“Animal Spirits. An Economic Theory of Emotion”

Dissertation

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To Anna and Karl-Heinz

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„[Im Rahmen großer Unsicherheit können Entscheidungen] nur auf die animalischen Instinkte zurückgeführt werden – auf einen plötzlichen Anstoß zur Tätigkeit, statt zur Untätigkeit, und nicht auf den gewogenen Durchschnitt quantitativer Vorteile, multipliziert mit quantitativen Wahrscheinlichkeiten.“

John Maynard Keynes, Allgemeine Theorie der Beschäftigung, des Zinses und des Geldes (2006), S. 137

I. The Emotion

„So sind wir nun einmal gemacht; wir überlegen nicht; wo wir fühlen, fühlen wir einfach."

Mark Twain, Ein Yankee aus Connecticut am Hofe König Arthurs, There are many theories which are about emotion and we will not discuss all of them. Among others one can distinguish behavioural, physiological, cognitive and ambitious theories. (Many can be found in Strongman (2003))

Theories of emotion, like the James-Lange-theory or the Cannon-Bard-theory, illuminate the connection between physiological and psychological aspects of emotion. The appraisal theory closes the gap between the stimulus and the resulting excitement. According to Magda Arnold this appraisal is subconscious and it weighs potential utility and damage, and the emotion is a felt tendency towards a subject or away from a subject (Arnold, 1960). LeDoux (1998) judges this theory as plausible, but finds fault with the tendency to introspection because from his point of view this doesn't lead to reliable results.

Schachter's (1970) two-factor theory of emotion emphasizes the interaction between physiological arousal and cognitive appraisal. Firstly we get aroused and afterwards we ask what have brought this state about.

Lazarus's (1991a) theory is about appraisal and coping. We search for stimuli and appraise them and this produces emotional response. Moreover because the stimuli often change the emotional reactions alter. The coping process can be distinguished into two sorts. Firstly by direct action, secondly by reappraisal. There are three primary appraisals, goal relevance, goal congruency and ego-involvement. The three secondary appraisals are concerned with blame or credit, the potential to cope and future expectations. The appraisal of the two sets of antecedent variables- personality and environmental- are integrated into a related meaning. If there is harm or benefit this leads to an innate action tendency.

Ellsworth's theory (1991) is about feelings that occur as a result of a combination of appraisals. The emotional expressions from this point of view are similar if the appraisal is similar, but differs because the appraisal will not be identical. Moreover emotion might alter the cognition, the appraisal of a predisposed angry man will be different from the appraisal of a predisposed sad man.

Oatley and Johnson-Laird (1987) emphasize individual goals and plans and a social aspect in form of mutual goals. Oatley and Johnson-Laird distinguish the two types of communication, propositional (symbolic and denotative) and non-propositional (simple and causal). Emotional signals that are non-propositional lead to a mode in which a goal becomes the most important until it is satisfied or abandoned. There are the following universal human emotion modes: happiness, sadness, anxiety, anger, disgust. In adults a conscious evaluation of planning is usually involved if there is an emotion, this leading to voluntary action. Moreover emotions coordinate the modular system and we can find emotions when plans are interrupted, allowing transitions to new aspects of plans. “Social interaction depends on dealing with mutual plans in which cognitive systems can cooperate.” In the case of complex emotions one mode leads to another after various appraisals. “So adult emotion has as an integral part the generation of self-conscioussness when a social plan becomes problematic.”

The appraisal theory neglects the difference between emotion and cognition. So this cognitive appraisal theory was questioned. A study of Lazarus and McCleary (1951) showed that the subconscious presentation of emotional conditioned stimuli in contrast to neutral stimuli activated the autonomous nervous system. Zajonc shows that it’s possible to have preferences without to infer (Zajonc 1980). Some studies are based on the psychological effect of mere presentation. If you show people patterns in a certain order and ask them if they prefer the new ones or the old ones, they prefer the old ones, only on basis of the presented order. The subconscious presentation of words, patterns or numbers has the same effect. Because there are no reasons for the choice according to Zajonc a decision must be possible without the cognitive system. In the case of priming Murphy and Zajonc (1993) present for 5 milliseconds an activating stimulus with a certain emotional connotation, like happy or angry faces. Afterwards they present for 2 seconds a letter. As you can guess the assessment depended on the emotional connotation (see also Bargh und Pietromonaco 1982; Strahan et al. 2002). From Zajonc' point of view this hints at the idea that the affect precedes the cognition and that it's independent of it. LeDoux (2010) argues that this must not be so, because the cognitive information processing could be subconscious and not independent.

Rick und Loewenstein (2008) distinguish expected emotions and immediate emotions. The expected emotions are consistent with the consequential traditional economic model. The immediate emotions can be distinguished in integral emotions which can be experienced in the decision process and incidental emotions which have nothing to do with the decision.

In the case of an uncertain decision the expected utility theory is the standard. Its asset integration assumption was questioned by Markowitz (1952) and Kahneman and Tversky (1979). Furthermore not realized results affect the realized outcomes in models of expected emotion (see Köszegi und Rabin (2006) or Mellers et al. (1997)). Or think about models which are about remorse (Loomes und Sugden 1982). Affective answers seem to be reference dependent, so that not only you have to think about the subjects in the foreground but also about their relationships with other subjects. Wilson und Gilbert (2003) show, that there is a difference between the expected emotion and the realized emotion (impact bias). The prediction referring to the valence work, also the specific emotions, but the statements about duration and intensity were wrong. You can find the reasons in Wilson and Gilbert (2003). An example for integral emotions is the study of Ariely und Loewenstein (2005), they find that sexual excitement influences the attitude towards risk, but not the risk perception. An example for incidental emotions is the study of Hirshleifer und Shumway (2003), which showed that there is a correlation between sunshine and returns on the stock market. While integral emotions can be build in the consequential framework the incidental emotions can't.

Because the work of Joseph LeDoux is of central importance for our approach we will now cite him:

"At the neural level, each emotional unit can be thought of as consisting of a set of inputs, an appraisal mechanism, and a set of outputs. But the appraisal mechanism also has the capacity to learn about stimuli that tend to be associated with and predictive of the occurrence of natural triggers. These we'll call "learned triggers". The place where a predator was seen last, or the sound it made when it was charging toward the prey are good examples. When the appraisal mechanism receives trigger inputs of either type, it unleashes certain patterns of response that have tended to be useful in dealing with situations that have routinely activated the appraisal mechanism in ancestral animals." LeDoux (1998), p.127

Our idea of emotion, as we will see in the next chapters, is that of integral emotions, which are about consequences and are experienced in the decision process.

II. Fear Conditioning

„Vielleicht ist der Mensch das furchtsamste Wesen, da zu der elementaren Angst vor Freßfeinden und feindseligen Artgenossen intellektuell begründete Existenzängste hinzukommen.“

Eibl-Eibesfeldt und Sutterlin (1990)

The mechanism of fear was examined by LeDoux (1998) looking at the fear conditioning. The basis of fear conditioning is the classical conditioning according to Pavlow, which combines an unconditioned stimulus (meat) with a conditioned stimulus (an acoustic signal) and presented this association several times one after the other. The result was that the innate reaction of flow of spittle, which takes place automatically while showing the meat, could be observed also by only presenting the acoustic signal. The innate reaction becomes a conditioned reaction. If we look at the fear conditioning of rats, a cat acts as the unconditioned stimulus and an associated acoustical signal correspondents to the conditioned stimulus and the freezing of the rat the conditioned reaction. The freezing of the rat can be activated by both by the innate and the learned trigger. Through the emotional conditioning the animal gets enormous flexibility. The natural fear of the cat is transferred to the context (Blanchard und Blanchard 1972), so the rat is able to react, while the dangerous stimulus does not yet appear. It's valid that „the danger predicted by these learned trigger stimuli can be real or imagined, concrete or abstract, allowing a great range of external (environmental) and internal (mental) conditions to serve as conditioned stimulus." LeDoux (1998), p.143.

Learning to avoid starts with the fear conditioning, followed by a reaction to reduce that fear. This reaction is neither an innate emotional action nor an arbitrary emotional action.

For the association it suffices to present the unconditional and the conditional stimulus once. And this association seems very persistent (Gleitman und Holmes 1967). If several times the acoustical signal does not appear with the appearance of the cat, we can observe the "extinction" of the fear reaction, but the association still survives (LeDoux 1998). The problem of the "spontaneous relaxation" (Pavlow 1927) and the disastrous effect of burdened events, which can reinstate fear reactions (Cambell und Jaynes 1966; Bouton 1994) seem to be based on the above mentioned observation.

LeDoux (1998) tried to find out, what lies between the conditioned auditory stimulus and the resulted fear reaction. He showed that the damage of the auditory cortex, which forms the end of information processing, has no consequence on the fear conditioning. The lesion of the next deeper level, the auditory Thalamus, prevents the fear conditioning entirely. Therefore the stimulus has to take an independent way from the cortex. Projections to four subcortical areas were found by retrograde marking, of which the projection to the amygdala was decisive. Studies show that the amygdala was responsible for autonomous reactions like the freezing, the suppression of pain and the strengthening of reflexes in case of fear conditioning (LeDoux 1993; LeDoux 1995). By anterograde marking LeDoux showed that the auditory stimulus projected from the auditory Thalamus to the lateral core of the amygdala, which also gets information from the cortex and can therefore be interpreted as interface. According to LeDoux (1998): "The fact that emotional learning can be mediated by pathways that bypass the neocortex is intriguing, for it suggests that emotional responses can occur without the involvement of the higher processing systems of the brain, systems believed to be involved in thinking, reasoning, and consciousness"(LeDoux (1998), p.161).

Moreover LeDoux (1998) shows that the processing from sensory Thalamus to amygdala is inaccurate. Jarrell et al. (1987) proved that two similar acoustical signals, from which only one was coupled with an electrical shock, both lead to fear reactions after damaging the auditory cortex, but with working auditory cortex only the actually coupled signal leads to fear reactions. So the auditory cortex prevents inappropriate reactions. LeDoux (1998) believes that the subcortical way would become stunted when it does not pursue an important purpose. He is quite sure that fast reactions, although inaccurate, lead to decisive advantages. We find the following on page 165 in LeDoux (1998): „From the point of view of survival, it is better to respond to potentially dangerous events as if they were in fact the real thing than to fail to respond. The cost of treating a stick as a snake is less, in the long run, than the cost of treating a snake of a stick.“

We believe that the context, a collection of stimuli, is represented in the Hippocampus. A damage of it leads to no more fear reaction, but the conditioned stimulus still does (Phillips und LeDoux 1992).

LeDoux (1998) believes that the amygdala seems to be a hub in the wheel of fear, see p.168 and p.169:

“The amygdala is like the hub of a wheel. It receives low-level inputs from the sensory-specific regions of the thalamus, higher level information from the sensory specific cortex, and still higher (sensory independent) information about the general situation from the hippocampal formation. Through such connections, the amygdala is able to process the emotional significance of individual stimuli as well as complex situations. The amygdala is, in essence, involved in the appraisal of emotional meaning.”

The results of experiments with animals can be transferred on humans, because we are, as LeDoux (1998) calls it on page 174, “emotional lizards”. Although the behavior of reptiles, birds and mammals is different in the case of danger, the neural basis is the same. For instance Bechara et al. (1995) observed that a woman with a damaged amygdala does show impaired fear conditioning.

LeDoux (1998) distinguishes two learning systems, which are connected with emotional memories: The declarative resp. explicit memory (conscious “memory of emotion”) and the implicit memory (subconscious “emotional memory”). An explicit emotional memory arises, when neutral explicit memories are associated with emotional reactions in the working memory. A patient of Claparede (1911) had a damaged memory, so that she couldn’t form new memories. Once while greeting her, the doctor pricks her with a needle. The next time the patient refused the handshake. So the doctor became a learned trigger of a fear reaction based on the implicit memory.

The explicit memory of an emotional situation is attributed to the Hippocampus and adjacent cortex. The emotional fear memory is associated with the amygdala. Because the explicit memory seems to be more forgetful than the implicit, stimuli, which are subconsciously perceived could generate fear, which can't be explained. Whereas the answers on the reversal of a conditioning in the orbifrontal Cortex change fast and flexible, we can observe inflexibility in the ventral amygdala, so Morris and Dolan (2004) argue that there are persistent „memories“ of the original conditioning.

In case of stress our kidney pours out a steroidhormone (McEwen und Sapolsky, 1995) to activate energy reserves. Increasing stress leads to a situation in which the amygdala becomes more active and fear conditioning becomes more and more effective (Servatius und Shors, 1994). Extinct or weak conditioned fear reactions can be reinforced in the case of stress.

Finally LeDoux (1998) concludes on page 266:

“The ability to rapidly form memories of stimuli associated with danger, to hold on to them for long periods of time (perhaps eternally), and use them automatically when similar situations occur in the future is one of the brain's most powerful and efficient learning and memory functions. But this incredible luxury is costly. We sometimes, perhaps all too often, develop fears and anxieties about things that we would just as well not have. What is so useful about being afraid of heights or elevators or certain foods or means of travel. While there are risks associated with each of these things, the chances of them causing harm are usually relatively small. We have more fears than we need, and it seems that our utterly efficient fear conditioning system, combined with an extremely powerful ability to think about our fears and an inability to control them, is probably at fault.”

III. The Hypothesis of Somatic Markers

„Die Vernunft ist nur Sklave der Affekte und soll es sein; sie darf niemals eine andere Funktion beanspruchen, als die, denselben zu dienen und zu gehorchen.“

David Hume, Ein Traktat über die menschliche Natur (1978), S.153

After LeDoux (1998), who mainly dealt with the neurological base of fear in animals, we turn towards humans, looking at the somatic marker hypothesis by Antonio R. Damasio (1994).

To decide one has to incorporate knowledge of the actual situation, the possible choices and the consequences, so according to Damasio (1994) one needs beside logical inferences also emotions. Especially when deciding personal or social questions, think of keeping one's job or one's status.

The theory of Damasio (1994) is mainly based on the observation of patients, whose prefrontal Cortex was damaged. For instance the case Phineas P. Gage. He was in 1848 foreman of the Rutland & Burlington Railroad, until an accident changed everything. A rod perforated parts of his brain. Surprisingly he survived and did not show any inabilities to move, feel, hear and see. But his personality changed radically. He became moody, disrespectful and impatient in social interactions. Gage lost his ability to decide in a favorable manner. Modern methods made it possible to reconstruct the damages of his brain (Damasio et al. 1994). We can observe damages of the prefrontal Cortex, above all the ventral and medial surfaces of both sides of his brain, but not the lateral area.

A similar case Damasio (1994) presents is Elliot, a man between 30 and 40, exemplary, in good shape. The doctors have found a tumor in his brain. The removal of the tumor led to obvious changes in his personality. His feeling of duty towards his boss dwindled and he lost his ability to organize his time. He cared about unimportant tasks and ignored the main ones. Once again one observed a damage of his prefrontal Cortex, particularly in ventromedial area. Strangely enough although one observed a disturbed social behavior the tests on the ability to percept, the long term and short term memory, the ability to learn, speak and calculate don't take effect. But the doctors observe an emotional distance towards the world and so Damasio (1994) concludes that possibly the ability to decide requires emotions.

The examination of several other patients with prefrontal damage showed similar symptoms (Brickner 1934; Hebb und Penfield 1940). For animals Myers (1975) showed the same. Every time we observe a correlation of weak decisions and poor emotions. Other areas where we can study such a phenomenon are the somatosensing cortices (Anderson und Tranel 1989), structures of the limbic system, like the amygdala (see Tranel und Hyman 1990), and the Gyrus cinguli (z.B. Posner und Petersen 1990).

Damasio (1994) distinguishes primary and secondary emotions. The primary emotions, belonging to the limbic system, are released through certain innate stimuli, like noise, movement or pain and cause changes in the body. But only the conscious perception, the emotion, leads to complex cognitive strategies concerning the stimulus. The secondary emotions are the systematic association of subjects and situations with the primary feelings. The processing needs both the structures of the limbic system and the prefrontal und somatosensing Cortex.

Therefore there exist stimuli which are „good“ or „bad“ because of an innate preference, and others whose meaning is the result of the association with those stimuli. The feeling leads to changes in the body, about which the brain is informed via neuronal and chemical route. To cite him:

„That process of continuous monitoring, that that experience of what your body is doing while thoughts about contents roll by, ist he essence of what I call a feeling.... In other words, a feeling depends on the juxtaposition of an image of the body proper to an image of something else, such as the visual image of a face or the auditory image of a melody."(p.145)

But Damasio (1994) doesn't demand that the feelings are connected with changes in the body. In the setting of "as if"-feelings, in case of the association of subjects and situations, the changes in the body could only be shown through neural mechanisms. But those „playbacks" seem to be far weaker than actually experienced feelings.

The medical studies show, according to Damasio (1994), that sensible decisions require the working of the emotions, which are connected with the survival system of the body.

„Nature appears to have built the apparatus of rationality not just on top of the apparatus of biological regulation, but also from it and with it. The mechanisms for behavior beyond drives and instincts use, I believe, both the upstairs and the downstairs: the neocortex becomes engaged along with the older brain core, and rationality results from their concerted activity." (p.128)

Fundamentally regarding our body we are in the optimal condition of Homeostasis, which changes when feeling an emotion. It changes through the following process (Damasio 2007; S.189): A conscious thought about a person or situation leads to images. The processing of those images leads to signals towards the network of the prefrontal Cortex. Dependent on the associations between situations and emotions the prefrontal Cortex reacts automatically and subconsciously to those signals and activates the amygdala and the Gyrus cinguli. There we can observe changes of our body, and cognitive changes concerning the exploration and appetence behavior. Secondary feelings use the expression channel of the primary feelings, whereas the innate dispositional representations of primary feelings are separated from those of the secondary feelings.

Simplifying the decision process in the experience-based learning process, emotion is associated with corresponding situations. The feeling while choosing an alternative with expected consequences, independent of conscious or subconscious experience, signals according to the somatic marker hypothesis the worth of this alternative. If an alternative is marked with a negative feeling, this alternative can be banished. The somatic marker, which is based on an internal preference system and under the influence of the environment, supports the logical thinking process and forms a tendency device. Damasio (1994) assumes the necessary basal attention and the basal working memory which are fundamental for the production of internal images is stimulated by the somatic marker mechanism to order and to end the logical thinking process. Damages of the prefrontal Cortex are so central for the decision process, because it receives signals about environmental facts, about bioregulatory preferences and states of the body, and puts images in order and initiates the with emotions associated body states (Damasio 1994).

Damasio (1994) draws our intention to the fact that the somatic marker can be curse or blessing. The simplification can lead to a disregard of objective probabilities, think for instance of fear of flying.

Bechara et al. (1994) initiated, to prove the somatic marker hypothesis, a game of chance. There were four stacks, whereas two of the four generate a regular payment of 100 dollar, interrupted by payments of 1250 dollar. While those stacks are risky, the other two stacks paid only regularly 50 dollar but those payments were interrupted by low punishments of 100 dollar. Bechara et al. (1994) showed that healthy participants preferred the alternative with low risk, also those who declared themselves as risk loving. The patients however preferred the first alternative and longer than patients with other damages. Damasio (2007, S.290f.) concludes that the missing of the somatic marker, as alarming bell, is responsible for this observation.

Bechara et al. (1993) proved that in case of rewards and punishments both the healthy participants and those with damage show skin conductance, but while imaging only the healthy do. Moreover the skin conductance of the healthy patients rises. Skin conductance is the result, initiated through the autonomous nervous system, of changes in the body, which activate perspiration glands and lead to the falling of the electric skin resistance.

IV. An Evolutionary Theory of Emotion

"Among these, the theory of evolution is by far the most important, because it draws together from the most varied sources a mass of observations which would otherwise remain isolated."

D. Futuyma, Evolution -Das Orginal mit Übersetzungshilfen, Elsevier, 2007, p.14

According to Rolls (2014) emotions are states which are elicited by rewards or punishment. Motivation is a state in which one seeks a reward respectively a state in which a punishment is being avoided or escaped from. One works to get a reward and one works to avoid a punishment. To work means voluntary acts. There are some stimuli which are by nature rewarding or punishing. Others are learned (secondary reinforcers). The learning mechanism is stimulus-reinforcer learning. Instrumental reinforcers are "stimuli that if their occurrence, termination, or omission is contingent upon making an act of action, alter the probability of the future emission of that action." (Rolls 2014, p.2). "A positive reinforcer increases the probability of the emission of an act on which it is contingent." (Rolls 2014, p.2). "The negative reinforcer increases the probability of an act which terminates the negative reinforcer or avoids it." (Rolls 2014, p.2). The punishment means to decrease the probability of an action.

Unconditioned reinforcers lead often to autonomic responses, which can be paired with a neutral stimulus, finally leading to classical conditioning, which is similar to stimulus-reinforcer association learning except that the responses are autonomic and endocrine and that the animal has no influence on the delivering of the unconditioned stimulus. Both kinds of learning, stimulus-reinforcer association learning and classical conditioning, are important in emotions. But the classically conditioned responses as an association between stimuli and responses do not need intervening states like emotions to follow a goal. If we think of stimulus-reinforcer association learning we have to emphasize that this kind of learning must be capable to correct within shortest time if the reward or punishment alter, this is the task of the orbifrontal cortex.

Stimulus-reinforcer association learning is a two-process learning. A previously neutral stimulus is associated with a primary reinforcer (stimulus-stimulus association learning) at the first stage. This kind of learning is very fast and can be reversed very rapidly. At the second stage there is action-outcome learning, by which an action to obtain the reward respectively to avoid the punishment is learned. It can be much slower (trial-and-error), but if there exist a response to a different type of reward and the stimulus can also be obtained using this strategy then it will be very fast. According to Rolls (2014) a key advantage of this kind of learning is that different rewards and punishers can be compared on a common scale. Having done this a cost-benefit analysis of net value follows, based on simple heuristics, leading finally to an action.

Comparing the brain systems of primates and non-primates there is considerable development, thinking for instance of the temporal lobe.

The two approaches of human brain imaging fMRI and PET are quiet coarse, so Rolls (2014) prefers to record the activity of single neurons or groups of single neurons.

Sensory processing is necessary for the appraisal of stimuli as rewards or punishment. Those signals turn to the decision system, where positive and negative aspects are processed, and from there to the action system, where it is decided which action, regarding its costs, is carried out.

Emotions define the goal for arbitrary acts, they are an intermediate state. Rolls (2014) asks if there are any rewards or punishment that do not lead to an emotion. His answer is no. Moreover the genes specify the primary reinforcers "in order to encourage the animal to perform arbitrary actions to seek particular goals, thus increasing the probability of their own (the genes) survival into the next generation." (Rolls 2014; p.16)

We can distinguish emotions by being positive or negative and their reinforcement contingency. There is an increasing intensity on a continuous scale. Emotions associated with the delivery of a reward include pleasure, elation and ecstasy. Emotions associated with the delivery of a punisher include apprehension, fear and terror. The omission of a reward or its termination leads to frustration, anger and rage. The omission of a punisher leads to relief. Beside the reinforcement contingency and the intensity there is room for multiple reinforcement associations, and that stimuli associated with different primary reinforcers will be different, and emotions will be different if the conditioned stimuli are different and finally emotions will differ if there is variation in the behavioral responses. Moreover the extent to which a stimulus is reinforcing depends on the history of reinforcement, think of sensory-specific satiety.

According to Rolls (2014) most reinforcing stimuli have their origin in the external environment, so one can debate if one excludes drive states that are produced by a change of the interial milieu. Furthermore emotional states can be produced by remembered reinforcing stimuli. In Rolls (2014) theory there is also room for cognitive processing, so that the stimulus from the environment is appraised as reward or punishment.

Cognition can also influence emotional responses, so that the word ("cheese", "body odour") influences the subjective pleasantness ratings. Moreover there exists the phenomenon of positive and negative contrast. If an animal is working moderately for a reward she will work very much harder for some time if there is a sudden increase of reward, but will then gradually come back to work at the old rate.

According to Rolls (2014) a motivational state is one in which a goal is desired. An emotion is a state elicited when a goal is obtained. A mood is a continuing state normally elicited by a reinforcer, and is thus part of what is an emotion. Mood states are not necessarily about an object.

A function of emotion is to elicit autonomic and endocrine responses to prepare the body for action. Another is the flexibility of behavioral responses. Moreover emotional states are motivating. Another function lies in the communication, in that one decodes the signal of another animal as reward or punisher. The social attachment is another function, the emotions associated with the attachment of the children to their parents or the attachment of the parents to each other. The mood can influence the cognitive evaluation of memories. Emotions can facilitate the memory storage. Emotional and mood states are persistent and help to produce persistent motivation. Finally emotions may trigger memory recall and influence cognitive processing.

On a higher complexity level one can find processing that includes syntactic operations on semantically grounded symbols, which leads to multistep one-off plans.

According to Rolls (2014) there are several layers regarding the processing of stimuli. The first layer gives answers to the question “what”. What is the taste, what is its intensity? The inferior temporal visual cortex includes the representations of objects and is invariant referring to the exact position on the retina, the size and the view angle. The second layer leads to the calculation of reward values of primary reinforcers in the orbifrontal cortex. Primary reinforcers are touch, taste, odour and possibly face expressions and novelty. The second layer includes also the association between neutral stimuli and primary reinforcers in the amygdala and the orbifrontal cortex. The third layer is the medial prefrontal cortex and is connected to the decision making. Finally we have the output systems. The autonomic and endocrine systems prepare actions. The unconscious or implicit actions are made in the basal ganglia for habit learning and the cingulated cortex for action-outcome learning. The last output system is the system which is capable of planning many steps ahead and is part of the linguistic system using syntactic processing to plan.

Regarding the secondary reinforcers the representation has the following requirements: Firstly invariance, there is no certain view angle necessary when learning. Secondly generalization of similar objects leading to a Hebb learning rule. Thirdly the graceful degradation, if a few of the input axons or synapses are damaged then the remainder can still produce the correct answer. Fourthly the high capacity meaning that it is capable of representing separately many different objects. Finally the independence from reward value, so that we don't go blind when they changed from rewarding to neutral.

