $u(c_{i,t+1})$ for each outcome $c_{i,t+1}$ and p_i is the probability of this outcome

- Solving the maximization problem
  - First, replace consumption levels by expressions from budget constraints
  - This gives nice trade-off for choosing s_t

$$U_t = u\left(w_t - s_t\right) + \beta \mathbb{E}_t u\left(\left(1 + r_{t+1}\right) s_t\right)$$

  - Next, let us be clear, what this expectations operator is
  - Then, assuming that the individual forms *rational expectations*, we write

$$\mathbb{E}_t u\left(\left(1 + r_{t+1}\right) s_t\right) = \sum_{i=1}^{n} p_i u\left(\left(1 + r_{i,t+1}\right) s_t\right)$$

  - Forming rational expectations means that the individual uses (i) the correct model and (ii) probability distributions to form expectations (e.g. Sargent, 2008)
  - The individual knows how (i) utility is related to savings and interest rates and (ii) correctly applies probabilities to realizations of utility

- Solving the maximization problem (cont'd)

  – Finally, we compute the first-order condition

$$\frac{dU_t}{ds_t} = \frac{d}{ds_t}\left[u\left(w_t - s_t\right) + \beta \sum_{i=1}^{n} p_i u\left(\left(1 + r_{i,t+1}\right) s_t\right)\right]$$
$$= -u'\left(w_t - s_t\right) + \beta \sum_{i=1}^{n} p_i u'\left(\left(1 + r_{i,t+1}\right) s_t\right)\left(1 + r_{i,t+1}\right) = 0$$

  – We rewrite this as

$$u'\left(w_t - s_t\right) = \beta \sum_{i=1}^{n} p_i u'\left(\left(1 + r_{i,t+1}\right) s_t\right)\left(1 + r_{i,t+1}\right)$$
$$= \beta \mathbb{E}_t\left[u'\left(\left(1 + r_{t+1}\right) s_t\right)\left(1 + r_{t+1}\right)\right]$$

  – Using the budget constraints again, we get

$$u'\left(c_t\right) = \beta \mathbb{E}_t\left[u'\left(c_{t+1}\right)\left(1 + r_{t+1}\right)\right]$$

- Understanding the first-order condition
  - First-order condition again

$$u'(c_t) = \beta \mathbb{E}_t \left[u'(c_{t+1})(1 + r_{t+1}) \right]$$

  - Optimal behaviour from the perspective of t compares marginal utilities – just as in deterministic world where the optimality rule would read

$$u'(c_t) = \beta u'(c_{t+1})(1 + r_{t+1})$$

    (only expectations operator is missing)
  - There are many possible marginal utilities in $t+1$ depending on the value the interest rate will take (i.e. on its realization)
  - The individual therefore looks at some average marginal utility (taking the term $1 + r_{t+1}$ also into account) where the weights for each realization is the probability p_i
  - The role of the discount factor β and the interest rate $(1 + r_{t+1})$ is the same as in the deterministic world

- An example

  - Let us use a Cobb-Douglas utility function (like in Makroökonomik I)

$$U_t = \gamma \ln c_t + (1 - \gamma)\, \mathbb{E}_t \ln c_{t+1}$$

  - We get simple rules for optimal behaviour

$$\begin{aligned} c_t &= \gamma w_t \\ s_t &= (1 - \gamma)\, w_t \\ c_{t+1} &= (1 + r_{t+1})\,(1 - \gamma)\, w_t \end{aligned}$$

- Is there any uncertainty left?

  - Yes, r_{t+1} is unknown in t and so is c_{t+1}
  - This implies that realized consumption in $t + 1$ differs from expected consumption

4.2 Ex-post emotions

- Models that analyze regret and elation
  - Disappointment theory of Bell (1985)
  - Regret theory by Loomes and Sugden (1982, 1986)
  - See Bleichrodt and Wakker (2015) for an appraisal of regret theory
  - Disappointment aversion by Gul (1991)
  - Comparison of various approaches by Grant, Kajii and Polak (2001)

4.2.1 Loomes and Sugden (1982) – regret and rejoicing

- Fundamental aspect: individuals compare the outcome of their choices to certain alternatives
- Experienced utility includes (standard) utility from the choice per se but also regret or rejoicing relative to the alternative
- An example
  - Imagine an individual can spend holidays at the beach in Italy (option 1) or in France (option 2)
  - They decides to go to Italy ...
  - ... but there is less sun than in France → they would regret
  - ... and there is more sun than in France → they would rejoice

- The utility function
  - (modified) utility of the individual is given by

$$u(c_{1j}, c_{2j}) = c_{1j} + R(c_{1j} - c_{2j})$$

    where c_{1j} is utility from the choice of option 1 in state j, c_{2j} is utility from choice 2 in state j and $R(.)$ measures regret or rejoicing
  - Individual compares utility when choosing action 1 to utility from action 2
  - This comparison leads to regret (when $c_{1j} - c_{2j} < 0$) or rejoicing (for $c_{1j} - c_{2j} > 0$)
  - When comparison reveals a difference of zero, then there is neither regret nor rejoicing, $R(0) = 0$

- Uncertainty
  - When the decision between 1 and 2 is to be made, the state of the world j is unknown. The individual forms expectations about utility from option 1,

    $$U_1^2 = \Sigma_{j=1}^n p_j u\left(c_{1j}, c_{2j}\right)$$

    and expected utility from option 2,

    $$U_2^1 = \Sigma_{j=1}^n p_j u\left(c_{2j}, c_{1j}\right)$$

  - Obviously, an individual prefers choice 1 to choice 2 when $U_1^2 > U_2^1$ (see Exercise 4.7.1).

4.2.2 Loomes and Sugden's motivation

- What is the basic motivation for regret theory?
- The most cited paper (according to Kim et al., 2006) in economic theory is the paper on 'prospect theory' by Kahneman and Tversky (1979)
- Kahneman and Tversky provide a fundamental critique of expected utility theory by
  - presenting a series of simple experiments where (hypothetical) behaviour of participants violated various assumptions of EU theory
  - providing an alternative theory – baptized prospect theory
- What are the (most important) violations of EU theory?
  - certainty effect: overweigh outcomes that are certain
  - reference point: individuals focus on gains and losses, not on absolute values
  - concavity: individuals are risk-averse and risk-loving

- What does the alternative theory look like?
  - There is a weighting function $\pi(p)$ that takes certainty effect into account
  - Utility of an individual depends on changes, i.e. a reference point is introduced
  - Individuals are risk-averse to gains but risk-loving to losses

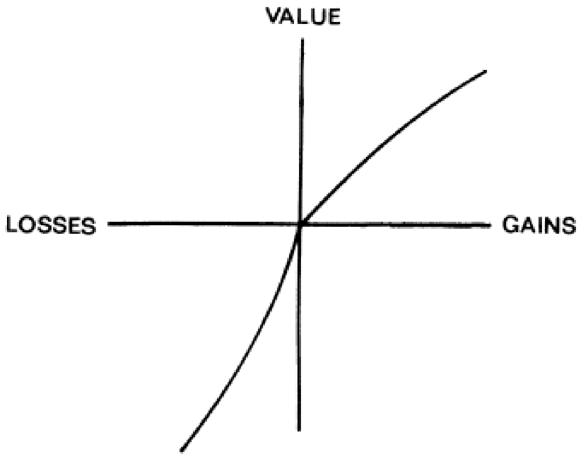


Figure 5 *The value function (fig. 3 from Kahneman and Tversky, 1979)*

- What is the new notation?

  - What is a lottery in EU theory is a prospect in prospect theory
  - Instead of utility function, the term value function is used (not to be confused with value function from dynamic programming)
  - Expected utility is denoted by V and reads (compare e.g. with eq. (1) in Kahneman and Tversky, 1979)

$$V = \sum_{i=1}^{n} \pi(p_i) \, u(x_{i,t+1})$$

    where the outcome in state i is defined relative to a reference point c^{ref}

$$x_{i,t+1} \equiv c_{i,t+1} - c^{\text{ref}}$$

- Reminder EU theory (for comparison purposes): $\mathbb{E}_t u(c_{t+1}) = \sum_{i=1}^{n} p_i u(c_{i,t+1})$ with $u(.)$ concave

4.2.3 Loomes and Sugden (1986) – disappointment and elation

- Their interest: feelings resulting from the difference between the outcome of a choice and some reference point

- Reference point is not another choice (there is no Italy vs. France) but the average consequence of this choice (i.e. utility from being on the beach at various sun intensities). Formally, the reference point for an action 1 is

$$\bar{c}_1 = \sum_{j=1}^{n} p_j c_{1j}.$$

  Expected utility from option 1 is now

$$U_1 = \sum_{j=1}^{n} p_j \left[c_{1j} + D\left(c_{1j} - \bar{c}_1 \right) \right].$$

  This option 1 (the beach) is then chosen relative to option 2 (the mountains) if $U_1 > U_2$.

- And $D(.)$ is a function measuring disappointment/elation

4.2.4 Gul (1991)

- Offers an axiomatic approach (preference based) to understanding disappointment aversion
- Strong alternative to Loomes and Sugden (1982, 1986)
- Motivation is Allais (1979) paradox (which is nicely explained in the paper and which violates the so-called independence axiom)
- Offers a nice overview of how researchers respond to this paradox
  - need for descriptive theory (Kahneman and Tversky, 1979, Loomes and Sugden, 1982, 1986) that ignores "basic desiderata of choice under uncertainty" (p. 669) (inter alia transitivity or stochastic dominance)
  - rejecting the normative appeal of the independence axiom
  - modifying the independence axiom (his approach)
- Offers a one-parameter extension of the von Neumann-Morgenstern expected utility model
- Details are very technical and beyond the scope of this course (but good for Master thesis for MSc Mathematics)

- General aspect raised by his introduction: do we want to model behaviour of individuals in any way which is descriptively acceptable or should we impose various consistency axioms (see above on preference-based approach)?
- (At least) two different "research programmes" (Lakatos) active at the same time
- (unlike "paradigm" (Kuhn) where a scientific revolution replaces one paradigm by another)

4.3 Ex-ante emotions - anxiety, worry and fear

4.3.1 The setup

- Ex-ante or anticipatory emotions (fear, anxiety, positive anticipation, suspense ...) are studied by Caplin and Leahy (2001)
- Applications include Caplin and Leahy (2004) and Kőszegi (2006)
- The setup
  - Two-period decision problem (as seen further above in sect. 4.1)
  - anticipatory emotions as in Caplin and Leahy (2001)

- Reminder of two-period decision problem
  - constraint in the first period (period t)

$$w_t = c_t + s_t$$

    where s_t is savings in t

  - constraint in the second period (individual is retired)

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

    where returns r_{t+1} are uncertain

  - Preferences

$$U_t = \mathbb{E}_t \left[\gamma u\left(c_t\right) + \left(1 - \gamma\right) u\left(c_{t+1}\right)\right]$$

    where γ is the weight on first-period utility relative to second-period utility

- Now we add (anticipatory) feelings
  - Extended utility function

$$U_t = \mathbb{E}_t \left[\gamma u \left(c_t, a_t \right) + (1 - \gamma) u \left(c_{t+1} \right) \right]$$

    where a_t is anticipatory feeling
  - Following Caplin and Leahy (2001), we model feeling as a function of the variance and of the mean of consumption in $t + 1$

$$a_t := a \left(Var_t c_{t+1}, \mathbb{E}_t c_{t+1} \right) \tag{4.1}$$

  - The anticipatory feeling is assumed to rise in the variance and fall in the mean

$$\frac{\partial a_t}{\partial Var_t c_{t+1}} > 0$$
$$\frac{\partial a_t}{\partial \mathbb{E}_t c_{t+1}} < 0$$

  - The feeling is therefore a negative feeling like anxiety

- To obtain tractable results, we need a more specific utility and anxiety functions
  - We assume a Cobb-Douglas structure for anxiety

$$a_t = (Var_t c_{t+1})^{\zeta} (\mathbb{E}_t c_{t+1})^{-(1-\zeta)}$$

  - The "personality parameter" ζ captures the weight of the variance as opposed to the mean
  - Applying logs, we get

$$\ln a_t = \zeta \ln [Var_t c_{t+1}] - [1-\zeta] \ln [\mathbb{E}_t c_{t+1}] \tag{4.2}$$

  - (Log of) Anxiety can take positive or negative values, depending on the variance and mean
  - In the case of a negative (log) anxiety, we would rather talk about 'pleasant anticipation' ("Vorfreude")
  - Why all these functional forms? To capture some intuition and make properties of anxiety plausible

- The overall utility function
  - We choose a Cobb-Douglas utility function as well and apply logs

$$U_t = \gamma \left[\ln c_t - \phi \ln a_t \right] + (1 - \gamma) \, \mathbb{E}_t \ln c_{t+1} \tag{4.3}$$

  - Consumption enters utility in the usual logarithmic way
  - Log-anxiety decreases utility in period t in a linear way due to parameter $\phi > 0$ and minus sign (which translates strong anxiety into negative utility)
  - Parameter γ captures impatience, with $\phi = 0$, we are back to emotion-free individual
  - Expectations $\mathbb{E}_t$ need to be formed about $\ln c_{t+1}$ only

4.3.2 Optimal behaviour and comparative statics

- Optimization
  - Computing the mean and variance of consumption for (4.1) and defining

$$\mu \equiv \mathbb{E}_t \left[1 + r_{t+1}\right],$$
$$\sigma^2 \equiv Var_t \left[1 + r_{t+1}\right],$$

    we can write the objective function as

$$U_t = \gamma \left[\ln \left[w_t - s_t\right] - \phi \left[\zeta \ln \left[s_t^2 \sigma^2\right] - \left[1 - \zeta\right] \ln \left[s_t \mu\right]\right]\right]$$
$$+ \left[1 - \gamma\right] \left[\mathbb{E}_t \ln \left[1 + r_{t+1}\right] + \ln s_t\right]$$

  - Let us try to recognize the individual components in this explicit and distinguish utility in t from utility in $t+1$, (sub-) utility from consumption in t from anxiety in t and the different components of anxiety

- Optimization ...
  - ... now works (as without emotions) by choosing savings s_t
  - ... takes the effects of savings on emotions into account

- Comparative statics: optimal behaviour with "scaring variance" only, i.e. for $\zeta = 1$ (see Exercise 4.7.2)

$$s_t = \frac{1 - \gamma - 2\gamma\phi}{1 - 2\gamma\phi} w_t$$

  - In the absence of anxiety a rational individual would save $s_t^* = (1 - \gamma) w_t$
  - In the presence of anxiety (only variance matters), the individual would save less, $s_t < s_t^*$
  - Why? To avoid anxiety due to consumption variance, the individual would save less as this reduces the consumption level in $t + 1$ and therefore its variance

- Optimal behaviour with pleasant anticipation, i.e. for $\zeta = 0$ (see Exercise 4.7.2)

$$s_t = \frac{1 - \gamma + \gamma\phi}{1 + \gamma\phi} w_t$$

  - We can now make two comparisons
    - Compared to the absence of any emotions ($\phi = 0$), the individual would now save more, $s_t > s_t^*$: the individual experiences positive anticipation only and higher savings lead to higher mean consumption in $t + 1$
    - Compared to the case when they only care about the variance ($\zeta = 1$), the individual saves more now for two reasons: with $\zeta = 1$, she saves less than for $\phi = 0$ (see previous slide), and with $\zeta = 0$, she saves more than with $\phi = 0$
  - For a formal derivation, see the solution to Exercise 4.7.2

- Optimal solution for the general case
  - For some general ζ, we get

$$s_t = \left(1 - \frac{\gamma}{1 - (3\zeta - 1)\gamma\phi}\right) w_t \tag{4.4}$$

  - Allows us to analyze the effect of a more emotional person (ϕ rises) and of a more negative focus (ζ rises, "glass is always half-empty")
  - We find an ambiguous effect for ϕ ...

$$\begin{aligned} \frac{ds_t}{d\phi} &> 0 \Leftrightarrow \frac{d}{d\phi}(1 - (3\zeta - 1)\gamma\phi) > 0 \\ &\Leftrightarrow -(3\zeta - 1)\gamma > 0 \Leftrightarrow \zeta < \frac{1}{3} \end{aligned}$$

  - ... and an unambiguous effect for ζ

$$\frac{ds_t}{d\zeta} < 0 \Leftrightarrow -\gamma\phi < 0$$

4.3.3 Health and fear

[not for the lecture]

- Recent years witnessed a major pandemic
- Individual behaviour adjusted due to infection risk
- Can the Caplin Leahy model be employed to understand behavioural adjustments?
- Setup
  - We study an individual in identical circumstances as above
  - They live two periods, can save and face two budget constraints
  - We endow our creature with feelings based on health

- Modelling feelings
  - Utility function
  $$U_t = \mathbb{E}_t \left[\gamma u\left(c_t, a_t\right) + (1-\gamma) u\left(h_{t+1}, c_{t+1}\right)\right] \tag{4.5}$$
  where a_t is anticipatory feeling and h_{t+1} is health in period $t+1$
  - The individual is healthy $(h_{t+1} = 1)$ with probability p and turns sick $(h_t = 0)$ with probability $1-p$
  - Feeling is a function of the (unknown) health status in $t+1$. As in Caplin and Leahy, we assume that anxiety
  $$a_t = a\left(Var_t h_{t+1}, \mathbb{E}_t h_{t+1}\right)$$
  rises in the variance and falls in the mean
  $$\frac{\partial a_t}{\partial Var_t h_{t+1}} > 0, \quad \frac{\partial a_t}{\partial \mathbb{E}_t h_{t+1}} < 0$$

- Functional forms
  - We assume Cobb-Douglas structures for utility and anxiety functions as before
  - Applying logs, we get

$$U_t = \gamma \left[\ln c_t - \phi \ln a_t\right] + (1-\gamma)\left(\mathbb{E}_t \ln h_{t+1} + \mathbb{E}_t \ln c_{t+1}\right) \tag{4.6}$$

$$\ln a_t = \zeta \ln \left[Var_t h_{t+1}\right] - [1-\zeta] \ln \left[\mathbb{E}_t h_{t+1}\right] \tag{4.7}$$

  - We let consumption in t affect health in $t+1$ (think about consuming a drink in a club in times of high infection risk) via infection risk

$$p = p\left(c_t\right) = \pi c_t$$

where π is sufficienty small such that $p < 1$.

- Solving the model
  - Expected health is given by

$$\mu \equiv \mathbb{E}_t h_{t+1} = p \times 1 + (1-p) \times 0 = p$$

  - The variance of health is

$$\sigma^2 \equiv Var_t h_{t+1} = (1-p)\, p$$

  - We can now express the objective function as

$$U_t = \gamma \left[\ln\left[w_t - s_t\right] - \phi\left[\zeta \ln\left[(1-p)\, p\right] - \left[1-\zeta\right] \ln p\right]\right] \quad (4.8)$$

$$+ (1-\gamma)\left(\mathbb{E}_t \ln h_{t+1} + \mathbb{E}_t \ln\left[1 + r_{t+1}\right] + \ln s_t\right) \quad (4.9)$$

    where

$$p = \pi\left[w_t - s_t\right].$$

- Optimal behaviour
  - Now assume for simplicity that $\zeta = 0$ (i.e. the individual only cares about the mean – what is an appropriate interpretation?)
  - Then the objective function simplifies to

$$
\begin{aligned}
U_t &= \gamma \left[\ln \left[w_t - s_t\right] + \phi \ln \pi + \phi \ln \left[w_t - s_t\right]\right] && (4.10) \\
&\quad + (1-\gamma)\left(\mathbb{E}_t \ln h_{t+1} + \mathbb{E}_t \ln \left[1 + r_{t+1}\right] + \ln s_t\right). && (4.11)
\end{aligned}
$$

  - The first-order condition then reads ... and interpretation is ... and people save more or less ... and the like ...

