GAME THEORY RELAUNCHED *edited by Hardy Hanappi*

Preface

The scientific discipline called game theory now has reached the age of 71 years, an age which for ordinary human individuals is reminding on retirement. Fortunately enough, profound scientific achievements do not lose their powers at the same speed as their human creators. If they provide exciting new ideas and are able to stimulate a broader scientific community, then they can become a public good, a precious intellectual heritage, which is passed on from generation to generation of researchers. And even if such theories are proven to be only special cases of a more general approach or are even falsified, even then their preliminary impasses or mistakes are usually acknowledged as necessary steps towards state-of-the art knowledge. There is no need for a pension system; such a theory lives on as an ingredient of ever expanding human knowledge.

When game theory entered the scientific arena in the 40-ties of the last century it was a highly acclaimed new star. A star launched by one of the most admired mathematical geniuses of the century, John von Neumann. In contrast to these high aspirations the name of the new discipline - 'Game Theory' – at first sight suggested that it might be not really a serious scientific project. It reminded of playing games, of card games like poker or board games like chess, or even of children not being able to understand how to spend time in serious activities and thus having to train their abilities in metaphorical game play. To some extent the tension between the most stern and most abstract scientific discipline, mathematics, on the one hand and the reference to the homo ludens, the fun of exploring reality by acting in sheltered simulated contexts on the other hand explains why game theory immediately was attractive for many young scientists on both sides of the Atlantic. It also explains why any attempt to change this name (some more 'serious' researchers have proposed to call it Theory of Strategic Behavior) should be avoided. Game theory still thrives on its ability to be sufficiently rigorous and open to a wide range of metaphorical game play at the same time. This is why it is so charming.

Additional profile came from the science onto which its two creators, John von Neumann and Oskar Morgenstern, decided to graft the new apparatus: economic theory. After the Great Depression of the world economy in the 30-ties few scientific disciplines were visibly in a more disastrous state than economics. In tight cooperation with the trained economist Morgenstern the extremely ambitious John von Neumann jumped on this subject to revolutionize it. But in doing so the two underestimated the resistance against deep changes, which is an unavoidable characteristic of established researchers trying to defend their own, with life-long great difficulties acquired, intellectual capital. The relatively sudden dismissal of game theory as a scientific fashion immediately after John von Neumann's death in the 50-ties certainly has another root in in the long-run upswing of a reconstructing world economy, which seemed to need no revolutionized economic theory. Some piece-meal social engineering based on Keynes ideas plus the mathematical framework of Paul Samuelson's 'Neoclassical Synthesis' seemed to be good enough to run the show. In economic theory game theory was out; and was left to some mathematical 'nerds' who mainly were elaborating refinements along the lines of John Nash's equilibrium approach to game-theoretic questions.

But ignorance of the economic mainstream could not kill the beast. The last three decades saw a slowly starting but exponentially rising influence of game theory in surprisingly different fields of science. In its old domain, the social sciences (mainly political economy), it now is hard to imagine that an innovative paper can succeed without at least to apologize why it not uses a more appropriate game-theoretic approach. But in many other areas – from biology via abstract network theory to ICT engineering – game-theoretic modeling has reappeared as indispensable tool.

This is the very reason why this book is called '**Game Theory Relaunched**'. Which parts of game theory are used and which kind of further development is contributed to game theory by the respective research does, of course, assume different forms, which in turn depend on the respective discipline. Game theory still is not a finalized body of knowledge – and (as chapter 1 argues) will not be for a very long time to come. Many existing textbooks on game theory therefore spend most of their pages on describing the very specific history of refinements of Nash's equilibrium concept – and mention the actually happening renaissance of game-theoretic thought across different disciplines and engineering activities at best as an exotic outlier. The collection in this book takes a different perspective; it proceeds along the lines of currently developed game-theoretic work. At the current stage of the renaissance of game theory all that can be done is to collect and to structure the diverse contributions: The book thus consists of four parts containing (1) social science oriented chapters, (2) chapters related to engineering problems, (3) chapters enhancing the mathematics of game theory, and (4) chapters that stress the transdisciplinary character of game theory. By working through this mosaic of building blocks of game theory the reader hopefully can get an impression of the breadth and depth of the intellectual potential, which the founders of this theory had envisaged.

All the chapters have been written by different authors spread all over the globe and thus showing how international the game theoretic community these days already is. It has been my honor to collect and to edit their contributions, but the intellectual surplus they produced is completely their own merit. Special thanks have also to go to InTech Publishers, and in particular to publishing process manager Oliver Kurelic whose patience and wise consultation made this book possible. This type of publishing provided by publishers like InTech will hopefully not only help young and innovative researchers in many countries but will also benefit students around the world. To them this book is dedicated.