Now let us turn to the orbifrontal cortex. The magnocellular, medial part of the mediodorsal nucleus to the orbifrontal surface of the prefrontal cortex is called orbifrontal cortex. It gets information from the inferior temporal visual cortex regarding the taste, odour and touch. Damage to the orbifrontal cortex leads in apes to less aggression towards humans and snakes, in humans to euphoria, irresponsibility, lack of affect and impulsiveness. They lack the ability to learn from non-reward, for instance if a reinforcement is reversed or if in extinction they respond to an object that is no more rewarded (Meunier, Bachevalier and Mishkin 1997). Rolls (2014) hypothesis is that the orbifrontal cortex is involved in representing reward value and its rapid updating. Some neurons are activated when there are primary reinforcers and represent outcome value. Hunger modulates this value in the orbifrontal cortex, contrary to the primary taste cortex (sensory-specific satiety, Critchley and Rolls 1996c). Other neurons are activated if there are learned secondary reinforcers and thus represent expected value. There exist negative reward prediction error neurons (Thorpe, Rolls and Maddison 1983).

Now let us turn to the amygdala. It receives inputs from higher stages of sensory processing, it receives inputs about objects that could become secondary reinforcers, because of pattern association with primary reinforcers. The amygdala influences the motor systems, autonomic systems, some cortical and limbic area.

Damage of the amygdala leads to tameness, lack of emotional answers, excessive examination of objects and eating previously rejected objects (Weiskrantz 1956). Murray and Izquierdo (2007) showed that selective amygdala lesions do not affect object reversal learning but lesions of the orbifrontal cortex do. So the orbifrontal cortex seems to be quiet important for one-trial learning and reversal (associative and ruled-based). –Besides there is the phenomenon of reconsolidation, that after a memory has been stored, it may be weakened or lost if recall is performed during the presence of a protein synthesis inhibitor. Sanghera, Rolls and Roper-Hall (1979) show that after reversal 10 out of 11 neurons did not reverse their responses. So Rolls (2014) comes on page 178 to the result that “the evidence now available indicates that primate amygdala neurons do not alter their activity flexibly and rapidly in relearning visual discrimination reversal learning.”

Now let us turn to the cingulated cortex, which gets inputs from the orbifrontal cortex about the outcome value respectively the expected value of stimuli. The anterior cingulated cortex in combination with the midcingulate motor area interfaces action to outcome (action-outcome-learning) and include the cost of the particular action (Walton, Bannerman, Alterescu and Rushworth 2003). The anterior cingulated cortex is sensitive to the devaluation of a value.

In the medial prefrontal cortex area 10 there are decisions between different stimuli (Rolls et al. 2010).

Finally we come to the output pathways for emotional responses. The first output system is the autonomic and endocrine system, which prepares the body for action. The second, thinking of implicit responses, is the motor system. The third is a system for explicit responses to emotional stimuli.

V. Heuristics and Rationality

„Hier kommt es auf den „Blick“ an, auf die Fähigkeit, die Dinge in einer Weise zu sehen, die sich dann hinterher bewährt, auch wenn sie im Moment nicht zu begründen ist, und das Wesentliche fest und das Unwesentliche gar nicht auffasst, auch wenn und gerade dann, wenn man sich über Grundsätze, nach denen man dabei verfährt, keine Rechenschaft geben kann. Gründliche Vorarbeit und Sachkenntnis, Weite des intellektuellen Verstehens, Talent zu logischer Zergliederung können unter Umständen zu Quellen von Misserfolgen werden.“

Joseph Schumpeter, Theorie der wirtschaftlichen Entwicklung (1997), S.125

Looking at decisions in modern economic theory all alternatives are weighted by incorporating all information and all the probabilities. This procedure, called rational, bases on the expected utility maximization by Daniel Bernouilli, it is connected with the view of omniscience (perfect knowledge) and omnipotence (unlimited computational power) and determinism. Therefore the optimizing individual can be described as Laplace's demon (Gigerenzer, 2008a). Such an optimization doesn't seem feasible for many economic problems, because one can't calculate the optimum in polynomial time (called NP-complete). So a game of chess is turned into Tic-Tac-Toe according to Gigerenzer (2008b). The problems are so much simplified that they don't deliver solutions to the real world any more. There is a trade-off between ruling the problems and the significance of the results. The followers of the rational view argue that it's only important that the prediction is correct but not the way towards it (Friedman 1953). But in reality we can frequently observe the problem of robustness resp. overfitting. The high number of parameters in utility maximization models enables intelligent designers to fit their model perfectly to the past, but many of those models deliver only bad predictions of the future. Moreover there are problems of subjective targets, for instance what is the optimal sound, infinite regress when problems are unfamiliar and time is scarce and the sensible weighting of multiple goals. From a neurological view a logical solution can take way too much time. So patients who suffer from a prefrontal damage show the tendency to lose themselves in the decision process (Damasio 2007, S.263f.).

Now let us turn to heuristics. Heuristics are the basis for gut feelings (Gigerenzer, 2008d, on page 57). Complete rationality will, according to Gigerenzer and Todd (1999), be replaced by ecological rationality. We turn from logic to the environment. From this point of view heuristics aren't inferior. Dependent on the environment heuristics can be the only rational answer. Gigerenzer und Todd (1999) speak of fast and frugal heuristics, fast because they needs little time, frugal because they needs little information. So they examine when those are ecological rational. The idea of a heuristic can be demonstrated by looking at the following example. The physical calculations to compute the place where a thrown ball hits the ground need in the simplest case the distance and the angle of the trajectory. After doing the maths using the first chapters of the Halliday et. al (2007) we can get the solution but in reality the problem is way harder. In reality we have to include the air resistance, the wind and the spin of the ball. It isn't realistic to believe that a human is able to find a solution to this very complex problem. Instead a person will use the following simple look heuristic:"Fix the ball, begin to run and adapt your speed so that the angle of view stays constant (Gigerenzer, 2008c, S.19). Or think of the decision to marry. Gigerenzer und Goldstein (1999) explain it in the following way (best-first heuristic). One after another we examine the following alternatives, in this case marry yes or marry no, concerning some decision keys. The procedure ends when one of the both alternatives is clearly better. It's obvious that the order of the keys is of high importance when using this heuristic. So the order depends on the past validity. According to Gigerenzer and Goldstein (1999) the inferences by the best-first heuristic are at least so exact as standard statistical procedures (for instance the multiple regression), but with far less work. Moreover the heuristic was very robust. (Czerlinski et al. 1999) show that the predictions of the best-first heuristic were the best ones.

Pingle und Day (1996) present in their work some past experiments. The question they asked to what extent actions, which are not procedural rational, are important in economic situations. Because of the high costs of rational procedures the result must not be optimal.

Decision cost and misuse cost have to be included. Not procedural rational actions are try and error, imitation (Pingle 1995), following an authority, habit, unmotivated search and intuition. Pingle und Day (1996) show that the existence of decision costs leads to actions which are not procedural rational. Moreover the use of not procedural rational decisions increases the efficiency of decisions. The authors believe that several methods are necessary to decide in a favorable way. Economic principles which are followed are diminishing returns, specialization and exchange. Furthermore Pingle und Day (1996) conclude that an optimal result is based on the use of evolutionary procedures, which unify the different actions. They believe also that the "as-if" hypothesis by Friedman (1953) isn't correct without doubt, there could be distortions on markets, so that a competitive equilibrium is prevented.

But also the emotion can be a heuristic. According to Slovic et al. (2003) the affect is a conscious or unconscious emotional state, which marks the positive or negative quality of a stimulus. They call decisions based on these emotional states the affect heuristic. They conclude in the following manner:

„This heuristic appears at once both wondrous and frightening: wondrous in its speed, and subtlety, and sophistication, and its ability to "lubricate reason"; frightening in its dependency upon context and experience, allowing us to be led astray or manipulated – inadvertently or intentionally – silently and invisibly."

The protruding emotions in the decision process depend on the task, the individual and their interaction. According to Slovic et al. (2004) humans use an affect-pool, where one can find all the positively and negatively marked images which differ in their intensity. Using the affect heuristic humans rely on their emotion regarding an object. Alkahami and Slovic (1994) show that in reality there is not a positive correlation between the felt risk and the felt benefit but an inverse relationship.

Also Clore and Schnall (2005), Forgas (1995) or Schwarz and Clore (1988) emphasize that individuals conclude from the emotion to the attitude regarding a product. Wright (1975) and Pham (1998) talk also about a connection of affect and product choice. Hsee and Kunreuther (2000) show that the purchase of an insurance depends of the emotional connotation of the product. Yamagishi (1997) proved that people who follow the presentation of relative frequencies regarding the mortality of a disease took the disease not as seriously as the presentation of pictures and the absolute frequencies.

Muramatsu and Hanoch (2005) refer in their work to emotions as activators of fast and frugal heuristics (Gigerenzer et al. 1999). The heuristic are activated after an assessment mechanism which judges if an object is friend or foe. If actually there is a danger or a chance, fast and frugal heuristics are nudged, for example stressing certain keys (Faucher und Tappolet 2002), reducing options (Earl 1986) and finally setting the clues for the end of information processing (Ketelaar und Todd 2000).

VI. Risk-as-Feelings

„It's a dangerous business, Frodo, going out your door."

J.R.R. Tolkien, The Lord of the Rings (London: Allen & Unwin, 1955)

Our emotional system discovers urgent risks and reacts accordingly (Armony et al. 1997). In this case there could be differences between cognitively judged and emotionally judged risks (Ness und Klaas 1994). According to Isaac and James (2000) and Barsky et al. (1997) the observable risk behavior is very variable and inconsistent. Slovic et al. (2004) distinguishes risk-as-feelings as fast instinctively and intuitive reaction in the case of danger and risk-as-analysis, based on logic, reason and scientific thinking. Hsee and Weber (1987) have shown the effect of emotions on the risk behavior. It was observed that the participants, based on their own emotions, were riskaverse, but they judge the average student as, not based on their emotions, as riskneutral.

The risk-as-feelings thesis of Loewenstein et al. (2001) tells us that answer in the case of uncertain decisions are based on angst, concern and fear. Cognitive evaluations lead to emotions which influence cognitive evaluations. Immediate risks are processed in a different way on the emotional level, not by multiplying the probabilities with the consequences. Contrary to the cognitive system, which is based on objective assessments, emotional assessments do include the vividness of images, the own experience and past conditionings. Other determinants are the time between announcement and realization of the decision or the evolutionary preparation (Loewenstein et al. 2001).

Regarding the vividness of the consequences Brown and Hoyt (2000) for example show that the acquaintance of a person, who survived a flood or an earthquake, rises the insurance probability. Emotionally stimulating anecdotes are more effective than bare statistics (Hendickxs et al. 1989). Johnson et al. (1993) discovered that an insurance that covers only terrorist attacks was more worth than an insurance which covers every kind of death. Slovic et al. (2000) ask doctors how risky they estimate the release of psychic ill patient. The likelihood of an aggression was expressed in frequencies and in probabilities. Because the description by frequencies leads to images of an aggressive patient, so that the judgment was more negative.

Now let us turn to Rottenstreich und Hsee (1999). They plead for strengthening the S-form of the weighting function, known from prospect theory, in the case of affective consequences. Hopes and fears lead to jumps at the edges of the weighting function, while one can observe a low marginal sensitivity in the middle. With an experiment they proved the low sensitivity regarding the probability. They asked the participants of the experiment how much they pay for avoiding an electric shock or the payment of 20 dollar. A probability of one percent led to median of seven dollar in the case of a threatening electrical shock and a median of one dollar in the second case. A probability of 99 percent led to a median of 10 dollar in the first case and to a median of 18 dollar in the second case. Sunstein und Zeckhauser (2011) confirmed this phenomenon. They refer to the availability heuristic of Tversky und Kahneman (1973), where available instances with risk lead to overreactions and not available instances lead to doing nothing. The probability is unimportant for the amount of excitement before a threatening electrical shock (Bankhart und Elliott 1974, Elliott 1975 und Monat et al. 1972), but the amount is important (Deane 1969). Loewenstein et al. (2001) speculate that fear has an all-or-nothing character and the bare possibility dominating the probability. Extreme behavior was observed by Ratner und Herbst (2005) after a successful broker showed a negative result. One could observe an overreaction of his customers who turn to a not that successful broker. The reason for this polarization is according to Pham et al. (2001) that affective decisions are by far more extreme than decisions based on reason and furthermore that humans search for confirmation of their initial emotion.

Baumeister et al. (2007) don't believe that emotion has a direct influence on the behavior. Rather the emotion acts as feedback (in this case the risk), so that we are able to learn from our behavior and the consequences. Baumeister et al. (2007) distinguish a direct automatic affect and a later entering conscious emotion.

VII. The Two Systems

„Humans, more than Econs, also need protection from others who deliberately exploit their weaknesses- and especially the quirks of System 1 and the laziness of System 2.“

Daniel Kahneman, Thinking, Fast and Slow, Penguin Books, 2011

Massey (2002) distinguishes based on the neuro anatomy two systems, an emotional and a rational, which although connected, act parallel and deliver different results. As we have seen, the work of LeDoux (1998) supports this idea. The information about a dangerous situation arrives in rats from the Thalamus above two ways towards the amygdala, a direct way through the limbic system and a way above the neocortex. Through simple conditioning which was canceled and a surgical operation which disconnects the nerve tract between the prefrontal cortex and the amygdala it was shown that the answer of both systems differs. Moreover the removal of huge parts of the cortex doesn't affect the emotional reaction, whereas the threshold sinks, so that the cortex seems to regulate the reaction (LeDoux 1987). Metcalfe and Mischel (1999) distinguish a hot emotional system (simple, reactive and fast) and a cold cognitive system (complex, reflexive and slow), whereas the actual behavior depends on the successful system.

Chaiken and Trope (1999) present an overall view of psychological two-processes-models.

Finally because of the faster „data line“ the emotional system should influence the rational system way more than vice versa (Carter, 1998; LeDoux, 1998). An information reaches the amygdale a fourth second earlier than the prefrontal Cortex. The output of the affective systems seems to be a prerequisite for decisions (Wilson and Schooler, 1991). If the ventromedial cortex, the connection between the affective and the cognitive system, is damaged this prevents the simplest decisions. Vice versa the influence on the affective system of the cognitive system seems difficult and has high emotional and physical costs and could end with the strengthening of the emotion (Ochsner and Gross, 2004). Loewenstein and O'Donoghue (2004) conclude:

„Affect not only holds greater sway over deliberation than vice-versa, but affective reactions tend to occur first, temporally, with deliberations typically playing a secondary, corrective, role."

Gilbert und Gill (2000) believe that humans are momentary realists, who trust primary their emotions and correct this view only slowly through a expensive cognitive process. Here fits an anecdote by Charles Darwin:

„I put my face close tot he thick glass-plate in front of a puff-ader in the Zoological Gardens, with the firm determination of not starting back if the snake struck at me; but, as soon as the blow was struck, my resolution went for nothing, and I jumped a yard or two backwards with astonishing rapidity. My will and reason were powerless against the imagination of a danger which had never been experienced."

(Charles Darwin, in LeDoux (1998), p.112)

Loewenstein und O'Donoghue (2004) also distinguish a cognitive and an affective system. They assume that both systems interact to finally fix a behavior. The cognitive system, which makes it possible to act goal-oriented, correspondents to the standard model of economics. But to explain certain phenomena one has to include emotions. Loewenstein and O'Donoghue (2004) tell us that already Plato distinguished both systems (Plato, Republic 441). Also Adam Smith stresses the fight between passion and the impartial spectator. Contrary to the neuroscience (for instance Carter, 1998) he sees the advantage on the side of the impartial spectator. But he makes the following statement:

„There are some situations which bear so hard upon human nature that the greatest degree of self-government, which can belong to so imperfect a creature as man, is not able to stifle, altogether, the voice of human weakness, or reduce the violence of the passions to that pitch of moderation, in which the impartial spectator can entirely enter into them.” (Smith (2002); 1759:29)

Loewenstein and O’Donoghue (2004) integrate the concept of willpower. Baumeister und Vohs (2003) prove that the willpower made it possible for the cognitive system to succeed. The willpower acts like a muscle, needing energy which is limited. Constantly deciding can weaken the willpower (Baumeister und Vohs, 2003). Shiv und Fedorikhin (1999) argue that load of the shortterm working memory in the prefrontal Cortex can lead to affectively dominated decisions. Shiffman and Waters (2004) show that this is also so in the case of stress.

Finally Massey (2002) argues in the following manner why the rationality should not be overemphasized: (1) The actions of our ancestors based on emotions. (2) The necessary tool for rationality, the prefrontal Cortex, developed very late regarding the human existence. (3) While we have the physiological foundations since 150000 years, it took more than 100000 years until the mental skills developed to use them in symbolic thinking. (4) It takes 45.000 years until words were packed in writing. (5) 5.000 years later education arises and so rationality became available for the mass. (6) Human behavior is based on the emotional and rational mentalities, whereas the emotional is way older and influences the rational one more strongly than vice versa.

VIII. Moods, Social Learning and Mirror Neurons

„Unsere gewöhnliche Stimmung hängt von der Stimmung ab, in der wir unsere Umgebung zu erhalten wissen.“

Friedrich Nietzsche, Morgenröte (Aph.283)

As Akerlof and Shiller (2009) tell us that the core of trust doesn’t lie in rationality. Believe replaces reason. Often information which is required to act rationally is completely ignored respectively so manipulated that the decision seems rational. The gut feelings succeed. Akerlof and Shiller (2009) explain on page 90:

„Trust is more as an individual state of mind. Trust of the individual is based on how confidently other people judge the mood of the others. It’s a way to see the world, a popular image of the world, a common understanding of the mechanisms of economic change, accompanied by the media and ordinary conversations. A climate of confidence is accompanied by inspiring stories, by stories about business activities and the way how others became rich.”

According to Schwarz und Bohner (1990) mood means a momentary, subjective state of a person which can be described by the dimension „good disposition-indisposition“. Moods are atmospheric diffuse, subdivided state experiences (Ewert, 1983) of low intensity. Moreover moods are contrary to emotions not directed towards a certain object. The cause of a certain mood, let it be a person or a situation, isn’t detected by the individual. The notion affect includes both the emotion and the moods. According to Bollnow (1956) moods arise after emotions.

In the influential work of Bower (1981) he compares humans with magnets that attract mood congruent material. His studies show that participants in good mood identify themselves with a happy character and remember facts about the happy character in a story with a happy and a sad person and vice versa for sad individuals. Bower (1981) argues that a sad mood leads to sad memories, which lead to an improved memory of the sad input. Alternatively congruent material strengthens the emotional intensity and this leading to better memorizing. Besides Bower (1981) presents the phenomenon of state dependent memory, with better memorizing if the participant is in the same mood like that when she learned the facts. Both phenomenon are explained in Bower‘s network theory (Bower 1981).

Regarding the memory one can observe that dependent on the mood better respectively worse memories are easier available (Bower 1981; Blaney 1986, Isen 1984). Because participants in bad mood search for positive memories (see Clark and Isen 1982), the influence of negative moods isn’t as obvious. Schwarz und Bohner (1990) argue that this is the result of the isolated situation the participants are in, so that in groups bad mood has more influence.

Besides the memories also assessments are influenced by moods (Isen et al. 1978; Clore et al. 1983). Schwarz (1988) argues that the mood is information which becomes part of the judgment. Hints that the mood distorts the judgment would neutralize its effect which actually can be observed (see Schwarz and Clore 1983). Humans rely on their emotions when an assessment is of affective nature, when there is little information, when the task is complex or when little time is available (Schwarz and Clore 2007). Greifeneder et al. (2011) ask also when humans rely on their emotion. The following moderators seem to be important: salience of the emotion (compared to other information); the representativeness of the emotions regarding the target (degree in which emotions arise from the target and reflect important characteristics); relevance (regarding an assessment); evaluative malleability (assessment is open to external influences); process intensity.

So there exist two opposing theories, the affect-as-information and the model of mood congruent memory, which attributes the distortion of an assessment to incomplete recall of information, so that the mood congruent information is in advantage.

Moreover a good mood leads to positive judgments of life contentment, products and past events (Wright und Bower 1992, Bagozzi et al. 1999). Mood is especially decisive when abstract assessments are demanded (Forgas 1995). In good mood simple heuristics were used (Bless et al. 1996), in bad mood we see detailed analytical activities (Sinclair und Mark 1995). Furthermore Johnson und Tversky (1983) show that negative mood increases the assumed frequencies of risks globally.

Studies prove that the risk attitude does not depend only on the amount of excitement, but also on the appraisal content (Lerner und Keltner 2001, Raghunathan und Pham 1999). If there is fear, so little control and high uncertainty, then the target of risk minimization was followed and the risk averse variant chosen. If sorrow dominates then the target of return maximization is followed and the risky variant chosen. Moreover Lerner and Keltner (2001) present that fear leads to risk averse choices and joy to optimistic choices.

For an overall view about the results of positive respectively negative affects read Schwarz and Clore (2007) or Pham (2007).

The realized mood is connected to the social environment of the individual. So Neumann and Strack (2000) prove the transfer of moods. The lecture with a sad respectively with a happy voice leads to corresponding moods in the listeners. This happened without asking the listeners to adopt the mood. The listeners aren't aware of the influence of the speaker. Neumann and Strack (2000) believe that there is a two-stage process of mood contagion. Firstly there is an imitation of the visible key signs of a mood, leading to a change in the mood.

There is evidence of the deterioration of moods in healthy individuals because of a contact with depressed persons (Coyne et al. 1987 or Joiner 1994). According to Mansfield et al. (1989) there were connected moods in pairs, who reported their mood every day. Also Hatfield et al. (1994) showed that there was a mood transfer in individuals. Anderson et al. (2003) examined during a year the relationship between date-partners and college-roommates and find an increasing similarity of the emotional answers. Moreover they find out that emotionally similar relationships were more stable and were destroyed with a smaller probability. The authors think that this can be as a sign that emotional adaption coordinates the thoughts and actions supporting the social cohesiveness. Conscious of their own mood, put in a good or bad mood, individuals decide to consume mood incongruent material when there will be an social interaction, maybe to neutralize its effect (Erber et al. 1996). This is not so, if they get the information that the partner in the interaction shows the identical mood.

The study of Bartel und Saavedra (2000) by observing 70 work groups shows tendencies to convergence. The convergence depended on the task, the social interdependency and the stability of the groups. The faces, voices and gestures were obvious hints for the mood and so communicate a certain mood. One can particularly recognize moods with a high degree of activation showing higher convergence and the existence of mood regulating norms. Bartel and Saavedra (2000) conclude from the convergence in eight mood categories that emotional comparisons and emotional contagion are responsible for it and not situational factors. In the case of an emotional comparison the individual assesses by comparison with other individuals the "correct" emotional answer (Schachter und Singer 1962). In the case of an emotional contagion there is a tendency to imitate automatically faces, movements and sounds (Hatfield et al. 1994).

Totterdell (2000) discovers that the average positive mood of a cricket-team is connected with the mood of the team members, independent of personal problems and the score. The more, the older the team members were and the more they felt connected to the team and the more they were susceptible to emotional contagion (Totterdell et al. 1998 show the same for nurses whose contact time with the other nurses amounts to only to $\frac{1}{5}$ of the working time). Common activities and a happy mood strengthen the mood connection. Moreover the assessment of the mood of the group was based on their own mood, so that it acts as an indicator. The assessment of the own performance depended on the mood.

According to Goleman et al. (2001) the mood of the leader of a firm causes chain reactions which influence all employees:

„Moods that start at the top tend to move fastest because everyone watches the boss. They take their emotional cues from him. Even when the boss isn't highly visible – for example, the CEO who works behind closed doors on an upper floor – his attitude affects the moods of his direct reports, and a domino effect ripples throughout the company." (S. 47)

Already Redl (1942) refers to the influence of group leaders on the emotion of the group. Sy et al. (2005) believe the mood signals if the progress is satisfying resulting in more or less coordination, more or less effort or using a more or less suitable strategy. Furthermore they show that in case of a positive mood of the leader the mood of the other group members was also more positive, the group specific affective tone (see George 1990) was also more positive, the result more coordinated and leading to less effort. Bono and Ilies (2006) find also mood contagion from the leader towards the employees, especially if the leader is charismatic (Cherulnik et al. 2001).

Finally we point at the fact that mood contagion depends on the group membership. Leach et al. (2003) tell us that football fans become happy when the other team has bad luck. Gordijn et al. (2001) present the following result, students show more positive affect and less negative affect when an individual outside their group experienced negative consequences. Similarly Weisbuch und Ambady (2008) argue that the membership is of highest importance for the affective answer towards an emotion expressing individual. If the member of the other group shows fears the opposite group members show spontaneous positive affective answers and vice versa. A nervous address of the other group signals dominance and lessens fears, while a nervous address of a member of the own group signals servility and leads to fear.

Now let us turn to the phenomenon of social learning of fear. An animal can by observation of an individual of the same species learn to fear dangerous stimuli. Because one can observe such a behavior in many species, for instance in the case of cats (John et al., 1968), one can assume that it leads to advantage in the survival of the fittest. The strength of the fear reaction of the observed victim is connected with the resulting fear reaction of the observer in primates (Mineka und Cook, 1993). The reason for this seems to be the highly developed ability to generate and to process facial expressions (Ekman, 1982). Studies with apes show that the face full of fear of the same species can be regarded as unconditioned stimulus, because there are huge parallels between social fear learning and classic conditioning (Mineka und Cook 1993). The same can be observed in humans (Vaughan und Lanzetta 1980; Olsson et al. 2004). In the case of children with phobias regarding certain objects or situations the reaction of their parents regarding those seems to be the reason (Mineka et al. 2006).

Because the social learning of fear seems to be related to the classic conditioning Olsson et al. (2007) conclude that the neuronal processes are the same. Actually they show the amygdala was activated in the case of social fear learning and classic conditioning.

Humans contrary to other species can learn to fear not only by observing the fear of others but also by hearing a fearful story or reading it (Olsson und Phelps 2007). Olsson und Phelps (2007) show that the reactions of classic conditioning, social fear learning and the association between stimulus and instructions are the same. But the subconscious presentation of the conditioned stimulus leads only to reactions in the case of classic conditioning and social fear learning. Olsson and Phelps (2007) think that learning by instruction has a different learning mechanism and needs conscious perception.