4.4 Immediate emotions

4.4.1 Hunger, thirst, pain, desire

- ‘Emotions that are the result of a bodily state’
- State-dependent preferences - an example (see Exercise 4.7.3)
  - Individuals are hungry and thirsty

$$u\left(c_{Food}, c_{Drink}\right) = \left(c_{Food} - h\right)^{\alpha}\left(c_{Drink} - t\right)^{1-\alpha}$$

  - Marginal utility from food $\alpha\left[\frac{c_{Drink}-t}{c_{Food}-h}\right]^{1-\alpha}$ rises, when hunger h rises
  - Same is true for drinks and thirst t
  - One could call marginal utility from food or drink a ‘desire’ – this would be an example how standard neoclassical analysis would allow the modelling of feelings
  - Tip for life: never go shopping when hungry, you buy way too much

- State-dependent preferences à la Loewenstein (2000)

  – General formulation by Loewenstein (2000)

$$U_t = \sum_{t=0}^{T} u(c_t, s_t)$$

  – This is more general in the sense of (i) there is some state s_t (not to be confused with savings from before!) with no specification of whether this is hunger or thirst or other, (ii) it captures many periods and (iii) c_t and s_t can be vectors, capturing many consumption goods and many states (angry at one person, happy about some big personal achievement and excited about holidays coming soon)

- Caveat: people generally do not remember well emotions in past visceral states, leading to projection bias (Loewenstein, O'Donoghue and Rabin, 2003)

4.4.2 Laibson (2001) - Cue theory of consumption

- 'Emotions that are the result of an external stimulus'
- The idea
  - Preferences of individuals are not stable and invariant over time and contexts
  - Preferences rather depend on the environment a person is in and on the cues present in this environment
  - There are clinical examples (think of addicts of alcohol or other drugs) but there are also everyday examples
  - "Consider cues like the smell of cookies baking, smell of perfume/cologne, sound of ice falling into a whiskey tumbler, sight of a bowl of ice cream, and sight of a pack of cigarettes" (Laibson, 2001, p. 82)
  - The economically revolutionary statement: "preferences are sensitive to cues like these" (p. 82)
  - Analysis builds on and combines earlier work by Becker and Murphy (1988, 1993)

- Evidence from psychological conditioning
  - Classic conditioning pairs a neutral stimulus (conditional stimulus, CS, in psychologists' terms) with a non-neutral stimulus (unconditional stimulus, UC)
  - Pavlov's dog heard a bell ring (CS) joint with injection of meat-powder in the dog's mouth (UC)
  - The meat-powder leads to salivation, to physiologically prepare the dog for food ingestion
  - When the two stimuli were presented jointly sufficiently often, the ring of a bell would also lead to salivation
- The idea in more detail
  - Central "translation" of psychological findings into economics: "cue-triggered preparatory <...> responses tend to raise the marginal utility of consumption" (p. 85)
  - What is generally called a "craving", "strong desire", "lust", "greed" or other is, in economic terms, "higher marginal utility"
  - The cue triggers a "preparatory process" (like salivation) which affects marginal utilities and makes preferences conditional on cues

- The individual's environment
  - Individual lives in discrete time $t = 1, 2, 3, ...$
  - At each point in time t, the world can be in two states i: either the cue can be RED or GREEN
  - We denote these states by $i \in \{R, G\}$ that occur with a certain probability

$$i_t = \left\{ \begin{array}{c} R \\ G \end{array} \right\} \text{with probability} \left\{ \begin{array}{c} \mu^R \\ 1 - \mu^R \equiv \mu^G \end{array} \right. .$$

  - (This seems not very intuitive. When we talk about a "bad cue" (like alcohol, tobacco or other adds), maybe one should think of RED as "cue is present" and GREEN = "not present")

- Preparatory process
  - (simplified version as compared to the paper)
  - Bodily state x_t is a function of the cue

$$x_t = x(i_t)$$

  - We assume that $x(R) > x(G)$, i.e. the body is better prepared for e.g. food when the cue is RED (i.e. present)

- Preferences
  - (simplified version as compared to paper)
  - In state i, the utility function of our consumer is given by

$$u\left(c_t^{\text{sweets}}, c_t^{\text{fruit}}\right) = \left(c_t^{\text{sweets}} - x_t\right)^{\alpha} \left(c_t^{\text{fruit}}\right)^{1-\alpha}$$

  - Preferences are clearly "cue-contingent"
  - As the cue is a state variable (it describes the state of the world/ environment of the individual), preferences are (again) state-dependent
  - Laibson writes "the functional form of this meta-utility function is not chosen by the consumer but is instead biologically predetermined"
  - In other words, α and functional structure is stable, but x_t changes

- Constraint
  - There are prices p^s and p^f and endowment E
  - This gives a standard budget constraint

$$p^s c_t^{\text{sweets}} + p^f c_t^{\text{fruit}} = E$$

- Optimal behaviour
  - Optimal behaviour similar to hunger and thirst setup: marginal utility from sweets rises in x_t
  - As x_t is higher in the presence of the RED cue (ads for chocolates or ice cream), cues induce individuals to change their consumption choices
  - We see the new intercept for c^{fruit} at $-x_t \frac{1-\alpha}{\alpha} \frac{p^{sweets}}{p^{fruit}} \rightarrow$ no matter how much c^{fruit} you consume, it cannot make up for c^{sweets} being below the minimum level (x_t) induced by the cue
  - see figure on next slide

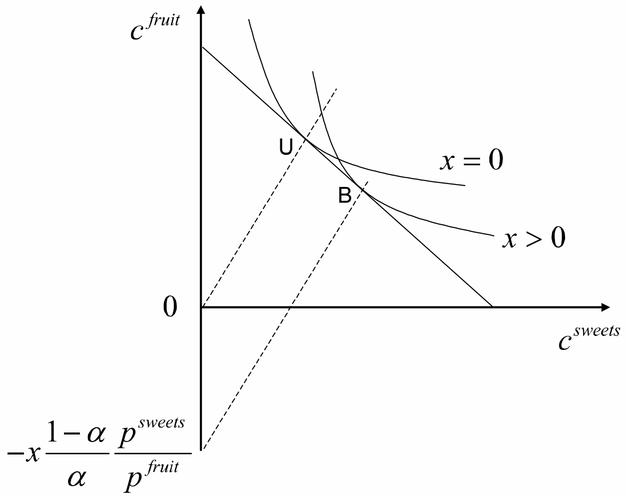


Figure 6 *Optimal consumption of sweets and fruit in the absence ($x = 0$ implies Unbiased consumption) and in the presence of cues ($x = 1$ implies Biased consumption)*

- Optimal consumption ratios satisfy (see Exercise 4.7.4)

$$\frac{c_t^{\text{fruit}}}{c_t^{\text{sweets}} - x_t} = \frac{1-\alpha}{\alpha}\frac{p^{\text{sweets}}}{p^{\text{fruit}}} \Leftrightarrow c_t^{\text{fruit}} = \frac{1-\alpha}{\alpha}\frac{p^{\text{sweets}}}{p^{\text{fruit}}}\left(c_t^{\text{sweets}} - x_t\right)$$

- What is the difference with hunger or thirst?
  - We have a formal theory of how external (non-chosen) cues affect human behaviour
  - Hunger and thirst can be seen as natural determinants of consumption behaviour
  - With advertisements (or cues, more generally), individual behaviour can be influenced from the outside
  - Individuals might experience certain desires only because of this influence
  - Individuals still behave optimally, but only subject to the exogenously given cues
  - If individuals were able to choose cues, they would experience higher utility
- Any real-world relevance?
  - The latter is to some extent the idea behind self-control and official control of advertisements
  - no ads for baby food in British maternity wards (Geburtsstationen in Kliniken)
  - no ads for sweets in kindergartens/ nurseries
  - no ads for tobacco and alcohol close to schools and kindergartens (only being discussed?)
  - for self-control, see e.g. www.werberat.de

4.4.3 Stress (Wälde, 2015)

- **Definition:** Stress occurs when demands exceed resources (Lazarus and Folkman, 1984, Stress, Appraisal and Coping)
- Psychological background
  - A standard view in psychology on stressful episodes can be illustrated as follows

$$\text{Stressor} \rightarrow \text{appraisal} \rightarrow \text{(change in) stress} \rightarrow \text{coping}$$

  - Two sources of stressors: daily hassles (e.g. 'losing keys'), rare events (e.g. 'getting married')
  - Appraisal process: evaluation of a stressor with respect to one's objectives
  - Outcome of appraisal leads to more (or less) stress
  - Coping: behaviour targeted at controlling stress level
  - Coping can be controlled vs. automatic, problem-focused vs. emotion-focused and functional vs. dysfunctional

- What is captured in the model?
  - Two sources of stressors
  - A (simple) appraisal process capturing personality of a person
  - Two coping styles: controlled and automatic ('emotional outburst')
  - Emotion-focused approach of coping (not problem-focused)
- Why care and what to do about stress?
  - Individual (experienced) utility $u(c(t), W(t))$ falls in stress $W(t)$
  - Stress also reduces labour effort (cognitive load argument)
  - Stress (=distress) is bad here (think about distress vs. eustress)
  - Individual maximizes utility by choosing controlled coping $m(t)$ in an optimal way anticipating the outbursts

- A sketch of the economic modelling of stress
  - Stress is a (subjective) state variable and changes as a function of daily hassles and rare events
  - Looking only at daily hassles, stress $W(t)$ follows an ordinary differential equation

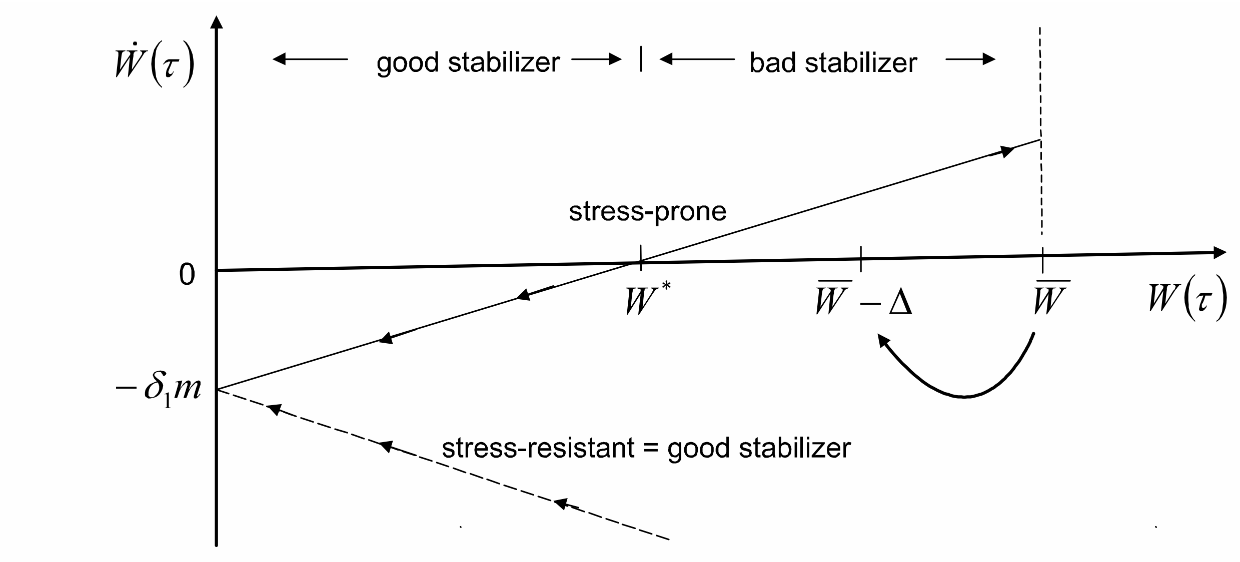
$$\dot{W}(t) = \Phi W(t) - \delta_1 m$$

  - the parameter Φ is the growth rate of stress

$$\Phi \equiv \phi \frac{p}{a} - \delta_0$$

  - daily hassles (the number of emails p relative to ability a) is the intensity of the stressors
  - controlled stress reduction methods m (talking to a friend, doing sports) is coping
  - the optimal amount (measured e.g. in hours per day) is constant (see paper, but **not** for exam)
  - the appraisal of the stressors is captured by the parameter $\phi > 0$
  - the effect of coping on stress reduction is described by δ_1
  - the parameter δ_0 describes an 'autonomous stress reduction potential'

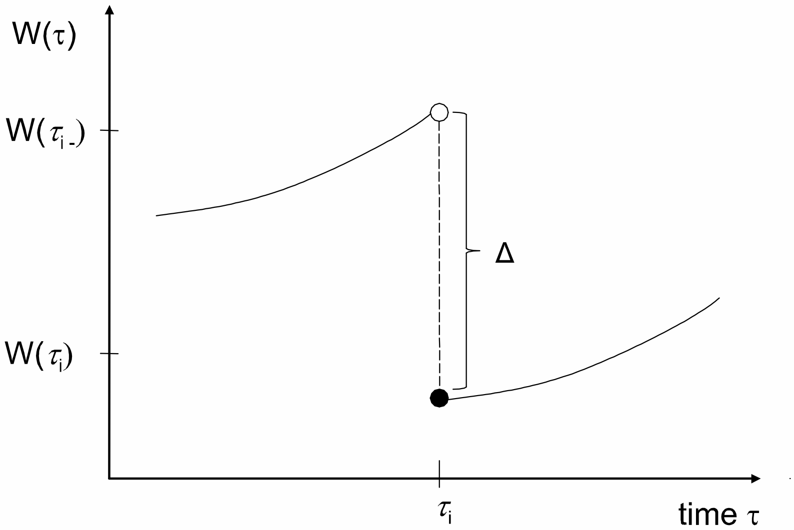
- A phase diagram illustration (see Exercise 4.7.5)



- The outburst level $\bar{W}$
  - Whenever the stress level rises too much, i.e. whenever it hits $\bar{W}$, the individual is 'overwhelmed', loses control over behaviour and experiences an emotional outburst
  - An emotional outburst can be anything from 'shouting at friends' to 'drinking excessively' (see the 'conflict tactic scale', e.g. Straus et al., 1996)
  - This is the uncontrolled (not rational expectations, behavioural) part of coping (behaviour)

- The good side of outbursts
  - Stress falls following an emotional outburst

$$W(\tau_i) = W(\tau_{i-}) - \Delta$$

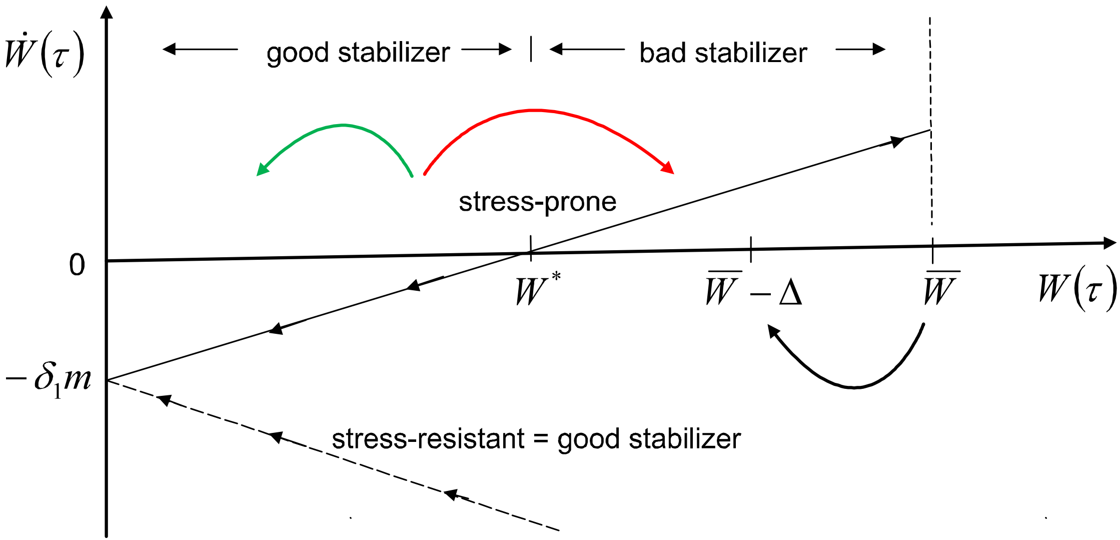


- The role of surprises
  - Coming back to rare events (like ‘getting married’, ‘losing a job’, ‘publishing a paper’ and other), they are modelled as surprises
  - Surprises $g(t)$ can be positive or negative
  - Random variable $h(t)$ and subjective expectation μ yield surprise

$$g(t) = h(t) - \mu$$

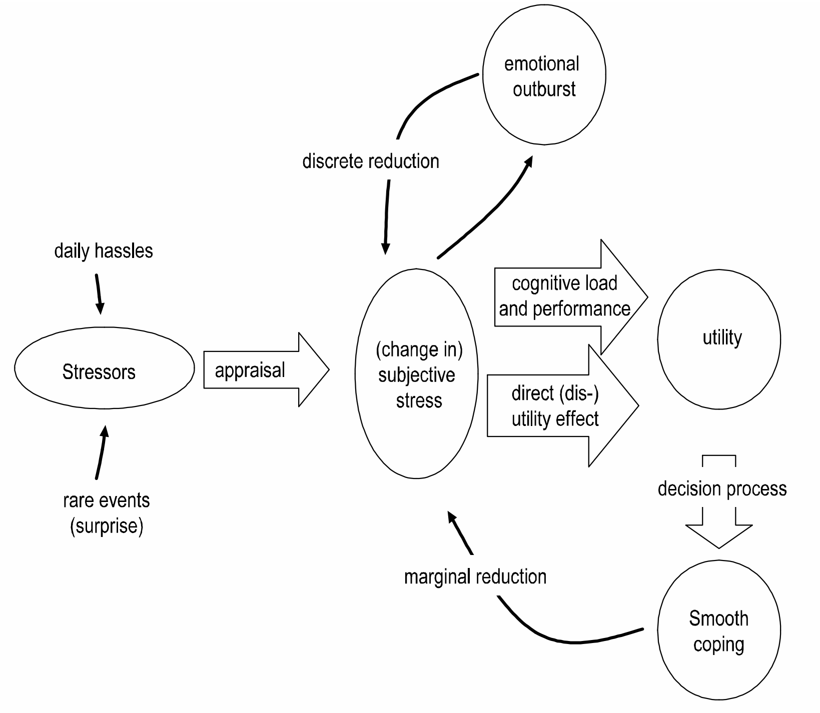
    (Bell, 1985, Loomes and Sugden, 1982, 1986)
  - surprises occur at a certain arrival rate
  - (dynamic continuous time model with Poisson uncertainty)

- Another (more complete) phase diagram illustration ...



- ... that also shows surprises and outbursts

- A graphical illustration of the model



- Results
  - Theory-consistent personality definitions: *stress-resistant* individuals never display outbursts, *stress-prone* individuals do if stress level is too high
  - Outburst theorem: any individual will turn from stress-resistant to stress prone if e.g. work-load rises
  - For a given work-load, (endogenous) coping measures can make outbursts disappear
  - Outbursts should not be suppressed
  - Temporary stressors can have permanent effects, but only for stress-prone individuals
  - Structural estimation of personality parameters possible
  - Analysis of therapy shows: being emotional and pessimistic maximizes subjective well-being

4.5 Belief-based emotions

4.5.1 Psychological game theory

- There is a general framework in economics that does *not* focus on one specific emotion but that proposes a general setup that can cover *classes* of emotions
- Geanakoplos, Pearce and Stacchetti (1989) model emotions that are based on *beliefs*
- Battigalli and Dufwenberg (2009) provide a generalization
- Downside of generality: they do not focus on one specific emotion and thereby cannot cover all the specific aspects of this one specific emotion
- Why is this of interest?
    - First, it allows us to understand emotions and their role in decision making
    - Second, models with beliefs are very common in economics
    - Third, game theory is also very useful tool
- Are belief-based emotions immediate, ex-ante or ex-post? Let's see ...

