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Bounded Rationality - Past, Present and Future
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1 Overview

Rationality in economics is defined by completeness and transitivity of preference relations. In a more applied sense, rationality means utility maximization or expected utility maximization in a world with uncertainty. This seminar looks at models that portray human behaviour as at least to some extent not being rational. This includes early models of bounded rationality, models of ad-hoc deviations from Bayesian learning, non-rational models of addiction, dual-self models that allow for some non-rational aspect (and we will see to what extend this applies to existing dual-self models), dual-process models from psychology and models of stress and coping.

2 The origin of bounded rationality

2.1 Rationality

Textbook analysis of rationality building on Mas-Colell, Whinston, and Green (1995) or Varian (1992).

2.2 Early models of bounded rationality

Bounded Rationality has fascinated economists for a long time. Simon (1955) was the one who coined the term 'bounded rationality' by proposing a positive theory of flesh-and-blood human's behavior. His theory directly competes with the neoclassical rationality paradigm as he puts a big question mark over the strong assumption which come along with the rationality concept. Simon does not neglect that humans, when making decisions, are subject to psychological and physiological restrictions. E.g. they have limited computational skills and knowledge or cannot solve complex optimization problems instantly and effortless. Therefore he proposes a theory, in which agents do not search for optimal solutions, but for satisfying ones. The idea of changing the goal (i.e. changing the opinion of what a satisfying solution would be) in the course of time gave raise to a dynamic version of Simon's basic model. Selten (1998) took up Simon's point and formulated a model of the adaption of aspiration when searching for satisfying solutions. However, Kahneman (2003) rather focused on the use of heuristics and rules of thumb to explain the bounds of rationality. His idea is also in line with Simons basic assumption of effortful optimization. But beyond a doubt the term 'bounded rationality' experienced a development over time and was used in different ways by researchers (see Conlisk (1996) for a classical survey article and Lee (2011) for further informations on the development of the term). Whereas Simon kicked off a fundamental rethinking of how to model economic agents, nowadays the tendency is to model bounded rationality in ways which are rather close to standard economic models (Klaes, Sent, et al. (2005)). In the more recent papers e.g. by Harstad and Selten

(2013) and Rabin (2013) the role of optimization-based vs non-optimization models is especially disputed. As required by Rabin, economic models that incorporate psychological insights should be porable extensions of existing models (PEEM).

3 Current views on bounded rationality

3.1 Ad-hoc deviations from Bayesian learning

- Rabin and Vayanos (2010) / Rabin (2002)

Rabin and Vayanos develop a model of the so called gambler's fallacy. That is, the mistaken belief of a gambler, that outcomes of i.i.d. processes are perceived to be correlated with outcomes in the past and therefore are not i.i.d. Or, put more simply, if you play roulette and black came up nine times in a row, then people often wrongly think, the probability that red comes up on the next spin must be very high. In their model, individuals receive signals that depend on an underlying state, which evolves according to an auto-regressive process and cannot be observed. What individuals observe is the state, plus an i.i.d. normal shock with mean zero and a certain variance. The bias caused by subjective perception is modelled as the mistaken belief that the observed sequence is not i.i.d. but rather depends on the history. Therefore they include a parameter, α, which measures the strength of the effect.

The model structure in Rabin (2002) is pretty similar to Rabin and Vayanos (2010), described above. An infinite sequence of i.i.d. signals is generated. The belief in the law of small numbers or the gamblers fallacy is modelled as the subject's misunderstanding that the world is i.i.d. Instead, the subject thinks, signals are drawn without replacement, which makes the signal in $t+1$ dependend on the signal in t.

- Rabin and Schrag (1999)

Rabin and Schrag develop a formalization of the so called confirmatory bias, i.e. that people misinterpret new information as supporting information for a certain hypothesis. The way people learn, departs from Bayesian updating, in so far, that reception and perception differ. If an agent believes that Hypothesis A is more likely than B, he interprets a received i.i.d. signal $s_t = a$ (reception) as $\sigma_t = \alpha$ (perception) correctly, while he misinterprets with probability q a received i.i.d. signal $s_t = b$ as $\sigma_t = \alpha$. The strength of the bias is hence captured by parameter q (which unrealistically does not depend on the agent's belief). Of course the individual's perception is not i.i.d. anymore.

- Gennaioli and Shleifer (2010)

Gennaioli and Shleifer propose a model of representativeness heuristic. In their paper they compare inferences made by a fully Bayesian individual with those made by a so called local thinker. Characteristic for the latter is, that he cannot remember all relevant information, i.e. he has limited recall and remembers just stereotypical information. The inferences he draws, using not all informations are then biased.