Now let us turn to the mirror neuron theory. For the life of a primate it is highly important to understand the actions of other individuals. Moreover humans possess the fascinating ability to imitate. For both the mirror neuron system seems to be of highest importance. As mirror neurons one describes a class of visuomotoric neurones, which unload if the ape exercises a certain motoric action and if the ape observes another ape doing that action. Firstly they were perceived in the premotoric cortex (Di Pellegrino et al. 1992, Gallese et al. 1996, Rizzolatti et al. 1996). The mirror neurons react only if an action is connected with an object. If the action is done by humans or apes doesn't make a difference. One can distinguish strictly congruent and broadly congruent mirror neurons dependent on the congruence between observed and own action (Gallese et al. 1996). Using the mirror neurons the individual gets the information what the result of an observed action is (Rizzolatti et al. 2001). Umilta et al. (2001) observe that the mirror neurons unload when seeing the last part of the reaching out for an object although the ape doesn't see this last part. More than the half of the mirror neurons unload.

The understanding of a motoric action is surely important but so is to understand the thoughts, emotions and intentions (for an overall view Oberman und Ramachandran 2007). Two theories compete in the theory of mind. The theory-theory is based on a cognitive theory to understand the thoughts, emotions and intentions, while the simulation theory is based on the internal simulation (Carruthers und Smith 1996). Obviously the simulation theory is connected to the mirror neuron theory.

The study by Dimberg und Lundqvist (1988) showed that the facial expressions of other individuals were imitated, also if the facial expressions were presented subconsciously (Dimberg et al. 2000). If one lowers the ability to imitate, Niedenthal et al. (2001) present the result that the transition from a happy to a sad face was perceived tardy in comparison to a control group.

By fMRI one can show that the regions between the own experience of emotions and the observed emotion overlap (Singer et al. 2004; Wicker et al. 2003). In the case of disgust certain stimuli lead to certain reactions (Rozin et al. 2000), connected to the insula. One can prove that the insula reacts in the case of disgust in others and that it depends on the strength of the disgust (Phillips et al. 1997, Wicker et al. (2003)). A damage of the insula does not only lead to less experience of disgust but also to the inability to perceive disgust in others (Calder et al. 2000). Adolphs et al. (2002) and Sprengelmeyer et al. (1999) show that a damaged amygdala impaired the ability to experience fear and to perceive fear in others.

IX. Worst Case and Best Case

“If someone is predisposed to be worried, degrees of unlikeliness seem to provide no comfort, unless one can prove that harm is absolute impossible, which itself is not possible.” Weingart (2001), p.362

According to Sunstein (2001): ”Many experiments suggest that when it comes to risk, a key question is whether people can imagine or visualize the “worst case” outcome. When worst case produces intense fear, little role is played by the stated probability that that outcome will occur. An important function of strong emotions is then to drive out quantitative judgments, including judgments about probability, by making the best case or worst case seem highly salient.”(p.6) Looking at casinos and insurance companies: “With respect to hope, those who operate gambling casinos and state lotteries are well-aware of the underlying mechanisms. They play on people’s emotions in the particular sense that they conjure up palpable pictures of victory and easy living. With respect to risks, insurance companies and environmental groups do exactly the same.” (p.14) Sunstein (2001) presents the “alarmist bias”, which means that “When presented with competing accounts of danger, people tend to move toward the more alarming account.” (p.14) Including the media: “If newspapers, magazines, and news programs are streaming certain harms from remote risks, people’s concern is likely to be out of proportion to reality.” (p.15)

Understanding the probability neglect, one can use this knowledge to do good things like decreasing the number of smokers: “And if government is attempting to increase public concern with a genuine danger, it should not emphasize statistics and probabilities, but should instead draw attention to the worst case scenario”. (p.5) But there is an asymmetry between increasing fear and decreasing it. If one wants to decrease the fear the best approach seems to be change the subject but if this is not possible: “Government should attempt to educate and inform people, rather than capitulating to unwarranted fear. On the other hand, public fear, however unwarranted, may be intractable, in the sense that it is imperious to efforts at reassurance. And if fear is intractable, it will cause serious problems, because fear is itself extremely unpleasant, and because fear is likely to influence conduct, producing (for example) wasteful and excessive private precaution. If so, a governmental response, via regulatory safeguards, would appear to be justified if the benefits, in terms of fear reduction, justify the costs.”(p.5-6) Moreover: “Because people suffer from probability neglect, and because neglecting probability is not fully rational, the phenomenon I identify casts additional doubt on the widespread idea that ordinary people have a kind of “richer rationality” superior to that of experts.” (p.5) Looking at markets Sunstein (2001) speculates: “But we might expect that risk markets will reduce the problem of neglect, if only because number of people will appreciate the relevant differences, and drive wage and prices in the appropriate direction.” (p.8) Moreover looking at the heterogeneity of people: “Those who are peculiarly insensitive to probability information are likely to do poorly in many domains, including economic markets.” (p.15)

There was an intense debate about whether the National Environmental Policy Act requires agencies to discuss the worst-case scenario in environmental impact statements.

Lopes (1986) presents a two-factor Theory for Risky Choice with a dispositional and a situational factor. “The dispositional factor describes the underlying motives that dispose people to be oriented at achieving security (risk averse) or to exploiting potential (risk seeking).” (p.18) “The situational factor describes people’s responses to immediate needs and opportunities.” (p.18) Moreover “risk averse and risk seeking individuals differ in whether they pay most attention to the worst outcomes in a distribution or the best outcome. Risk averse people appear to be motivated by a desire for security whereas risk seeking people appear to be motivated by a desire for potential.” Furthermore “in mathematical terms, security motivation corresponds to weighting the worst outcomes in a lottery more heavily than the best outcomes and potential motivation corresponds to the opposite… Second weights reflect individual's goals and not their perception of probabilities or values." (p.18) "The theory puts risk seekers and risk averse people on equal footing. Although their choices may differ profoundly, their choice processes have more similarities than differences. They understand risk in the same way (cumulatively) and trade off the same factors. Their goals may differ, but they have the same conceptual equipment." (p.24) The second factor is the aspiration level, a "situational variable that reflects the opportunity at hand ("What can I get?") as well as the constraints imposed by the environment ("What do I need?")." (p.19) The aspiration level can reflect 3 different sources, the direct assessment of what is reasonable or safe to hope for, the direct contextual influence of the alternatives in the choice set and finally the outside influence. There can be conflict between security/potential and aspiration level. For security motivated people for gains there is a positive correlation between security and aspiration, while there is a conflict between security and aspiration for losses. For potential motivated persons for gains potential and aspiration seem to be negatively correlated and losses seem to be positively correlated.

Experiments show that in virtually every case, the lottery judged to be riskier was the one whose Lorenz curve lay further from the diagonal at the low end. The risk seeking people preferred lotteries whose Lorenz curves lay far from the diagonal at the high end. According to Lopes (1986) "subjects tend to evaluate lotteries in terms of inequalities." (p.17) To the extent that the tickets for the lotteries have unequal prizes, the Lorenz curve bows away from the diagonal. "Lorenz curves are convenient for lotteries cumulatively and for comparing lotteries selectively on either low or high outcomes. They also highlight differences and similarities among lotteries that are not immediately apparent by direct inspection of the lotteries." (p.13) Lopes (1986) presents protocols: "Notice the inequalities: the keynote of these protocols in the cumulative likelihood of meeting or exceeding a goal (e.g., "greater chances of winning a little something,""a good chance of winning $71 or more," "do better than the best") The protocols also suggest that the subjects are mostly concerned about doing badly (getting zero or a small amount." (p.13) According to Lopes (1986): "Moment models have major difficulties. Some of these are technical as, for instance, the fact that, subjectively speaking, risk doesn't act like variances. More serious, however, is that such theories implicitly assume that moments have independent psychological reality. That seems doubtful except for the simplest comparisons." (p.12)

X. Group Polarization

„Darling I don’t know why I go to extremes, too high or too low there ain’t no in-between.”

Billy Joel, I Go To Extremes, Storm Front (1989)

Interestingly there is the tendency in groups after group internal discussions to decide more extremely than one would expect observing their initial position. This is quite surprisingly because one would expect a movement towards the mean.

Moderate feminists became stronger feminists after a group discussion (Myers 1975). The difference between a group with strong racists and a group with little prejudices became stronger after discussions (Myers und Bishop 1970). Johnson and Andrews (1971) present that products which led to a high desire were even more asked for after a discussion and vice versa for a product of low desire. A positive expectation value of a bet led to more risk after group discussions and vice versa for a negative expectation value (Davis et al. 1974). There is a clear polarization towards risk for the stock market (Deets und Hoyt 1970). For an overall view see Myers und Lamm (1976).

The first studies look primarily at risk. The participants answered a Choice Dilemmas Questionaire. The individual has to decide how likely a risky alternative has to be to finally choose it (Kogan und Wallach 1964). Regularly a risky shift was observed after group discussions. But one can also observe a conservative shift if this was the dominated direction before the discussion. So the term group polarization (for instance Moscovici and Zavalloni 1969). Regarding the dominated direction the neutral point lied between 60 and 70 percent. Under 60 percent there one can observe a tendency towards risk, over 70 percent a tendency towards caution (Myers und Aronson 1972). Teger und Pruitt (1967) show that a stronger movement towards risk depended on the number of group members (minimal movement for 3 members, moderate movement for 4 members, huge movement for 5 members). The initial position and the strength of movement were highly influenced by the considered problem.

Regarding the phenomenon of group polarization there exist many different theories, of which we will present the most important now.

Burnstein and Vinokur (1977) propagated the so called model of persuasive arguments, saying that the position of an individual is a function of the number and the persuasiveness of the remembered arguments. From a cultural pool of arguments some are remembered, which differ in their availability, direction and persuasiveness. The persuasiveness depends on the validity and the novelty character according to Burnstein (1982). A new argument can lead to a complete turnaround. The discussion will lead to the alternative which has more and better arguments in the group. The initial positions already having a direction will finally move further in this direction.

Contrary we have the model of social comparison (Sanders und Baron 1977). It is based on the assumption that individuals wanted to be perceived advantageously. Having detected a direction they will try to become the avant-garde and take a more extreme position. Teger und Pruitt (1967) show that the bare information about the position of other group members led to a substantial movement towards risk. For other evidence see Blascovich et al. (1975). Goethals and Zanna (1979) show that the perceived similarity of the group members influences the polarization. The stronger the similarity, the more polarization.

Here two important forms of this theory.

Firstly the plurastic ignorance theory (Levinger and Schneider 1969). Humans show compromises between the tendency to follow one's own ideal and not to deviate from the group. Because the group norm is underestimated before the discussion, we can observe the polarization after the discussion.

Secondly now let us turn to the release-theory (Pruitt 1969). Pruitt (1969) stresses the conflict between attractive risk seeking behavior and reason. That another person takes an extreme position releases the individual from the social chains of restraint (see Asch 1952). The opinion of the most risk seeking individual becomes the model for the other group members.

Myers (1973) show that the own ideal is more extreme than the group average. Other studies present the following result. Individuals who have a more extreme opinion are socially more reputable (Baron et al. 1973; Jellison and Davis 1973). Ferguson and Vidmar (1971) show that only the individuals with a moderate position move and the individuals with the extreme opinion stay the same.

Finally Isenberg (1986) concludes after viewing 21 studies that both theories, the theory of persuasive arguments and the theory of social comparison, are responsible for the phenomenon of group polarization, while the first stronger.

XI. Extreme Value Theory

„Verbindet die Extreme, so habt ihr die wahre Mitte"

Friedrich Schlegel, Ideen

If we interpret emotions as situation specific recall of extreme events self experienced or acquired by the observation of other individuals, it seems reasonable to look at the extreme value theory. Because extreme values are per definitionem rare events, one has to estimate probabilities for events, which have not been observed. The extreme value theory, based on asymptotic considerations, leads to models, which extrapolate from observed events to yet not observed events. Examples can be found in Coles (2001), for instance the maximal yearly sea level in Port Pirie or the minimal efficiency of chain link. Moreover one has to pay attention to a possible complex structure like the data showing a time trend or a short term cluster of extreme values.

One searches for the distribution of the maximum M_n after n observations $X_1, X_2 \ldots X_n$. Assuming that the n observations are identically and independently distributed with the distribution function F, we get for the distribution of M_n:

$$Pr\{M_n \leq z\} = Pr\{X_1 \leq z, \ldots, X_n \leq z\}$$

$$= Pr\{X_1 \leq z\} \times \ldots \times Pr\{X_n \leq z\}$$

$$= \{F(z)\}^n$$

If we don't know exactly the distribution of the X_i, we can try to estimate F, although knowing that little distortions regarding F can strongly distort F^n. So we are approximating the distribution of the M_n.

If we let run n against infinity, the M_n would degenerate to z_+, whereas z_+ is the smallest value for which $F(z) = 1$ is valid. We can solve this approximation by the following normalization with constant series $\{a_n > 0\}$ and $\{b_n\}$:

$$M_n^* = \frac{M_n - b_n}{a_n}$$

One can show: If the constant series $\{a_n > 0\}$ and $\{b_n\}$ exist, so that for $n \to \infty$ $Pr\left\{\frac{M_n - b_n}{a_n} \leq z\right\} \to G(z)$ is valid, then the non-degenerate distribution function G must belong to one of the following three families of distributions:

$$I: G(z) = exp\left\{-exp\left[-\left(\frac{z-b}{a}\right)\right]\right\}, \quad -\infty < z < \infty;$$

$$II: G(z) = \begin{cases} 0, & z \leq b; \\ exp\left\{-\left(\frac{z-b}{a}\right)^{-\alpha}\right\}, & z > b; \end{cases}$$

$$III: G(z) = \begin{cases} exp\left\{-\left[\left(\frac{z-b}{a}\right)^{\alpha}\right]\right\}, & z < b; \\ 1, & z \geq b \end{cases}$$

This three families are known as extreme value distributions. They are characterized by the location parameter b, the scale parameter a and for Fréchet and Weibull in addition by the form parameter α. Regarding z_+ one can observe in the case of Weibull that it has an end. The density decreases in the case of Gumbel contrary to Fréchet exponentially and not polynomially.

With the help of Cramer-von Mises we can simplify the situation and write:

$$G(z) = exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

Fréchet correspondents with $\xi > 0$, Weibull with $\xi < 0$ and finally Gumbel with $\xi = 0$, interpreted as limit for $\xi \to 0$. The so called generalized extreme value distribution family is defined on the set $\left\{z: 1+\xi\left(\frac{z-\mu}{\sigma}\right) > 0\right\}$, for the location parameter we have $-\infty < \mu < +\infty$, for the scale parameter $\sigma > 0$, and finally for the form parameter $-\infty < \xi < +\infty$. Because of the generalized extreme value distribution family we don't have to decide in favor of one of the three families when analyzing the situation.

Now turning to the limit distribution to get an approximation of the distribution of the maxima we get:

$$Pr\left\{\frac{M_n - b_n}{a_n} \leq z\right\} \approx G(z)$$

So we get also:

$$Pr\{M_n \leq z\} \approx G\left\{\frac{(z-b_n)}{a_n}\right\} = G^*(z)$$

Whereas $G^*(z)$ belongs to the family of generalized extreme value distribution. So we have found the approximation of the distribution of the maxima.

This leads to the following block method to estimate the parameters. We shape m blocks with n observations. Often the observations of a year become a block. There is a trade-off between distortion and variance. If the blocks are too small the approximation of the distribution of the maxima by $G(z)$ leads to strong distortions. Larger blocks have too few values for M_n leading to an increasing variance.

The log-likelihood of the parameters of the generalized extreme value distribution is for $\xi \neq 0$ assuming independent block maxima $Z_1, \ldots, Z_m$ is:

$$l(\mu,\sigma,\xi) = -m \log \sigma - \left(1+\frac{1}{\xi}\right)\sum_{i=1}^{m} log\left[1+\xi\left(\frac{z_i-\mu}{\sigma}\right)\right]$$
$$-\sum_{i=1}^{m}\left[1+\xi\left(\frac{z_i-\mu}{\sigma}\right)\right]^{-1/\xi}$$

, provided that

$$1+\xi\left(\frac{z_i-\mu}{\sigma}\right) > 0, für\ i = 1, \ldots, m$$

If this restriction isn't valid the end points of the generalized extreme value distribution are exceeded respectively fall below and the probability of this parameter combination becomes zero.

For $\xi = 0$ we get:

$$l(\mu, \sigma) = -m \log \mu - \sum_{i=1}^{m} \left(\frac{z_i - \mu}{\sigma}\right) - \sum_{i=1}^{m} \exp\left\{-\left(\frac{z_i - \mu}{\sigma}\right)\right\}$$

Using numerical optimization algorithms we can estimate the parameters $\mu, \sigma \; und \; \xi$, which correspond to the highest probability.

The return level z_p of the extreme value distribution of the maxima is surpassed by a probability of p. So one can expect that on average a surpassing can be observed all $\frac{1}{p}$ years.

If we search for the distribution of minima $\widetilde{M}_n = min\{X_1, X_2 \dots X_n\}$ in the case of identical and independent random variables we get:

$$Pr\{\widetilde{M}_n \leq z\} = 1 - Pr\{X_1 > z, \dots, X_n > z\}$$

$$= 1 - (Pr\{X_1 > z\} \times \dots \times Pr\{X_n > z\})$$

$$= 1 - (1 - F(z))^n$$

If we don't know the $F(z)$, we have to turn to the extreme value theory. If we write $Y_i = -X_i$ for the $i = 1, \dots, n$ we get $M_n = max\{Y_1, Y_2 \dots Y_n\}$ and finally $\widetilde{M}_n = -M_n$. Moreover the generalized extreme value distribution for the minima is:

$$\tilde{G}(z) = 1 - exp\left\{-\left[1 + \xi\left(\frac{z - \tilde{\mu}}{\sigma}\right)\right]^{-1/\xi}\right\}$$

, defined on $\left\{z: 1 - \frac{\xi(z-\tilde{\mu})}{\sigma} > 0\right\}$ with $-\infty < \tilde{\mu} < +\infty$, σ>0, $-\infty < \xi < +\infty$ und $\tilde{\mu} = -\mu$

Now let us turn to both the maximum and minimum. If we write $X_{(1)}, \dots, X_{(n)}$ for the order statistics $(X_{(1)} \leq X_{(2)} \leq \dots \leq X_{(n)})$, of a random sample $X_1, \dots, X_n$, on basis of a continuous distribution function $F_X(x)$ with a density $f_X(x)$. For the density of $X_{(i)}$ and $X_{(j)}$ we get for $1 \leq i < j \leq n$:

$$f_{X_{(1)},X_{(n)}}(u, v) = n(n-1)f_X(u)f_X(v)(F_X(v) - F_X(u))^{n-2}$$

For $-\infty < u < v < \infty$

Because often we don't know the distribution function $F_X(x)$ we have to use approximative methods. Gumbel (1946) proved that the distribution of the maximum and the distribution of the minima can be assumed as independent for huge n if the following is true:

$$\lim_{x=-\infty} \frac{f_X'(x)}{f_X(x)} = \lim_{x=-\infty} \frac{f_X(x)}{F_X(x)}; \qquad \lim_{x=\infty} \frac{f_X'(x)}{f_X(x)} = -\lim_{x=\infty} \frac{f_X(x)}{1-F_X(x)}$$

It is true if the unconstrained continuous density is of the exponential type. Tippett (1925) showed for a normally distributed sample with $n \geq 200$ that the correlation can be neglected. So Gumbel (1947) tells us to depict the asymptotical distribution of the maximum and minimum $h(x_1, x_n)$ as product of the asymptotical distribution of the minimum $a_1(x_1)$ and the asymptotical distribution of the maximum $a_n(x_n)$:

$$h(x_1, x_n) = a_1(x_1) * a_n(x_n)$$

For the density of the mid range $w = X_{(n)} - X_{(1)}$ we have:

$$g(w) = n(n-1) \int_{-\infty}^{\infty} f_X(y) f_X(y+w)(F_X(y+w) - F_X(y))^{n-2} dy$$

,corresponding to the following distribution function.

XII. Chemical Reactions

„Sumpf'ger Schlange Schweif und Kopf
Brat und koch im Zaubertopf:
Molchesaug und Unkenzehe;
Hundemaul und Hirn der Krähe;
Zäher Saft des Bilsenkrauts,
Eidechsbein und Flaum vom Kauz;
Mächt'ger Zauber würzt die Brühe,
Höllenbrei im Kessel glühe!"

William Shakespeare, Macbeth, S.49

Target of the chemistry is to attribute macroscopically observable reaction rates and mechanisms to elementary microscopically processes. At centre are the chemical reaction rates, the time rates of change of the concentration, which depend on the temperature, the pressure, the volume, the concentration of the reactants and on the existence of a catalyst.

It’s assumed that the macroscopic reaction rate can completely be described by unimolecular, bimolecular and termolecular microscopic reactions.

In the case of unimolecular reactions a single molecule reacts ($A \to products$). Because the change of the number of products will be proportional to the number of A, we get the following reaction of first order:

$$\frac{d[products]}{dt} = -\frac{d[A]}{dt} = k[A]$$

In the case of bimolecular reactions we can observe the collision of two molecules ($A + B \to products$). So because the change of products is proportional to the number of possible collisions we observe the following reaction of second order:

$$\frac{d[products]}{dt} = -\frac{d[A]}{dt} = k[A][B]$$

Finally we come to the termolecular reactions ($A + B + C \rightarrow products$). We can observe the reaction of third order:

$$\frac{d[Produkte]}{dt} = -\frac{d[A]}{dt} = k[A][B][C]$$

A termolecular reaction can often be seen as two bimolecular reactions.

If we look at living cells the description of the concentration change as deterministic system seems dubious because of the small number of reactants (not more than1000). So we have to replace the continuous differentiable concentration function by a stepwise stochastic increase to incorporate the fluctuations. This description can be especially important in nonlinear systems with chemical instabilities. We observe a Markovian random walk in the N-dimensional space of N molecules.

The fundamental hypothesis, which forms the basis of the stochastic formulation of chemical kinetics, is that we can define a parameter c_μ in the following way (Gillespie 1976): $c_\mu \delta t$ is defined as the average probability, to first order in δt, that a particular combination of R_μ reactant molecules react accordingly in the next time interval δt.

$h_\mu(n_1, \ldots, n_N)$ is the number of different combinations of the R_μ reactant molecules, if there are exactly n_i of S_i molecules and that $X_i(t)$ is the number of molecules of species S_i in the system at time t $(i = 1, \ldots, N)$.

Gillespie (1992) proved the following theorems. Firstly, if $X(t) = n$, then the probability that there is exactly one R_μ reaction in the system in the time interval $[t, t + dt)$ is equal to $c_\mu h_\mu(n)dt + o(dt)$, whereas $o(dt)$ strives faster against zero then dt.

Secondly, if $X(t) = n$, then the probability that there is no reaction in the time interval $[t, t + dt)$ is equal to $1 - \sum_\mu c_\mu h_\mu(n)dt + o(dt)$.

Thirdly the probability that there is more than one reaction in the system in the interval $[t, t + dt)$ is equal to $o(dt)$.

The physical basis for the collision probability is the following three assumptions. Firstly the system is spatially homogenous, an uniform distribution of the molecules in the volume V. Secondly the distribution of the kinetic energy is Maxwell-Boltzmann distributed. And finally there should be by far more elastic pushes than inelastic.

This all leads to the master-equation, which describes the change of probability $P(\boldsymbol{n}, t)$ of a vector of $\boldsymbol{n}$ molecules by a gain-loss balance, whereas the transition probabilities $\tau_{\boldsymbol{nn'}}$ are equal to the probability of change from a state $\boldsymbol{n'}$ towards a state $\boldsymbol{n}$:

$$\frac{\partial P(\boldsymbol{n}, t)}{\partial t} = \sum_{\boldsymbol{n'}} \tau_{\boldsymbol{nn'}} P(\boldsymbol{n'}, t) - \tau_{\boldsymbol{n'n}} P(\boldsymbol{n}, t)$$

Using the step operator $\boldsymbol{E}$, we can simplify the notation. $\boldsymbol{E}$ increases in the case of E_i^k the variable i of the function $f(n_1, n_2, \dots, n_i, \dots)$ by k:

$$E_i^k \, f(n_1, n_2, \dots, n_i, \dots) = f(n_1, n_2, \dots, n_i + k, \dots)$$

Moreover we present the stoichiometric matrix $\boldsymbol{S}$ whose components describe the rise or fall of the molecule i in the case of reaction j. The reaction j leads in the i molecule to S_{ij}: $n_i \overset{\nu_j}{\rightarrow} n_i + S_{ij}$. The vector $\boldsymbol{\nu}$ describes the reaction rates. This leads to the following master equation with R reactions and N molecules:

$$\frac{\partial P}{\partial t} = \Omega \sum_{j=1}^{R} \left[\left(\prod_{i=1}^{N} E_i^{-S_{ij}} \right) - 1 \right] \nu_j \left(\frac{\boldsymbol{n}}{\boldsymbol{\Omega}} \right) P(\boldsymbol{n}, t)$$

For the number of molecules n, the density X and the system size Ω we can observe the following function:

$$n = \Omega * X$$

If we look at the density $\frac{n_i}{\Omega} = x_i$ the deterministic rate equation becomes:

$$\frac{d\boldsymbol{x}}{dt} = \lim_{\Omega \to \infty} \boldsymbol{S} * \boldsymbol{\nu}$$

The microscopic and macroscopic reaction rates differ a little bit. Let us take the reaction $2A + B \to C$, the reaction rate is proportional to $(A * B * (A - 1))$. Macroscopially we ignore this connection (A^2B).

To solve master equations with nonlinear transition probabilities, we can use numerical simulations (Gillespie, 1976/1977), which leads to trajectories of the probability distribution $P(n,t)$. If we simulate a huge number of paths we get a better or worse approximation of $P(n,t)$ dependent of the number of simulations.

The „direct" method by Gillespie isn't based on the probability distribution $P(n,t)$ but on the reaction probability density function $P(\tau,j)d\tau$, therefore on the probability in t that the next reaction is in the time interval $(t+\tau, t+\tau+d\tau)$ and the reaction is R_j. The algorithm delivers a pair (τ,j) on basis of the common probability density $P(\tau,j)$. So we get the exact time development of the system.

The approach of Gillespie uses contrary to the reaction rate $v_j\left(\frac{\boldsymbol{n}}{\Omega}\right)$ the function $g_j(\boldsymbol{n}) = c_j h_j(n)$, which one can get by simply multiplying $\Omega * v_j\left(\frac{\boldsymbol{n}}{\Omega}\right) = g_j(\boldsymbol{n})$.