4.5.2 Game theory: background and extensive form games

- Background → see slides Mikroökonomik I
- To understand insights on emotions, we only need “common sense”

4.5.3 Psychological game theory: the bravery game

Geanakoplos, Pearce and Stacchetti (1989, p. 66)

- The idea (first part)
  - Imagine there are two individuals, called player 1 and player 2
  - Player 1 must take a decision and is concerned what his friend (player 2) thinks about him
  - His strategy space is $A = \{\text{bold,timid}\}$, player 2 does not make any decision
  - Player 1 can choose pure strategies or attach a probability p to being bold when playing mixed strategies
  - Payoffs for player 1 are (for the time being) given by 2 and 3 as shown in the figure

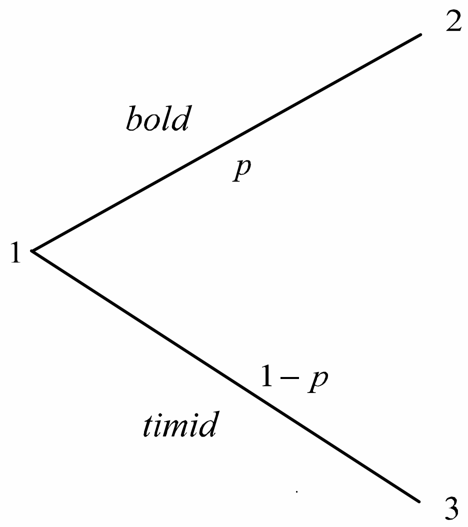


Figure 7 *A (not so hard) decision to be made by player 1 with standard payoffs*

- Player 1 will optimally decide to be timid as payoffs are highest with this pure strategy $(3 > 2)$

- The idea (second part)
  - While player 2 does not make a decision, it is good for player 2 if player 1 is actually bold
  - This is what we see in the extended figure with payoffs for both players depending on the decision of player 1
  - The payoff of player 1 is given first, followed by the payoff of player 2

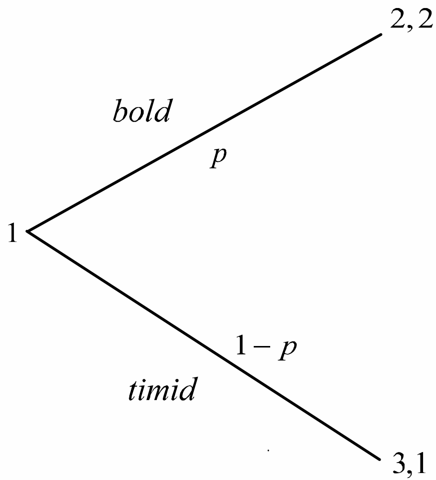


Figure 8 *A decision to be made by player 1 with standard payoffs for both players*

- Choice of player 1 would now depend on the weight he attaches to payoff of player 2
  - focus only on own payoff: be timid
  - focus only on other payoff: be bold

- The idea (interesting and final part – which makes this a psychological game)
  - Beliefs of player 2
    - Player 2 prefers to think of her friend as bold
    - This "materializes" in payoffs of player 2 to depend on her belief q about the probability p that player 1 acts bold (formally, q is the mean of p: $q = \mathbb{E}[p]$)
    - As player 2 *prefers* to think that player 1 is bold, the payoff of 2 rises in q when 1 *acts* bold and falls in q when 1 *acts* timid (big disappointment)
    - [$\rightarrow$ is this minus sign in $1 - q$ convincing?]
  - Beliefs of player 1
    - As player 1 is also concerned about what his friend thinks about him (see above), player 1's payoff also depends on what he believes about what player 2 believes
    - This belief is denoted by $\tilde{q} = \mathbb{E}[q]$
    - We assume that player 1 does not want to disappoint player 2 (who wants to think of player 1 as bold). As a consequence, the payoff of player 1 falls in $\tilde{q}$
  - Psychological game theory: games where payoffs depend on beliefs and not only on actual real outcomes

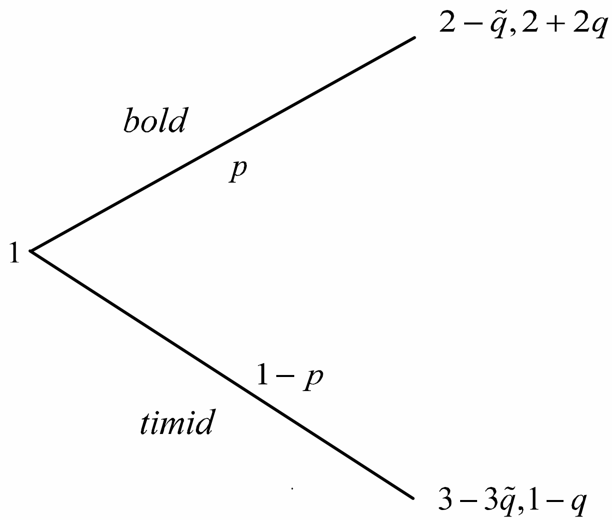


Figure 9 *The full structure of the bravery game*

- Who wants what?
  - Beliefs obviously play a central role in this game

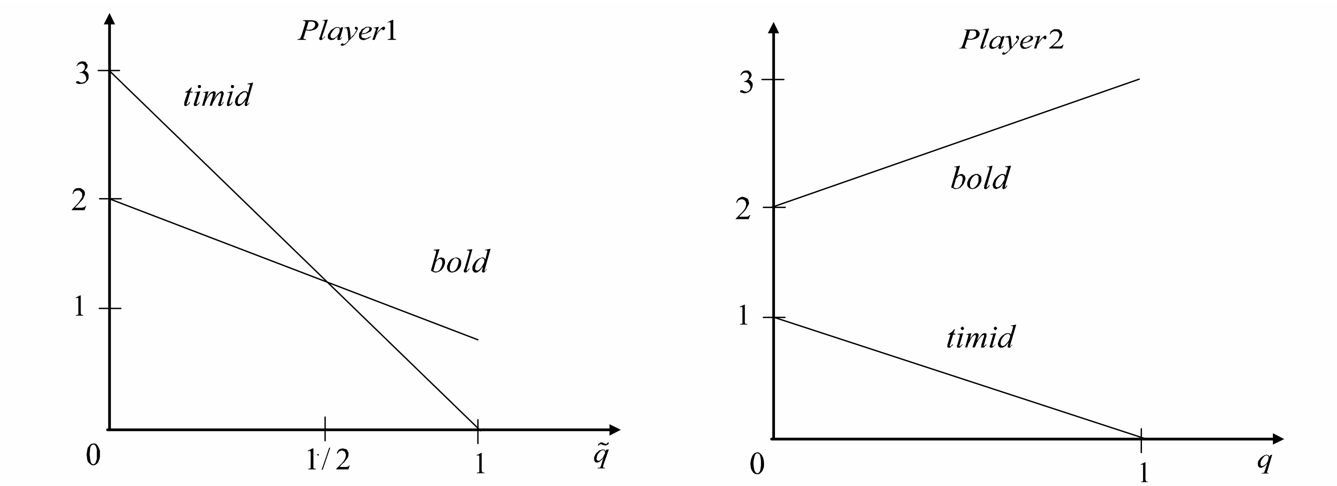


Figure 10 *Payoffs as a function the behaviour of player 1 and of beliefs*

- What is equilibrium behaviour?
  - Big question: how does player 1 behave?
  - What if there were no beliefs (i.e. if this was not a psychological game)?
    - Then we would be back to fig. 7 and player 1 would act timid
    - There would be a unique equilibrium
  - If there are beliefs, various equilibrium assumptions are imposed: equilibrium requires (by definition of equilibrium) that
    - beliefs are consistent with behaviour: an outcome would *not* be called an equilibrium if e.g. player 2 believes that player 1 is bold but player 1 acts timid
    - beliefs are shared among players: $p = q = \tilde{q}$
  - How does player 1 behave under these assumptions?
  - We will now see that the introduction of beliefs introduces more equilibria than in the absence of beliefs

- Equilibrium behaviour (see Exercise 4.7.6)
  - Let us try: can $p = 1$ (and thereby $q = \tilde{q} = 1$ as well) be an equilibrium?
    * In this case, payoffs are $(1, 4)$ for bold and $(0, 0)$ for timid
    * Player 1 would choose bold
    * ... which is consistent with the belief of player 2 that player 1 is bold
    * One equilibrium found!
  - Can $p = q = \tilde{q} = 0$ be an equilibrium?
    * In this case, payoffs are $(2, 2)$ for bold and $(3, 1)$ for timid
    * Player 1 would choose timid
    * ... which is consistent with the belief of player 2 that player 1 is timid
    * Another equilibrium found!
  - Any other equilibrium on offer? Looking at fig. 10 suggests $p = q = \tilde{q} = 1/2$
    * In this case, payoffs are $(1.5, 3)$ for bold and $(1.5, 0.5)$ for timid
    * Payoffs for mixed strategy are $(1.5, 1.75)$
    * Player 1 would be indifferent
    * ... which is consistent with the belief of player 2 that player 1 is indifferent
    * And another equilibrium found!

- What do we learn about emotions?

  - Maybe not so much?
  - Emotion words are used (timid, bold), but they can be replaced by anything (red-green, up-down, left-right, ...)
  - Beliefs are very important and obviously play a huge role in determining behaviour of individuals
  - But why do beliefs stand for emotions? Is there any surprise (as in regret theory) or any anticipation, any tension between demands and resources (as in stress theory)?
  - Maybe emotion words are only colourful and bloomy words for an important but simple concept: expectations

- Let us see whether applications of this theory bring us closer to understanding emotions (see next section)

4.5.4 Guilt

- Psychological background

  - Baumeister et al. (1993) document that a person who rejects a relationship partner often suffers from guilt
  - Baumeister et al. (1994, 1995, p. 174) report that: "the prototypical cause of guilt is inflicting harm or distress on a relationship partner"

- Economic models

  - Dufwenberg (2002), with guilt in marriage seems to be the paper where guilt is first introduced
  - Charness and Dufwenberg (2006) "promises and partnership" models guilt and guilt aversion joint with communication
  - They stress that this is important more generally – analysis of guilt in trust games (Battigalli and Dufwenberg 2007)
  - Battigalli and Dufwenberg (2007) have two concepts of guilt aversion - "simple guilt" means that "a player cares about the extent to which he lets another player down" and "guilt from blame"
  - Charness and Dufwenberg (2011) is application to experiments

- The simplest model (Dufwenberg, 2002, on marriage)

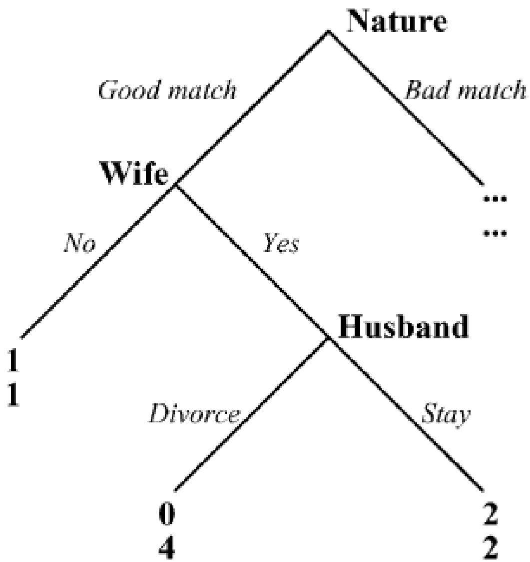


Figure 11 *The marital investment game (Dufwenberg, 2002, fig. 1)*

- The idea of the game
  - A man and a woman meet – and nature determines whether it is a good or bad match
  - If nature leads to a good match, the wife can support her husband and e.g. support his application to a job where she works, stay in her current job and take fewer holidays or not
  - If she does not support the husband, they both earn some income leading to a payoff of $(1, 1)$
  - If she does support the husband, he can study and get a more rewarding job (going with the second example above)
  - The husband can now be opportunistic and *divorce*. His payoff would be 4, the wife's payoff would be 0
  - If the husband *stays*, he would share his income and payoffs are $(2, 2)$

- Equilibrium
  - How do husband and wife behave optimally in this setup?
  - First, neither of the two prefers a *no* by the wife to a *yes-stay*
  - Both prefer a stable marriage with the husband earning money and splitting the total income at home to the wife and husband both earning a bit of money
  - But, once wife has said *yes*, it is optimal for husband to quit ("dominant strategy")
- Solution concept
  - subgame perfect equilibrium: a strategy profile is a subgame perfect equilibrium if it represents a Nash equilibrium of every subgame of the original game
  - Unique strategy profile is (*no*, *divorce*)
  - Husband cannot credibly promise to *stay* when wife makes support/no-support decision
  - This strategy profile is inefficient

- Remark on a personal note
  - Looking at partnerships in this way is scary, weird, simply “gruselig”
  - Emotional aspect is missing – affection to wife/husband and kids
  - Let us see how Dufwenberg makes the analysis more emotional

- Adding guilt to the marital investment game

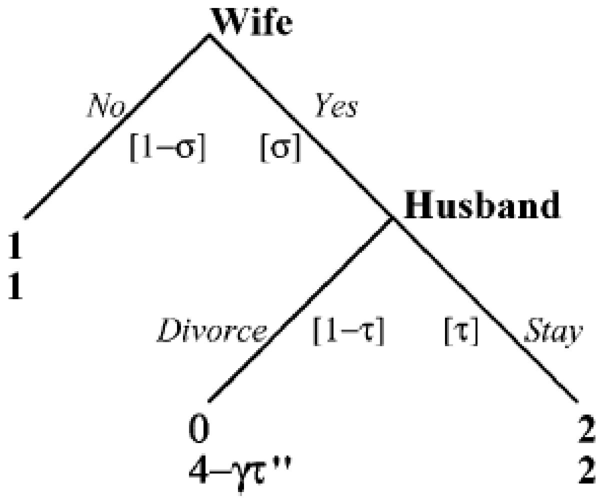


Figure 12 *The psychological marital investment game with guilt τ'' and guilt sensitivity γ of the husband (Dufwenberg, 2002, fig. 1)*

- The idea of the game
  - Individuals might not necessarily only play pure strategies – we therefore add probabilities σ and τ to capture mixed strategies
  - Individuals form beliefs about probabilities (as in psychological game theory above)
    * Belief τ' of wife about husband's probability τ to *stay*, called her trust (first feeling in game): $\tau' = \mathbb{E}[\tau]$
    * Belief τ'' of husband about wife's belief τ': $\tau'' = \mathbb{E}[\tau']$
  - In case the husband *divorces*, he experiences a loss in his utility the more he believes (i.e. cares) his wife trusts him
  - The loss in utility is given by $\gamma\tau''$ and consists of γ, his "guilt sensitivity", and his guilt τ'' (second emotion in this game)

- Equilibrium definition
  - Equilibrium is defined in analogy to equilibrium definitions in psychological games
  - **Definition (**Dufwenberg, 2002, p. 65**):** A profile (σ, τ) is a marital equilibrium if
    (i) (σ, τ) is a subgame perfect equilibrium for a given τ''
    (ii) $\tau'' = \tau' = \tau$ and
    (iii) If $4 - \frac{\gamma}{2} < 2$ then $\tau = 1$
- What does this mean?
  - (i) If we know τ'', then we have a normal (a.k.a. non-psychological) game where equilibrium is found by imposing subgame perfection
  - (ii) Beliefs must be consistent across individuals
  - (iii) If γ satisfies this condition, then the husband must choose '*stay*'. Why?
    * Condition requires $\gamma > 4$. Why should husband stay with $\gamma > 4$?
    * Wife knows that γ equals, say, 4.00001. Assume she plays '*yes*'. She would do so only if she believes that $\tau = 1/2$ or larger as only then her expected payoff from '*yes*' ($\frac{1}{2} * 0 + \frac{1}{2} * 2 = 1$) exceeds the payoff from '*no*' (which equals 1)
    * When the husband believes that $\tau' = 1/2$ or larger, his guilt implies a payoff of $4 - \gamma\tau'' = 4 - 2.000005 < 2$ for divorce and therefore he *stays*. Hence $\tau = 1$

- Equilibrium behaviour for $0 \leq \gamma < 2$
  - In words, the husband does not care a lot about guilt (guilt sensitivity γ is low)
  - Even if $\tau'' = 1$, the payoff from divorce, $4 - \gamma$ is larger than the payoff from staying, 2
  - When the wife knows the husband will divorce ($\tau = 0$), she will say '*no*'
  - Equilibrium beliefs are $\tau'' = \tau' = 0$
  - Unique equilibrium strategies are (*no*, *divorce*) and equilibrium payoff is $(1, 1)$
- Equilibrium behaviour for $\gamma > 4$
  - In this case, the husband cares a lot about guilt
  - Equilibrium beliefs are $\tau'' = \tau' = 1$
  - Unique strategies are (*yes*, *stay*) and payoffs are $(2, 2)$
  - Idea as for equilibrium property (iii) from above

- Equilibrium behaviour for $2 \leq \gamma \leq 4$

  - Three equilibria exist, belief of the wife selects which one is implemented
  - If she believes he will *divorce*, i.e. if $\tau' = 0$, she will say '*no*' and payoff is $(1, 1)$
  - If she believes he will *stay*, i.e. if $\tau' = 1$, she will say '*yes*' and payoffs are $(2, 2)$
  - Third equilibrium has $\tau = \tau' = \tau'' = 2/\gamma > 1/2$, for $\gamma > 4$. Then strategies are (*yes*, *stay*) and payoffs are $(2, 2)$

- (Note that divorce is never observed in equilibrium)

- What have we learned

  - A lot about (psychological) game theory
  - About applications of feelings written into payoffs
  - In the present case, feelings of
    * husband, guilt, seem to be ex-post feelings as they occur after the decision to divorce
    * wife, trust, seem to be ex-ante feelings

4.6 Fairness and altruism

- Rabin (1993) "Incorporating fairness into game theory and economics"
  - Builds on and extends psychological game theory
  - Explains why people reward and punish other people at own costs
- Fehr and Schmidt (1999) "A theory of fairness, competition, and cooperation"
  - study preference for equality
  - economic environment determines whether fair or selfish types dominate equilibrium
- More traditional approaches (e.g. Baumol, 1986, but also macroeconomics literature)
- utility function of person A reads $u\left(c^A, c^B\right)$ or $u\left(c^A, c^{\text{average}}\right)$
- envy and altruism are determined by derivatives

$$\left.\begin{array}{c}\text{envy}\\ \text{altruism}\end{array}\right\} \text{ if } \frac{\partial u\left(c^A, c^B\right)}{\partial c^B} \lesseqgtr 0$$

4.7 Exercises

4.7.1 Regret theory (Loomes and Sugden, 1982)

Imagine that you have to choose between France and Italy to go on a beach holiday. Having this decision to make you know that there are two possible states you can find yourself in, let us write these states as follows, where s_{1j} is the value of option 1 (vacationing in France) in state $j \in \{a, b\}$

$$\left\{ \begin{array}{c} s_{1a} = 8 \\ s_{2a} = 5 \end{array} \right\}, \text{ i.e. more sun in France,}$$

$$\left\{ \begin{array}{c} s_{1b} = 5 \\ s_{2b} = 8 \end{array} \right\}, \text{ i.e. more sun in Italy.}$$

You do not know, a priori what the realization of those states will be, so you have to weigh the probabilities of each, and decide which option yields the best expected utility (where U_1^2 represents the utility of choosing option 1 over option 2), given by

$$U_1^2 = \sum_{j=1}^{2} p_j u\left(c_{1j}, c_{2j}\right) \quad \text{and} \quad U_2^1 = \sum_{j=1}^{2} p_j u\left(c_{2j}, c_{1j}\right),$$

where we sum over the number of possible states, i.e. 2 here, with

$$u(c_{1j}, c_{2j}) = c_{1j} + R(c_{1j} - c_{2j}),$$

where c_{1j} is the consumption for option 1 in state j. Assume the following functional forms and probabilities for the states of the world (i.e. *Case* 1 and *Case* 2)

$$c_{1j} = s_{1j} \quad ; \quad R(c_{1j} - c_{2j}) = (s_{1j} - s_{2j})^3 .$$

Case 1	*Case* 2
$p_a = 0.3$	$p_a = 0.55$
$p_b = 0.7$	$p_b = 0.45$

1. Which destination will actually be chosen in Case 1?

2. Which destination will actually be chosen in Case 2?

4.7.2 Anticipatory emotions and anxiety (Caplin and Leahy, 2001)

Consider the utility function in 4.3:

$$U_t = \mathbb{E}_t \left[\gamma \left[\ln c_t - \phi \ln a_t\right] + (1 - \gamma) \ln c_{t+1}\right], \tag{4.12}$$

where $\gamma \in (0, 1)$ represents the individual's relative preference for period t utility and a_t is the anticipatory feeling in t. The budget constraint in t reads

$$w_t = c_t + s_t, \tag{4.13}$$

where w_t is the wage and s_t is savings at time t. In $t+1$, the individual faces the following constraint, where consumption equals savings plus interests:

$$\left(1+r_{t+1}\right)s_t = c_{t+1}, \tag{4.14}$$

where r_{t+1} is unknown at t and is assumed to have constant mean and variance given by:

$$\mathbb{E}_t\left[1+r_{t+1}\right] \equiv \mu, \tag{4.15}$$

$$Var_t\left[1+r_{t+1}\right] \equiv \sigma^2. \tag{4.16}$$

We model anticipatory feelings as falling in the mean and rising in the variance of next period consumption, c_{t+1}:

$$a_t \equiv a\left(c_{t+1}\right) = Var_t\left[c_{t+1}\right]^{\zeta}\,\mathbb{E}_t\left[c_{t+1}\right]^{-(1-\zeta)}, \tag{4.17}$$

where $\zeta \in (0,1)$ captures the relative importance of the variance of future consumption for anticipation.