- Barberis, Shleifer, and Vishny (1998)

Barberis et al develop a model of investor's belief formation, which is consistent with empirical findings regarding under-/ and overreaction of stock prices to good or bad news. They consider an investor, who's job is to forecast earnings. Earnings in t depend on earnings in $t-1$ plus a shock to earnings in t. In fact, the earning stream follows a random walk, but the investor mistakenly thinks, earnings are determined by one of two current states of the world ('Model 1' or 'Model 2') and in neither of the two states earnings follow a random walk. However, underreaction of stock prices to news is a consequence of the investor thinking Model 1 is the true current state, while it comes to an overreaction to news, if he thinks Model 2 is the true state. The investor never finds out, that both models are wrong, even when he observes earnings for a long time. His task is to figure out, which of the two actual wrong models generate the earnings. Therefore he continuously updates his belief that the shock was generated by Model 1, using Bayes Rule. Given his observations and his belief regarding the true state of the world, he infers the price of a stock, which is then simply its value as perceived by him.

- Daniel, Hirshleifer, and Subrahmanyam (1998)

Daniel et al built a theory of security market over- and underreactions, which is grounded on investor's overconfidence about the precision of private information and biased self-attribution. When being overconfident, the investor overweights the private information relative to his prior belief, which is modelled such that the precision of the noisy private signal is assessed too high (or the variance too low) and this in turn makes the stock prices overreact. In the opposite way he underweights public information, which makes stock prices underreact.

Moreover the investor observes the outcomes of his actions and updates the confidence in his own abilities (self-attribution). Here, he overweights observations, which confirm his actions and underweights events, which disconfirm them.

In their model investors are quasi-rational Bayesian updaters, which means that they update their beliefs using Bayes' rule, but overassess private information as they are biased in updating the informations precision. That is, at a certain point in time, investors receive a noisy private signal about the underlying security value. The signal consists of the terminal value of the security plus an error term (the noise). While the error term is normally distributed with mean zero and a certain precision, the investor's perception of this precision differs from the true precision.

- DeMarzo, Vayanos, and Zwiebel (2003)

"[...] boundedly rational model of opinion formation in which individuals are subject to persuasion bias; that is, they fail to account for possible repetition in the information they receive."

- Kahneman and Frederick (2002)

Kahneman and Frederick show that Bayes' Theorem does not describe how humans in reality deal with probabilistic information. They found, e.g. in their famous Linda experiment that humans in fact neglect base rates. After reading a description about a person (Linda), participants were asked (inter alia) if they think Linda is rather a bank teller or bank teller and active in the feminist movement. Most of the participants ranked the conjunction higher than its constituent, although it is clear, according to the fundamental properties of probability, that the probability that Linda is a bank teller must be higher than the conjunction. This shows that people neglect base rates and rely on representativeness instead, meaning they substitute a difficult question with an easier one, here "How well fits the description to a stereotype?"

3.2 Dual-self

- Loewenstein and O'Donoghue (2005)

They consider a dual-process model, in which behavior is the outcome of the interaction between a deliberative process and affective process. Where the deliberative process follows utility maximization "as usual", the affective process takes motivations and emotions into account. Both systems have distinct objectives. The authors assume a principal-agent structure, i.e. that the affective system has initial control, but that the deliberative system can influence behavior through the exertion of effort, or willpower. The deliberative system then chooses which behavior to implement by trading off its objectives against the cost of exerting this willpower. They also investigate several factors that alter the relative influence of the two systems. In their model, both systems can be activated by stimuli: E.g. seeing a snake (cue) evokes fear and thus the motivation to escape (affective), while seeing a snack (cue) perhaps reminds one, that (s)he is on diet (deliberative). The proximity (geographic, temporal, visual, ...) of a stimulus determines to which degree the affective system will be activated.

- Alonso, Brocas, and Carrillo (2014)

Research in the brain sciences has established that individual decision making requires the allocation of scarce processing resources to different brain systems. Following this evidence, Alonso, Brocas and Carillo model the brain as an hierarchical organization in which a coordinator (the principal) allocates limited resources to the brain systems (the agents) responsible for the different tasks.

- Brocas and Carrillo (2008)

Brocas and Carrillo use a dual-self model with a principal-agent structure to model the human brain as a dual-system organization subject to three conflicts: First, an asymmetric information conflict, capturing the fact, that different informations are available in different parts of the brain. Second, a temporal horizon conflict, which is based on the assumption, that temporally close events are relatively more important than temporally distant events. And third, an incentive salience conflict, which means that the relative weight in utility attached to tempting versus non-tempting goods differs.

- Fudenberg and Levine (2006)

Fudenberg and Levine use a Stackelberg game setup to examine self-control. In the game there is a sequence of short-run myopic impulsive selves (one per period) and a patient long-run self, playing against each other. The short- as well as the long-run self have the same preferences over stage-game outcomes and differ only in how the regard future. In other words, the utility of the long-run self equals the discounted sum of utilities of the short-run selves. In the first phase of the game, the long-run self chooses the short-run player preferences. The short-run self then observes the decision of the long-run self, prior to choosing the own action in the second phase. The model is applied i.a. to an intertemporal consumption-saving problem.