On basis of the reaction rate g_j we get a probability distribution, which determines the time τ for the next jump and also a probability distribution, which determines the next reaction of the j reactions. Then the time will be changed to $t + \tau$ and the state to $n_i \overset{g_j}{\rightarrow} n_i + S_{ij}$.

The probability that one can observe a R_j reaction in the next time interval $(t + \tau, t + \tau + d\tau)$ is equal to $c_j h_j(n) d\tau$. The probability of none jumps in $(t, t + \tau)$ is:

$$\mathrm{P}_0(\tau) = \exp[-a(\boldsymbol{n})\tau]$$

, with

$$\left[\sum_{j=1}^{N} g_j(\boldsymbol{n})\right] \equiv a(\boldsymbol{n})$$

So we get $P(\tau, j)$:

$$P(\tau, j) = g_j(\boldsymbol{n}) \exp[-a(\boldsymbol{n})\tau]$$

Moreover on basis of the conditional probability:

$$P(\tau, j) = P_1(\tau) P_2(j|\tau)$$

The probability $P_1(\tau)$, that there is a reaction between $t + \tau$ and $t + \tau + d\tau$ is:

$$P_1(\tau) = \sum_{j=1}^{J} P(\tau, j)$$

The probability $P_2(j|\tau)$ that the next reaction is of type j is:

$$P_2(j|\tau) = P(\tau, j) / \sum_{j=1}^{J} P(\tau, j)$$

Finally we get:

$$P_1(\tau) = a(\boldsymbol{n}) \exp[-a(\boldsymbol{n})\tau] \qquad (0 \leq \tau < \infty)$$

$$P_2(j|\tau) = \frac{g_j(\boldsymbol{n})}{a(\boldsymbol{n})} \qquad (j = 1,2, \dots, J)$$

The probability $P_1(\tau)$ can be simulated with help of a uniformly between 0 and 1 distributed random number s_1. So we get for τ:

$$\tau = \frac{1}{a(\boldsymbol{n})} \ln(\frac{1}{s_1})$$

The distribution $P_2(j|\tau)$ can also be simulated on basis of a uniformly between 0 and 1 distributed random number s_2:

$$\frac{1}{a(\boldsymbol{n})}\sum_{\mathrm{j}}^{\varphi} g_j(\boldsymbol{n}) > s_2$$

The first number φ for which the inequality is fulfilled describes the reaction in $t+\tau$ leading to an increase of S_{ij}.

If the model depends on the temperature it's possible to include this feature by renewing the reaction parameter each period. But it's required that the change of temperature is only small (Gillespie, 1976).

Examples of the jump processes are predator-prey models or the „Brusselator“ (Gillespie 1977).

Let us look at the model of Volterra with Y_1 as prey and Y_2 as predator:

$$\frac{dY_1}{dt} = c_1XY_1 - c_2Y_1Y_2$$

$$\frac{dY_2}{dt} = c_2Y_1Y_2 - c_3Y_2$$

The equilibrium is:

$$Y_{1s} = \frac{c_3}{c_2} \ and \ Y_{2s} = \frac{c_1X}{c_2}$$

For the parameter values of $c_1X = 10, c_2 = 0.01, c_3 = 10$ one can observe strong oscillations, a changing amplitude and a stable frequency in the case of $Y_{1s} = 1000$ and $Y_{2s} = 1000$. An increase of the number of prey leads to an increase of the number of predators until the number of prey decreases and so does the number of predators. In the deterministic case the solution is neutral stable, one can observe a closed orbit. Gillespie (1977) describes the observed behavior as „drunkard's walk“ about the continuum of concentric, neutral stable solution orbits. Neutral stable solutions lead in the case of a stochastic observation to one of two absorbing states, $(Y_1 = 0, Y_2 = 0)$ or $(Y_1 = \infty, Y_2 = 0)$.

XIII. Ants, Van Kampen and the Socio Dynamics

„Die Meinungen der Menschen, ihre geistige Haltung, sind für die Richtung der Wirtschaftspolitik vielfach wichtiger als die wirtschaftliche Tatsache selbst.“

Walter Eucken, Grundsätze der Wirtschaftspolitik (2008)

The first of three in the following presented models is the model of Kirman (1993). Deneubourg et al. (1987) and Pasteels et al. (1987) show that ants in the case of foraging in a symmetric situation act asymmetrically and firstly plunder one of two identical, constantly restocked, food sources, but change later to the other food source. The same phenomenon was seen for the usage of two different ways to the food source. So Kirman (1993) assumed that such a behavior is based on the interaction of the group members and can't be explained by looking at an isolated ant. So such a herd behavior can explain the volatility of the stock exchange.

According to the criticism by Gould and Lewontin (1979) that the optimality is overemphasized in the biological context, because surviving does not mean optimality and there could exist local optimality preventing evolution.

Let us now turn to the model. There exist two food sources a black and a white one. N ants visit the black or white one. The system state is defined by the number k which visit the black food source, so we have

$$k \in (0,1,\ldots,N)$$

We pick two ants at random of which the first picked ant takes over the opinion of the second ant with the probability (1-δ). But the first picked ant changes its opinion also autonomously with the probability ε, so that we prevent a latching in the case of k=0 and k=N. The connection between δ and ε can be described in the following way. Firstly the ant changes its opinion autonomously with the probability ε, if that doesn't happens the ant takes over the opinion of the other ant with probability γ. So δ is equal to $(1-\gamma+\gamma\varepsilon)$. The autonomous opinion swing is based on exogenous information or the exchange of ants. In a small time interval we can observe the following change of k:

$$k \rightarrow \begin{cases} k+1, \;\; mit\; P(k \rightarrow k+1) = p_1 \\ k, \qquad mit\; P(k \rightarrow k) = 1 - p_1 - p_2 \\ k-1, \;\; mit\; P(k \rightarrow k-1) = p_2 \end{cases}$$

Moreover we get:

$$p_1 = P(k \rightarrow k+1) = \frac{N-k}{N}\left(\varepsilon + (1-\delta)\frac{k}{N-1}\right)$$

$$p_2 = P(k \rightarrow k-1) = \frac{k}{N}\left(\varepsilon + (1-\delta)\frac{N-k}{N-1}\right)$$

For ε=0.5 and δ=1 we get the Ehrenfest urn model with a stationary distribution which is binomially distributed:

$$prob(k) = B(k; 0.5; N) = \binom{N}{k} 0.5^N$$

ε=0 leads to the final state k=N or k=0, whereas the probability of k=N with an initial state k_0 is equal to k_0/N.

The stationary distribution has the following characteristics. For a strong autonomous part $\varepsilon > \frac{1-\delta}{N-1}$ we get an unimodal distribution round k=N/2. For a relative strong herd part $\varepsilon < \frac{1-\delta}{N-1}$ the distribution is bimodal and the probability is concentrated round k=0 and k=N. Finally for $\varepsilon = \frac{1-\delta}{N-1}$ we get an uniform distribution. Föllmer proved that the continuous limit distribution in the case of $N \to \infty$ and $\varepsilon = \alpha/N$ and $\delta = 2\alpha/\mathrm{N}$ is equal to the symmetric beta distribution.

Because herd behavior can in reality generate a positive rent according to Kirman (1993) this should strengthen the observed herd behavior. Moreover it seems hard to hedge one against a change of opinion because we have a memoryless Markov process and so can't predict exactly the consequences of an opinion swing.

The influence of another individual can be explained in the following way. The individual could be convinced that the other one has superior abilities, because conformism has a positive externality or because the other one is a sample.

De la Lama et al. (2006) distinguish in their opinion model based on the „Linear Noise Approximation“ by Van Kampen (2007) three parties, *A*, *B* and the irresolute I.

They assume the following changes of opinion: $I \leftrightarrows A$ und $I \leftrightarrows B$. The number of followers of A is N_A, the number of followers of B is N_B and the number of irresolute individuals I is equal to N_I. The reaction equations are:

$$A \rightarrow I \; with \; the \; rate \; \alpha_1 N_A$$

$$I \rightarrow A \; with \; the \; rate \; \alpha_2 N_I$$

$$B \rightarrow I \; with \; the \; rate \; \alpha_3 N_B$$

$$I \rightarrow B \; with \; the \; rate \; \alpha_4 N_I$$

$$A + I \rightarrow 2A \; with \; the \; rate \; \frac{\beta_1}{\Omega} N_A N_I$$

$$B + I \rightarrow 2B \; with \; the \; rate \; \frac{\beta_2}{\Omega} N_B N_I$$

Because of the constraint $N_A + N_B + N_I = N$ we can write for N_I: $N_I = (N - N_A - N_B)$. So we get the following master-equation:

$$
\begin{aligned}
&\frac{\partial}{\partial t}P(N_A, N_B, t) \\
&\qquad = \alpha_1(N_A+1)P(N_A+1, N_B, t\ ) \\
&\qquad + \alpha_3(N_B+1)P(N_A, N_B+1, t\ ) \\
&\qquad + \alpha_2(N-N_A-N_B+1)P(N_A-1, N_B, t) \\
&\qquad + \alpha_4(N-N_A-N_B+1)P(N_A, N_B-1, t) \\
&\qquad + \frac{\beta_1}{\Omega}(N_A-1)(N-N_A-N_B+1)P(N_A-1, N_B, t) \\
&\qquad + \frac{\beta_2}{\Omega}(N_B-1)(N-N_A-N_B+1)P(N_A, N_B-1, t) \\
&\qquad - [\alpha_1 N_A + \alpha_3 N_B + \alpha_2(N-N_A-N_B) \\
&\qquad + \alpha_4(N-N_A-N_B+1)P(N_A, N_B, t)]
\end{aligned}
$$

Now to the results. For the symmetric case $\alpha_1 = \alpha_3 = \alpha$, $\alpha_2 = \alpha_4 = \alpha'$ und $\beta_1 = \beta_2 = \beta$ one can show that the expectation value of the fluctuations $\langle\xi_A(t)\rangle = \eta_A$ and $\langle\xi_B(t)\rangle = \eta_B$ of the stationary solution strives for $t \to \infty$ against zero. For the correlations of the fluctuations we have $\sigma_A = \langle\xi_A(t)^2\rangle$, $\sigma_B = \langle\xi_B(t)^2\rangle$ and $\sigma_{AB} = \langle\xi_A(t)\xi_B(t)\rangle$ for $t \to \infty$ $\sigma_i^{st} \neq 0\ (mit\ i = A, B, AB)$.

The macroscopic behavior is described, with $\rho = \frac{N}{\Omega} = 1$, by:

$$\frac{d}{dt}\Psi_A = -\alpha_1\Psi_A + [\alpha_2 + \beta_1\Psi_A](\rho - \Psi_A - \Psi_B)$$

$$\frac{d}{dt}\Psi_B = -\alpha_3\Psi_B + [\alpha_4 + \beta_2\Psi_B](\rho - \Psi_A - \Psi_B)$$

One can show that there exists only one stationary solution.

$$\Psi_A(t \to \infty) = \Psi_A^{st}$$

$$\Psi_B(t \to \infty) = \Psi_B^{st}$$

We can write for the fluctuations:

$$\begin{aligned}
\frac{\partial}{\partial t}\Pi(\xi_A, \xi_B, t) \\
&= \frac{\partial}{\partial \xi_A}[(\alpha_1\xi_A + (\alpha_2 + \beta_1\Psi_A)(\xi_A + \xi_B) \\
&- \beta_1\xi_A(\rho - \Psi_A - \Psi_B))\Pi(\xi_A, \xi_B, t)] \\
&+ \frac{\partial}{\partial \xi_B}[(\alpha_3\xi_B + (\alpha_4 + \beta_2\Psi_B)(\xi_A + \xi_B) \\
&- \beta_2\Psi_B(\rho - \Psi_A - \Psi_B))\Pi(\xi_A, \xi_B, t)] \\
&+ \frac{1}{2}[\alpha_1\Psi_A + [\alpha_2 + \beta_1\Psi_A](\rho - \Psi_A - \Psi_B)]\frac{\partial^2}{\partial \xi_A^2}\Pi(\xi_A, \xi_B, t) \\
&+ \frac{1}{2}[\alpha_3\Psi_B + [\alpha_4 \\
&+ \beta_2\Psi_B](\rho - \Psi_A - \Psi_B)]\frac{\partial^2}{\partial \xi_B^2}\Pi(\xi_A, \xi_B, t)
\end{aligned}$$

If one increases the population from 100 to 1000 one can see that the fluctuations decrease. In an example De la Lama et al. (2006) show that the probability to win the election decreases from 25.7% in the case of a population of 100 to 1.5% in the case of a population of 1000. The probability decreases in such a case proportional to N^{-1}.

The socio dynamics tries to model dynamic processes for many social systems and uses concepts which are known to us from the chapters before. We will present now an approach in an economic context created by Lux (1995).

Criticizing the efficient market hypothesis (West 1988) Lux (1995) presents a model for herd behavior, emphasizing sociological and psychological aspects. One can observe parallels to the model of Kirman (1993). Lux (1995) wanted to describe the behavior of noise-traders and to integrate the observation of a mean-reversion of stock prices (Poterba und Summers 1988).

Let us look at the model for the dynamic development of two opinions, one optimistic one pessimistic (see also Weidlich und Haag 1983). Lux (1995) assumes traders who have only one source of information namely their colleagues. So following the herd doesn't seem too irrational. Dependent on the opinion of the agent we have dynamically changing transition probabilities. At the centre we have the Geschäftsklimaindex x_t:

$$x_t = \frac{n_t}{N} = \frac{n_t^+ - n_t^-}{2N}$$

There exist 2N group members, of which n_t^+ are in a positive mood and n_t^- are in a negative mood. The moods can change by jump processes. Pessimists change to optimists with the individual transition rate $p_{\uparrow}$, optimists change to pessimists with the individual transition rate $p_{\downarrow}$. Moreover the transition probabilities depend on the number of optimists respectively pessimists and are equal for the individuals. We get the following equation system:

$$dn_t^+ = n_t^- p_{\uparrow} dt - n_t^+ p_{\downarrow} dt$$

$$dn_t^- = n_t^+ p_{\downarrow} dt - n_t^- p_{\uparrow} dt$$

The rates of the transition probability are:

$$p_{\uparrow} = v \exp(U), \qquad p_{\downarrow} = v \exp(-U)$$

For U we have:

$$U = \alpha_0 + \alpha_1 x$$

An increase in v increases the transition rates, the α_0 distorts the model regarding the opinions and α_1 determines the degree of conformism.

We get the following differential equation (see also Weidlich 2006):

$$\dot{x} = v[(1 - x) \exp(U) - (1 + x)\exp(-U)]$$

We can observe the following results:

1) For $\alpha_1 \leq 1$ there exists a single stable equilibrium at $x = 0$

2) For $\alpha_1 > 1$ we get two additional stable equilibrium with $x_+ > 0$ and $x_- < 0$, whereas $x = 0$ isn't stable anymore

We get the following master-equation:

$$\frac{dP(n;t)}{dt} = [w_\uparrow(n-1)P(n-1;t) + w_\downarrow(n+1)P(n+1;t)] - [w_\uparrow(n)P(n;t) + w_\downarrow(n)P(n;t)]$$

,whereas

$$w_\uparrow(n/N) = n_- p_\uparrow(n/N)$$

$$w_\downarrow(n/N) = n_+ p_\downarrow(n/N)$$

Now turn to the following results (Weidlich und Haag 1983):

1) For $\alpha_1 \leq 1$ we get a stationary distribution with a single maximum, which shifts dependent on α_0.
2) For $\alpha_1 > 1$ and small α_0, we get two maxima with $x_+ > 0$ and $x_- < 0$, whereas α_0 influences the Schiefe and the concentration of the probability mass.
3) If $|\alpha_0|$ increases over the bifurcation value $\overline{\alpha_0}$ $cosh^2(\overline{\alpha_0} - \sqrt{\alpha_1(\alpha_1 - 1)})$ the bimodal distribution becomes unimodal
4) The mean escape time depends on the number of agents

The above propagated Langevin-equation is valid exactly for an infinite population. The dynamics in case of a finite population are badly depicted by it, especially when there are multiple equilibriums.

Now Lux (1995) includes dynamic share prices to depict the volatility of the markets.

At every time a trader can buy or sell a fixed number of shares. An optimistic trader buys t_N shares, while a pessimistic one sells t_N shares. We get a demand D_N:

$$D_N = n_+ t_N - n_- t_N = 2n t_N$$

Because we have $n = Nx$ we can write:

$$D_N = 2Nx t_N, \qquad T_N \equiv 2N t_N$$

Besides the chartists there exists the fundamentalists, who orient themselves by the fundamental data. Their demand is:

$$D_F = T_F(p_f - p), \quad T_F > 0$$

The T_F describes the exchange volume. A market maker adapts the price until the equilibrium $p^* = \left(\frac{T_N}{T_F}\right) x + p_f$ is reached:

$$\frac{dp}{dt} = \beta(D_N + D_F) = \beta[xT_N + T_F(p_f - p)]$$

The change of price is incorporated in the transition probabilities:

$$p_{\uparrow} = v \exp\left(a_1 \frac{\dot{p}}{v} + a_2 x\right), \qquad p_{\downarrow} = v \exp\left(-a_1 \frac{\dot{p}}{v} - a_2 x\right)$$

The constants a_1 and a_2 weigh the strength of the price effect and the herd behavior.

We get the following differential equation system:

$$\dot{x} = 2v\left[Tanh\left(a_1 \frac{\dot{p}}{v} + a_2 x\right) - x\right] Cosh(a_1 \frac{\dot{p}}{v} + a_2 x)$$

$$\dot{p} = \beta[xT_N + T_F(p_f - p)]$$

We get the following results according to Lux (1995):

1) A single equilibrium exists for $a_2 \leq 1$ at $E_0 = (0, p_f)$, two additional equilibria for $a_2 > 1, E_+(x_+, p_+)$ and $E_-(x_-, p_-)$.
2) If $E_{\pm}$ exists then E_0 is instable.
3) For $a_2 < 1$ the stability depends on the condition $2[a_1\beta T_N + v(a_2 - 1)] - \beta T_F < 0$.
4) At least one can observe one limit cycle and all trajectories strive against a periodic orbit, if E_0 is single and not stable.

In the case of a cycle we observe negative mood and a falling price and in the optimistic case a positive mood and an increasing price, whereas we reach in both cases a turning point so that there is no lasting positive or negative majority.

The equilibria different from zero in the case $a_2 > 1$ are identical to the basic model. The generated price lies for $E_+(x_+, p_+)$ above the fundamental value and for $E_-(x_-, p_-)$ under it. In both cases we observe trade.

Looking at simulations one can observe for $a_2 > 1$ and for a huge parameter range stable equilibria $x_\pm$, moreover there was a case of a limit cycle in which all three equilibria were locked in.

Last but not least Lux (1995) includes with a_0 an endogenous mechanism to prevent bubbles and crisis:

$$p_\uparrow = v\, exp(a_0 + a_1 \frac{\dot{p}}{v} + a_2 x)$$

$$p_\downarrow = v\, exp(-a_0 - a_1 \frac{\dot{p}}{v} - a_2 x)$$

The variable a_0 depends on the difference of rents $(r + \dot{p})/p$, with r as constant dividend, and the average expected rents R:

$$\frac{da_0}{dt} = \tau[\frac{(r + \tau^{-1}\dot{p})}{p} - R]$$

If $p = p_f + (\frac{T_N}{T_F})x$, therefore if there is market clearance, then we get the following differential equation system, assuming additionally $\frac{r}{p_f} = R$:

$$\dot{x} = 2v[Tanh(a_0 + a_2 x) - x]Cosh(a_0 + a_2 x)$$

$$\dot{a}_0 = \tau\{\left[r + r^{-1}\left(\frac{T_N}{T_F}\right)\dot{x}\right] / \left[p_f + (\frac{T_N}{T_F})x\right] - R\}$$

We get the following results:

1) There exist a single equilibrium at $E = (0,0)$
2) The equilibrium is stable (not stable) for $a_2 - 1 + \frac{\frac{T_N}{T_F}}{p_f} < (>) 0$
3) In the not stable case there exist at least one limit cycle to which all trajectories converge

In the case of a cycle we notice that falling (increasing) rents lead to a falling number of optimists (pessimists) until we observe a crisis (bubble).

Lux (1995) bases his work on the following macroscopic equation. We have for the average $< Y >$, with $W(y'|y)$ as transition probability per unit time from y to y':

$$\frac{d}{dt} < Y >= \int y \frac{\partial P(y,t)}{\partial t} dy$$

$$\approx \iint (y' - y) W(y'|y) P(y,t) dy dy'$$

Now let's define the jump moments $a_v(y)$

$$a_v(y) = \int (y' - y)^v W(y'|y)\, dy' \qquad (v = 0,1,2 \ldots)$$

The exact consequence of the master-equation is

$$\frac{d}{dt} < Y >= \int a_1(y) P(y,t) dy =< a_1(Y) >$$

If $a_1(y)$ is a linear equation then we get

$$\frac{d}{dt} < Y >= a_1(< Y >)$$

If $a_1(y)$ is a non linear equation one has

$$< a_1(Y) >= a_1(< Y >) + \frac{1}{2} < (Y - < Y >)^2 > a_1''(< Y >) \ldots$$

The evolution of $< Y >$ depends on fluctuations around this average, it is not a closed equation for $< Y >$ for higher moments enter. Ignoring these fluctuations the result is Lux (1995) with his model of good and bad mood.

We opt for an agent-based model with a numerical simulation of moods or modes, extended by emotions. So we aren't able to present an analytical model like Lux (1995) which connects the above presented dynamical model of moods with a simple price building framework based on chartists and fundamentalists as we have already seen. But including emotions, respectively the extremes in our life, we can get a far more precise model of what happens if we are in a good, bad or neutral mood respectively mode, in much wider circumstances. It destroys the frontier between psychology, with its emphasis on trauma, and economics and leads hopefully to a better understanding of the world with its rationality and its emotions.

XIV. Prospect Theory, Disappointment Theory and Emotion-based Choice

“Men believe themselves to be free, simply because they are conscious of their actions, and unconscious of the causes whereby those actions are determined.”

B. Spinoza, Ethics, Works of Spinoza, New York: Dover, 1955

The expected utility theory dominates both as normative and descriptive model of rational choice. The prospect theory describes an alternative descriptive theory (Kahneman und Tversky 1979).

The expected utility theory is based on three pillars:

i) Expectation: $U(x_1, p_1; \dots; x_n, p_n) = u(x_1)p_1 + \cdots + u(x_n)p_n$
ii) Asset Integration: $(x_1, p_1; \dots; x_n, p_n)$ is accepted with wealth w only if $U(w + x_1, p_1; \dots; w + x_n, p_n) > u(w)$
iii) Risk aversion: u is concave $(u'' < 0)$

The following effects can be observed. The certainty effect says that humans overweigh a sure outcome relative to an only possible outcome.

The reflection effect means that the reflection against zero reverses the preference order. We can observe risk aversion in the positive domain and risk seeking in the negative domain.

The isolation effect says that humans don't focus on common parts of prospects but on the differing parts.

The prospect theory distinguishes two different stages. The editing phase consists of a temporary analysis, which leads to a simplified representation. One distinguishes the coding of gains and losses, the fixation of a reference point, the combination of probabilities in the case of identical outcome and the separation in a risky and a riskless part and finally the deletion of a common first stage. Moreover we have the rounding of outcomes, the disregard of extremely improbable outcomes and the search for dominant prospects.

The editing phase is followed by the evaluation stage, choosing the best prospect. Here the scales $\pi(p)$ and $v(x)$ are important. $\pi(p)$ assigns to the probabilities a certain weight, but this isn't a probability measure. $v(x)$ assigns to the gains and losses relative to a reference point a subjective value.

The $v(x)$ is assumed to be concave above the reference point and under it to be convex. $v(x)$ is steeper for losses than for gains.

Now let us turn to the following two models. According to Bell (1985) disappointment is a psychological reaction if the outcome is worse than expected. The bigger the difference, the bigger the disappointment. Enthusiasm is he reaction if the outcome is better than expected. Bell examined the anticipation of those feelings when uncertain alternatives are compared by the decision maker. So Bell (1985) argues that one should include feelings like disappointment or enthusiasm in a rational analysis.

Bell (1985) presents the following simple model. A person owns a lottery, which pays $\$x$ with probability p and $\$y$ with the probability $(1-p)$, whereas $\$x$ is preferred to $\$y$. The lottery is described by the triple (x,p,y). With the constant d we get disappointment as:

$$d(px+(1-p)y-y)=dp(x-y)$$

With the constant e we get enthusiasm as:

$$e(x-px-(1-p)y)=e(1-p)(x-y)$$

The utility is:

$$whole\ utility = economic\ payoff + psychological\ satisfaction$$

If $d>e$, then we have for the lottery (x,p,y) the certainty equivalent:

$$px+(1-p)y+(e-d)p(1-p)(x-y)$$

Bell (1985) views the part $(e-d)p(1-p)(x-y)$ as a risk measure.

Köszegi und Rabin (2005) build a model of reference dependent preferences. The utility of a sure outcome is

$u(c|r)$, with $c = (c_1, c_2 \dots, c_K) \in R^K$ as consumption and $r = (r_1, r_2 \dots, r_K) \in R^K$ as reference level of consumption. Finally the utility is:

$$U(F|G) = \int \int u(c|r) dG(r) dF(c)$$

, whereas the reference point is a probability measure G about the R^K and the consumption is drawn on the basis of the probability measure F.

The outcome is compared with the outcome of the reference lottery. If the reference lottery is a game between 0 and 100 dollar, the outcome of 50 dollar is a gain in the case of a reference of 0 dollar and a loss in the case of a reference of 100 dollar. The result is a mixture of both feelings.

The utility has two parts, the consumption utility $m(c)$ and the gain-loss utility $n(c|r)$:

$$u(c|r) = m(c) + n(c|r)$$

The consumption utility is additively separable between the dimensions, with every $m_k(.)$ differentiable and strictly increasing.