1. Derive the Euler equation for this system and determine optimal savings. Provide an economic interpretation of both the Euler equation and optimal savings.

2. Imagine the individual does not care about the mean (i.e. set ζ equal to 1 in the FOC). Compute optimal savings and provide an economic interpretation. How does it compare to the standard case, when $\phi = 0$?

3. Imagine the individual is not worried about the variance (set ζ equal to 0 in the FOC). Compute optimal savings and provide an economic interpretation. How does it compare to the standard case, when $\phi = 0$? How does it compare to the case above when $\zeta = 1$?

4.7.3 Immediate emotions and state-dependent preferences

Assume the following functional form for preferences (as an example for Loewenstein, 2000)

$$u\left(c_x, c_y\right) = c_x^{\alpha} c_y^{1-\alpha},$$

where $\alpha = f\left(\text{mood}\right)$. Let mood stand for the emotional state of the individual such that α captures state-dependent preferences. The budget constraint for this problem is given by

$$e = p_y c_y + p_x c_x,$$

where e is the endowment, and p_y and p_x are the price of goods y and x, respectively.

1. Draw the indifference curve and budget constraint, and derive the optimal consumption ratio as a function of the mood.

2. We now model state-dependence as Laibson (2001), talking about endogenous preferences and stable meta-preferences. To this end, assume a utility function that reads

$$u\left(c_x, c_y\right) = \left(c_x - h\right)^{\alpha} \left(c_y - t\right)^{1-\alpha},$$

   and call x food and y drink such that individuals eat more when they are hungry and drink more when they are not. The states are described by h for hunger (an immediate emotion, a visceral factor) and t for thirst. Using the same budget constraint as in (a) above, draw the indifference curve and derive the optimal consumption ratio as a function of h and t.

4.7.4 Cue theory of consumption (Laibson, 2001)

Consider the following setup described in the lecture:

$$\max_{\left\{c_t^s, c_t^f\right\}} u\left(c_t^s, c_t^f\right) = \left(c_t^s - x_t\right)^{\alpha} \left(c_t^f\right)^{1-\alpha}$$
$$\text{s.t.} \quad p^s c_t^s + p^f c_t^f = E$$

In this context we have instantaneous utility that depends on consumption of two different goods (namely, $f \equiv fruits$ and $s \equiv sweets$). However, the utility from s depends also on the bodily state x_t, call it a craving in this case, which is defined below as a function of the state of the world (or cues):

$$x_t = x\left(i_t\right), \text{ where } i_t = \left\{ \begin{array}{c} P \\ A \end{array} \right\} \text{ with probability } \left\{ \begin{array}{c} \mu^P \\ 1 - \mu^P \equiv \mu^A \end{array} \right\}$$
$$\text{and } x\left(P\right) > x\left(A\right)$$

Where P represents a cue that is present, and A a cue that is absent. In other words, when the individual faces a cue for s, his craving, x_t, increases, relative to when the cue is absent.

1. Derive the optimal consumption ratio, then determine the demand function for c_t^f and for c_t^s. What happens when $x_t = 0$?

2. Describe how the cues evolving over time affect the individual's optimal demand functions, i.e. what is their marginal effect on the demand functions derived above. Explain your result.

3. Working from the demand function for c_t^f, what is the effect of an increase in α? What does it imply for the individual?

4.7.5 Stress (Wälde, 2016)

1. (General phase diagram) How can we find the steady-state of a first-order autonomous differential equation of the form: $\dot{x} = f(x(t))$? Under which conditions is a steady-state stable/unstable? Illustrate with a graphical example.

2. (Stress phase diagram) Using the following equation: $\dot{W}(t) = \Phi W(t) - \delta_1 m$, where $\Phi \equiv \phi \frac{p}{a} - \delta_0$, with $\phi > 0$, explain the corresponding phase diagram from the lecture.

4.7.6 Psychological Game Theory: the Bravery Game

Consider the Bravery Game from the lecture, where payoffs are now given by the table below:

Normal-Form game

P1 strategy	*Payoffs (P1,P2)*
bold	$3 - \tilde{q}$, $\frac{2}{3} + q$
timid	$4 - 4\tilde{q}$, $2 - 2q$

1. Are there any pure-strategy equilibria?
2. Is there a mixed-strategy equilibrium, where $P1$ is indifferent between either strategy? If so then what is the corresponding value of $\tilde{q}$?

5 Conclusion

We asked two questions

- What is the role of emotions in expected utility maximization?
- How do economists model emotions?

Expected utility maximization theory comes in two guises

- Preference-based approach
- Choice-based approach
- Choice-based approach is purely behaviouristic/ positivistic approach – no place for emotions
- Preference-based approach leaves a lot of room for emotions

How do economists model emotions?

- Allow for experienced-utility as opposed to decision-utility (anticipatory emotions, ex-post emotions)
- Let payoffs (utility) depend on beliefs (psychological games)
- Make preferences state-dependent (immediate emotions, cue theory)
- Model emotions as state variables (stress)

Why care about emotions? (not covered in lecture - general remark)

- Economists outside their office would all agree that emotions matter for decisions
- Emotions in decision models allow to understand deviations from predictions of expected utility theory
- Many individuals are not aware of their true preferences
  - Understanding one's true preferences can lead to a personally more fulfilling life
  - Many problems of society can be overcome only if individuals change their attitudes (preferences)
  - Learning one's own preferences is emotionally (and other) very costly
  - Emotions need to be understood better, individuals should be more aware (and open) about their emotions, we need a better understanding of emotional processes

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Macroeconomics II: Behavioural Macro

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www.macro.economics.uni-mainz.de
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Part II
Behavioural economics

6 Introduction

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 behaviour 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 and Levine (2006), Krieger and Wälde (2016)
  - Time inconsistency: Strotz (1955), Laibson (1997), O'Donoghue and Rabin (1999), Benhabib and 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
  - Kőszegi and Rabin (2006) – endogenous reference point
  - Föllmi, 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
- Makroökonomik 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 selves 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 (e.g. the illy 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 the 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

$$c + qx = y \tag{7.1}$$

  - 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 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 cannot 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)

$$u(c, x, z) = \phi c^{\sigma} + x^{\sigma} + \beta z \tag{7.2}$$

  where $\phi, \beta > 0$ and $0 < \sigma < 1$ and

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

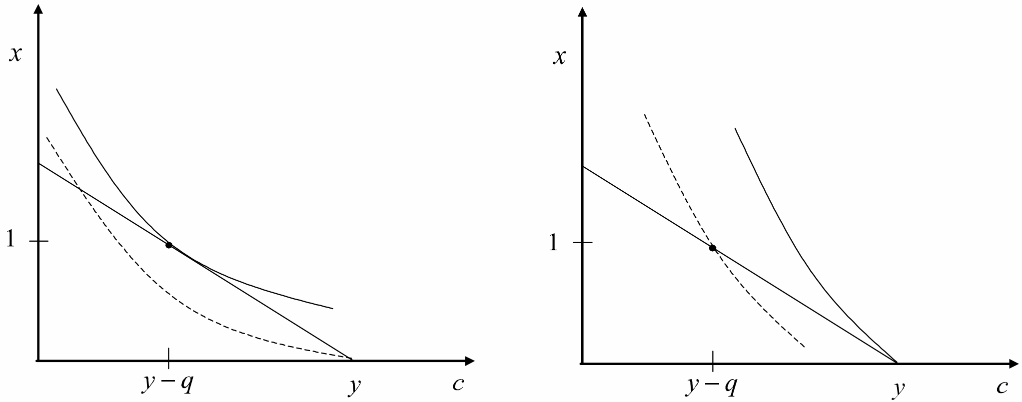


Figure 13 *Budget constraint and pseudo-indifference curves for c and x for a "drug-prone" individual (left panel) and a "drug-resistant" individual (right panel) ('pseudo' as x is indivisible)*

- 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* ϕ, 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 (7.2)

$$u(y, 0, z) = \phi y^{\sigma} + \beta z \tag{7.3}$$

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

$$u(y - q, 1, z) = \phi [y - q]^{\sigma} + 1 + \beta z$$

  - To understand that it falls, remember that we look at a drug-resistant individual in the 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

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

Consider an individual who maximizes 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:

$$\max_{\{c,x\}} u(c, x, z) = \phi c^{\sigma} + x^{\sigma} + \beta z \tag{7.4}$$

$$\text{s.t. } c + qx = y \tag{7.5}$$

Where c is the standard consumption good whose price is normalized to unity, $x \in \{0, 1\}$ represents consumption of the addictive good at price q, and $z = \{1, 2, 3\}$ is a representation of the activity (or lifestyle) that the individual chooses, given by $a = \{E, A, R\}$. Each state carries a certain probability, p^a, 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 (7.5) and (7.4), 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. Draw the indifference curves for our problem. First for an addiction-resistant individual (high ϕ) and then for an addiction-prone individual (low ϕ).

4. Show graphically what happens to an addiction-resistant individual 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 time *consistency* actually 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
$$U_t = \ln c_t + \delta \ln c_{t+1} \tag{8.1}$$
  - subject to period t
$$w_t = c_t + s_t,$$
  - and period $t+1$ constraints,
$$(1 + r_{t+1})\, s_t = c_{t+1}.$$
- Optimal behaviour reads
$$c_t = \frac{1}{1+\delta} w_t, \qquad s_t = \frac{\delta}{1+\delta} w_t, \qquad c_{t+1} = \frac{\delta}{1+\delta} (1 + r_{t+1})\, w_t. \tag{8.2}$$

8.1.2 Three-period utility maximization under uncertainty

- Setup

  - We now start one period earlier, in period $t-1$
  - Income w_{t-1} is only earned in one period, as before
  - Meaning the individual now needs to save twice: in $t-1$ (for period t) and in t (for period $t+1$)
  - 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 $t-1$

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

    one for period t

$$(1 + r_t)\, s_{t-1} = c_t + s_t, \tag{8.3}$$

    and one for period $t+1$

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

- Timing of the models

time index	$t-1$	t	$t+1$
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 $t-1$ is split between consumption and savings (see Exercise 8.3.1),

$$\begin{aligned} c_{t-1} &= (1-B)w_{t-1}, \\ s_{t-1} &= Bw_{t-1} \end{aligned} \tag{8.4}$$

    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,

$$\begin{aligned} c_t &= (1-A)\,(1+r_t)\,s_{t-1}, \\ s_t &= A\,(1+r_t)\,s_{t-1}, \end{aligned} \tag{8.5}$$

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

$$c_{t+1} = (1+r_{t+1})\,s_t \tag{8.6}$$

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

- General feature
  - Individuals behave the same, independently of *when* the decision was made (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 (8.2) in 2pm)

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

  - Consumption in $t+1$ from the perspective of $t-1$ (see (8.6), (8.5) and the definition of A in 3pm)

$$\begin{aligned} c_{t+1} &= (1 + r_{t+1}) s_t \\ &= (1 + r_{t+1}) \frac{\delta}{1+\delta} [1 + r_t] s_{t-1} \end{aligned} \tag{8.7}$$

  - wage in t in two-period model (2pm) corresponds to $(1 + r_t) s_{t-1}$ in three-period model (3pm)
  - individual in 2pm starts in t with wage/ endowment w_t
  - individual in 3pm continues in t with endowment $e_t \equiv (1 + r_t) s_{t-1}$
  - we can write (8.3) as $e_t = c_t + s_t$ and therefore (8.7) as

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

  - *The rule is always the same:* Consume in $t+1$ a share $\delta/(1+\delta)$ 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 *in*consistency
  - 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 and Nelson (2010) footnote 6
  - Caplin and 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

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

  - Instantaneous utility function $u\left(c_\tau\right)$
  - Geometric/ exponential discounting at discount factor $0 < \delta < 1$
  - 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 à 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

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

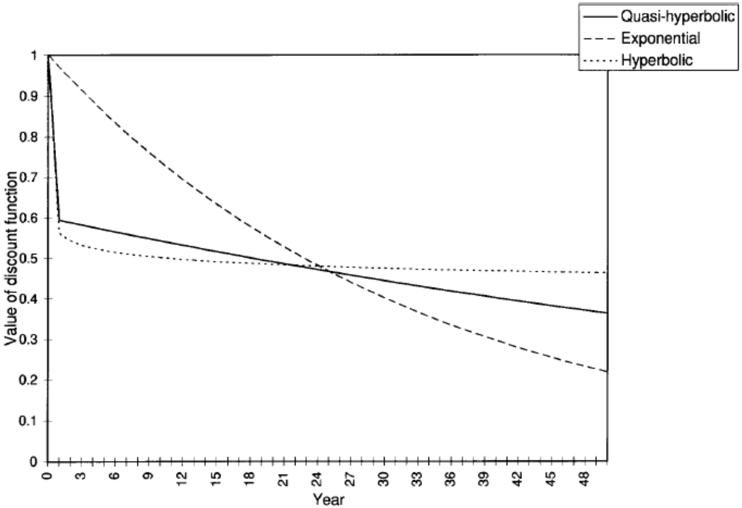
but also anything else like e.g. hyperbolic

$$\begin{aligned} \lambda_{\text{example 2}}(\tau - t) &= (1 + \alpha[\tau - t])^{-\rho/\alpha} \text{ where } \alpha, \rho > 0 \\ &\quad \text{(generalized hyperbolic discount function, Laibson, 1997)} \end{aligned} \tag{8.8}$$

- 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 (8.8) is $-\rho/\left(1+\alpha\tau\right)$ (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 (8.8)) 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
    * i.e. there is a present bias



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

exponential $e^{-\rho[\tau-t]}$ (or $\delta^{\tau-t}$)

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

Figure 14 *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)

$$U_t^{TC} = \sum_{\tau=t}^{T} \delta^{\tau-t} u_\tau \tag{8.9}$$

    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

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

    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)

$$U_t = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau, \quad \beta < 1 \tag{8.10}$$

    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

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

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

$$\left\{ \begin{array}{c} V_t(t) = \beta v - c_t \\ V_t(\tau) = \beta v - \beta c_\tau \end{array} \right\} \text{if the activity is undertaken in} \left\{ \begin{array}{c} t \\ \tau > t \end{array} \right\} \tag{8.11}$$

- 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, deadline approaches meaning less time to work on paper)

- Optimal behaviour of TCs
  - By (8.11), the TCs compute the value of acting in period 1 or afterwards at some point τ
$$\left\{\begin{array}{c} V_1(1) = v - c_1 \\ V_1(\tau) = v - c_\tau \end{array}\right\} \Rightarrow V_1(1) > V_1(\tau) \Leftrightarrow c_\tau > c_1$$
  - By comparing these gains, they see that the value of acting in 1 is larger as the cost c_τ is larger than the cost in 1
  - As a consequence, TCs write paper in period 1

- Optimal behaviour of naifs
  - From (8.11), 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 $\beta = 0.1$
    * then $\beta c_2 = 0.2 < c_1 = 1$ 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 $\beta c_3 = 0.3$ 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 would)

- 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

8.3.1 Three-period savings problem

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

$$U\left(c_{t-1}, c_t, c_{t+1}\right) = \ln\left(c_{t-1}\right) + \delta \ln\left(c_t\right) + \delta^2 \ln\left(c_{t+1}\right) \tag{8.12}$$

Subject to the following constraints:

$$w_{t-1} = c_{t-1} + s_{t-1} \tag{8.13}$$

$$\left(1 + r_t\right) s_{t-1} = c_t + s_t \tag{8.14}$$

$$\left(1 + r_{t+1}\right) s_t = c_{t+1} \tag{8.15}$$

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) [MATLAB]

Consider the three main types of discount functions listed below for the continuous-time case:

exponential:	$e^{-\rho[\tau-t]}$
hyperbolic:	$(1+\alpha[\tau-t])^{-\frac{\rho}{\alpha}}$
quasi-hyperbolic:	$\beta e^{-\rho[\tau-t]}$

where $\alpha, \rho > 0$, $\beta \in (0,1)$, and $\tau \in [t, \infty)$.
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?
3. Show that the exponential discount function is a special case of the hyperbolic discount function when α goes to 0. (optional)
4. How does each discount function evolve over time? Graph your answer. [*see MATLAB script*]
5. Graph discounted utility over time for each of these discount functions. [*see MATLAB script*]

6. Given that each yields the same discounted utility in period 25 (for certain parameter values), which discount function leads to the highest lifetime utility? [*see MATLAB script*]

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 understanding economic issues ...
  - ... such as macro – to which we now turn

Johannes Gutenberg-University Mainz
Bachelor of Science in Wirtschaftswissenschaften

Macroeconomics II: Behavioural Macro

Summer 2024

Prof. Dr. Klaus Wälde (lecture) and Niklas Scheuer (tutorials)

www.macro.economics.uni-mainz.de

January 15, 2024

Part III
How behavioural macro could look like

10 Introduction

- We take three typical macroeconomic fields
  - business cycle analysis
  - unemployment and
  - growth
- We get to know standard models that allow us to understand why there are
  - business cycles
  - unemployment and
  - growth

- We then replace our well-known but far-off-track homo oeconomicus by more emotional counterparts
- We see how predictions in emotional (or behavioural) macro models differ from standard predictions: what can we now understand that we did not understand earlier?
- Is this prediction in any sense meaningful i.e. can we empirically distinguish between the extended version and the original one? (tough one)

11 Unemployment and time inconsistency

11.1 Models of unemployment

Makroökonomik I told us that we can distinguish between

- Models of labour supply ("voluntary unemployment")
- Traditional views of unemployment based on static models
- Modern models of unemployment looking at the dynamics of a labour market (search and matching models)

11.1.1 A reminder of voluntary unemployment

... understood as a labour supply decision

- The setup
  - Consider an individual that values consumption c and leisure l and is described by
$$u(c,l) = \left[\gamma c^{\theta} + (1-\gamma)\, l^{\theta}\right]^{1/\theta}, \quad \theta < 1, 0 < \gamma < 1$$
  - Real budget constraint (wage expressed in units of consumption good)
$$c = \left(\bar{l} - l\right) w$$
    where $\bar{l}$ is time endowment of the individual and w is the real wage
- Optimal leisure/ labour supply decision
  - The amount of leisure
$$l = \frac{1}{1 + \left(\frac{\gamma}{1-\gamma}\right)^{\frac{1}{1-\theta}} w^{\frac{\theta}{1-\theta}}} \bar{l}$$
  - Does leisure increase in labour income w?
$$\frac{dl}{dw} \lesseqgtr 0 \Leftrightarrow \theta \gtreqless 0$$
  - Leisure increases if the income effect dominates the substitution effect

11.1.2 A reminder of involuntary unemployment

- Real wage lies above the market clearing wage
- workers are off their labour supply curve
- more workers would want to work at the going wage $\bar{w}$ which exceeds the market clearing wage
- Examples for involuntary unemployment: why is the real wage too high?
  - minimum wage (but keep the monopsony setup in mind)
  - wage bargaining between trade unions and employers' federations
  - efficiency wages set by firms (Solow, 1979): firms pay a wage that is higher than the market clearing wage as this allows firms
    * to have a larger pool of applicants and
    * to motivate workers to provided more effort (identify more with the firm, be more careful ...)