3.3 Cue-Theory and non-rational models of addiction

- Bernheim and Rangel (2004)

Bernheim and Rangel present a new theory of addiction, incorporating insights about addictive behavior from psychology, neuroscience, and clinical practice into an otherwise standard intertemporal decision-model. In their model, individuals can enter a "hot mode" (cue-triggered), in which they always consume an addictive substance, independently from their preferences in "cold mode". Behavior in the model results from the soulution of a dynamic programming problem with stochastic preferences (cue-triggered mistakes). They do not explicitly model the source of behavior in hot mode, but assume it follows a simple rule ("always consume drugs"). In fact, they focus on behavior in cold mode, i.e. optimization as usual, but taking into account the possibility of entering the hot mode.

- Laibson (2001)

Laibson models the psychological idea, that cues and consumption goods become complements by repeated pairing. He develops a model with a single, fully rational, agent, in a setting where there are two cues, "green lights" and "red lights". In his model cues elicit changes in preferences and behavior, as cues raise the desire (marginal utility) of a consumption good. That is, utility from the consumption of an addictive good when a given light is on depends on the agent's past behavior under that particular light. Laibson's cue-theory is used to understand addictive/habit-forming behaviors and marketing.

- Gruber and Kőszegi (2004)

Is addiction rational? Gruber and Kőszegi compare rational with non-rational models of addiction. They develop a model of addiction based on time-inconsistency as in Laibson.

- Ameriks, Caplin, Leahy, and Tyler (2007)

How would people ideally allocate a prize over time? Would they be tempted to deviate from this ideal? Would their actual choice deviate from the ideal? Ameriks et al develop a survey instrument based on a simple hypothetical choice scenario to measure self-control problems.

3.4 Satisficing

- Caplin, Dean, and Martin (2011)

Everyday decisions are often made without full examination of all available options. Thus, the best available option may sometimes be missed. Caplin et al develop a search-theoretic choice experiment to study the impact of incomplete consideration on the quality of choices. Their findings bring them to the conclusion that many decisions can be understood using Simon's satisficing model.

4 The future

4.1 Dual-process models

Dual-process literature suggests that two systems which are active in different situations or in parallel exist within one individual. Evans (2008) in his survey article finds that different papers like Toates (2006), Stanovich and West (2000), Smith and DeCoster (2000), Kahneman and Frederick (2002) and many others agree on a common characterization: 'system 1' is described as fast, automatic, unconscious, instinctive, innately programmed and formed by associative learning processes, where Toates (2006) especially stress the stimulus-boundedness of the automatic system. And 'system 2' can be characterized as slow, deliberative, conscious, demanding, permits abstract hypothetical thinking. Moreover it is commonly argued that automatic cognition controls a significant share of our behavior.

See also the short survey by Alos-Ferrer and Strack (2014).

4.2 Pavlovian-Instrumental Transfer

Human behavior can be seen a series of decisions. Most of these decisions are goal-directed. That is, people decide e.g. to buy a product in order to satisfy a certain desire. But goal-directed behavior can easily be manipulated. Research in psychology (Allman, DeLeon, Cataldo, Holland, and Johnson (2010), Hogarth, Dickinson, Wright, Kouvaraki, and Duka (2007), Paredes-Olay, Abad, Gámez, and Rosas (2002), Balleine and Ostlund (2007) and Cartoni, Puglisi-Allegra, and Baldassarre (2013)) and neurology (Bray, Rangel, Shimojo, Balleine, and O'Doherty (2008), Talmi, Seymour, Dayan, and Dolan (2008), Geurts, Huys, den Ouden, and Cools (2013), Lewis, Niznikiewicz, Delamater, and Delgado (2013), Prévost, Liljeholm, Tyszka, and O'Doherty (2012), Holmes, Marchand, and Coutureau (2010) and Corbit, Janak, and Balleine (2007)) has repeatedly and consistently shown that human goal-directed behavior can be influenced by the presence of Pavlovian conditioned stimuli. This phenomenon is known as 'Pavlonian-Instrumental Transfer' (PIT).

In consequence, some behaviors are executed without any justification from utility maximization. And - beyond that - Pavlovian conditioned stimuli can even trigger mistaken or inappropriate behaviors, i.e. behaviors which are detrimental from a utility maximizing perspective.

Thus, contrary to what Rational Choice Theory (RCT) predicts, human behavior is substantially driven by mechanisms other than utility maximization. Non-utility driven behavior is - by construction - non-existent in neoclassic theory. The theory of revealed preferences constructs utility functions such that they allow to describe human behavior "as if" it resulted from utility maximization. By the nature of this building principle, behavior must be driven by utility maximization. Even large parts of behavioral economics uses utility maximizing frameworks (see below for a more detailed discussion). How can repeated evidence on behavior which is not driven by utility maximization then be understood?

4.3 Stress and coping

Stress is ubiquitous in society. The paper by Wälde (2014) presents a model where stressors translate into subjective stress via an appraisal process. Stress reduces instantaneous utility of an individual directly and via a cognitive load argument. Coping can be functional and under the control of the individual or more automatic with dysfunctional features. The analysis predicts the occurrence and frequency of controlled vs uncontrolled coping – emotional outbursts – as a function of an individual's personality and environment. It shows that outbursts cannot always be avoided. It also show that artificially delaying emotional outbursts can lead to even more outbursts. The model implies that success of psychotherapy is discontinuous and characterized by breakthroughs.

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