Moreover we look at the universal gain-loss function $\mu(.)$ with properties according to Kahneman und Tversky (1979):

$$n_k(c_k|r_k) = \mu(m_k(c_k) - m_k(r_k))$$

The gain-loss utility is separable. Köszegi und Rabin (2005) assume that the reference point is reflected by the current expectations. They will be assumed as completely rational. A person predicts the environment and her reaction in the personal equilibrium and maximizes her utility on basis of those expectations. If a person expects to choose F_l of a set D_l, then she expects the distribution of outcomes $\int F_l dQ(l)$, with this reference point the person chooses actually F_l from D_l.

Because multiple personal equilibriums are possible, they are ordered by their ex ante expected utility (preferred personal equilibrium). A preferred personal equilibrium can't be distinguished from a model which is solely based on consumption utility when the selection set of the decider is deterministic and the selection deterministically.

Now let us turn to the emotion-based choice presented by Mellers et al. (1999). Firstly they talk about the minimax principle of risky choice based on anticipated regret by Savage (1951, 1954), namely that one should minimize the maximum regret. But as Mellers et al. (1999) explain, his theory was never adopted on either normative or descriptive grounds, because it was a violation of the axiom of independence of irrelevant alternatives and there seems to be an unrealistic degree of risk-aversion because of the focus on worst-case scenarios. Secondly they discuss the disappointment theory, whereas disappointment focuses, as we have already seen, on counterfactual comparisons across alternative states of the world (Loomes and Sugden 1986, Bell 1985). It forms the basis for their theory, Mellers et al. (1999) call it decision affect theory. They argue that the pleasure of an outcome increases when the unobtained outcome was worse, and that surprising wins were more pleasurable than expected wins, and surprising losses were more painful than expected losses. So they model the emotional response to an outcome A relative to outcome B as:

$$R_A = J_R[u_A + d(u_A - u_B)(1 - s_A)]$$

J_R is a linear response function that links an implicit feeling to a rated response. u_A and u_B are the utilities of the obtained and unobtained outcomes. d is a disappointment function. s_A is the subjective probability.

Mellers et al. (1999) show that the subjective expected pleasure theory gives a good account of choices, whereas maximizing the maximum pleasure and minimizing the maximum possible pain do poorly at describing choice.

But, important for us, they don't distinguish happy, neutral and fearful people. Mellers et al. (1999) argue that maximizing subjective expected pleasure is not the same as maximizing subjective utilities, for instance emotions depend on beliefs and emotional pleasure need not increase with the size of the outcome.

Furthermore Mellers et al. (1999) provide the following results. "The pleasure of winning and the pain of losing are more intense when outcomes are surprising." (p.336) "The disappointment effect was so strong to make a loss of $8… feel slightly pleasurable." (p.336) Moreover there were regret effects, so that people felt better about their own outcome if the outcome of another gamble was worse. Furthermore for the "majority of people, disappointment was greater than elation (61%) and regret was greater than rejoicing (76%)." (p.338) There was no evidence that people are imaging outcomes for either wins or losses. Looking at anticipated vs. actual emotions the data show that people can accurately predict their emotions. Emphasizing the reference point the following seems valid: "When counterfactual comparisons are less obvious, people may use a variety of the reference points that need not be counterfactual comparisons." (p.342) "The harder it was to imagine the event, the more surprising the outcome and the greater the impact of the counterfactual comparisons." (p.343) Last but not least: "Choices based on instructions to maximize pleasure or minimize pain were best predicted by an average of anticipated feelings, but pleasurable or painful feelings were weighted more when instructions said to maximize pleasure or minimize pain respectively." (p.343, based on Schwartz et al. 1999) All these results will become important in our theory.

XV. A Model

"Man soll die Dinge so einfach wie möglich machen, aber nicht noch einfacher."

Albert Einstein

Let's look at the innovation process in the case of M firms. The τ_1 stands for the number of runs. We model the following jump processes. G means good mood, B means bad mood and finally N stands for neutral mood. M_G stands for the number of firms in good mood, M_B stands for the number of firms in bad mood and M_N stands for the number of firms in neutral mood.

The following is valid:

$$\alpha_\omega^r dt = \text{ probability, to first order in } dt, \text{that a particular combination of reactant people with type } \omega = (t_1, \dots, t_k) \text{ will react in the next time interval } dt \text{ to become of type } r = (\tilde{t}_1, \dots, \tilde{t}_k)$$

Moreover on the basis of the addition theorem for mutually excluding probabilities:

$$h_\omega(M)\alpha_\omega^r dt = \text{probability, to first order in } dt, \text{that a reaction will appear in the next time interval } dt$$

$h_\omega(M_1, \dots, M_N)$ is the number of different combinations of the reacting people in the system, if exactly M_i people are available.

The theory behind this jump processes builds on the work of Oatley and Johnson-Laird (1987). Emotions are according to the conflict theory "disturbances which accompany interruptions and discrepancies among multiple goals and representations." (Oatley and Johnson-Laird 1987, p.30) But Oatley and Johnson-Laird (1987) emphasize the cognitive functions of emotions: "Emotions are part of a management system to co-ordinate each individual's multiple plans and goals under constraints of time and other limited resources." (Oatley and Johnson-Laird 1987, p.31) "It communicates junctures in mutual plans among individuals in social groups". (Oatley and Johnson-Laird 1987, p.31) "Plans become mutual when one negotiates, exchanges knowledge, corrects misunderstandings, and enters in shared intentions." (Oatley and Johnson-Laird 1987, p.44) Moreover "emotionally toned moods can maintain the system in specific states, and it's a common observation that episodes of emotion can occur, and moods can persist, long after the event that elicited then is past." (Oatley and Johnson-Laird 1987, p.32) The function of these specific states, called emotional modes, is "to enable one priority to be exchanged for another in the system of multiple goals, and maintain the priority until it is satisfied or abandoned." (Oatley and Johnson-Laird 1987, p.33) There is a small number of basic emotion modes: happiness, sadness, anxiety (or fear), anger and disgust. In our theory we observe only three modes, one neutral and the two emotional modes happiness/surprise and fear, called here positive and negative mood. Surprise is also an universal emotion according to Ekman (1973). According to Oatley and Johnson-Laird (1987) if the juncture of current plan leads to happiness that means that subgoals have been achieved and the state to which transition occurs is to continue with plans and modify it when necessary. If the juncture leads to anxiety there was a self-preservation goal threatened and the state to which transition occurs is to stop, attend vigilantly to the environment and/or to escape. In adults there is also a conscious evaluation of the juncture in planning, so that propositional signals reach the operating system which give meaning to the emotion and leading to voluntary action. So many emotions occur when planned behavior is interrupted and the likely success of a plan changes. The function of the modes is "to organize a transition to a new phase of planned activity directed to the priorities of the mode with associated goals." (Oatley and Johnson-Laird 1987, p.35)

The junctures are modeled in our model as a stochastic jump process, which leads from one mode to another. In the modes ambiguities have to be resolved. The decisions which have to be made are whether the current plan should be abandoned altogether or only temporarily, about the levels of change, the changing of goals and the revising of current models of the world. The changing of goals will have a prominent role in our model.

Moreover Oatley and Johnson-Laird (1987) emphasize the social aspect of emotions, "most emotions of interest to humans occur in the course of our relation with others" (Oatley and Johnson-Laird 1987, p.41), needing a model of the self. Adult emotions are "complex founded on a basic, non-propositional emotion mode, but have a propositional evaluation which is social." (Oatley and Johnson-Laird 1987, p.46) In our model the different emotional modes lead to different appraisal mechanisms as we will see later. A neutral person bases her action on the expectation value, while a happy/surprised person will focus on the chances of different alternatives and the fearful person will act according to the inherent risk. This all happens as a secondary appraisal after the primary appraisal with its emotion modes.

The basis for this secondary appraisal is laid by Han et al. (2007), in their appraisal-tendency framework (ATF). They distinguished the effects of specific emotions on judgments and decision making, while focusing on incidental emotions. The ATF is a multidimensional theoretical framework with valence as only one dimension. The most important dimensions are certainty, pleasantness, attentional activity, control, anticipated effort and responsibility. For instance anger is connected to an appraisal of certainty about what happened and individual control for negative events, while fear is connected to an appraisal of uncertainty about what happened and situational control for negative events. To cite Han et al. (2007): "emotions not only can arise from but give rise to an implicit cognitive predisposition to appraise future events in line with the central appraisal themes that characterize the emotions (emotion-to-cognition)". These appraisal tendencies affect content as well as depth of people's thought. Raghunathan and Pham (1999) show that anxious people choose an option that reduces risk; whereas sad people choose the option that maximizes reward. Furthermore there is a matching constraint: "The influence of emotion is limited to spheres of judgment related to emotion's appraisal." (Han et al. 2007, p.161), Finally the ATF emphasizes the deactivating conditions, so that "goal-attainment assumes that appraisal tendencies will be deactivated when an emotion-eliciting problem is solved", or that "the cognitive-awareness hypothesis assumes that appraisal tendencies will be deactivated when decision makers become aware of their own judgment and choice process." (Han et al. 2007, p.162), The ATF includes two streams of research, the assessment of risk and the assessment of monetary values. In the following we focus on the assessment of risk. The following jump processes are valid:

Individual:

$$t_1 \rightarrow t_2 \; with \; the \; rate \;\; \alpha_{t_1}^{t_2} M_{t_1}$$

$$t_1 \rightarrow t_3 \; with \; the \; rate \;\; \alpha_{t_1}^{t_3} M_{t_1}$$

, also for t_2 and t_3.

Social interaction:

$$t_1 + t_2 \rightarrow 2t_1 \; with \; the \; rate \;\; \frac{\alpha_{t_1 t_2}^{t_1 t_1}}{M} M_{t_1} M_{t_2}$$

$$t_1 + t_2 \rightarrow 2t_2 \; with \; the \; rate \;\; \frac{\alpha_{t_1 t_2}^{t_2 t_2}}{M} M_{t_1} M_{t_2}$$

, also for t_2 and t_3, and t_1 and t_3, We use the Gillespie algorithm to simulate these jump processes (Gillespie 1976). The number of reactions is assumed to be constant and is μ_1. There are obvious similarities to the models of Kirman (1993), Lux (1995) and De la Lama et al. (2006).

Regarding the work of Lux (1995) we will not include a social temperature in which case the jump probability depends on the business climate index, everything one needs to know about such a dependency can be found in Lux (1995). Our theory takes the chemical kinetics as basis and we end with an opinion model like in Kirman (1993) and De la Lama et al. (2006) with its emphasis on social interaction. Social interaction leads to junctures in mutual plans and so to emotional modes, which we can't depict in a model based on the business climate index.

The decision each firm has to make is if in the next τ_2 periods it shall try to innovate or to imitate. If the firm has made the decision, an imitation is successful with the probability μ_2 in every of the τ_2 periods, and the innovation is successful with the probability μ_3. If an imitation is successful the firms gets the best productivity currently on the market. A successful innovation leads to a stochastic variable with the expectation value as the current own productivity A_{it} (see

Nelson und Winter 1982). We denote the productivity in the case of a successful imitation as $A_t^{max} = \max(A_{it}|i = 1, \dots, N_t)$. The productivity of a successful innovation is denoted by $\tilde{A}_{it}$ und is a normally distributed variable wit mean A_{it} and variance σ_1^2. If $\tilde{A}_{it}$ is smaller than A_{it}, A_{it} stays as productivity.

LeDoux (1998) concludes on page 266: “The ability to rapidly form memories of stimuli associated with danger, to hold on to them for long periods of time (perhaps eternally), and use them automatically when similar situations occur in the future is one of the brain’s most powerful and efficient learning and memory functions.” Let us go one step further. If the emotion has something to do with risk, what we truly believe, then it seems reasonable that while having an emotion we remember the highest loss or the highest gain. So the emotion becomes an extreme value and we act accordingly. The following sources strengthen this proposition. The literature on group polarization hints at the fact that group decisions are more extreme than the individual decisions. So it follows from the theory of social fear conditioning (Olsson und Phelps 2007) that the maximum emotion over the group members gets her way through, so that the individual decisions approach the most extreme one. In the game of Bechara et al. (1993)

we get the information that throughout the game the skin conductance rises, once more a clear hint that that it is the maximum emotion that gets her way through. Cambell and Jaynes (1966) show that there is a reinstatement of fear reactions after a burdened situation. Furthermore Morris and Dolan (2004) show that there are persistent „memories“ of the original conditioning. Rolls (2014) emphasizes the flexibility of neurons in the orbifrontal cortex after the reversal of a conditioning in the sense of an expected value and the inflexibility of neurons in the amygdala. A hint that it is the amygdala where the extremes lie. There is also the phenomenon of reconsolidation, that after a memory has been stored, it may be weakened or lost if recall is performed during the presence of a protein synthesis inhibitor. The brain seems capable to handle new information flexibly, so that it’s the biggest loss or the biggest gain that is remembered. There are studies that show that in the case of a colonoscopy people remember the maximum pain and the end (Ariely 1998, Fredrickson und Kahneman 1993, Kahneman et al. 1993, Varey und Kahneman 1992). Finally Lopes (1987) has found tendencies to focus on the “worst case” outcomes. This all correspondents to the idea of risk as a feeling and a rudimental statistical analysis based on implicit memories, memories of extremes.

One has to decide which emotion is exactly remembered. This could be the actual extreme value, or the extreme gains or losses, needing a reference point. Thirdly we could take the expected value and add or subtract the gains and losses. To be honest we can only guess which option is the best one, but as Kahneman (1979) emphasize the gains and losses in situations of risk we take those. The choice to take the extreme gains and losses increases the weight of the emotion in relation to the cognition with its expected value.

The expected sales $\bar{Q}_{ijt}$ of firm i, currently following strategy j, is the mean of sales Q_{ijt} of the last τ_4 observed periods. It is the output of the cognition. Is the current result Q_{ijt} bigger than the expected sales $\bar{Q}_{ijt}$ and if the difference is bigger than the positive emotion $D_{ij(t-1)}^{max}$, then this difference is equal to the new D_{ijt}^{max}. This will be important in good mood:

$$D_{ijt}^{max} = \begin{cases} Q_{ijt} - \bar{Q}_{ijt}, & if\, Q_{ijt} - \bar{Q}_{ijt} > 0 \; and \; Q_{ijt} - \bar{Q}_{ijt} > D_{ij(t-1)}^{max} \\ & D_{ij(t-1)}^{max}, else \end{cases}$$

According to Lerner and Keltner (2001) the choice in a risky situation depends on the mood. So we can expect that the decision procedure or call it appraisal differs dependent on the mood. The simplest procedure seems to be this one. In good mood the strategy j will be chosen, which generates the highest positive emotion D_{ijt}^{max}:

$$max\left(D_{ijt}^{max} \middle| j = 1, \dots, J\right)$$

Is the current result Q_{ijt} smaller than the expected sales $\bar{Q}_{ijt}$ and if the difference is bigger than the negative emotion $D_{ij(t-1)}^{min}$, then this difference is equal to the new D_{ijt}^{min}. This will be important in bad mood:

$$D_{ijt}^{min} = \begin{cases} Q_{ijt} - \bar{Q}_{ijt}, \ \ if\, Q_{ijt} - \bar{Q}_{ijt} < 0 \ and \ Q_{ijt} - \bar{Q}_{ijt} < D_{ij(t-1)}^{min} \\ D_{ij(t-1)}^{min}, else \end{cases}$$

Like above we take the following simple appraisal. (It is not an accident that it looks like the maxmin strategy found in game theory!) In bad mood the strategy j will be chosen, which generates the lowest negative emotion D_{ijt}^{min}:

$$max\left(D_{ijt}^{min} \middle| j = 1, \dots, J\right)$$

Emphasizing the emotion in the case of neutral mood, Alkahami and Slovic (1994) show that in reality there is not a positive correlation between the felt risk and the felt benefit but an inverse relationship. Moreover the literature on the two systems leads to the fact that emotions play an important part in cognition (for example Carter, 1998; LeDoux, 1998, Wilson and Schooler, 1991). So we won't take solely the expected value for a decision in neutral mood but the output of the cognition, the expected value, will be added to the emotions, to the gains and losses, to get finally two values. These both values, $(\bar{Q}_{ijt} + D_{ijt}^{max})$ and $(\bar{Q}_{ijt} + D_{ijt}^{min})$, have to be weighted, so we will take the following procedure.

The mean range S_{ijt} equals:

$$S_{ijt} = \frac{(\bar{Q}_{ijt} + D_{ijt}^{max})\big/_{\lambda_1} + (\bar{Q}_{ijt} + D_{ijt}^{min})}{(1 + {}^{1}\!/_{\lambda_1})}$$

The gains are $(\bar{Q}_{ijt} + D_{ijt}^{max}) - S_{ijt}$ and the losses are $\lambda_1[S_{ijt} - (\bar{Q}_{ijt} + D_{ijt}^{min})]$. So S_{ijt} is the point where the gains equal exactly the losses. This procedure allows us to incorporate a loss aversion parameter in our model (Kahneman 1979).

In neutral mood the chosen strategy j has the highest mean range S_{ijt}:

$$max\left(S_{ijt} \middle| j = 1, \dots, J\right)$$

A strategy is chosen for τ_2 periods, whereas the positive and negative emotions and the mean range will be raised only for the τ_3 last periods to prevent us from difficulties to which strategy an innovation respectively an imitation is linked after a change of strategies.

This innovation model will be expanded by the following consumption model. There are O consumers. O_G stands for the number of consumers in good mood, O_B stands for the number of consumers in bad mood and O_N stands for the number of consumers in neutral mood. The following jump processes are valid:

Individual:

$$t_1 \rightarrow t_2 \; with \; the \; rate \;\; \beta_{t_1}^{t_2} O_{t_1}$$

$$t_1 \rightarrow t_3 \; with \; the \; rate \;\; \beta_{t_1}^{t_3} O_{t_1}$$

, also for t_2 and t_3.

Social interaction:

$$t_1 + t_2 \rightarrow 2t_1 \; with \; the \; rate \;\; \frac{\beta_{t_1 t_2}^{t_1 t_1}}{O} O_{t_1} O_{t_2}$$

$$t_1 + t_2 \rightarrow 2t_2 \; with \; the \; rate \;\; \frac{\beta_{t_1 t_2}^{t_2 t_2}}{O} O_{t_1} O_{t_2}$$

, also for t_2 and t_3, and t_1 and t_3, Once again we use the Gillespie algorithm to simulate these jump processes (Gillespie 1976). The number of reactions is assumed to be constant and is μ_5.

Each firm has the following production function with L_{it} as number of employees:

$$Q_{it} = A_{it} L_{it}$$

The price of the product is a markup on the cost per part, with w_t as wage and μ_6 as constant:

$$p_{it} = \frac{w_t}{A_{it}}(1 + \mu_6)$$

The wage w_t increases with time, because, ignoring competition, we need a counterweight to the increasing productivity which erodes the profit of the firms because of the mark-up rule:

$$w_t = w_{t-1} + w_{t-1} * 0{,}001$$

Consumers who use products experience positive and negative surprises of utility. The difference is normally distributed around zero with variance σ_2^2. It is as if the felt price of the chosen product becomes higher or lower than the actual price. Read careful, everything is vice versa. The price plays now the role of the expected value in the innovation model. E_{klt}^{max} is now the negative emotion and not the positive one, it increases the price. E_{klt}^{min} is now the positive emotion, it reduces the price.

Is the result of a draw $x_{klt}^{rnd}$by consumer k of product l bigger than zero and bigger than the negative emotion $E_{kl(t-1)}^{max}$ then this difference equals the new E_{klt}^{max}:

$$E_{klt}^{max} = \begin{cases} x_{klt}^{rnd}, & if x_{klt}^{rnd} > 0 \; and \; x_{klt}^{rnd} > E_{kl(t-1)}^{max} \\ & E_{kl(t-1)}^{max}, else \end{cases}$$

In bad mood the consumer k chooses the product l, which generates the smallest negative emotion E_{klt}^{max}:

$$min(E_{klt}^{max} | l = 1, \dots, L)$$

Is the result smaller than zero and is the difference smaller than positive emotion $E_{kl(t-1)}^{min}$ then the difference becomes the new E_{klt}^{min}:

$$E_{klt}^{min} = \begin{cases} x_{klt}^{rnd}, & if x_{klt}^{rnd} < 0 \; and \; x_{klt}^{rnd} < E_{kl(t-1)}^{min} \\ & E_{kl(t-1)}^{min}, else \end{cases}$$

In good mood the consumer k chooses the product l, which generates the highest positive emotion E_{klt}^{min}:

$$min\left(E_{klt}^{min} \middle| l = 1, \dots, L\right)$$

It’s interesting that this explains the status quo bias (Samuelson and Zeckhauser 1988), the tendency for people to prefer status quo options over other options. In happy mood we don't change the status quo.

The mean range T_{klt} equals:

$$T_{klt} = \lambda_2\left(p_{lt} + E_{klt}^{min}\right) + (1 - \lambda_2)(p_{lt} + E_{klt}^{max})$$

With, $\lambda_2 \in [0, \ldots, 1]$.

In neutral mood the consumer k chooses the product l, which generates the smallest mean range:

$$min(T_{klt} | l = 1, \ldots, L)$$

In neutral mood with probability μ_7 the prices are updated and so it is a parameter for the strength of the price competition.

Now let us turn to the statistics. The base case is the following. It is not more than a first guess. There exist 4 firms and 600 consumers. The $\alpha' s$ and $\beta' s$ are equal to 0,01. μ_1 is 300. μ_2 and μ_3 are 0,05. μ_4 is 0, μ_5 is 8 and μ_6 is equal to 0,1, μ_7 is 0,25. λ_1 is 1 and λ_2 is 0,5. σ_1^2 is 0,01, σ_2^2 is equal to 21. τ_1 is 2000, τ_2 is 10, τ_3 is 5 and finally τ_4 is 3.

Besides, the value means accumulated profits. The productivity gap means the mean of the difference of the maximum productivity and the actual productivity of the firm. We use the Wilcoxon signed-rank test, with a 5% significance level.

Now let's look at the base case. At first have a look at the productivity and the market share for a single run (Figure 1 and 2). We see the pattern of small stepwise improvements by single firms with fast imitation, which is quite common for Nelson-Winter type models.

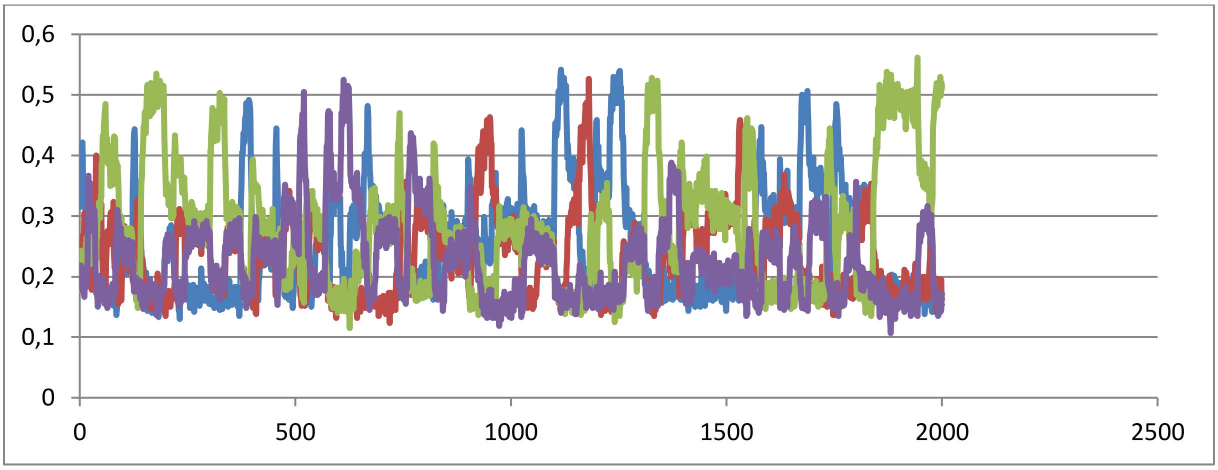

Figure 1: Trajectories of all four firms' market share for a single run

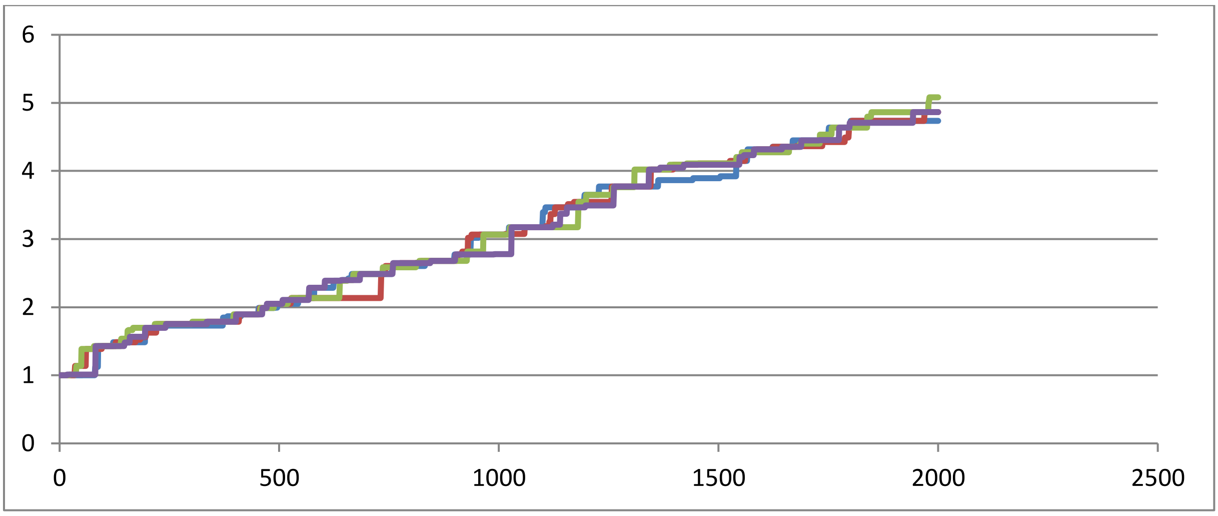

Figure 2: Trajectories of all four firms' productivity for a single run

The different moods of the consumers move around 200 as we can observe in figure 3. They never reach the frontiers of more than 250 respectively less than 150 consumers with a common mood.