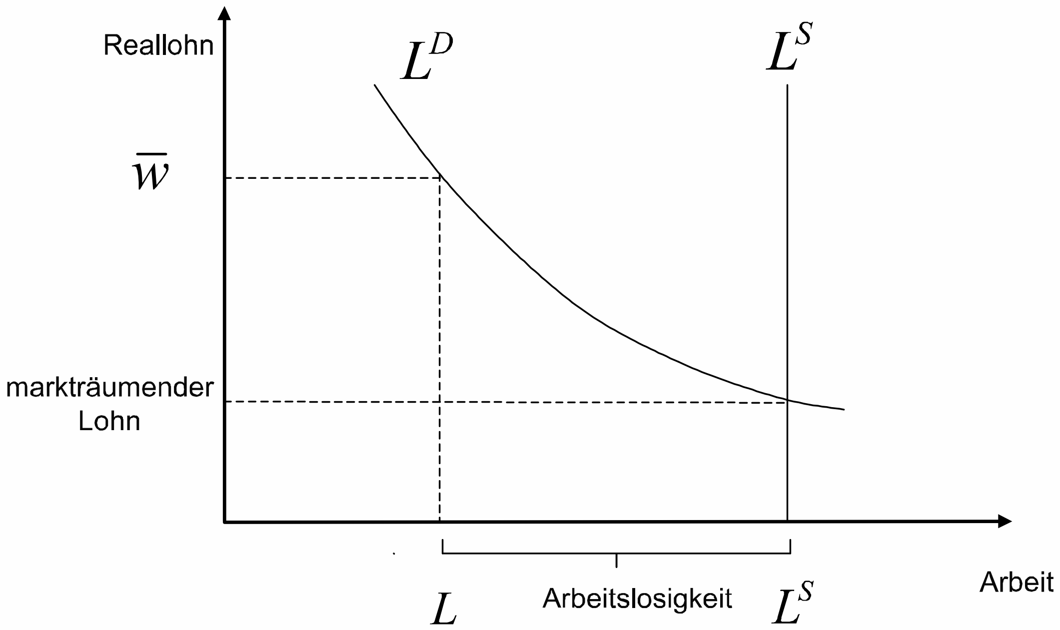


Figure 15 *Real wage rigidity and unemployment*

11.1.3 A reminder of matching models of unemployment

- Pissarides (2000) Equilibrium unemployment theory
- The central assumptions and insights
  - Finding a job and finding a worker takes time due to incomplete information
  - Search processes play an important role
  - Adjustment of the unemployment rate takes time
  - One can compute how much time this adjustment process takes
  - Vacancies (job opening by firm) play an important role

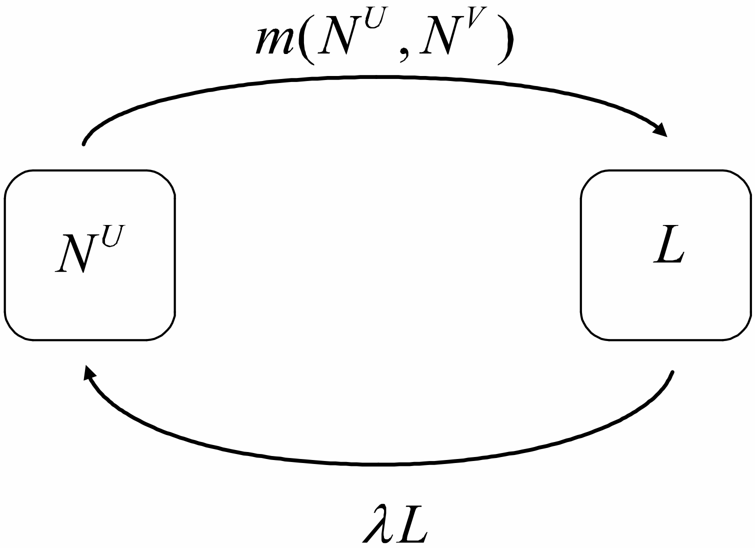


Figure 16 *Inflows λL into the pool of N^U unemployed workers and outflows which are determined by the matching function $m\left(N^U, N^V\right)$ – notation: separation rate λ, number L of employed workers and number N^V of vacancies*

- Dynamics of the unemployment rate
  - We fix the number of vacancies per unemployed worker for simplicity (see Masters programme for details)
  - Denote the
    - individual job finding rate by μ
    - the initial unemployment rate at some $t = 0$ by u_0
  - The unemployment rate is then given by

$$u(t) = \frac{\lambda}{\lambda + \mu} + \left(u_0 - \frac{\lambda}{\lambda + \mu} \right) e^{-(\lambda+\mu)t}$$

- In words
  - The unemployment rate at $t = 0$ is given by u_0
  - The unemployment rate for $t \to \infty$ is given by $\frac{\lambda}{\lambda+\mu}$
  - We can therefore define $u^* \equiv \frac{\lambda}{\lambda+\mu}$ as the long-run unemployment rate
  - When $u_0 \left\{ \begin{matrix} > \\ < \end{matrix} \right\} u^*$, the unemployment rate $u(t) \left\{ \begin{matrix} \text{falls} \\ \text{rises} \end{matrix} \right\}$ over time t

11.2 A pure search model of unemployment

- Understanding the dynamics of unemployment should proceed in steps
- The starting point is the analysis of *one* unemployed worker
- We ask
  - how this unemployed worker can behave optimally and
  - how this behaviour affects their expected duration in unemployment
- What do we learn from a methodological perspective?
  - Beyond the analysis of unemployment, we get to know 'Bellman equations'
  - They are a (the?) standard tool in economics to solve maximization problems
- Reading
  - Cahuc and Zylberberg (2004, ch. 3) for the economics
  - Wälde (2012) for the methods
- Once this is understood, one would proceed to an equilibrium analysis of unemployment (that would explain the number N^V of vacancies which were assumed to be constant)

11.2.1 The basic idea

- Reason for search: lack of information about job availability and the wage paid per job
- Setup
  - look at *one* unemployed worker
  - They receive unemployment benefits
  - Intensity of search is *not* chosen
  - *Cannot* look for another job once employed
  - Stationary environment
- Question we can ask: which wage is accepted once an offer is made?

11.2.2 Expected utility once employed

- What is the value of being employed?
- To understand this, we start with behaviour of unemployed worker
- Unemployed worker does
  - not know which wage will be offered once a job is found
  - know that wages are drawn from a (continuous cumulative) distribution $H(w)$ with density $h(w)$
  - see next figure ...

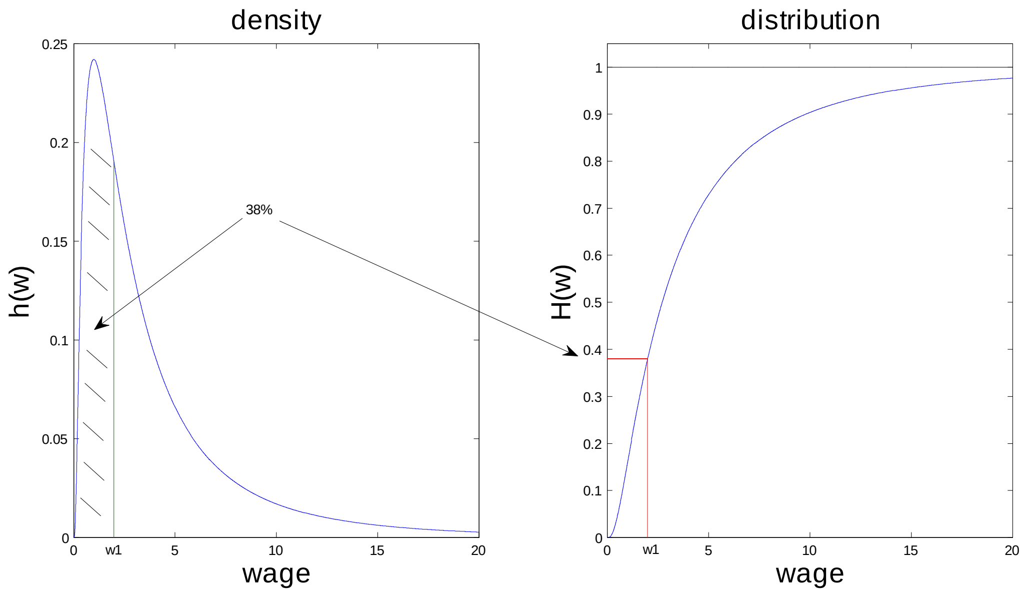
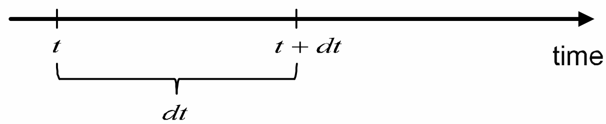


Figure 17 *Illustration of wage offer density and distribution from which workers draw the wage*

- Unemployed does (copied from above)
  - not know which wage will be offered once a job is found
  - know that wages are drawn from a (continuous cumulative) distribution $H(w)$ with density $h(w)$ ($:= dH(w)/dw$)
- Worker is risk neutral
  - utility function is linear in income
  - here: utility function is given by real labour market income (wage or benefit)
- When employed the worker loses the job
  - at (separation) *rate* $s > 0$, meaning that
  - the *probability* to lose the job over period of time of length dt is given by sdt



  - (Poisson process in continuous time)

- A simple example
  - Assume the rate s to lose a job is 0.2 or 20%
  - Assume further we fix the unit of time to be one month
  - Then the probability to lose the job within a month is given by

$$F(1) = 1 - e^{-s} = 1 - e^{-0.2} = 18.12\%$$

- More background on $F(1)$
  - The equation used here can be expressed more generally as

$$F(T) = 1 - e^{-sT}$$

  - It says that the probability that an individual loses the job within T units of time is given by $F(T)$
  - $F(T)$ is the distribution of T, i.e. the length in employment
  - $F(T)$ is an exponential distribution
  - Duration in a state is exponentially distributed when the exit rate is constant
- Empirically convincing exit rates for Germany for the end of the 1990s are
  - e.g. a rate of 20% (e.g. out of unemployment) where the unit of time is one month (see figure 3 in Elsby et al., 2013)

- Rates and probabilities
  - A rate s is defined by a probability over a short time horizon
  - To understand this, consider the state of having a job and ask
    * what the probability is that
    * an individual loses the job at some point in time between t and $t + \Delta$
    * conditional on having a job in t
    * This probability can be denoted by $\text{Prob}(t \leq T \leq t + \Delta | T \geq t)$
  - As an example,
    * let t be tomorrow and Δ be 1 week
    * Then $\text{Prob}(t \leq T \leq t + \Delta | T \geq t)$ is the probability for an individual that has a job tomorrow (this is the conditional part "$|T \geq t$") will lose the job tomorrow or on any day in the 6 days to follow
    * If t is Sunday, then $\text{Prob}(t \leq T \leq t + \Delta | T \geq t)$ is the probability of a worker that has a job on Monday (morning) that he will lose the job on any day between Monday and Sunday (evening)

- Now let Δ be 3 days
  * Then $\text{Prob}(t \leq T \leq t + \Delta | T \geq t)$ is the probability of a worker that has a job on Monday (morning) that he will lose the job on any day between Monday and Wednesday (evening)
- We now assume that t is in 2 hours from now and Δ is two minutes
  * Then $\text{Prob}(t \leq T \leq t + \Delta | T \geq t)$ is the probability of a worker that has a job in 120 minutes that he will lose the job between 120 minutes from now and 122 minutes from now
- When Δ becomes smaller and smaller,
  * we end up with the "instantaneous probability" or, the appropriate term,
  * the rate of losing a job
  * It is defined as

$$s(t) \equiv \lim_{\Delta \to 0} \frac{\text{Prob}(t \leq T \leq t + \Delta | T \geq t)}{\Delta}$$

- A simple case for rates and probabilities
  - We start with the simple case where the rate $s(t)$ is constant, $s(t) = s$
  - The length T in time that someone remains employed is then
    * exponentially distributed with parameter λ (see tutorial or e.g. Lancaster, 1990, ch. 2.1)
    * The distribution of T is given by $F(T) = 1 - e^{-\lambda T}$ and gives the probability that an individual loses the job within T units of time
  - Then the probability to lose a job over a period of 3 units of time is

$$F(3) = 1 - e^{-3s}$$

- How can we then understand the definition of the arrival rate?
  - We can write

$$\begin{aligned} s(t) &\equiv \lim_{\Delta \to 0} \frac{\text{Prob}\left(t \leq T \leq t + \Delta | T \geq t\right)}{\Delta} \\ &= \lim_{\Delta \to 0} \frac{1 - e^{-s\Delta}}{\Delta} = \lim_{\Delta \to 0} \frac{se^{-s\Delta}}{1} = s \end{aligned}$$

    where the first equality computed the probability of losing the job in a period of length Δ and the last but one equality used L'Hôpital's rule

- An example for rates and probabilities
  - How can we understand $\frac{\text{Prob}(t \leq T \leq t+\Delta | T \geq t)}{\Delta}$ in the definition of $s(t)$?
  - Imagine Δ is 4 weeks and the probability to lose a job is 5%
  - Then $\frac{\text{Prob}(t \leq T \leq t+\Delta | T \geq t)}{\Delta}$ is an approximation to lose the job in 1 week, which would be given by 1.25%
  - Assuming a constant rate, a rate of $s = 0.0128 = 1.28\%$ would yield a 5% probability over a period of 4 weeks
    * To get this, solve the following for s

$$F(3) = 1 - e^{-4s} = 0.05$$

    * Note that we have fixed the units of time as weeks by this equation
  - The exact probability to lose the job over 1 week is

$$F(1) = 1 - e^{-s} = 1 - e^{-0.0128} = 1.27\%$$

  - When we measure Δ as 28 days, the probability to lose the job in 1 day is approximately $5\%/28 = 0.178\%$
  - The exact probability is

$$F(1) = 1 - e^{-s/7} = 1 - e^{-0.0128/7} = 0.183\%$$

- Real instantaneous interest rate r: invest a Euro in t and receive $1 + rdt$ Euro in $t + dt$
- Discount factor of $\frac{1}{1+rdt}$ useful for computing present values
- This gives us value of being employed between t and $t + dt$

$$V_e = \frac{1}{1 + rdt} \left[wdt + (1 - sdt) V_e + sdtV_u \right]$$

where w is the instantaneous wage rate and V_u is the value of being unemployed and $(1 - sdt)$ is the probability to keep the current job

- (technically: this is heading towards a Bellman equation)
- rearrange this to make it simpler → Exercise 11.4.1

$$rV_e = w + s \left[V_u - V_e \right]$$

(this is presentation in terms of classic Bellman equation)

- rewrite this for later purposes as

$$V_e(w) - V_u = \frac{w - rV_u}{r + s} \tag{11.1}$$

11.2.3 The optimal search strategy

- we assume job searcher only meets one employer at a time
- an offer consists of a fixed wage w
- choice between 'accept' or 'reject'
- optimality criterion: is V_e or V_u higher?
- accept $\Leftrightarrow V_e(w) > V_u$, which from (11.1) is the case if and only if $w > rV_u \equiv x$
- we have thereby defined the reservation wage x
- intuition why ever reject
  - Disadvantage from accepting a job consists in the inability to further look for jobs (as there is *no* on-the-job search)
  - Employee is stuck with wage w for a potentially long time
  - It might be better to reject and hope for better offer (with higher wage w)

11.2.4 The discounted expected utility (value function) of a job seeker

- Arrival rate of job: λ
- λ reflects labour market conditions, personal characteristics (age, educational background), effort (time and carefulness put into writing applications, not modeled here)
- Unemployment benefits b and opportunity costs of search c give instantaneous utility when unemployed, $z \equiv b - c$
- Value of receiving an offer

$$V_\lambda = \int_0^x V_u h(w)\, dw + \int_x^\infty V_e(w)\, h(w)\, dw$$

- Value of being unemployed over a period of length dt

$$V_u = \frac{1}{1 + rdt} \left[zdt + \lambda dt V_\lambda + (1 - \lambda dt)\, V_u \right]$$

- Rearranging (see Exercise 11.4.1), we get the Bellman equation for unemployed worker

$$rV_u = z + \lambda \int_x^\infty \left[V_e(w) - V_u \right] h(w)\, dw$$

11.2.5 Reservation wage

- Last equation has intuitive interpretation, but hard to use for comparative statics
- But note that it is also an expression for the reservation wage $x = rV_u$
- After further steps (see Exercise 11.4.1), we get final expression for the reservation wage x

$$x = z + \frac{\lambda}{r+s} \int_x^\infty (w-x)\, h(w)\, dw$$

- Interpretation as above for rV_u, apart from $r+s$ in denominator
  - $\frac{\pi}{r}$ is the present value (when discounting with r) of receiving income (profits) π forever
  - $\frac{\pi}{r+s}$ is the present value of receiving π as long as it randomly stops at rate s
  - hence $\frac{\int_x^\infty (w-x)h(w)dw}{r+s}$ is the present value of receiving a wage above x until exit rate s hits
  - z is received instantaneously as a flow and λ is the arrival of a job offer

11.2.6 Hazard rates and average duration in unemployment

- What is hazard rate (exit rate with which an individual leaves unemployment)?

$$\text{exit rate} = \lambda \left[1 - H\left(x\right)\right]$$

  where λ is the job offer rate and $1 - H\left(x\right)$ is the probability of accepting a job

- What is the average duration T_u in unemployment?

$$T_u = \frac{1}{\lambda \left[1 - H\left(x\right)\right]}$$

  (using a standard property of Poisson processes, duration is exponentially distributed)

- An example

  - Assume the exit rate is 0.2 (as in example above)
  - Assume further we fix the unit of time to be one month
  - Then average duration in unemployment is

$$T_u = \frac{1}{0.2} = 5 \text{ months}$$

- This forms basis of some simple policy analyses

- What are determinants of duration in unemployment (unemployment rate)?
- How does a change in reservation wage x affect duration in unemployment?
- How can reservation wage x be influenced?

11.3 Search unemployment and time inconsistency

- Remember time inconsistent behaviour as in O'Donoghue and Rabin (1999) above (ch. 8.2.4)
- Individuals can be time consistent, naif and sophisticated
- This framework was applied to pure search by Paserman (2008) building on DellaVigna and Paserman (2005)
- We first look at the setup with time-consistent (TC) individuals ($\beta = 1$)
- Then we allow for time inconsistency ($\beta < 1$)

11.3.1 Pure search in discrete time with time consistent behaviour

Describing the individual

- We extend objective function (8.9), which reads $U_t^{TC} = \sum_{\tau=t}^{T} \delta^{\tau-t} u_\tau$, by
  - letting the planning horizon start at 0
  - specifying utility from consumption explicitly
  - adding search effort e_t and cost $c(e_t)$ from search and
  - taking uncertainty into account

$$U_0^{TC} = \mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t \left[u(c_t) - c(e_t) \right] \tag{11.2}$$

- As before, discounting takes place at the discount factor $0 < \delta < 1$
- Uncertainty arises as consumption depends on
  - the employment status of the worker and
  - on the uncertain wage level as workers draw from a wage distribution
- We capture the effect of uncertainty by using an expectations operator $\mathbb{E}_0$ (compare the two-period setup in (8.1))

- Consumption is given by
  - the (uncertain) wage w when employed
  - unemployment benefits b when unemployed
- The probability of being employed in $t+1$ depends on search effort in t

$$\text{Prob}\left(c_{t+1} = w\right) = p\left(e_t\right)$$

  with effort increasing the employment probability, $p'\left(e_t\right) > 0$
- With a probability q, an employed worker loses a job

Optimal behaviour

- Consider an unemployed worker in 0
- The objective function (11.2) can be written as

$$U_0^{TC} = u(b) - c(e_0) + \mathbb{E}_0 \delta [u(c_1) - c(e_1)] + \mathbb{E}_0 \sum_{t=2}^{\infty} \delta^t [u(c_t) - c(e_t)] \tag{11.3}$$

where

$$\mathbb{E}_0 u(c_1) = p(e_0) \mathbb{E}_w u(w) + (1 - p(e_0)) u(b) \tag{11.4}$$

- Expected utility
  - depends on the probability of being employed
  - on utility $u(b)$ when unemployed and
  - on expected utility $\mathbb{E}_w u(w)$ when having a job
- Now let the worker choose effort e_0 and the reservation wage R optimally (we do not do this explicitly here)
- How does the optimality condition look like?