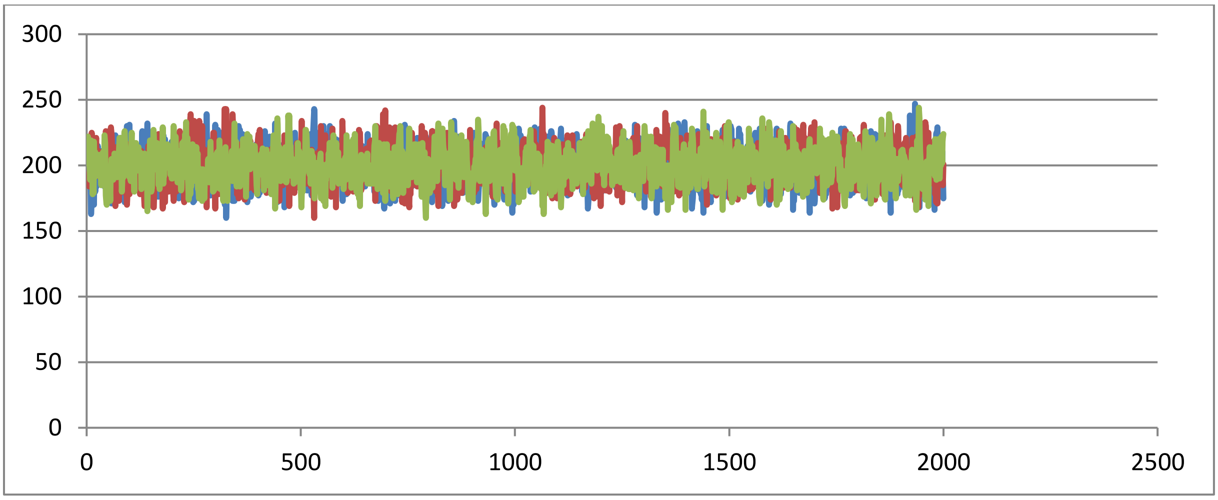

Figure 3: Trajectories of consumers' mood for a single run

Before turning to emotions, let us look at the number of firms in good mood, with mean 1,31 and standard deviation of 1,01, bad mood, with mean 1,32 and standard deviation of 1,03, and finally neutral mood with mean 1,36 and standard deviation of 1,02.

Now let's turn to the emotions, firstly we see for firm 1 in figure 4 that in the beginning the positive emotion of innovating becomes bigger than that of imitating and stays thereafter constantly above the positive emotion of imitating.

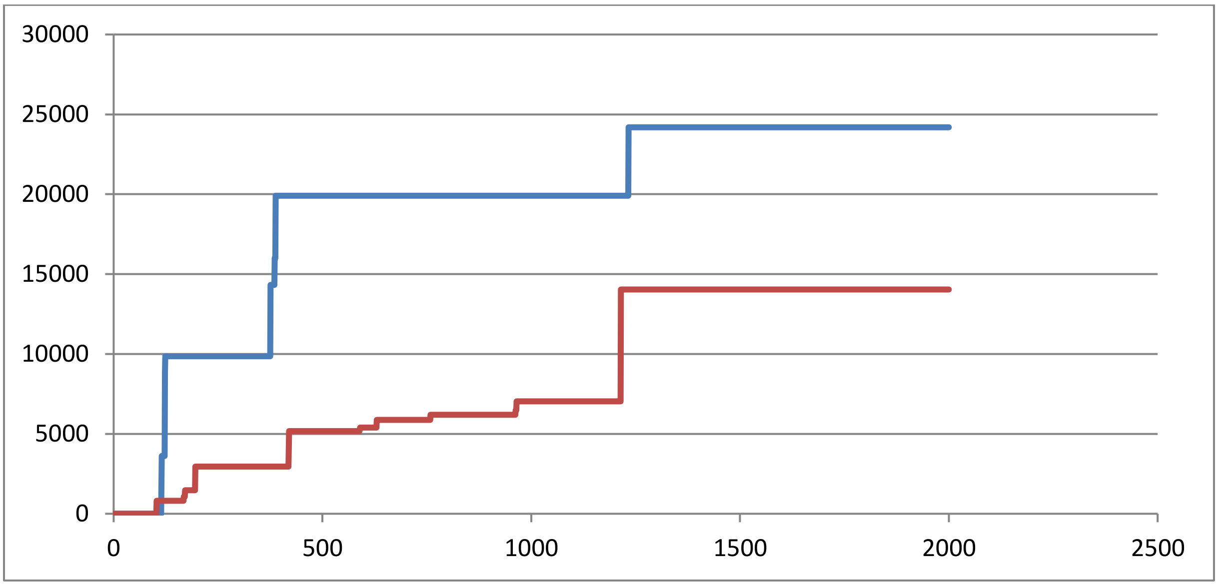

Figure 4: Trajectories of the positive emotion of strategy innovate (blue) and imitate (red) of firm 1

Secondly we see for firm 1 in figure 5 that in the beginning the negative emotion of innovating becomes bigger than the negative emotion of imitating and stays thereafter constantly under the negative emotion of imitating. So the firm 1 innovates when in good mood and imitates when in bad mood.

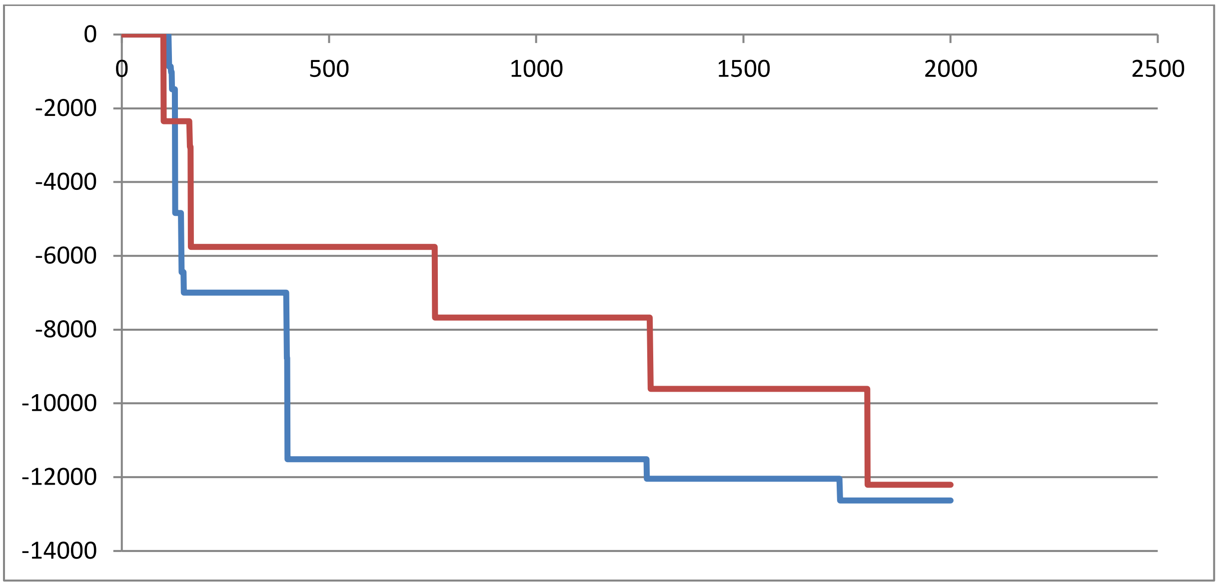

Figure 5: Trajectories of the negative emotion of strategy innovate (blue) and imitate (red) of firm 1

Thirdly we see for firm 1 in figure 6 that the trajectories of the mean range move in the same direction, whereas the strategy to innovate seems more often to succeed.

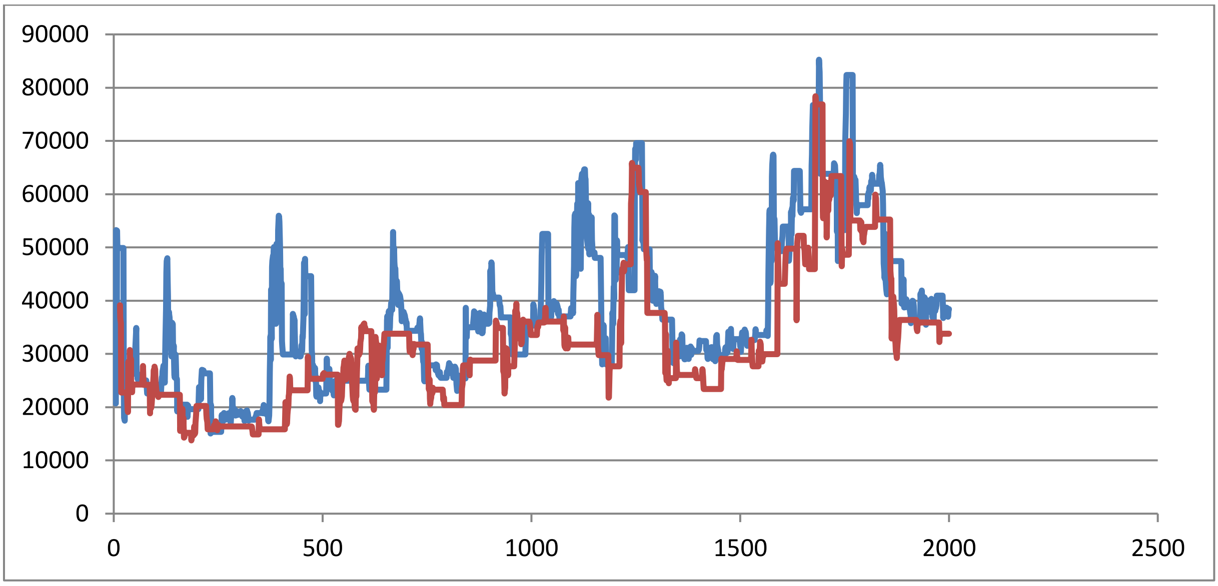

Figure 6: Trajectories of mean range of strategy innovate (blue) and imitate (red) of firm 1

Looking at the Herfindahl index in figure 7 one sees that frequently it is between 0,25 and 0,3 and sometimes for short periods above 0,3.

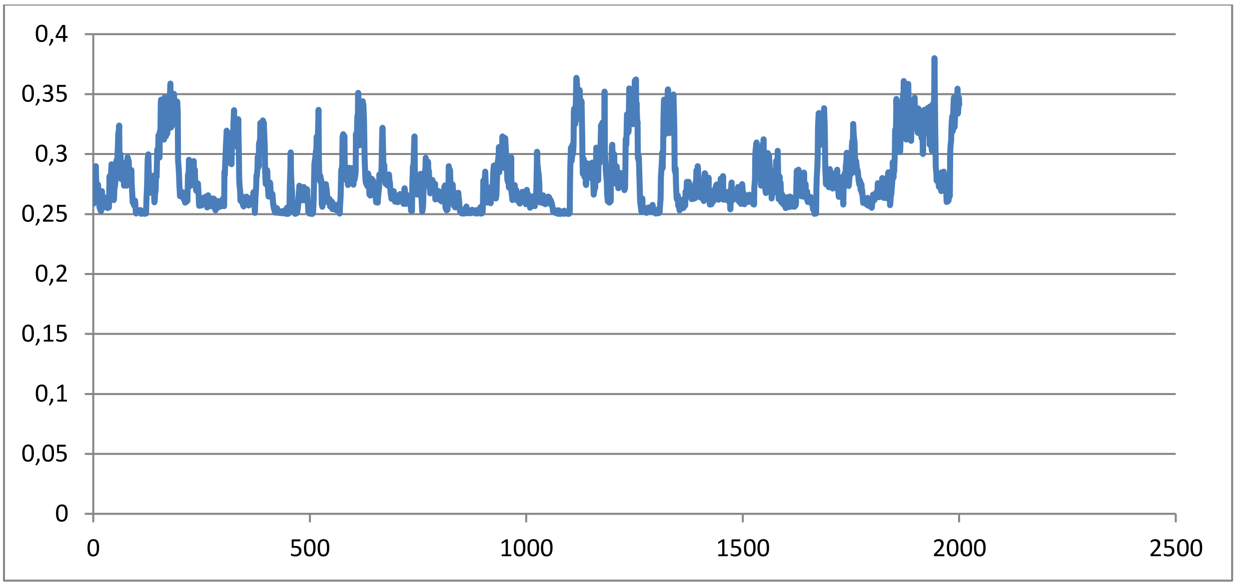

Figure 7: Trajectory of the Herfindahl index for a single run

In figure 8 one sees that the firm 3 is the winner of the competition, the accumulated profits are way higher than for the other firms.

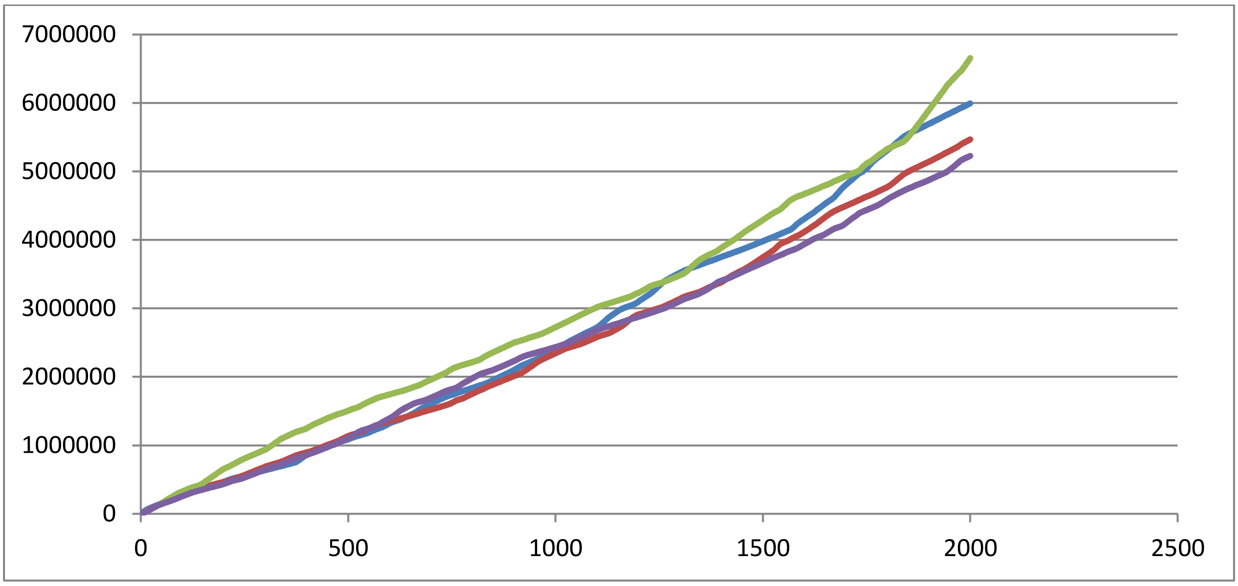

Figure 8: Trajectory of the value added of all four firms for a single run

In Figure 9 one sees that the price falls in the beginning, stays constant for 1500 periods and rises sharply in the last 500 periods, result of the rising wage.

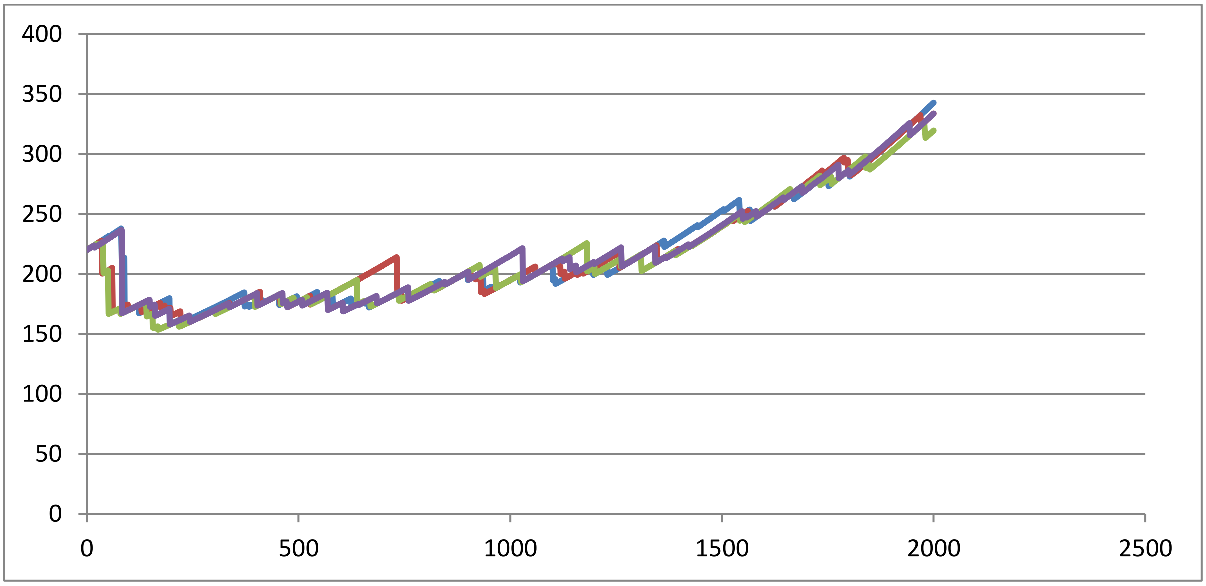

Figure 9: Trajectory of the price of the four firms for a single run

Last but not least we look at the trajectories of profit and sales, with the same pattern as the development of the market share in figure 1.

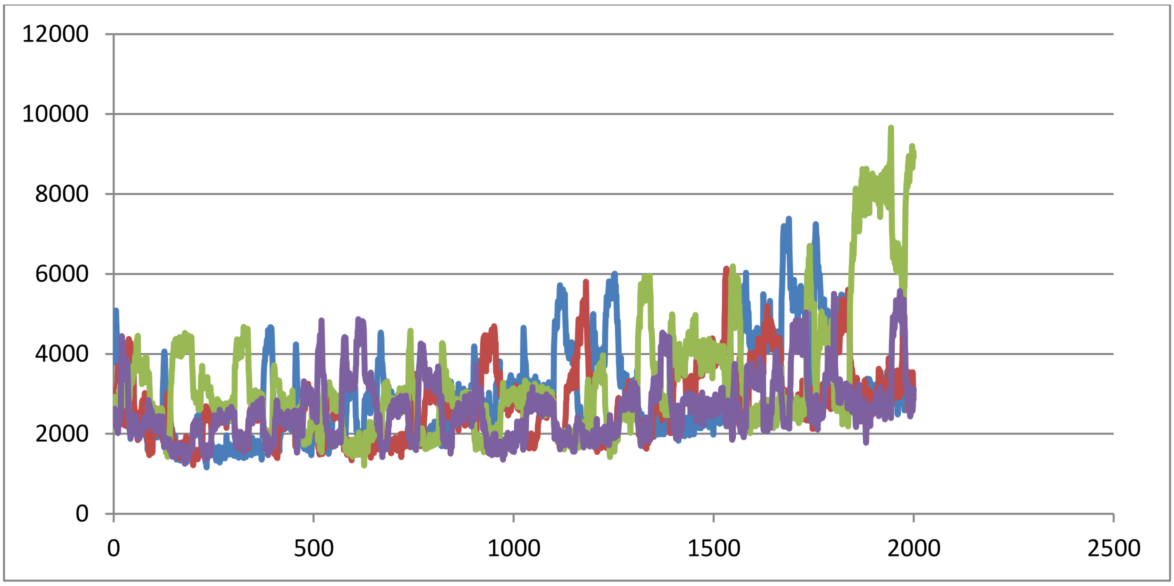

Figure 10: Trajectory of the profit of the four firms for a single run

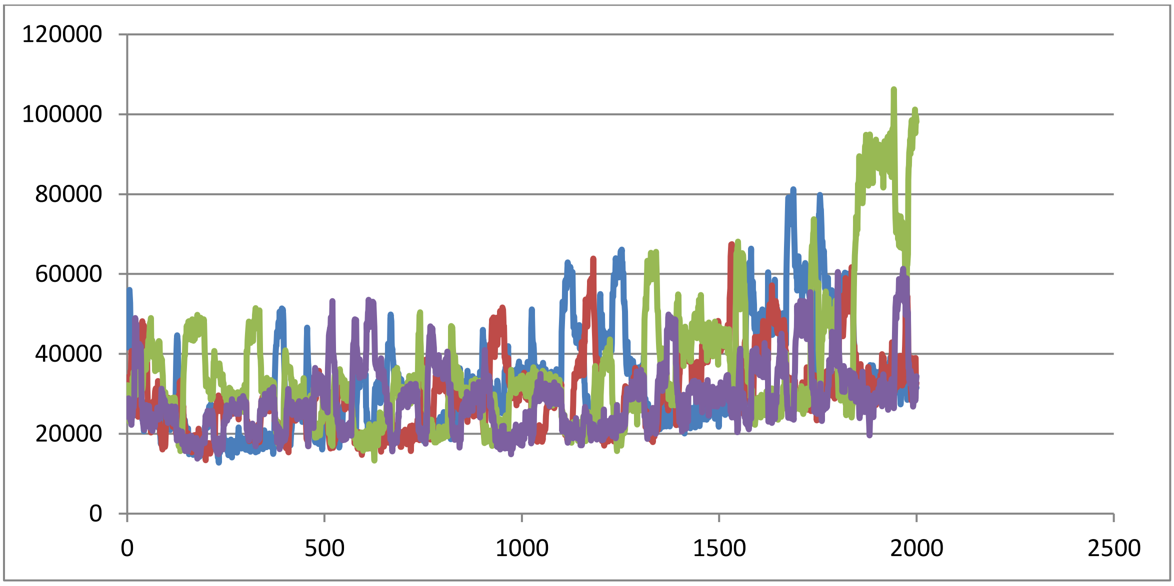

Figure 11: Trajectory of the sales of the four firms for a single run

T9 (base case):

We see in table 9a that the average price and its slope increase. The reason we see such increase is that the wage increases and this increase leads to an increase in profit because of the mark-up rule. Ignoring the competition the productivity drives the profit down, but the wage drives it up. Lastly this results in an increasing profit which can be seen. In table 9b Im/In means that the agent imitates in good mood and innovates in bad mood, In/Im means that she innovates in good mood and imitates in bad, Im/Im means that she imitates in both moods and finally In/In means that she innovates in both moods. Moreover we see that the distribution of agents seems rather stable. Besides, the case, that there is no change of emotion after period 500, appears 24 times, while in 56 cases there is such a change.

In this base case we see in table 9b that the innovation in both moods dominates the picture, while especially the later the time, while the agents who innovate in good mood and imitate in bad mood dominate in the early phase. In table 9c we see that the profit and value is not significantly different between agents In/In and the other three types of agents, but the productivity and sales are significantly smaller in the case of In/In.

T11:

T11 means compared to the base case an increase of the loss aversion parameter λ_1 to 10.

We see in table 11a the same picture like earlier. The average profit increases despite the increase of the average productivity, a result of the increasing wage. Comparing this case with the base case we see in table 22 that its average productivity and the maximum productivity is significantly smaller, its herfindahl index is significantly smaller and finally the average profit and the average price are significantly higher. The distribution of agents over the whole period is rather stable. But here the agents who innovate in good mood and imitate in bad moods (In/Im) dominate the picture not the In/In type. Nearly half of the population consists of the type In/Im. While the profit of the In/In type isn't significantly smaller, the value, the productivity, the sales and the market share are. In the case of Im/Im only the value is significantly smaller.

What is happening here is that, because of the higher loss aversion, the agents act in the neutral mood like in the bad mood and because in bad mood the imitation dominates there is more imitation and less innovation so we get this picture.

T12:

T12 means compared to the base case an increase of the imitation probability μ_2 to 0,15.

Now let's come to the case with higher imitation probability. The average profit rises, like the average productivity and the average price. Not new to us. In comparison to the base case we see the following. The average and the maximum productivity are significantly higher, its herfindahl index is significantly smaller and the average profit and price are significantly smaller. Moreover we see once again that the distribution of agents is rather stable. In contrast to the base case the type In/Im clearly dominates and we see less agents of the In/In type, consistent with a higher imitation probability. Looking at the statistics for the different types of agents we see the known picture. The profit of the In/In type is significantly smaller than the profit of the In/Im type but its value is not. The productivity and the sales and the market share are significantly smaller, the price obviously higher.

T14:

T14 means compared to the base case an increase of the innovation probability μ_3 to 0,15.

The development of the average price, the average productivity and the average profit is equal to the cases above. The average and maximum productivity is significantly higher than in the base case, the herfindahl index is significantly higher, the consumption and productivity gap is significantly smaller, the average profit and price are significantly smaller. The distribution of the agent types is very similar to the base case, but there are more agents of the type Im/Im. Although the sales are significantly less and the price is significantly higher the profit and value are not significantly different, comparing the type Im/Im with type In/Im. Furthermore although the innovation probability rises the type In/In in comparison to the type In/Im has significantly less profit and value.

T15:

T15 means that the mood of the consumers doesn’t change and stays good.

The herfindahl index is significantly smaller, the consumption and productivity gap are bigger than in the base case. The distribution of agents is stable, but gives a very different picture. The pure types Im/Im and In/In clearly dominate the picture. And both types don’t differ significantly in their profit, value, productivity, sales, price and finally their market share.

What is happening in this case? At the beginning of the run we can observe the following. If there is a jump in the productivity this means in the case T15 that the profit erodes, the market share stays the same forever. But the negative jump of profit is higher the earlier we look at it. So if the first jump occurs while being an imitator in bad mood the agent changes to an innovator strategy, but the next changes in profit because of a rising productivity will all be smaller than the first one. So we get an innovator in bad mood. But the more times we are in a bad mood, the higher gets the probability of a rising profit because of a rising wage. So finally we get an innovator in bad and good mood.

T16:

T16 means that the mood of the consumers doesn’t change and stays bad.

Comparing the dynamics of the average price, average productivity and average profit we get the same picture as before. Comparing T16 with the base case the only thing we can mention is that the herfindahl index is significantly smaller; all other numbers aren’t significantly different. The distribution of agents looks very different. There are by far more types Im/Im and Im/In, which seems a logical consequence of the probability structure. A jump in profit is a result of chance and not of a higher productivity. Comparing the different types of agents, we can say the following. While the sales are significantly higher for In/Im and Im/Im compared to In/In, all the other numbers aren’t significantly different. But the numbers of Im/In are quite differently compared to In/In. The profit and value are significantly smaller, while the productivity and price are significantly higher.

T17:

T17 means that the mood of the consumers doesn't change and stays neutral.

In comparison with the base case we can say the following. The average and maximum productivity are significantly higher, the herfindahl index is significantly higher, the consumption gap is significantly smaller and the average profit and price is significantly smaller. Looking at the distribution of agents, we can observe a change from the dominant In/Im to the type In/In from the first periods to the period 2000. Comparing Im/Im with In/Im the productivity is significantly smaller, the price significantly higher and the market share significantly smaller. Last but not least the profit and value are significantly smaller in the case of In/In compared with In/Im, the productivity, the sales and the market share are significantly smaller, the price is significantly higher.

T18:

T18 means that the mood of the firms doesn’t change and stays good.

Compared to the base case the average and maximum productivity are significantly smaller, like the herfindahl index. The average profit is significantly higher and the average price also. The distribution of agents is stable. Chance leads in the beginning to an innovation or imitation strategy and because the agent is always in a good mood the strategy doesn’t change. But the losses with this strategy become higher and higher with time, so an agent who is an innovator in good mood becomes an imitator in bad mood leading to the type In/Im. Comparing the type Im/In with In/Im we see that the productivity and the sales and the market share are significantly higher.

T19:

T19 means that the mood of the firms doesn’t change and stays bad.

Compared to the base case in the case T19 the average and maximum productivity is significantly smaller, the average profit is significantly higher. Looking at the dynamics of the distribution of agents we see that the type In/Im rises until period 1500 while thereafter its number declines. Contrary the type In/In rises by 10 from period 1500 to 2000. The profit and value of type In/Im are significantly higher than of type In/In, the sales and the market share are significantly higher.

T20:

T20 means that the mood of the firms doesn’t change and stays neutral.

The comparison of case T20 to the base case shows only that the herfindahl index is significantly smaller, while all other numbers are not significantly different. The distribution of agents is rather stable, the only thing one notices is the increase of type Im/In and that the distribution is very similar to T18. The profit and value of type In/Im are significantly smaller than of the type Im/In, the productivity is significantly higher and the price significantly smaller. One can observe cases where there are only imitators with very good results for type Im/In, this seems the reason for the significantly different results. Moreover one can explain the similarity to case T18. For example after some bad draws the agent chooses innovation as strategy, but if the condition gets better the agent stays with this strategy as long as the condition gets worse than the first time. So one can observe that after some time the agents don’t change their strategy just like in the case T18.

T21:

T21 means that the firms change their strategies randomly, with equal chance of an imitation or an innovation strategy.

In this random strategy case one can see that the average and maximum productivity are significantly higher, the herfindahl index is significantly smaller, the consumption and productivity gap are significantly smaller, and the average profit and the price are significantly smaller.

T10:

T10 means that the firms choose their strategy according to the higher mean $\bar{Q}_{ijt}$ ignoring emotions completely.

This case shows that the average and maximum productivity are significantly smaller, the average profit and price are significantly higher than in the base case.

T13:

T13 means that the firms choose the imitation strategy whenever the difference between the maximum productivity and the firm's productivity is higher than

0,0398, the expected increase of the innovation strategy, ignoring any price effects.

This case shows that the average and maximum productivity are significantly higher, the herfindahl index is significantly smaller, the consumption and productivity gap are significantly smaller, and the average profit and the price are significantly smaller.

Discussion

We see that the whole model is very stable and acts like it should in the case of higher risk aversion, higher imitation probability and higher innovation probability.

Emotions will act positively on the stability of the economy, if the following picture is true. To cite again LeDoux (1998): „From the point of view of survival, it is better to respond to potentially dangerous events as if they were in fact the real thing than to fail to respond. The cost of treating a stick as a snake is less, in the long run, than the cost of treating a snake as a stick." Strategies which are too risky in relation to their chances will be abandoned more quickly than in the case without emotion. So emotions can be a tool to survive in a risky environment and so a tool for stability.

But the introduction of emotions has come with a problem, the moods. If we look at depressed people and people with bipolar disturbances we can imagine the dark side of the emotion. The people don't act no more as maximizer's of the expected value but focus completely on risk or chance, leading to enormous problems. Often depressed people stay the whole day in bed. In our theoretical framework this is the result of the maxmin strategy in bad mood. The illness has serious consequences on the whole social life of those depressed people. Moreover people with bipolar disturbances show depressed behavior alternated with episodes full of risky behavior. This fits our framework if we look at good moods. Those in good moods use the maxmax strategy and focus completely on chances without looking at the bad side. If we look at the economy episodes of depression have also enormous problems, high unemployment and political problems.

So summing up the introduction of moods seems to have in reality obviously negative consequences for the individual and the economy as a whole. Justified can its introduction only be by the introduction of emotions in neutral mood which can stabilize the economy and the personal decisions. So there seems to exist a trade-off, more stability and better results in neutral mood and less stability and suboptimal choices in good and bad moods.

So let’s take a look if our model can lead to some answers.

Besides in the case of no emotion the firms try to maximize their expected value, with a probability of 12,5% to change to the worse strategy for an updating, and consumers try to maximize their stochastic utility described in the above model. The expected sales $\bar{Q}_{ijt}$ of firm i, currently following strategy j, is the mean of sales Q_{ijt} of the last τ_4 observed periods. It is the output of the cognition. Consumers who use products experience positive and negative surprises of utility. The difference is normally distributed around zero with variance σ_2^2. It is as if the felt price of the chosen product becomes higher or lower than the actual price.

Now let’s turn to the results of table 23. The average productivity is smaller in the case of constant good mood (T18), constant bad mood (T19) or in the case of constant neutral mood (T20) than in the case of no emotion, but not significantly different from the average productivity in case T9. So the melting of the three moods in one model (T9) leads to an insignificant result. The maxmax and maxmin strategies in the case of T18 and T19 lead to less changes of strategy as in the case of no emotion and so the significantly higher prices. If we look at the herfindahl index it is bigger in the case of T18 and smaller in T19 and T20. The average profit is in the cases T18, T19 and T20 bigger than in the case of no emotion and the average price is significantly higher, but not in the base case T9, there the average profit and average price are indifferent between the case T9 and the case of no emotion.

Looking at the case where there is no emotion for the firm (it follows its expected value) and full emotion for the consumers (T26), as in the base case T9, we get the following picture for T26. The average productivity is significantly higher, the herfindahl index is significantly smaller, the productivity gap is significantly smaller, the average profit is significantly smaller like the average price and the maximum productivity is significantly higher than in the case of no emotion.

So having emotions seems to be quiet advantageous for the consumers, if one compares it with the case of no emotion on both sides. But in the moment we include additionally emotions for the firm, looking especially at T20, the picture changes. The advantage lies then on the side of the firm and no more on the consumer's side, the average profit and price become significantly higher. But if we include moods the advantage on side of the firm vanishes and we are left with insignificant results for T9 vs. the case of no emotion. This is quiet what one would have expected after the initial discussion.

	av. prod	herfindahl	prod. Gap	av profit	av.price	max. prod
Tab 9	n.s.	n.s.	>	n.s.	n.s.	n.s.
Tab 18	<	>	>	>	>	<
Tab 19	<	<	n.s.	>	>	<
Tab 20	<	<	n.s.	>	>	n.s.
Tab 26	>	<	<	<	<	>

Tab.23 Tabx vs. no emotion (10% level), Wilcoxon signed-rank test

Now let us turn to the case (T27) and to table 24 where the firms have full emotion, like in case T9, and the consumers have none and maximize their stochastic utility. The table 24 shows that only the herfindahl index is significantly lower than in the case of no emotion all other indicators don't differ significantly. We would have expected here that the average profit and price are significantly higher but this does not materialize. Looking at T17, with basic emotions on the consumers side we get what we expected. The average productivity is significantly higher, the average profit and price are significantly smaller. The cases where the consumers are in a constant good mood or in a constant bad mood leave us with worse results, the key indicators are all not significantly different from the case of no emotion, so that was expected. The melting of both moods with the emotion in neutral mood, case T9, leads also to non significant results, what was expected.

	av. prod	herfindahl	prod. Gap	av profit	av.price	max. prod
Tab 15	n.s.	<	>	n.s.	n.s.	n.s.
Tab 16	n.s.	<	n.s.	n.s.	n.s.	n.s.
Tab 17	>	>	n.s.	<	<	>
Tab 27	n.s.	<	n.s.	n.s.	n.s.	n.s.

Tab.24 Tabx vs. no emotion (10% level), Wilcoxon signed-rank test

So let us turn now to the confidence intervals and let us explore what we can learn about them. We have only data for the periods 500, 1000, 1500 and 2000. The upper band is green, the mean blue and the lower band is red.

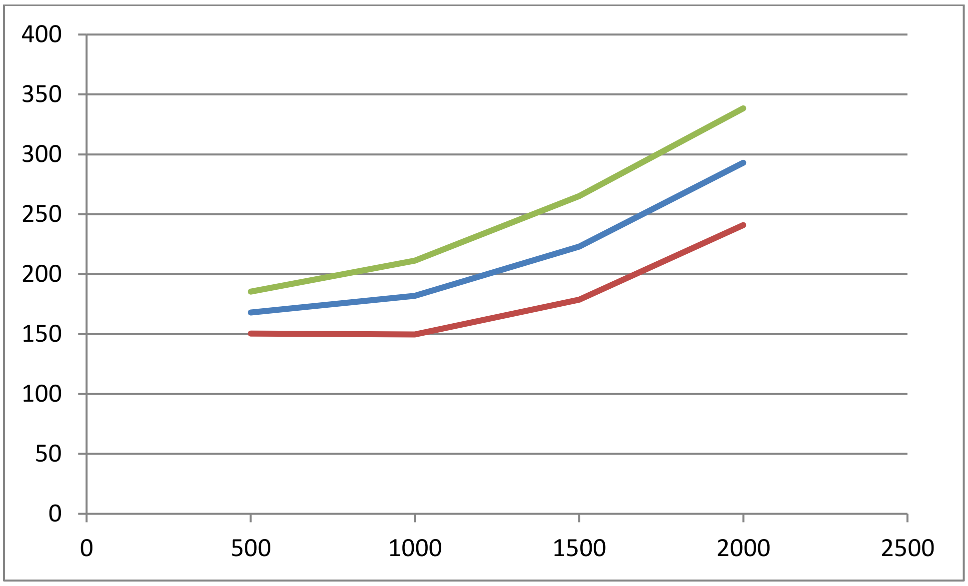

Figure 12: the development of the average price with its confidence interval (90%) (no emotion)

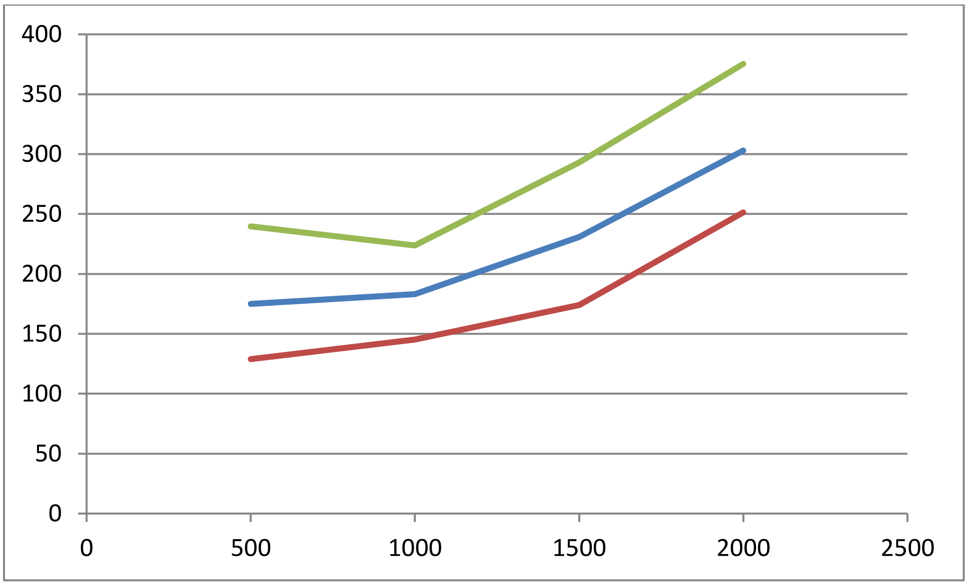

Figure 13: the development of the average price with its confidence interval (90%) (base case T9)

If we look at the average price we can see that the upper band of the base case T9 lies constantly above the upper band in the case of no emotion. For the lower band two out of four values lie under the lower band of the case with no emotion.

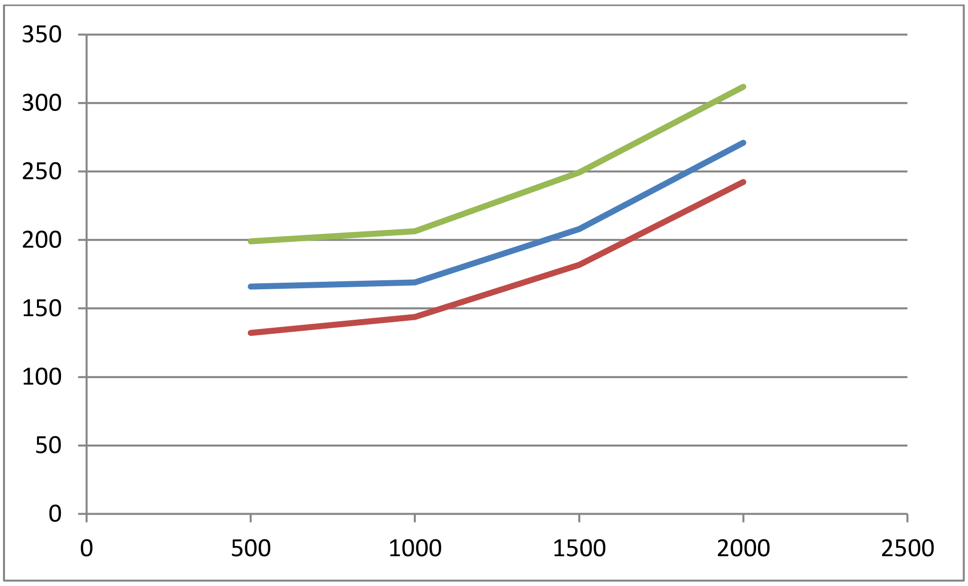

Figure 14: the development of the average price with its confidence interval (90%) (T26)

If we look at the lower band in case T26 we see that it is nearly the same than in the case of no emotion. The upper band is in three out of four cases smaller than in the case of no emotion.

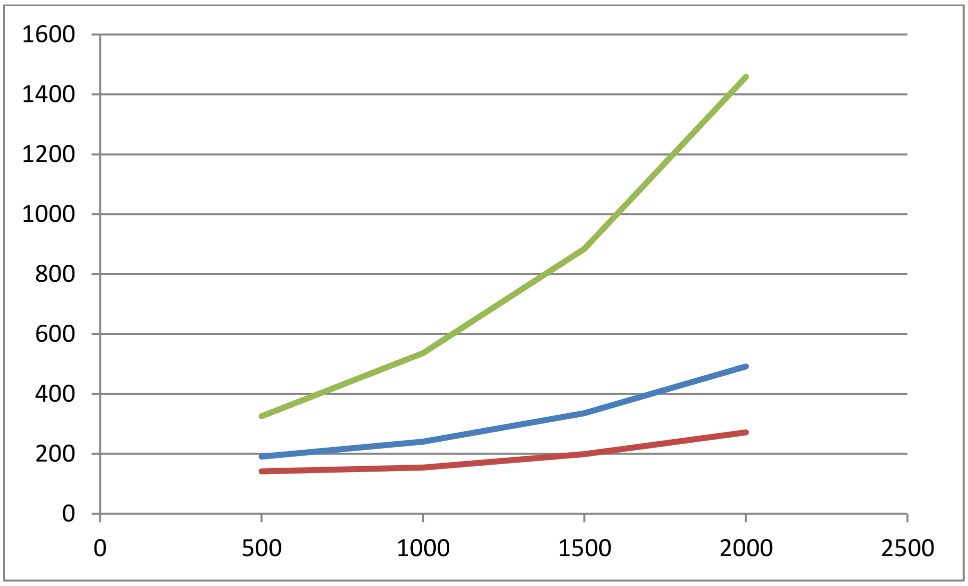

Figure 15: the development of the average price with its confidence interval (90%) (T20)

The upper band of the price in the case T20 lies constantly above the upper band in case of no emotion. The lower band values for the case T20 are in the cases 1000, 1500 and 2000 bigger than in the case with no emotion. The development of the upper band becomes understandable if one notices that in the case T20 one can observe cases where there are only imitators leading to very high prices.

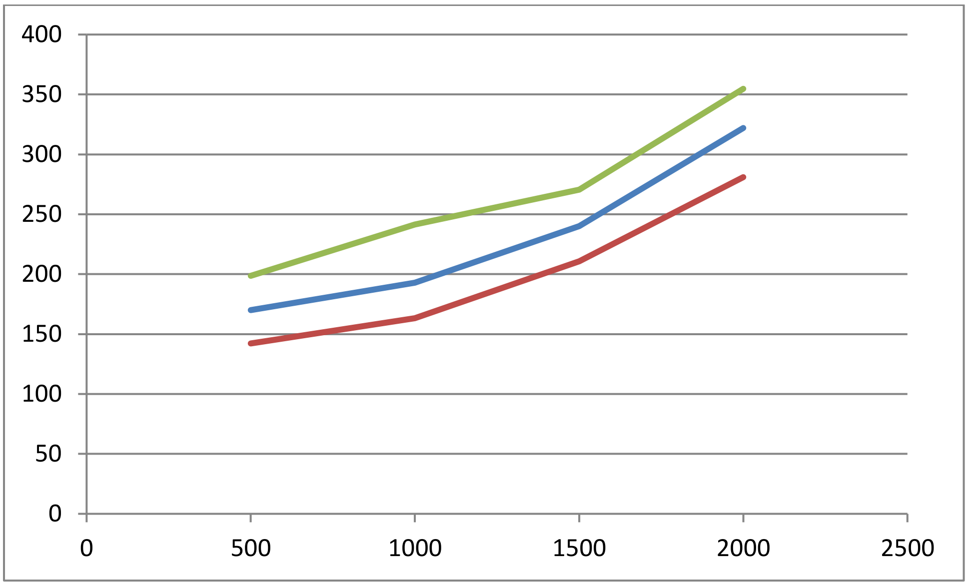

Figure 16: the development of the price with its confidence interval (90%) (T18)

Looking at the upper band of the price in T18 the values of the upper band lie above those in the case of no emotion. The lower band values for the case T18 are in the cases 1000, 1500 and 2000 bigger than in the case with no emotion.

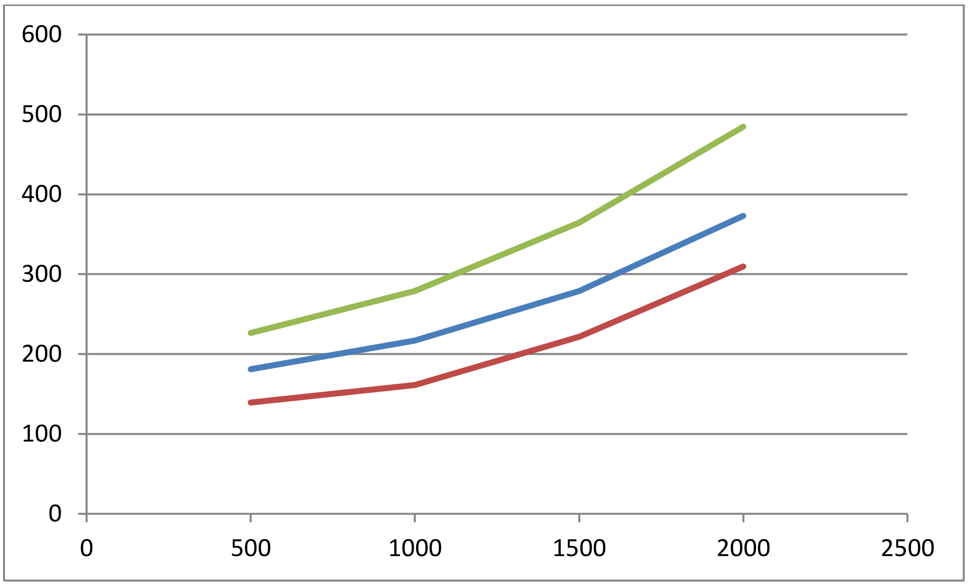

Figure 17: the development of the price with its confidence interval (90%) (T19)

The upper band of the price in the case T19 lies constantly above the upper band in case of no emotion. The lower band values for the case T19 are in the periods 1000, 1500 and 2000 bigger than in the case with no emotion.

So looking at the average price one gets bad news for the consumers if one incorporates emotions. The upper band of the cases T18, T19 and T20 lies constantly above the upper band of the case with no emotion. Furthermore in the mentioned cases in the periods 1000, 1500 and 2000 the values of the lower band are bigger than in the case of no emotion. The situation is somewhat better in the case T9, where for the lower band we have only two values which are higher than in the case of no emotion.

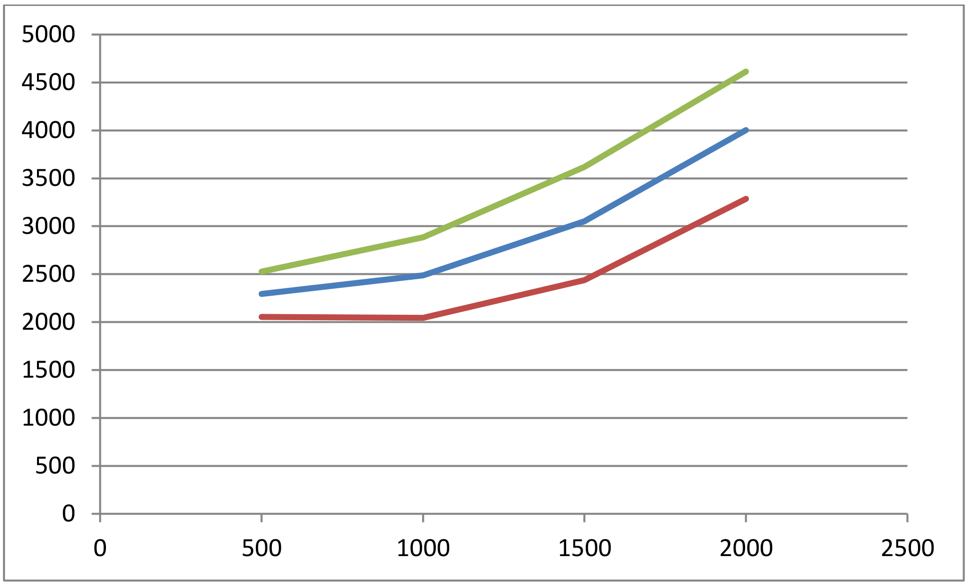

Figure 18: the development of the average profit with its confidence interval (90%) (no emotion)

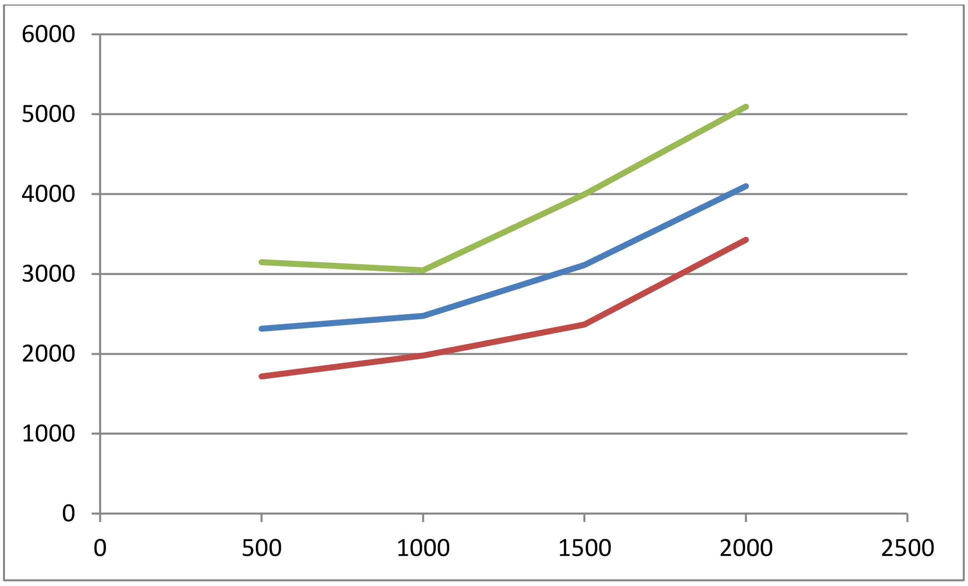

Figure 19: the development of the average profit with its confidence interval (90%) (base case T9)

The upper band of the average profit in the case T9 is bigger than in the case of no emotion, but the lower band is only in period 2000 bigger otherwise smaller.

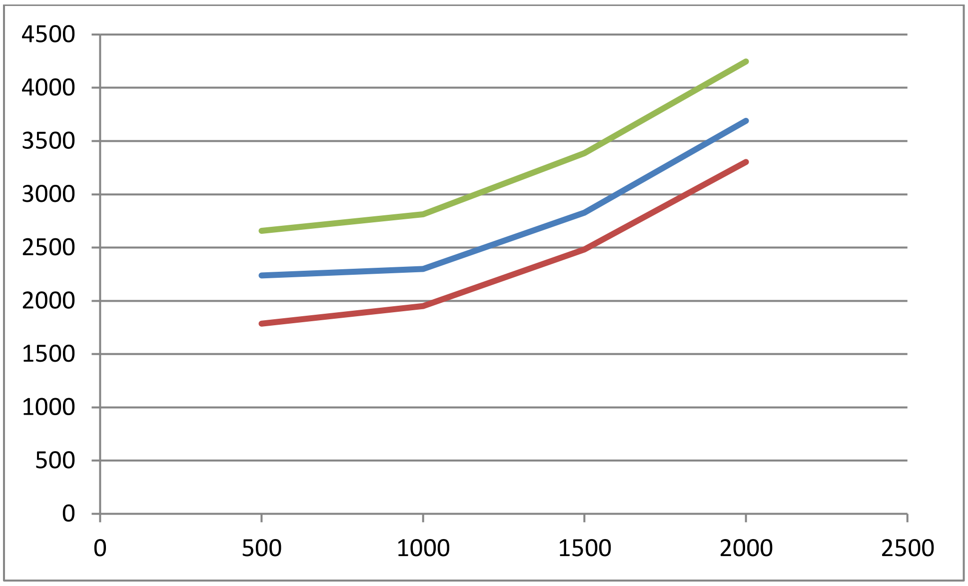

Figure 20: the development of the average profit with its confidence interval (90%) (T26)

The lower band in case T26 is nearly the same as the lower band in the case of no emotion. The upper band is in periods 1000, 1500 and 2000 smaller than in the case of no emotion.