- How does the optimality condition look like?

$$c'(e_0) = \delta p'(e_0)\left[\mathbb{E}_w u(w) - u(b)\right] \tag{11.5}$$

- It tells us that (as always) marginal costs must equal marginal benefits
  - Marginal costs are given by instantaneous marginal costs $c'(e_0)$ from effort
  - Benefits occur (i) in the future (next period discounted by δ) with (ii) only a certain probability
  - Marginal benefits are the increase in the gain $\mathbb{E}_w u(w) - u(b)$ from getting a job
  - [note that our first-order condition (11.5) differs from the paper by a factor $1/(1-\delta)$. The paper uses a different solution concept]

- We see from this equation that optimal effort is independent of time
  - the individual lives in a stationary environment
  - the general condition for any point t in time reads

$$c'(e_t) = \delta p'(e_t)\left[\mathbb{E}_w u(w) - u(b)\right] \tag{11.6}$$

- See Exercise 11.4.2 for an example where one can explicitly compute e_0 (and thereby e_t)

11.3.2 Pure search and time inconsistency

- Instead of (11.3), the objective function now contains the present-bias parameter β from (8.10) and reads

$$U_0^{TI} = u(b) - c(e_0) + \beta \left\{ \delta \left[\mathbb{E}_0 u(c_1) - \mathbb{E}_0 c(e_1) \right] + \mathbb{E}_0 \sum_{t=2}^{\infty} \delta^t \left[u(c_t) - c(e_t) \right] \right\}$$

where $0 < \delta, \beta < 1$ and e_t again is effort put into finding a job

- The first-order condition for e_0 now reads

$$c'(e_0) = \delta \beta p'(e_0) \left[\mathbb{E}_w u(w) - u(b) \right]$$

and displays the β

- The first-order condition from the perspective of zero for $t = 1$ or higher has the *same* structure as the time-consistent case (11.6)

$$c'(e_t) = \delta p'(e_t) \left[\mathbb{E}_w u(w) - u(b) \right] \text{ for } t \geq 1$$

as there is no present-bias for $t \geq 1$ from the perspective of 0

- This is the same basis of time inconsistent behaviour as in Strotz/ Laibson/ O'Donoghue and Rabin and others
- Individual is assumed to be sophisticated

- Question of Paserman (2008)
  - How large are δ and β?
  - Is there really time-inconsistency in real-world data?
  - Is time-inconsistency important (is β much smaller than 1)?
- Estimates (see table 2 in Paserman, 2008)
  - δ (discount factor) is around 0.999 (per week)
  - β (measure of time inconsistency) is between 0.4 and 0.89
- What does this tell us?
  - Discounting by δ hardly plays a role
  - Estimates of present bias β are significantly below 1 in an economically large sense
  - Present bias is an important feature that should be taken into account in analysis of (economic) behaviour

11.4 Exercises

11.4.1 Pure search model of unemployment

Consider the following value function for an employed worker:

$$V_e = \frac{1}{1+rdt}\left[wdt + (1-sdt)\, V_e + sdtV_u\right]$$

Where $\frac{1}{1+rdt}$ is a discount factor, computing the present value of being employed, $1+rdt$ is the value at $t+dt$ in Euros of investing 1 Euro in t and earning interest r. And $1-sdt$ is the probability of keeping a job between t and $t+dt$.

Also, consider the following value function for an unemployed worker:

$$V_u = \frac{1}{1+rdt}\left[zdt + \lambda dtV_\lambda + (1-\lambda dt)\, V_u\right],$$

with

$$V_\lambda = \int_0^x V_u h(w)\, dw + \int_x^\infty V_e(w)\, h(w)\, dw.$$

Where $1 - \lambda dt$ is the probability of staying unemployed, and λdt is the probability of receiving an offer. And $z = b - c$, is instantaneous utility when unemployed, which is equal to the difference between unemployment benefits, b, and the opportunity cost of searching for a job, c.

1. Derive the employed worker's discounted expected utility, V_e, as a function of the wage rate, w, the job destruction rate, s, the interest rate, r, and the unemployed worker's discounted lifetime utility, V_u, such that time increments no longer appear.
2. Derive the unemployed worker's discounted expected utility, V_u, as a function of the net income, z, the job-offer arrival rate, λ, the interest rate, r, and the employed worker's discounted lifetime utility, V_e, such that time increments no longer appear.
3. Given your answer above, derive the expression for the reservation wage, $x \equiv rV_u$, that solely depends on the model's parameters.
4. What are the effects of the model's parameters on the reservation wage x? Take the partial derivatives, using the implicit function theorem.

11.4.2 Pure search in discrete time and time consistent behaviour [MATLAB]

Consider the discrete-time model of unemployment with search effort. The lifetime utility of the individual is given by

$$U = \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \delta^t \left[u\left(c_t\right) - c\left(e_t\right) \right] \right],$$

where $0 < \delta < 1$ is the discount factor, e_t is effort at time t, and $c\left(e_t\right)$ is the cost of searching for a job. Consumption is given by

$$c_t = \left\{ \begin{array}{c} w \\ b \end{array} \right\} \text{ if the individual is } \left\{ \begin{array}{c} \textit{employed} \\ \textit{unemployed} \end{array} \right. .$$

Unemployed individuals can increase their probability of becoming employed in $t+1$ by increasing their search effort in t, that is we have

$$\text{Prob}\left(c_{t+1} = w\right) = p\left(e_t\right),$$

with $p'\left(e_t\right) > 0$, and $0 \leq p\left(e_t\right) \leq 1$.

1. Determine the optimal effort in period 0, i.e. e_0, for an unemployed worker. Use the

setup above and the following functional forms

$$\begin{aligned} u\left(c_t\right) &= \ln c_t, \\ c\left(e_t\right) &= e_t, \\ p\left(e_t\right) &= 1-\exp\left(-e_t\right), \\ \mathbb{E}_w u\left(w\right) &= u\left(w\right), \end{aligned}$$

where $\sigma \geq 0$ is the inverse of the intertemporal elasticity of substitution.

2. Now turning to the time inconsistent case, where lifetime utility is given by

$$U = u\left(b\right) - c\left(e_0\right) + \beta\mathbb{E}_0\left[\sum_{t=1}^{\infty}\delta^t\left[u\left(c_t\right)-c\left(e_t\right)\right]\right],$$

How does search effort change over time, for various search costs (low, moderate, high)? First solve the model as in question 1 above, and then look at how effort evolves over time past the first period. [*see MATLAB script*]

3. How can we see that behaviour is inconsistent over time? [*see MATLAB script*]

12 Growth, cues and automatic behaviour

- One of the most discussed properties of any real world economy is its growth rate
  - Usually laymen and policy makers want higher growth rates
  - But then think about global warming – there are arguments that growth rates are too high
- Independently of political or social objective function, we want to understand
  - what drives short-run and especially long-run growth
  - whether drivers of growth can be influenced by policy
- This chapter looks at
  - models of growth and at
  - extensions of those models that allow for behavioural features of decision maker
  - The growth part covers exogenous and endogenous growth models
  - The behavioural growth part allows for cues and automatic behaviour (in the sense of Laibson, 2001)

12.1 Models of growth

12.1.1 The Solow model with technological progress and population growth

- Technologies and saving behaviour
  - (see e.g. Aghion and Howitt, 1998, ch. 1.1)
  - Production technology

$$Y(t) = K(t)^{\alpha} [A(t) L(t)]^{1-\alpha} \tag{12.1}$$

  - Capital accumulation

$$\dot{K} = sK(t)^{\alpha} [A(t) L(t)]^{1-\alpha} - \delta K(t),$$

    population growth and factor productivity A growth

$$L(t) = L_0 e^{nt}, \quad A(t) = A_0 e^{gt}.$$

- The dynamics of the economy

  – Define an auxiliary variable $\tilde{k}$ to simplify the analysis as

$$\tilde{k}(t) = \frac{K(t)}{A(t)L(t)} \tag{12.2}$$

  – The growth rate of $\tilde{k}(t)$ is (see Exercise 12.3.1)

$$\frac{d\tilde{k}(t)/dt}{\tilde{k}(t)} = s\tilde{k}(t)^{-(1-\alpha)} - (\delta + g + n). \tag{12.3}$$

  – Its dynamic properties can easily be understood via a graphic analysis

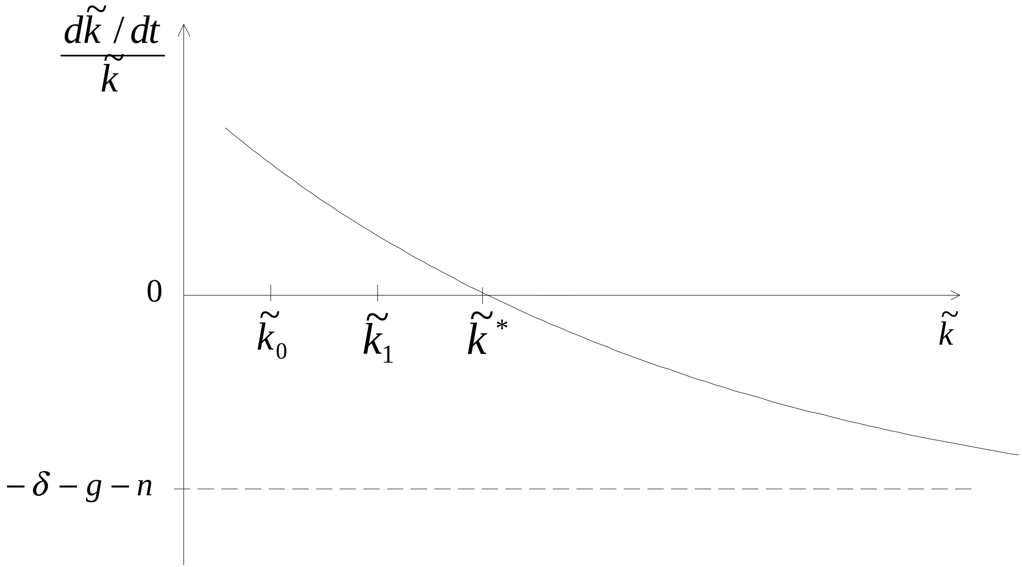


Figure 18 *A phase diagram analysis for the Solow growth model with technological growth, population growth and exogenous saving rate*

- Growth rates in the long-run equilibrium
  - Steady state value of capital per effective labour $\tilde{k}$ is constant (see Exercise 12.3.1)

$$\tilde{k}^* = \frac{K(t)}{A(t)L(t)} = \left(\frac{s}{\delta + g + n}\right)^{1/(1-\alpha)}. \qquad (12.4)$$

  - Computing the time derivative yields the long run growth rate (note that right hand side of (12.4) is constant) yields (see also Exercise 12.3.1)

$$\frac{\dot{K}(t)}{K(t)} = \frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)} = g + n.$$

- Growth rate of GDP is given by

$$\frac{\dot{Y}(t)}{Y(t)} = \alpha \frac{\dot{K}(t)}{K(t)} + (1-\alpha)\left[\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right] = \frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)} = g + n$$

- In words
  - growth rate of GDP is driven only by growth rate of TFP and population growth
  - capital growth per se does not play a role in the long-run
  - capital is not a "driver" of growth, drivers are TFP and population growth

- Growth rate of GDP per capita $y(t) \equiv Y(t)/L(t)$

$$\frac{\dot{y}(t)}{y(t)} = \frac{\dot{Y}(t)}{Y(t)} - \frac{\dot{L}(t)}{L(t)} = g + n - n = g$$

- In words,
  - inhabitants of a country become richer only by an increase in total factor productivity $A(t)$
  - population growth can "kill" GDP growth, i.e. measures of GDP growth are uninformative about whether a nation is better off over time
- To see the huge importance of the population growth rate n, consider the following figures

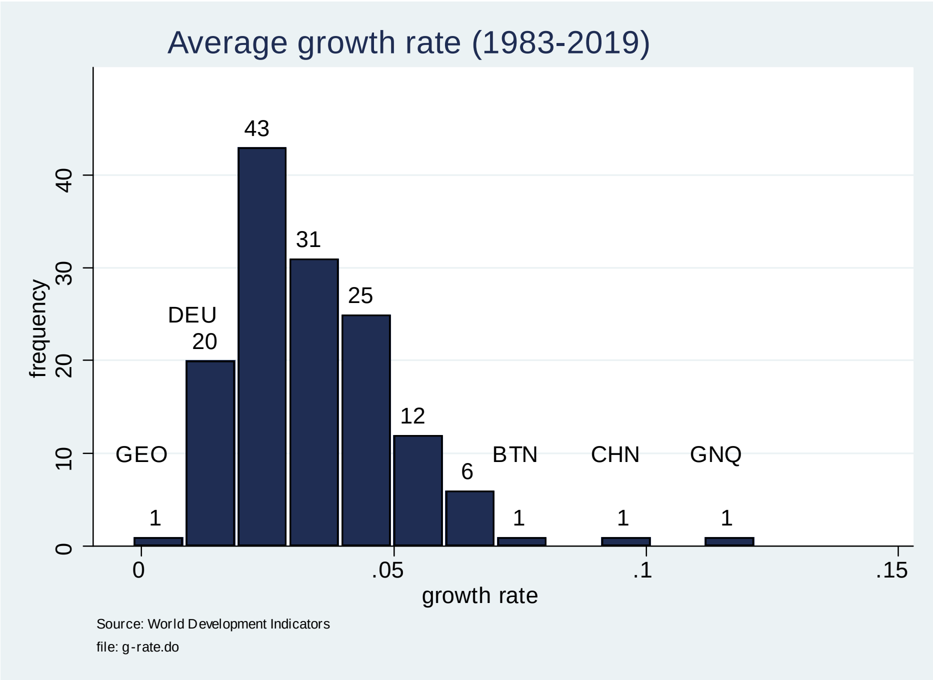


Figure 19 *Frequencies of growth rates of GDP (averages from 1983 to 2019)*

- For country codes, see wits.worldbank.org/wits/WITS/WITSHELP/Content/Codes/Country_Codes.htm

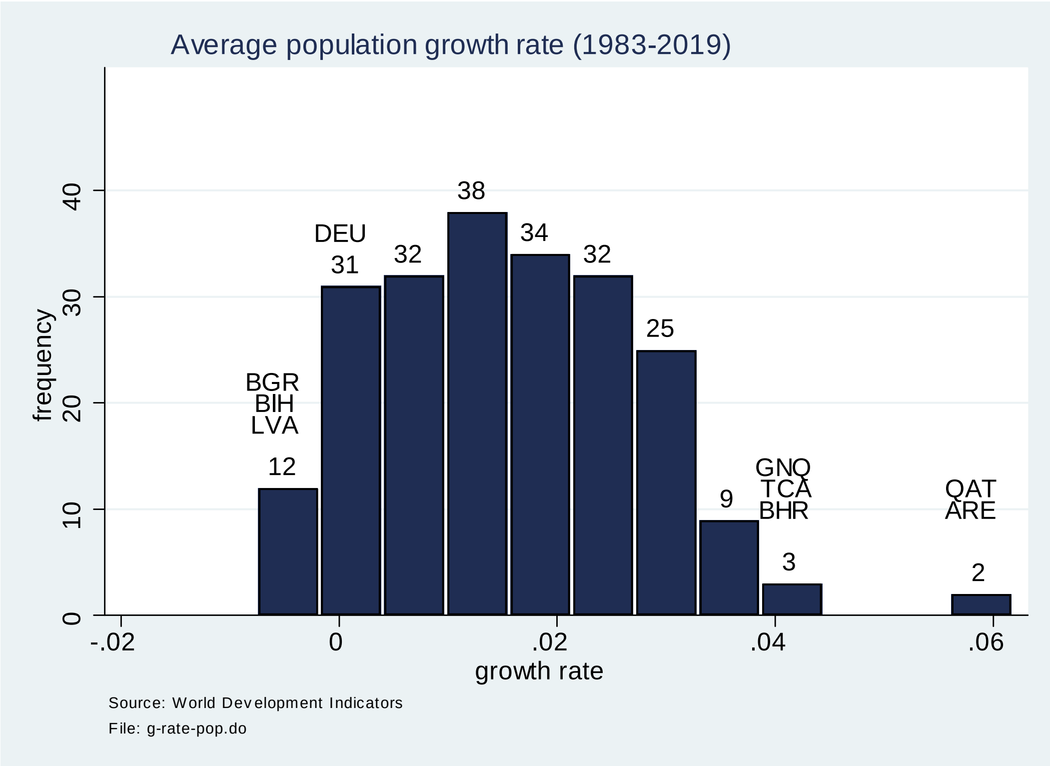


Figure 20 *Frequencies of growth rates of population (averages from 1983 to 2019)*

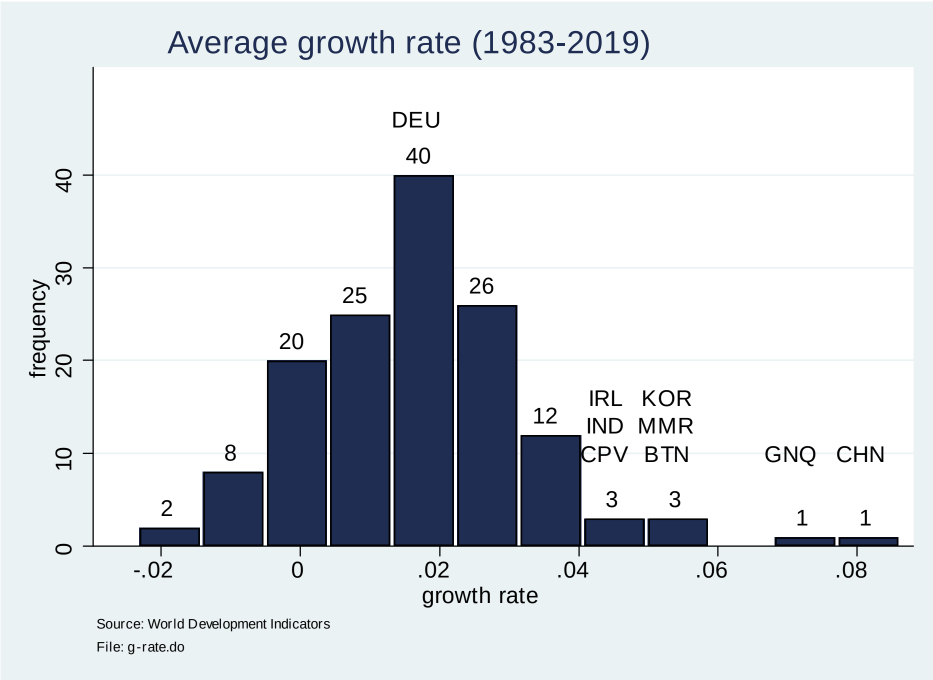


Figure 21 *Frequencies of growth rates of GDP per capita (averages from 1983 to 2019)*

- What these figures tell us
  - Hardly any country has negative average annual growth rates over 4 decades
    - Georgia (GEO) seems to be the big exception
    - Note that for shorter time periods, more countries have average negative growth rates
  - By contrast, more than 10 countries have negative average growth rates of GDP per capita
  - Stresses again that only per capita values are informative when describing a country

- Policy implications of Solow growth model
  - Growth of total factor productivity seems to be the only truly convincing policy option
  - Unfortunately, TFP growth is exogenous and the Solow model does not allow us to understand how TFP growth can be influenced
  - Only saving rate s can be influenced by policy – allowing to study only short-run effects
  - We need models with endogenous long-run growth rates

12.1.2 A simple model of endogenous growth: the AK model

- Background on the "new" endogenous growth theory
  - Some general discontent with the prediction of the neoclassical growth model
    - Why do countries grow with very unequal growth rates over long periods of time?
    - Why do not all countries catch up?
    - Why is the long-run growth rate unaffected by any economic incentive?
  - As a response, a series of theoretical papers were written that developed new growth models providing an endogenous explanation of long-run growth rates

- Various channels have been identified in the literature
  * Constant returns to scale for all factors of production that can be accumulated (Romer, 1986, Lucas, 1988, Rebelo, 1991)
  * Mechanisms include positive externalities from capital accumulation (Romer, 1986) or accumulation of both physical capital and human capital (Lucas, 1988, Rebelo, 1991)
  * Endogenous technological change (Romer, 1990, Grossman and Helpman, 1991, Aghion and Howitt, 1992)
  * This is achieved by knowledge spillovers from R&D (also a positive externality)
- Second wave of new growth models followed afterwards ...