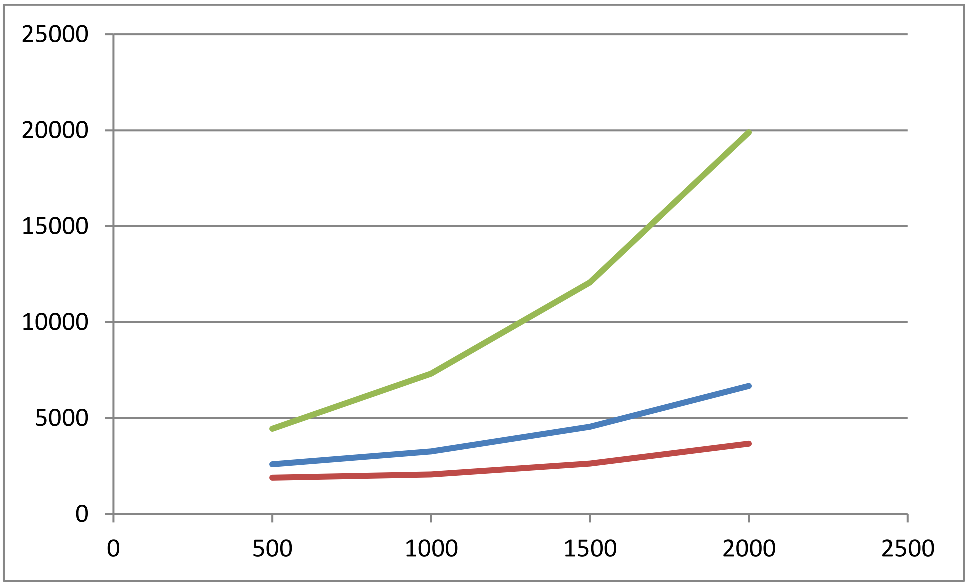

Figure 21: the development of the average profit with its confidence interval (90%) (T20)

The upper band of the average profit is in case T20 constantly bigger than in the case of no emotion. The lower band in case T20 lies from period 1000 constantly above the lower band in the case of no emotion. This fits well the theory developed before. The development of the upper band becomes understandable if one notices that in the case T20 one can observe cases where there are only imitators leading to very high profit.

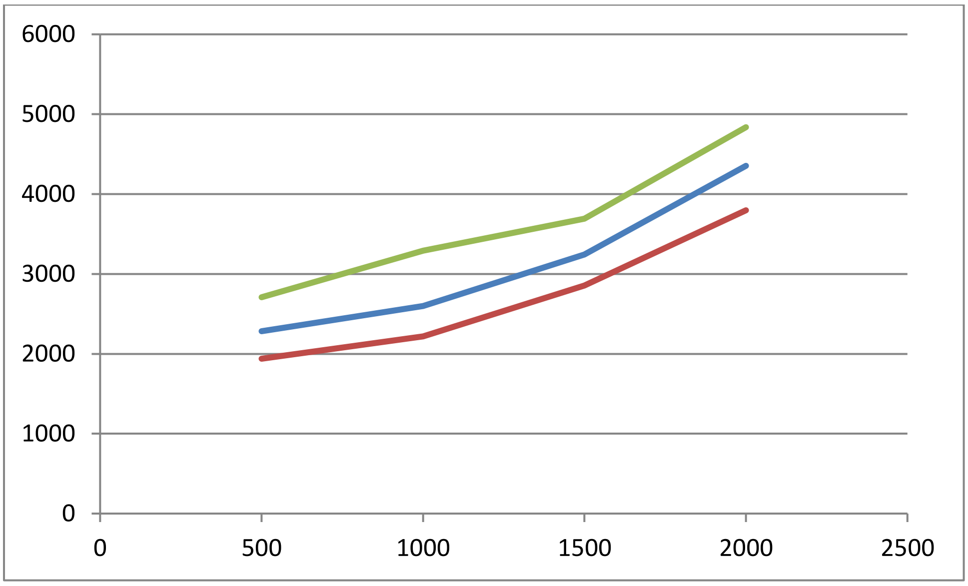

Figure 22: the development of the average profit with its confidence interval (90%) (T18)

The upper band in the case T18, looking at average profits, lies constantly above the upper band in the case of no emotion. The lower band of case T18 lies in periods 1000, 1500 and 2000 above the lower band in the case of no emotion. So choosing the alternative with the highest chance (maxmax strategy) leads also to favorable values for the lower band.

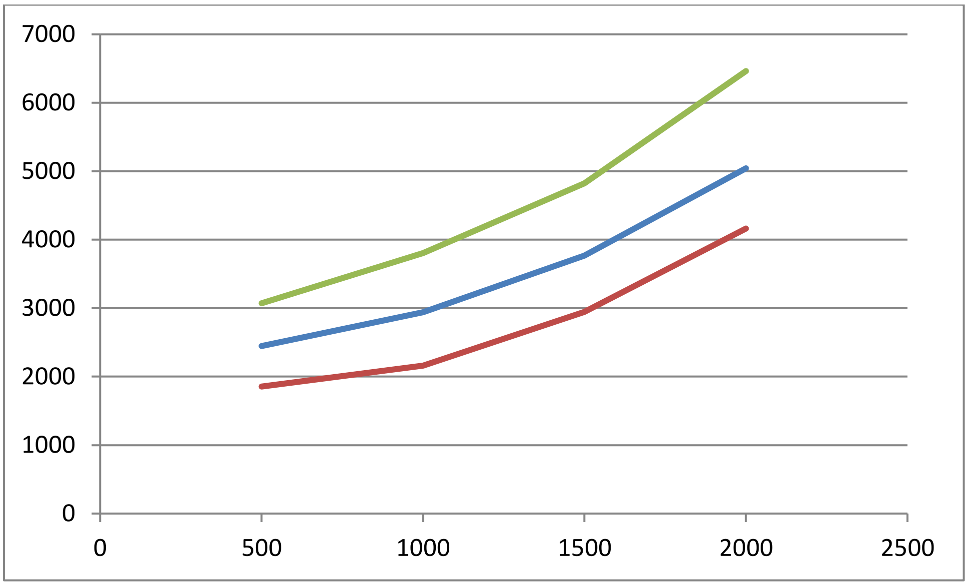

Figure 23: the development of the average profit with its confidence interval (90%) (T19)

From period 1000 onward the lower band of the case T19 lies above the lower band in the case of no emotion, which is not surprising because of the use of the maxmin strategy. Further looking at the average profit the upper band of case T19 lies constantly above the upper band in the case of no emotion. So choosing the alternative with the lowest risk (maxmin strategy) leads also to favorable values for the upper band.

Investigating the average profits we get the following picture. Without positive and negative moods (case T20) the inclusion of emotions leads to favorable results. If we look at the case T18 respectively T19 they also lead to favorable results comparing them to the case with no emotion. But the melting of the three moods in one model (T9) leads not to favorable results looking at the lower band, but only if we look at the upper band. In three cases (500, 1000, 1500) the lower band is lower in the case T9 compared to no emotions.

Our model hints moreover at the fact that emotions can lead to serious problems in asset markets. If all the market participants look for the same “safe harbor” there will be heavy problems if this “safe harbor” becomes risky. This happens if the asset, which is seen as safe by most participants, reaches a negative extreme (emotion) which is more negative than all the other assets in the short list of the investors. Suddenly after the shock all the market participants who are in bad mood will switch their strategy, leading to panic and jumps in the prices for those assets and sometimes to complete market breakdowns. On the other side if an asset becomes a chance, because the asset reaches a positive extreme, there will be a flow in from all the participants in good mood whose positive extreme in their short list is lower. Suddenly after this positive shock there will be a switch by those participants leading to a positive jump in the price for that asset. So moods can obviously lead to a destabilization of asset markets.

Now let’s look how we can include such problems in our model. We call it an emotional shock if a negative emotion in one period of a firm is more negative than all other negative emotions of that firm and the other firms looking at that particular strategy. In this case there will be a chance of 50% that all the firms in the market will overtake the negative emotion of that strategy. We include the emotional shock in the base model.

	av. prod	herfindahl	prod. Gap	av profit	av.price	max. prod
Tab Schock	n.s.	<	n.s.	n.s	n.s.	n.s.

Tab.25 emotional shock vs. no emotion (10% level), Wilcoxon signed-rank test

So according to table 24 the inclusion of an emotional shock leads not to significant results at the 10% level, comparing it with the case of no emotion. We would have expected a better result for the firms because of cases where all firms become suddenly imitators, but this didn’t materialize.

We now turn to the consumption side and to the results of table 25. Like above we take T9 as basis and include the following emotional shock. A negative emotion in one period of a consumer is more negative than all other negative emotions of that consumer and the other consumers for that particular product. In this case there will be a chance of 50% that all the consumers in the market will overtake the negative emotion of that strategy.

This second inclusion of an emotional shock leads mostly to insignificant results comparing it with the case of no emotion. So summing up there is no simple answer what the inclusion of emotions will lead to, one has to carefully analyze each case.

	av. prod	herfindahl	prod. Gap	av profit	av.price	max. prod
Tab Schock 2	n.s.	>	n.s.	n.s.	n.s.	n.s.

Tab.26 emotional shock 2 vs. no emotion (10% level), Wilcoxon signed-rank test

Conclusion

So what can we finally learn from our model? We can learn what an emotion in an economic model can look like. Simply speaking in a wider sense it is an appraisal mechanism with a specific goal and with extremes as input. We have distinguished three goals: minimizing the risk, maximizing the chance and maximizing the midrange. This has led to the inclusion of moods which specify which goal has priority. Moods can be modeled as stochastic jump processes as we have argued. So building on the work of so many we achieved an understanding of the underlying mechanisms when we talk about an emotion. This knowledge made it possible to build an economic model based on Schumpeterian competition including emotions. These experiments resulted firstly in the findings how the number of different types of agents, according how they react in bad and good mood, developed in different environments compared to a base case and how they differ. We saw that innovation in good mood and imitation in bad mood dominates in many environments, followed by innovation in both moods. Secondly we compared cases with no emotion and cases with emotion leading to the findings that the cases with emotion are better or insignificant, strengthening our position of valuable emotions.

Statistics

	500	1000	1500	2000
Av. price	172 (33)	183 (26)	231 (35)	303 (42)
Av. productivity	2,17 (0,39)	3,32 (0,49)	4,37 (0,69)	5,45 (0,75)
Av. profit	2314 (435)	2473 (351)	3113 (489)	4099 (557)

Tab.9a (in parentheses standard deviation)

	500	1000	1500	2000
Im/In	11	5	6	14
In/Im	34	34	39	26
Im/Im	16	16	12	10
In/In	19	25	23	30

Tab.9b

	Im/In	In/Im	Im/Im	In/In
profit	4123 (1977)	4101 (1524)	3808 (4183)	4183 (2020)
value	5743662 (617254)	5723318 (900909)	5624210 (1178478)	5442362 (1093437)
productivity	5,36 (0,54)	5,67 (0,86)	5,9 (0,84)	5,16 (0,64)
sales	306345 (22616)	307828 (18429)	314709 (28452)	285074 (51909)
price	306 (33)	293 (49)	280 (45)	319 (38)
market share	0,249 (0,12)	0,256 (0,08)	0,252 (0,06)	0,243 (0,12)

Tab.9c

	profit	value	productivity	sales	price	market share
Im/In	n.s.	n.s.	>	>	n.s.	n.s.
In/Im	n.s.	n.s.	>	>	<	>
Im/Im	n.s.	n.s.	>	>	<	n.s.

Tab.9d Im/In vs. In/In; In/Im vs. In/In; Im/Im vs. In/In

	500	1000	1500	2000
Av. price	180 (26)	194 (24)	242 (25)	325 (27)
Av. productivity	2,05 (0,29)	3,12 (0,4)	4,11 (0,46)	5,04 (0,47)
Av. profit	2437 (358)	2625 (319)	3282 (335)	4401 (368)

Tab.11a

	500	1000	1500	2000
Im/In	4	6	3	7
In/Im	36	42	35	39
Im/Im	20	12	21	16
In/In	20	20	21	18

Tab.11b

	Im/In	In/Im	Im/Im	In/In
profit	4294 (1555)	4430 (984)	4362 (576)	4316 (1869)
value	5753207 (745105)	618420 (643048)	5787305 (762116)	5442568 (590411)
productivity	5,02 (0,54)	5,04 (0,41)	5,22 (0,55)	4,88 (0,67)
sales	290318 (32171)	308600 (24997)	306715 (22497)	278164 (39274)
price	326 (33)	323 (23)	313 (30)	338 (43)
market share	0,246 (0,1)	0,251 (0,05)	0,261 (0,02)	0,237 (0,11)

Tab.11c

	profit	value	productivity	sales	price	market share
In/In	n.s.	<	<	<	n.s.	<
Im/Im	n.s.	<	n.s.	n.s.	n.s.	n.s.

Tab.11d In/In vs. In/Im; Im/Im vs. In/Im

	500	1000	1500	2000
Av. price	158 (24)	161 (20)	202 (26)	271 (26)
Av. productivity	2,35 (0,38)	3,76 (0,45)	4,95 (0,63)	6,1 (0,83)
Av. profit	2136 (329)	2187 (267)	2739 (358)	3670 (495)

Tab.12a

	500	1000	1500	2000
Im/In	12	4	3	4
In/Im	43	50	47	43
Im/Im	10	12	11	10
In/In	15	14	19	23

Tab.12b

	Im/In	In/Im	Im/Im	In/In
profit	4335 (880)	3748 (860)	3748 (774)	3376 (1040)
value	5587740 (883282)	5040868 (564888)	5465459 (921386)	4849697 (723759)
productivity	6,01 (0,8)	6,4 (0,87)	6,04 (0,8)	5,59 (0,73)
sales	322506 (30590)	306308 (18631)	319610 (25293)	275769 (36677)
price	273 (32)	258 (36)	273 (38)	295 (40)
market share	0,292 (0,05)	0,266 (0,05)	0,251 (0,03)	0,211 (0,06)

Tab.12c

	profit	value	productivity	sales	price	market share
In/In	<	n.s.	<	<	>	<
Im/Im	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Tab.12d In/In vs. In/Im; Im/Im vs. In/Im

	500	1000	1500	2000
Av. price	85 (10)	80 (7)	90 (6)	115 (7)
Av. productivity	4,32 (0,55)	7,53 (0,72)	10,92 (0,81)	14,19 (1)
Av. profit	1156 (146)	1086 (107)	1231 (86)	1561 (103)

Tab.14a

	500	1000	1500	2000
Im/In	9	8	8	6
In/Im	31	31	33	30
Im/Im	16	16	16	18
In/In	24	25	23	26

Tab.14b

	Im/In	In/Im	Im/Im	In/In
profit	1637 (282)	1622 (272)	1574 (155)	1464 (289)
value	2630438 (318316)	2742262 (269031)	2723993 (154472)	2493885 (304267)
productivity	14,72 (1,52)	14,46 (1,03)	14,04 (0,79)	13,87 (1,5)
sales	307169 (19970)	313567 (15831)	303407 (14222)	280334 (42455)
price	108 (10)	112 (7)	116 (6)	118 (12)
market share	0,271 (0,04	0,263 (0,03)	0,249 (0,02)	0,23 (0,05)

Tab. 14c

	profit	value	productivity	sales	price	market share
In/In	<	<	<	<	>	<
Im/Im	n.s.	n.s.	n.s.	<	>	n.s.

Tab.14d In/In vs. In/Im; Im/Im vs. In/Im

	500	1000	1500	2000
Av. price	164 (19)	182 (18)	225 (30)	297 (39)
Av. productivity	2,23 (0,27)	3,32 (0,32)	4,46 (0,54)	5,55 (0,65)
Av. profit	2247 (261)	2480 (253)	3067 (412)	4058 (538)

Tab.15a

	500	1000	1500	2000
Im/In	17	9	6	5
In/Im	10	8	8	5
Im/Im	19	23	25	27
In/In	34	40	41	43

Tab.15b

	Im/In	In/Im	Im/Im	In/In
profit	3549 (494)	3343 (376)	4130 (661)	4154 (591)
value	5481487 (482838)	5180904 (452771)	5545131 (618969)	5551098 (686045)
productivity	6,23 (0,78)	6,41 (0,5)	6,32 (0,74)	5,4 (0,65)
sales	296543 (19687)	288914 (20882)	302919 (12927)	299859 (22387)
price	263 (35)	254 (21)	300 (49)	305 (39)
market share	0,247 (0,01)	0,24 (0,01)	0,252 (0,01)	0,249 (0,01)

Tab. 15c

	profit	value	productivity	sales	price	market share
Im/Im	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Tab.15d Im/Im vs. In/In

	500	1000	1500	2000
Av. price	164 (22)	178 (22)	221 (22)	292 (27)
Av. productivity	2,25 (0,31)	3,41 (0,38)	4,51 (0,45)	5,61 (0,52)
Av. profit	2243 (314)	2436 (302)	3022 (305)	3991 (373)

Tab.16a

	500	1000	1500	2000
Im/In	13	12	13	15
In/Im	19	15	14	11
Im/Im	22	23	24	26
In/In	26	30	29	28

Tab.16b

	Im/In	In/Im	Im /Im	In/In
profit	3620 (284)	3909 (520)	4112 (541)	4109 (649)
value	5133741 (374116)	5633139 (464388)	5456752 (561272)	5570042 (623317)
productivity	6,03 (0,56)	5,76 (0,52)	5,51 (0,55)	5,44 (0,64)
sales	297505 (10205)	305039 (10251)	303143 (8664)	296440 (9865)
price	272 (25)	283 (26)	297 (30)	302 (38)
market share	0,243 (0,01)	0,252 (0,02)	0,253 (0,02)	0,25 (0,02)

Tab. 16c

	profit	value	productivity	sales	price	market share
Im/In	<	<	>	n.s.	<	n.s.
In/Im	n.s.	n.s.	n.s.	>	n.s.	n.s.
Im/Im	n.s.	n.s.	n.s.	>	n.s.	n.s.

Tab.16d Im/In vs. In/In; In/Im vs. In/In; Im/Im vs. In/In

	500	1000	1500	2000
Av. price	153 (25)	165 (22)	204 (24)	269 (42)
Av. productivity	2,43 (0,41)	3,69 (0,51)	4,88 (0,58)	6,14 (0,75)
Av. profit	2056 (335)	2212 (294)	2750 (340)	3615 (604)

Tab. 17a

	500	1000	1500	2000
Im/In	5	5	7	3
In/Im	47	50	51	41
Im/Im	19	17	14	17
In/In	9	8	8	19

Tab.17b

	Im/In	In/Im	Im/Im	In/In
profit	2514 (2187)	4361 (2156)	4025 (1658)	1813 (2583)
value	5257275 (1638742)	5237034 (1181329)	4990267 (1080791)	4056661 (2050446)
productivity	6,18 (0,63)	6,4 (0,52)	5,67 (1,17)	5,98 (0,68)
sales	296947 (83727)	327473 (59721)	293634 (50813)	246997 (112993)
price	264 (28)	255 (21)	300 (75)	274 (31)
market share	0,185 (0,16)	0,318 (0,15)	0,241 (0,077)	0,125 (0,17)

Tab.17c

	profit	value	productivity	sales	price	market share
Im/Im	n.s.	n.s.	<	n.s.	>	<
In/In	<	<	<	<	>	<

Tab.17d Im/Im vs. In/Im; In/In vs. In/Im

	500	1000	1500	2000
Av. price	170 (24)	193 (23)	240 (23)	322 (26)
Av. productivity	2,19 (0,29)	3,15 (0,36)	4,14 (0,38)	5,08 (0,43)
Av. profit	2283 (331)	2599 (324)	3243 (330)	4354 (367)

Tab. 18a

	500	1000	1500	2000
Im/In	37	38	38	38
In/Im	40	40	41	40
Im/Im	2	1	1	1
In/In	1	1	0	1

Tab.18b

	Im/In	In/Im	Im/Im	In/In
profit	4397 (678)	4264 (1346)	3901 (n.a.)	6784 (n.a.)
value	5799735 (560861)	5672532 (1022029)	8179665 (n.a.)	6197748 (n.a.)
productivity	5,2 (0,46)	4,99 (0,53)	4,16 (n.a.)	4,8 (n.a.)
sales	308856 (15580)	289685 (60379)	329709 (n.a.)	346425 (n.a.)
price	314 (27)	328 (35)	390 (n.a.)	337 (n.a.)
market share	0,256 (0,03)	0,242 (0,08)	0,183 (n.a.)	0,36 (n.a.)

Tab.18c

	profit	value	productivity	sales	price	market share
Im/In	n.s.	n.s.	>	>	n.s.	>

Tab.18d Im/In vs. In/Im

	500	1000	1500	2000
Av. price	181 (27)	217 (37)	279 (52)	373 (72)
Av. productivity	2,04 (0,32)	2,83 (0,48)	3,66 (0,68)	4,49 (0,79)
Av. profit	2447 (364)	2939 (515)	3766 (715)	5043 (981)

Tab.19a

	500	1000	1500	2000
Im/In	10	2	4	6
In/Im	28	33	37	29
Im/Im	14	10	6	2
In/In	28	35	33	43

Tab.19b

	Im/In	In/Im	Im/Im	In/In
profit	3619 (707)	5560 (1107)	7345 (2117)	4785 (2169)
value	6015461 (452318)	6863512 (994859)	8044221 (67534)	6209558 (111265)
productivity	4,66 (0,71)	4,55 (0,85)	3,57 (1,01)	4,47 (0,8)
sales	298737 (34452)	311086 (29768)	330475 (37351)	291283 (30397)
price	354 (51)	369 (72)	451 (102)	374 (73)
market share	0,193 (0,06)	0,28 (0,04)	0,28 (0,00)	0,235 (0,09)

Tab.19c

	profit	value	productivity	sales	price	market share
In/Im	>	>	n.s.	>	n.s.	>

Tab.19d In/Im vs. In/In

	500	1000	1500	2000
Av. price	191 (59)	241 (124)	336 (228)	492 (404)
Av. productivity	2,03 (0,46)	2,9 (0,91)	3,73 (1,32)	4,57 (1,72)
Av. profit	2591 (824)	3259 (1705)	4552 (3141)	6672 (5540)

Tab. 20a

	500	1000	1500	2000
Im/In	34	32	39	41
In/Im	32	29	28	31
Im/Im	3	4	2	1
In/In	11	15	11	7

Tab.20b

	Im/In	In/Im	Im/Im	In/In
profit	9099 (6820)	4154 (1137)	3577 (n.a.)	4054 (1334)
value	9214155 (5028586)	5606633 (1056731)	5810160 (735028)	5511881 (1375210)
productivity	3,81 (2,07)	5,3 (0,73)	6,64 (n.a.)	5,26 (0,9)
sales	304864 (17519)	295659 (52811)	320928 (n.a.)	287750 (44163)
price	663 (498)	313 (47)	244 (n.a.)	317 (59)
market share	0,254 (0,03)	0,247 (0,07)	0,268 (n.a.)	0,235 (0,06)

Tab.20c

	profit	value	productivity	sales	price	market share
In/Im	<	<	>	n.s.	<	n.s.

Tab.20d In/Im vs. Im/In

	500	1000	1500	2000
Av. price	209 (58)	257 (126)	353 (234)	507 (416)
Av. productivity	1,84 (0,39)	2,68 (0,79)	3,47 (1,13)	4,31 (1,47)
Av. profit	2812 (824)	3469 (1741)	4778 (3221)	6864 (5708)

Tab. 10

	500	1000	1500	2000
Av. price	98 (17)	88 (11)	105 (13)	131 (14)
Av. productivity	3,8 (0,63)	6,82 (0,83)	9,5 (1,15)	12,42 (1,22)
Av. profit	1337 (244)	1212 (157)	1433 (179)	1799 (193)

Tab. 13

	500	1000	1500	2000
Av. price	143 (17)	144 (15)	174 (14)	219 (14)
Av. productivity	2,55 (0,3)	4,19 (0,46)	5,69 (0,48)	7,41 (0,49)
Av. profit	1956 (230)	1961 (209)	2372 (203)	2994 (193)

Tab.21

	500	1000	1500	2000
Av. price	168 (19)	182 (20)	223 (26)	293 (32)
Av. productivity	2,17 (0,26)	3,31 (0,37)	4,46 (0,54)	5,6 (0,65)
Av. profit	2294 (270)	2487 (283)	3050 (358)	4003 (445)

Tab.27 (no emotion) (in parentheses standard deviation)

	500	1000	1500	2000
Av. price	166 (22)	169 (18)	208 (21)	271 (23)
Av. productivity	2,22 (0,30)	3,56 (0,37)	4,77 (0,48)	6,03 (0,50)
Av. profit	2238 (288)	2299 (259)	2827 (296)	3690 (314)

Tab.28 (firm has no emotion, consumers possess full emotion (T26))

	av. prod	herfindahl	prod. Gap	av profit	av.price	max. prod
Tab 10	<	<	n.s.	>	>	<
Tab 11	<	<	n.s.	>	>	<
Tab 12	>	<	n.s.	<	<	>
Tab 13	>	<	<	<	<	>
Tab 14	>	>	<	<	<	>
Tab 15	n.s.	<	>	n.s.	n.s.	n.s.
Tab 16	n.s.	<	n.s.	n.s.	n.s.	n.s.
Tab 17	>	>	n.s.	<	<	>
Tab 18	<	<	n.s.	>	>	<
Tab 19	<	n.s.	n.s.	>	>	<
Tab 20	n.s.	<	n.s.	n.s.	n.s.	n.s.
Tab 21	>	<	<	<	<	>

Tab.22 Tx vs. base case (5% level), Wilcoxon signed-rank test

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Eidesstattliche Versicherung

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<u>Versicherung</u>

Ich versichere, dass ich die Dissertation selbstständig und ohne Benutzung anderer als den angegebenen Quellen angefertigt habe.

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