- The AK model (Rebelo, 1991)
  - We look here at the simplest model of endogenous growth
  - It allows us to understand the central insight of this literature very quickly
  - We extend the model to allow for a tax rate and government expenditure
  - This illustrates the central insights even better :-)
- Preferences
  - Consider an individual (or a central planner) having the following intertemporal objective function

$$U(t) = \int_t^\infty e^{-\rho[\tau-t]} u(C(\tau))\, d\tau \tag{12.5}$$

  - Overall utility is denoted by $U(t)$, and $C(\tau)$ is consumption at τ
  - The planning period starts in t, time is continuous (whence we have the integral) and the planning horizon goes to infinity
  - The time preference rate is ρ
  - Instantaneous utility is characterized by constant relative risk aversion (CRRA)

$$u(C(\tau)) = \frac{C(\tau)^{1-\sigma} - 1}{1-\sigma}, \quad \sigma \geq 0,\ \sigma \neq 1$$

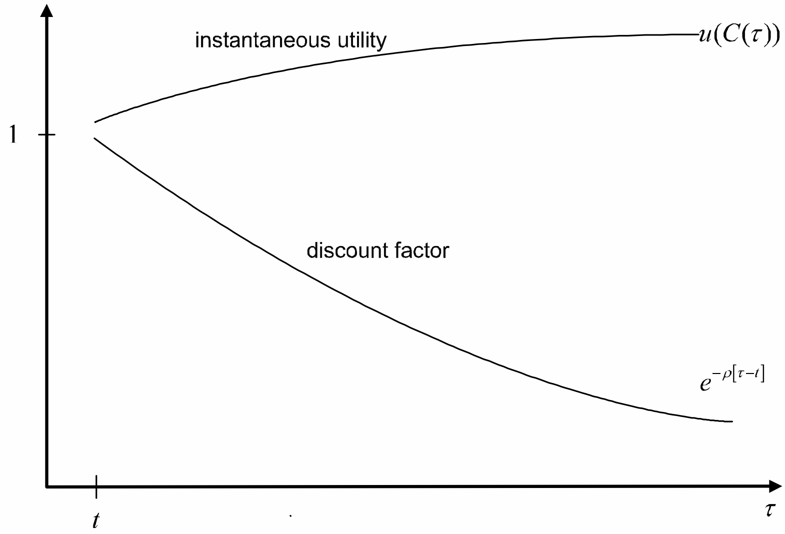


Figure 22 *Illustration of the objective function (recall Makro I)*

- Technology
  - We follow the approach of constant returns to factors of production that can be accumulated
  - Why should this be the case?
  - Romer (1986): total factor productivity changes as a function of the knowledge associated with more and more capital, $Y = A(K)\,K^{\alpha}L^{1-\alpha}$
  - When $A(K)$ happens to equal $K^{1-\alpha}$, we get $Y = KL^{1-\alpha}$
  - Lucas (1988): accumulate both physical capital K and human capital H, $Y = AK^{\alpha}H^{1-\alpha}$
  - Rebelo (1991): accumulate K and H or simply assume

$$Y(t) = AK(t) \tag{12.6}$$

  - Why can we have long-run growth? Marginal productivity of capital does *not* fall when K increases (as in the Solow growth model)

- Resource constraint
  - We study the economy as a whole
  - An alternative would consist in solving individual maximization problems (with budget constraints) and then aggregating individual behaviour
  - At the aggregate level, capital rises if output (net of taxes) minus depreciation exceeds consumption,

$$\dot{K}(t) = (1-\tau) Y(t) - \delta K(t) - C(t) \tag{12.7}$$

  - Tax income $\tau Y(t)$ is used for government purposes (not modelled)

- Solving the maximization problem
  - Maximize the social welfare function $U(t)$ given the technology $Y(t)$ and the constraint
  - Optimality condition is provided by the Keynes-Ramsey rule (see Exercise 12.3.2)

$$\frac{\dot{C}(t)}{C(t)} = \frac{(1-\tau) A - \rho}{\sigma} \tag{12.8}$$

  - If the net return to capital A exceeds the time preference rate ρ, there is consumption growth

- The growth rate of the economy – procedure
  - After having obtained our dynamic system consisting of
    * the resource constraint (12.7)
    * the technology (12.6) and
    * the Keynes-Ramsey rule (12.8)
  - we have obtained two differential equations for two variables, K and C
  - We proceed similarly to models without economic growth (cmp. Makroökonomik I): we look for
    * a long-run equilibrium and (maybe) afterwards for
    * behaviour outside of the long-run equilibrium (transitional dynamics)

- The growth rate of the economy – the question/ the guess
  - If marginal productivity A of capital is sufficiently large, the growth rate of consumption is positive,

$$\frac{\dot{C}(t)}{C(t)} = \frac{(1-\tau)A - \rho}{\sigma} \equiv g > 0$$

  - Using the resource constraint and the technology, we can express the growth rate of capital as

$$\frac{\dot{K}(t)}{K(t)} = (1-\tau)A - \delta - \frac{C(t)}{K(t)}$$

  - Question: is there a solution to these equations where $\frac{\dot{C}(t)}{C(t)} = \frac{\dot{K}(t)}{K(t)} = g$?

- The growth rate of the economy – verification
  - We now guess that there is a solution for which $\frac{\dot{C}(t)}{C(t)} = \frac{\dot{K}(t)}{K(t)} \equiv g$. Then we would have found a "growth equilibrium" or a "balanced growth path"
  - We verify by writing

$$\begin{aligned} g &= (1-\tau) A - \delta - \frac{C(t)}{K(t)} \Leftrightarrow \\ \frac{C(t)}{K(t)} &= (1-\tau) A - \delta - g = (1-\tau) A - \delta - \frac{(1-\tau) A - \rho}{\sigma} \end{aligned}$$

  - In words, there is a balanced growth path, if the ratio of consumption to capital is given by

$$\frac{C(t)}{K(t)} = (1-\tau) A - \delta - \frac{(1-\tau) A - \rho}{\sigma}$$

    where the right-hand side needs to be positive (see Exercise 12.3.2 for a calibration example)
  - Then, both consumption and capital grow at the rate g

- The growth rate of the economy (cont'd)
  - Given that K grows at the rate g, we can then compute the growth rate of output (12.6)
$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\dot{K}}{K} = 0 + g = g$$
  - The growth rate of GDP per capita is (assuming constant population) then also given by g
- Is there transitional dynamics?
  - Not in this setup
  - AK structure implies constant return A for investments

- What are the determinants of the growth rate?
  - The long-run growth rate is not given by a constant parameter but it is a function of parameters of the model
  - If agents are more impatient (ρ rises), the growth rate would fall (not so in Solow growth model)
  - If the government decreases the tax τ, the growth rate would rise (as the return to capital would rise – not so in the Solow model)
  - When the intertemporal elasticity of substitution $1/\sigma$ rises, the growth rate rises
- This endogeneity is a huge progress compared to exogenous growth rates
  - One can understand why countries grow at different rates
  - One can understand how policy affects economic growth (tax policy, trade policy, labour market policy ...)
  - One can understand whether growth rates are too high (global warming) or too low (poverty)

12.2 Cues and automatic behaviour

- Do humans behave in such a forward looking behaviour as just seen in neoclassical and endogenous growth models?
- Are they not rather influenced by advertisements?
- Are preferences not biased by all types of cues?
- Given the strong role of preferences in predicting the long-run growth rate of an economy, should richer models of human behaviour be taken into account?

12.2.1 Reminding of cues

- Laibson's (2001) cue theory of consumption
  - Preferences

$$u\left(c_t^{\text{sweets}}, c_t^{\text{fruit}}\right) = \left(c_t^{\text{sweets}} - x_t\right)^{\alpha}\left(c_t^{\text{fruit}}\right)^{1-\alpha} \tag{12.9}$$

  - Budget constraint

$$p^s c_t^{\text{sweets}} + p^f c_t^{\text{fruit}} = E$$

- Optimal behaviour

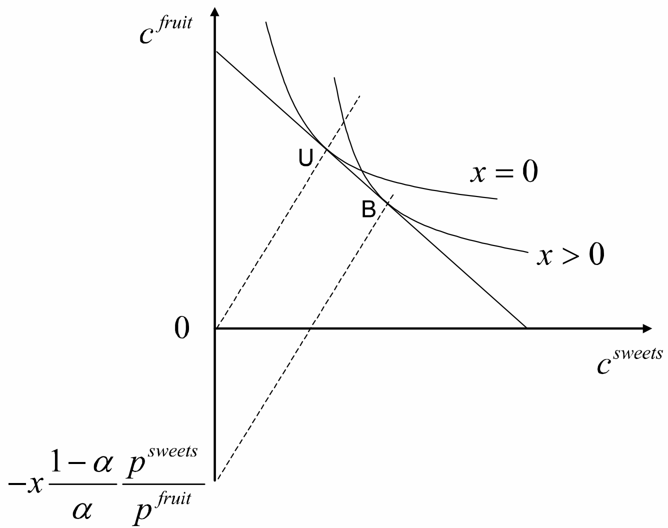


Figure 23 *Optimal behaviour in the presence of cues*

12.2.2 Reminding of automatic behaviour

Bernheim-Rangel (2004) model of addiction

- Preferences

$$u = \phi c^{\sigma} + x^{\sigma} + \beta z \tag{12.10}$$

- Budget constraint

$$c + qx = y$$

- Optimal behaviour

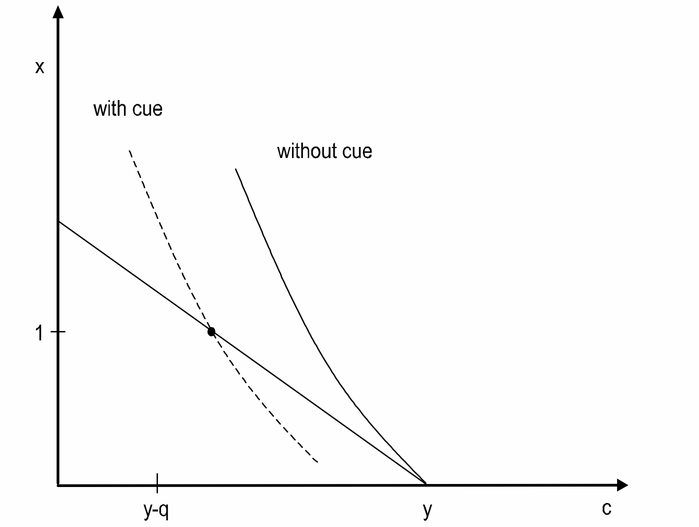


Figure 24 *The "drug-resistant" individual and indifference curves with and without cues*

12.2.3 Linking the two

What would be an interesting question?

- What is the effect of advertising (in the sense of Becker and Murphy, 1993) or the effect of cues (in the sense of Laibson, 2001) on the saving behaviour of an individual?
- What is the effect of addictive goods on consumption and saving behaviour of an individual?
- How do these modified saving behaviours affect the long-run growth rate of an economy?

How could this be modeled?

- One would embed the static utility functions (12.9) and (12.10) in an intertemporal utility function like (12.5)
- One would embed the static budget constraints into dynamic budget or resource constraints like (12.7)
- One would compute optimality conditions
- One would try to understand them and derive the corresponding growth rates
- A lot remains to be done ...

12.3 Exercises

12.3.1 Growth paths [MATLAB]

Consider a production sector employing a technology

$$Y(t) = K(t)^{\alpha} [A(t) L(t)]^{1-\alpha}, \quad \alpha \in (0,1)$$

where production,Y, depends on capital, K, labour inputs, L, and productivity, A. Capital accumulates over time, by saving a fixed share of output, sY, and depreciates at rate δ,

$$\dot{K} = sY(t) - \delta K(t).$$

Exogenous growth rates of the population and total factor productivity (TFP) are constant such that

$$\frac{\dot{L}(t)}{L(t)} \equiv n,$$
$$\frac{\dot{A}(t)}{A(t)} \equiv g.$$

1. What do the differential equations for $L(t)$ and $A(t)$ mean in words?

2. Derive the growth rate of capital per effective labour, $\frac{d\tilde{k}(t)/dt}{\tilde{k}(t)}$, where $\tilde{k} \equiv \frac{K(t)}{A(t)L(t)}$.

3. What is the steady-state value of $\tilde{k}(t)$, i.e. where $\frac{d\tilde{k}(t)/dt}{\tilde{k}(t)} = 0$, denoted $\tilde{k}^*$?

4. Show that the growth rate of capital in the steady state is given by $\dot{K}(t)/K(t) = g + n$.

5. Draw the phase diagram of $\frac{d\tilde{k}(t)}{dt}$ with respect to $\tilde{k}(t)$ and provide an intuitive explanation. (Note here we are talking about $\frac{d\tilde{k}(t)}{dt}$, the change in capital per effective labour over time, **not** its growth rate). [*see MATLAB script*]

6. Now draw the phase diagram of the growth rate of capital per effective labour, $\frac{d\tilde{k}(t)/dt}{\tilde{k}(t)}$, as a function of $\tilde{k}(t)$. [*see MATLAB script*]

12.3.2 Optimal consumption paths

Consider the following problem, where the central planner maximizes lifetime utility in aggregate consumption

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

where utility is CRRA:

$$u(C(\tau)) = \frac{C(\tau)^{1-\sigma} - 1}{1 - \sigma}$$

and aggregate output is produced according to the following technology, with a constant TFP:

$$Y(\tau) = AK(\tau)$$

and aggregate capital accumulates according to

$$\dot{K}(\tau) = (1-\theta)Y(\tau) - \delta K(\tau) - C(\tau),$$

where a share $1-\theta$ of output is reinvested into capital, depreciation is $0 < \delta < 1$, and consumption reduces the accumulation of capital.

1. Using the Hamiltonian method, derive the Keynes-Ramsey rule for consumption, which describes the growth rate of consumption over time as a function of parameters only.

2. Given your answer above, what is the backward solution to the resulting differential equation in $C(\tau)$?

3. Plot the growth rate of consumption, $\frac{\dot{C}}{C}$, as a function of θ, and determine TFP, A, using the following initial calibrations,

$$\begin{aligned}
&\theta = 19\% && \text{– VAT in Germany} \\
&\rho = 2\% && \text{– estimated to represent a discount rate of ca. 0.98} \\
&\sigma = \tfrac{3}{4} && \text{– low degree of risk aversion (high IES)} \\
&g \equiv \tfrac{\dot{C}}{C} = 2 && \text{– annual growth rate of Germany's GDP 1971-2015}
\end{aligned}$$

13 Business Cycles and Anxiety

13.1 Business cycles in an OLG model

- As before for growth, we are developing a model – this time on business cycles and anxiety
- This is all very research-oriented teaching
  - this model does not yet exist but
  - there is more progress than with the growth model
- We start with standard macro and look at the simplest possible DSGE (dynamic stochastic general equilibrium) model
- This builds on business analysis in Makro I
  - we had a dynamic structure ...
  - we had no uncertainty ......
- We can use insights from emotion-part of lecture where we studied uncertainty ...

13.1.1 The structure of a simple RBC model

- individuals live for 2 periods (e.g. young working and old retired)
- young and old individuals overlap (see figure below)
- rational expectations, all uncertainty is taken into account
- firms act under perfect competition
- closed economy in general equilibrium
- time is discrete

13.1.2 Some references

- Kydland and Prescott (1980) "A Competitive Theory of Fluctuations and the Feasibility and Desirability of Stabilization Policy"
- Kydland and Prescott (1982) "Time to Build and Aggregate Fluctuations"
- Wälde (2012) "Applied Intertemporal Optimization" (ch. 8.1)

13.1.3 Technology

- Aggregate technology

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

  where K_t is capital stock and L_t is employment in t and $0 < \alpha < 1$

- Crucial new aspect

$$A_t \tilde{}\, \text{LN}\left(A, \sigma^2\right)$$

  - Total factor productivity A_t is lognormally distributed with mean A and variance σ^2
  - drawing takes place from identical distribution for each t
  - TFP A_t is i.i.d. (identically and independently distributed)
  - implication: there is _ **no**_ growth in this model
  - economic importance: TFP is random, i.e. there are technology shocks

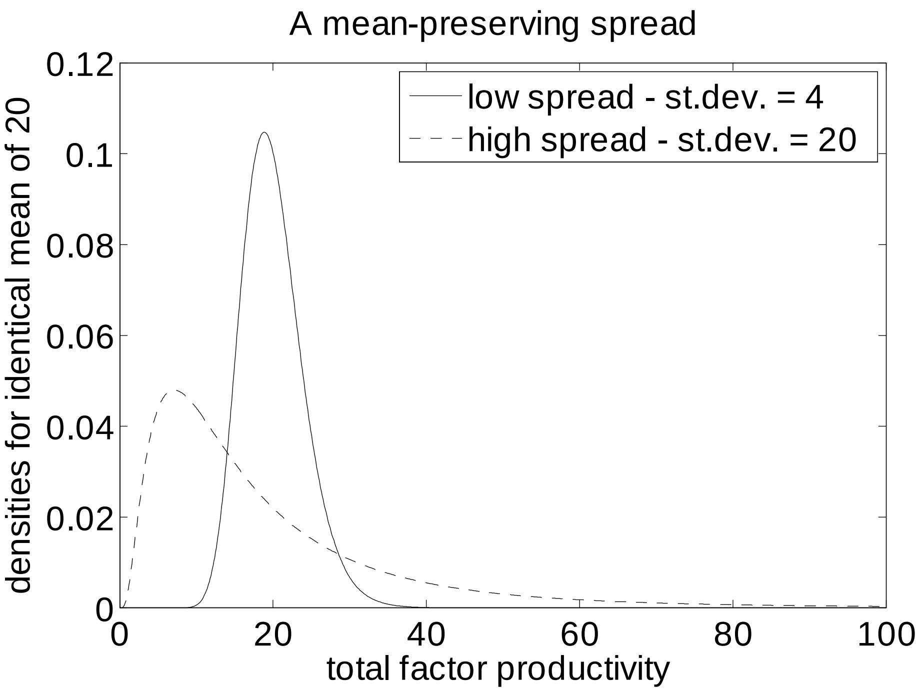


Figure 25 *Illustrating the distributional assumption for TFP for low and high spread at unchanged mean*

13.1.4 Timing

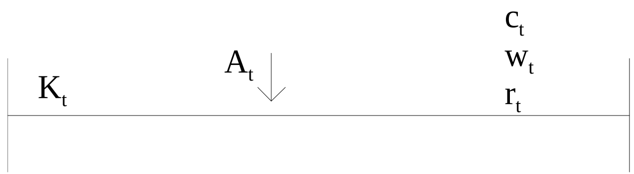


Figure 26 *The timing of events within a period t*

- As time is discrete and as there is uncertainty, we need to know when various "things" happen
- K_t is inherited from last period
- A_t is realized afterwards (realization of random variable TFP is known – like throwing a realization 4 (or 1 or 2 or 3 or 5 or 6) with a die
- afterwards firms pay wage and interest rate and households choose consumption

13.1.5 Firms

- Is life of firms more complicated? Do their decisions need to take uncertainty into account?
- No, firms maximize profits in a deterministic fashion as
  - they rent factors of production (K and L) in each period on spot markets
  - they know realization of TFP before making this decision

$$w_t = p_t \frac{\partial Y_t}{\partial L_t}$$
$$r_t = p_t \frac{\partial Y_t}{\partial K_t}$$

  - firms equate value (p_t) marginal productivities to factor rewards (w_t and r_t)
  - firms do not bear any risk

13.1.6 Households and intertemporal optimization

- (This is familiar from emotion part of the lecture)
- Objective function
  - households/individuals live for 2 periods (only)
  - individual consumes in both periods

$$\max_{\{c_t, c_{t+1}\}} \mathbb{E}_t \left[u\left(c_t\right) + \beta u\left(c_{t+1}\right) \right]$$

    and needs to form expectations as consumption (via wage, via TFP A_t) is uncertain
  - individual works only in period t
  - $\mathbb{E}_t$ is the expectations operator saying that individual forms expectations in t and takes all knowledge up to and including t into account

- Constraints
  - constraint in the first period (period t)

    $$w_t = c_t + s_t$$

    where s_t is savings in t
  - constraint in the second period (individual is retired)

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

    where left-hand side is income in period $t + 1$ (savings plus interest on savings) and right-hand side is consumption expenditure

- An example
  - A Cobb-Douglas utility function

$$\mathbb{E}_t \left[\gamma \ln c_t + (1-\gamma) \ln c_{t+1}\right]$$

  - Optimal behaviour

$$\begin{aligned} c_t &= \gamma w_t \\ s_t &= (1-\gamma)\, w_t \\ c_{t+1} &= (1+r_{t+1})\,(1-\gamma)\, w_t \end{aligned} \tag{13.1}$$

- Is there any uncertainty left?
  - yes, r_{t+1} is unknown in t
  - actual, realized consumption in $t+1$ differs from expected consumption

13.1.7 Aggregation over individuals and firms

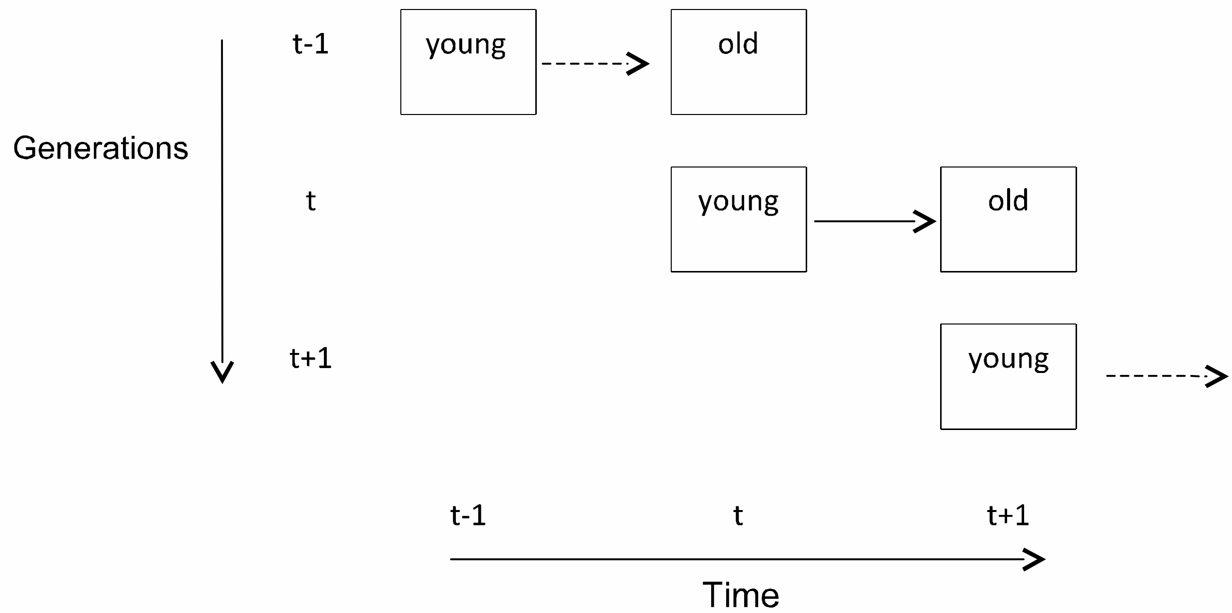


Figure 27 *Overlapping generations*

- What is the capital stock in $t+1$?
  - Let population size be given by $2L$
  - As individuals work only while young, size of the labour force (in each period) is L
  - When the young save in t, the capital stock in $t+1$ originates from these savings

$$K_{t+1} = Ls_t$$

- Now construct a difference equation for capital
  - use savings expression from above
  - replace wage by marginal productivity of labour
  - rearrange and find (see Exercise 13.3.1)

$$K_{t+1} = Ls_t = L(1-\gamma)w_t = (1-\gamma)(1-\alpha)A_t K_t^{\alpha} L^{1-\alpha}$$

- This equation describes the intertemporal evolution of the economy by linking period t to period $t+1$ (by looking at the capital stock)
- It allows us to understand the role of uncertainty as TFP A_t is on the right-hand side

13.1.8 The dynamics of TFP, the capital stock and output

- The phase diagram

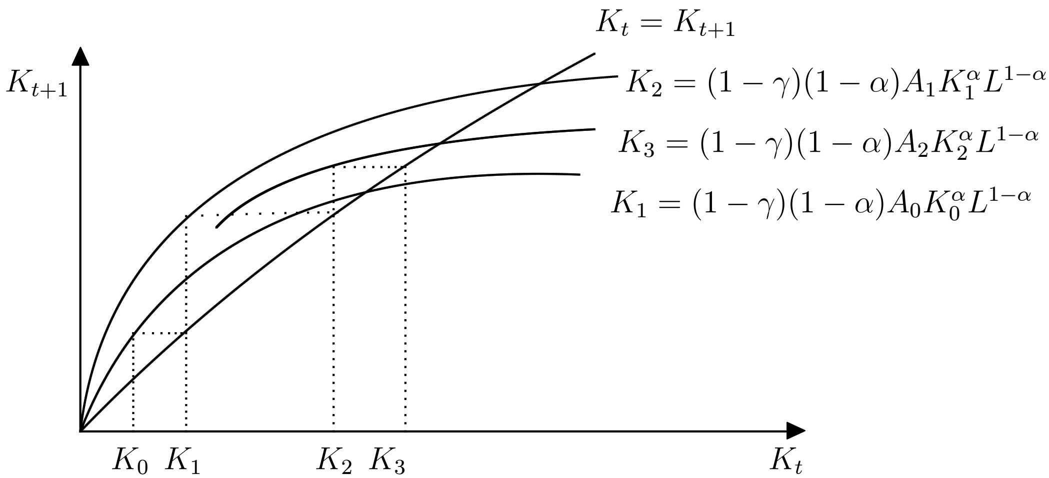


Figure 28 *Convergence towards a "stochastic steady state"*

- Feeling for dynamics of K_t comes from figure
  - in 0 we can predict K_1 but not K_2 as TFP A_1 is unknown
  - but we know distribution of A_t
  - now assume $A_0 < A_t < A_1$ (which is a stronger assumption than lognormal distribution from above)
  - in case of $A_t = A_0$ (always recession), we end up at low steady state
  - in case of $A_t = A_1$ (always boom), we end up at high steady state
  - in most cases TFP lies between these extremes
  - in the long-run the capital stock is distributed between K^{low} and K^{high}
  - we do not get statements about capital stock in the long run but only about its distribution ("where will it probably be")

13.1.9 What have we learned?

- The origins of business cycles
  - Business cycles are the results of shocks to technology
  - (One can just as easily imagine shocks to preferences, international prices, endowment)
  - These shocks are random and their realization cannot be predicted
  - Agents know however that there are shocks and they know the distribution of these shocks (rational expectations)
  - Shocks in the real business cycle approach are as exogenous as technological growth in the Solow growth model
- The implications for economic model building
  - One can no longer talk about time paths or a steady state of an economy
  - One needs to talk about distributions and stationary distributions
  - In certain cases (in fact, in this model), one can compute the average capital stock and its variance (advanced bachelor thesis)

- Which of the observed business cycles can plausibly be explained by technology shocks?
  - Oil price shocks of the 1970s
  - Reunification of Germany (negative technology shock)
  - What about the financial crisis starting 2007? $\rightarrow$ A TFP shock was not the cause, but maybe a consequence ...

13.2 Business cycles and anxiety: towards a complete analysis

13.2.1 The effect of anxiety

- We replace the standard expression $s_t = (1-\gamma) w_t$ from (13.1)
- We now use $s_t = \frac{1-\gamma-(3\zeta-1)\gamma\phi}{1-(3\zeta-1)\gamma\phi} w_t$ from (4.4) in the anxiety analysis in the emotion-part of the lecture
- For notational and pedagogical simplicity, we write it as

$$s_t = (1-\Gamma) w_t \text{ where } \Gamma \equiv \frac{\gamma}{1-(3\zeta-1)\gamma\phi} \tag{13.2}$$

13.2.2 Aggregation over individuals and firms

- The capital stock in $t+1$
  - Population size still at $2L$, labour force at L
  - Capital stock still given by

$$K_{t+1} = Ls_t$$

- Now construct a difference equation for capital
  - We follow the same steps as before
  - we find (do not see tutorial but compare γ with Γ)

$$K_{t+1} = (1-\Gamma)(1-\alpha) A_t K_t^{\alpha} L^{1-\alpha} \tag{13.3}$$

- Phase diagram analysis
  - qualitatively, there is no difference to fig. 28
  - only the γ is replaced by the Γ
- Economic relevance is huge, however
  - Understand the effect of anticipatory emotions on expected equilibrium capital stock
  - Understand the interaction between precautionary saving ("excess saving" compared to saving in the absence of uncertainty) and emotional saving
  - Can the two be separated, i.e. can we quantify how strong each of these channels is? (also advanced bachelor thesis)

13.2.3 How anxiety affects the distribution of wealth

- We now compute the effect of anticipatory emotions on the capital stock in an economy
- To do this, we need to be able to compute the capital stock – of which we know that it evolves in a stochastic way
- We therefore do not know what the *realized* capital stock will be in the future
- We can compute the *expected* capital stock in the future, however!
- We do this in the following way ...

- We do this in the following way ...
  - Rewrite the equation for the capital stock (13.3) by applying logs

$$\ln K_{t+1} = \ln\left[(1-\Gamma)(1-\alpha)L^{1-\alpha}\right] + \alpha \ln K_t + \ln A_t$$

  - Define $k_t \equiv \ln K_t$, $c_0 \equiv \ln\left[(1-\Gamma)(1-\alpha)L^{1-\alpha}\right]$ and $\varepsilon_t \equiv \ln A_t$. Then we obtain

$$k_{t+1} = c_0 + \alpha k_t + \varepsilon_t$$

  - Define further expected wealth as $\mu_t = \mathbb{E}_0 k_t$, in words, μ_t is the expected (logarithmic) capital stock for some future point in time t when we form expectations at 0
  - Applying expectations to this difference equation, we get

$$\mu_{t+1} = c_0 + \alpha\mu_t + \mu_A \tag{13.4}$$

    where $\mu_A \equiv E_0\varepsilon_t$, in words, μ_A is the mean of the log of the capital stock
  - This is a simple difference equation for the expected capital stock!

- Analysis of this equation as in all previous examples for dynamic systems
  - Is there a steady state?
  - Are there transitional dynamics?
- Steady state analysis
  - If there is a steady state, it must satisfy $\mu_{t+1} = \mu_t \equiv \mu$
  - Using (13.4), the expected capital stock in the steady state is given by

$$\mu = c_0 + \alpha\mu + \mu_A \Leftrightarrow \mu = \frac{c_0 + \mu_A}{1 - \alpha}$$

  - (We do not look at transitional dynamics at this point.)

- Back to economics: how does expected wealth depend on emotions?
  - How does expected wealth depend on emotion parameters in (4.2) and (4.3), i.e. on ϕ (importance of anxiety) and ζ (personality parameter for variance of return)?
  - Answers come from computing the derivative of μ with respect to emotion parameters – see tutorial or exam :-)

$$\begin{aligned} \frac{d\mu}{d\phi} &= \frac{dc_0/d\phi}{1-\alpha}, \\ \frac{d\mu}{d\zeta} &= \frac{dc_0/d\zeta}{1-\alpha}, \end{aligned}$$

where one should take into account that $c_0 \equiv \ln\left[(1-\Gamma)(1-\alpha)L^{1-\alpha}\right]$ and that $\Gamma = \frac{\gamma}{1-(3\zeta-1)\gamma\phi}$ from (13.2) collects all the emotion parameters

13.3 Exercises

13.3.1 Business cycles [MATLAB]

Consider a representative household living for two periods only, maximising expected lifetime utility:

$$\max_{\{c_t, c_{t+1}\}} U_t = \mathbb{E}_t \left[u\left(c_t\right) + \beta u\left(c_{t+1}\right) \right], \quad \beta \in (0, 1).$$

The constraint in the first period reads

$$w_t = c_t + s_t,$$

where w_t is wage at time t, c_t is consumption and s_t represents savings. In the second period, i.e. at $t+1$, the constraint reads

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

where $r_{t+1} \sim N\left(r, \sigma_r^2\right)$ is the stochastic interest rate, and consumption at $t+1$ is given by the value of savings at t plus interests. The representative firm maximizes profits

$$\max_{\{K_t, L_t\}} \pi_t = Y_t - \left(1 + r_t\right) K_t - w_t L_t$$

$$\text{s.t. } Y_t = A_t K_t^{\alpha} L_t^{1-\alpha},$$

where K_t is aggregate capital at t and L_t represents aggregate labour at t. $A_t \sim LN\left(A, \sigma_A^2\right)$ is the log-normally distributed total factor productivity (TFP). Capital next period is determined entirely by aggregate savings

$$K_{t+1} = L_t s_t.$$

1. Solve the maximization problem of the household by substitution, and determine the consumption Euler equation.

2. Using your answer from above, and the Cobb-Douglas preferences below, find optimal consumption and savings as functions of the wage w_t,

$$\max_{\{c_t, c_{t+1}\}} \mathbb{E}_t \left[\gamma \ln c_t + (1 - \gamma) \ln c_{t+1} \right], \quad \gamma \in (0, 1) .$$

3. Solve the firm's maximization problem, and determine the optimal demand functions for K_t and L_t as functions of the wage.

4. Using the results from (*2*) and (*3*) above, derive the law of motion for capital, that characterizes this economy and draw its phase diagram (drawing K_{t+1} as a function of K_t). Show what happens under various realizations of TFP. Give an interpretation to the graph. [*see MATLAB script*]

14 Conclusion

14.1 The relation of unemployment and time-inconsistent behaviour

- What have we learned about unemployment?
  - We looked at the pure-search model
  - There is no instantaneous labour market clearing as it takes time to find a job
  - Finding a job is split into
    - receiving a job offer
    - accepting the job offer
  - Unemployment arises due to necessity to search (involuntary unemployment) and because of rejection of wage offers (voluntary unemployment)
  - Unemployment can be reduced via all channels that reduce the reservation wage
  - Model is "very one-sided" as demand side by firms is not modeled
  - Policy conclusions are (at least) incomplete

- How important is time inconsistent behaviour for unemployed workers?
  - We looked at pure-search model extended for present-bias
  - We found the usual tension in first-order conditions where discounting between one period and the next depends on when the decision is made
  - Empirically, Paserman shows that measure β of present bias can be considerably below 1
  - He finds estimates between 0.4 and 0.89
  - Present bias is an important feature of search effort of the unemployed
- Are there policy implications?
  - Policy tools for time-inconsistent behaviour can be applied here as well
  - Any commitment device is desirable
  - Taxation in the form of "sin taxes" might be advisable for public employment agencies as well

14.2 Growth and automatic behaviour

Neoclassical growth theory

- The complete Solow growth model was introduced
- Compared to the version with capital accumulation only ("Makro I version"), we allowed for
  - exogenous population growth
  - exogenous technological progress
- In an economy with population growth
  - there is long-run growth of GDP
  - there is *no* long-run growth of GDP per capita
- In an economy with technological progress
  - there is long-run growth of GDP
  - there is also long-run growth of GDP per capita

- Shortcomings of the model
  - One cannot understand why countries empirically seem to grow at different long-run growth rates
  - It is also hard to understand why some countries do not seem to catch up at all
  - Any policy measure has no impact on the long-run growth rate

Endogenous growth literature

- A new wave of growth models emerged
  - as of the end of the 1980s
  - that stressed the importance of economic mechanisms that influence the growth rate of an economy
- Various mechanisms why there is endogenous long run growth
  - Positives spillovers from R&D
  - Joint accumulation of human capital and physical capital (technically: constant returns to scale in accumulable factors of production)

- Determinants of long-run growth
  - Size of the economy (shortcoming - see semi-endogenous and non-scale growth models)
  - Preferences of households
  - Technological parameters (e.g. productivities or elasticities of substitution)
  - Policy parameters (e.g. tax or subsidy rates)
- New insights from growth theory
  - Observations on growth rates can better be understood
  - Catching-up, falling-behind or constant (relative) distance can be understood
  - Much more flexibility for growth analyses than with "old" growth theory

Automatic behaviour

- Careful analyses exist that study non-choice behaviour
  - Laibson's (2001) cue theory of consumption
  - Bernheim-Rangel (2004) model of addiction
- These analyses can be combined with intertemporal saving behaviour
- Looking for a good Bachelor thesis or seminar paper (in a Master programme)?

14.3 Business cycles and anxiety

Real business cycle analysis

- We studied a complete optimal saving model under uncertainty
- Uncertainty is explicity modelled (in contrast to Makro I) and taken into account by risk-averse households
- We understood capital accumulation process over time and across shocks

The role of anticipatory emotions

- We looked at example of anxiety
- Anxiety affects saving behaviour
- Additional motive to precautionary saving
- Again, behavioural views extend frame within which we can give interpretation to observations

Part IV
Summary

What was the general idea of this lecture again?

- This was a lecture on behavioural macroeconomics
- The lecture had the following structure
  - Emotional economics
  - Behavioural economics
  - How behavioural macroeconomics could look like
  - Wealth distributions and redistribution

- Structure was chosen as the field of behavioural macro is developing
  - We first look at behavioural foundations
  - Then we look at macroeconomic models (unemployment, growth, business cycles) and discuss their extension to allow for behaviour features
  - Wealth distribution chapter is pure macro (so far) – empirical economists (Dynan, Skinner and Zeldes, 2004) argue that behavioural features are required
- Good example of "research-based teaching", a concept favoured by JGU

What are the 'big messages'?

- What are the messages that should survive from this lecture?
  - Every detail of the course for the rest of everybody's life ;-)
  - Strong belief that psychological research is extremely useful for understanding economic questions
  - Strong(er) belief that economic methods are even more useful to further develop psychological thinking
  - Example of interdisciplinary research where every discipline learns something from the other discipline

- The most striking insight from emotional and behavioural economics
  - Models of time inconsistency
  - Individuals make plans – and they do not stick to them
  - This is because individuals keep being surprised by their changes in preferences (the present-bias parameter β)

- What is THE issue in macroeconomics?
  - Inequality in GDP per capita and in its average growth rates over decades around the world
  - Yes, there is inequality in wealth distributions within a country
  - Yes, there is unemployment
  - But none of this is as strong as inequality in GDP per capita

- Do we need economics to solve these problems?
  - Yes and no – where the *no* is stronger
  - Yes as we need methods to meaningfully run a country, to manage a market economy, to internalize externalities, to control competition by reducing market power of firms that are too large
  - But – in most cases – reasonable methods are known
  - So: no, we need rethinking of human beings
  - We need more sharing, more compassion, more thinking in terms of groups than thinking in individual terms – so keep in mind $u = u\left(c^{\text{me}}, c^{\text{the others}}\right)$
  - How this works: Know Thyself

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