Vienna, March 2013 Hardy Hanappi

Chapter 1 The Neumann-Morgenstern Project

Game Theory as a formal language for the Social Sciences

Hardy Hanappi

In 1942 John von Neumann and Oskar Morgenstern published their book ‘Theory of Games and Economic Behavior’. The impact of this book on the scientific community and in particular on the further development of the social sciences was tremendous. John von Neumann’s reputation as a mathematical genius and Oskar Morgenstern’s ability to contribute truly innovative and original ideas to economic theory helped to spread the fame of their monumental masterpiece. Since this first wave of excitement in the last 70 years the theory of games has experienced a rather mixed fate, periods of ignorance changing with periods of redirection towards new fields of interest, or even new re-definition of its basic aims. There is no doubt that in each of these emerging sideways towards which specific scientific communities modified the original formal framework tremendous scientific progress was stimulated. The range of the diversity of the affected fields can hardly be exaggerated; it reaches from political economy via sociology and psychology to pure mathematics. But the price paid for these wide-spread singular success stories was another effect accompanying it: an increasing disintegration of the original project. Moreover the incredible swelling of research papers in each area during the last decades made it impossible - even for large research teams – to survey what was going on with the use of the theory of games in science. This is the starting point for the line of argument presented in this chapter.

The need for a re-integrative attempt of the basic tenets of a theory of games probably currently is felt most urgently in the area of political economy. In this area the mainstream theory of economic policy seems to be particularly helpless when confronted with questions arising in times of global economic crisis. To answer most of these questions would require to formulate, non-linear strategic behavior in situations of disequilibrium, a task which the equilibrium centered part of economic game theory hardly can tackle. Therefore in this chapter the modest attempt is made to return to the original Neumann-Morgenstern project to learn from it how to frame a formal language that is able to capture the essence of such a situation. In doing so it can be shown that the development of algorithmically oriented evolutionary economics (e.g. agent-based simulation) can play an important role to approach the Neumann-Morgenstern project. From the opposite side, namely the most advanced formalization attempts of disequilibrium economics, economists like Vela Velupillai (compare (Velupillai, 2011)) are aiming to bridge the distance to algorithmic considerations too.

The result of the chapter will be the formulation of an updated version of the Neumann-Morgenstern project. On the basis of this research program the most recent structural crisis in economic theory building, and its possible future merits will appear in a new, more comprehensive light.

The Origins of Game Theory – Personalities and Milieus

John von Neumann, probably the most influential scientist of the 20th century, for many researchers in the structural sciences has been the unique personality, the reference point, from which the theory of games has been developed. Indeed John von Neumann's lifelong work, his intellectual trajectory leading him through a whole range of different disciplines, is an excellent starting point for a better understanding of the *logical* origin of the theory of strategic games. But before using von Neumann's biography to develop this argument it is useful, even necessary, to recognize that his contribution can easily be interpreted as a rediscovery and a more general redesign and unification of older theory fragments, which can be traced back in history almost two thousand years.

Strategic considerations are implicitly enabled by the characteristic feature, which distinguishes the human species from earlier forms of living organisms: the capacity to use internal model building as an instrument for survival and growth. In this context the adjective 'internal' evidently means internal to the species, to the respective tribe. Model building therefore is congruent to the existence of a communication system of the tribe. And this in turn implies that the constituent parts of a communication system have emerged. As there are:

- The ability of the members of the tribe to send, to perceive, and to store signals inside and outside their brains.
- The ability of the members of the tribe to interpret signals as representations of dynamics going on outside the world of signals.
- An environment of the tribe which is favorable enough for the tribe to allow for a fast enough adaption of the communication system to adjust to (possibly) deteriorating conditions.

As soon as these features are added to a purely animal species - and some sophistication of their evolution has occurred – systems of spoken and written language will serve as the major constituting element of the tribe. Members of a tribe will recognize other members as mirror images of themselves, and the division of labor within the tribe will open up the road to the interplay of cooperation and conflict. In other words, with the emergence of language all the ingredients necessary for setting up a strategic game in terms of modern game theory are given.

First consider cooperation. Division of types of activity within the tribe, division of labor, needs coordination, needs an internal image of this division in the mind of each member. Moreover this common image only exists since it is maintained via an externalized common language. To control the self-consciousness of the tribe perpetuated by the common communication system is itself a task carried out by a specialized group of tribe members. In game theoretic terms it works by producing images in the minds of tribe members which align their behavior by predicting individual disasters in case of breaking the rules of traditional cooperative behavior. The most archaic model of such an internalized game in strategic form is shown in figure 1.

		T	
		G	P
M_i	TB	C^M, C^T	F^M, F^T
	NTB	E^M, E^T	D^M, D^T

Figure 1: Cooperation enforcing mental model of M_i

A tribe member M_i can either follow its *traditional behavior* choosing actions TB, or it can decide to deviate from choosing NTB (not choosing TB). But a look inside its model shows that these two options lead to results which also depend on the reaction of the entity tribe, called T. In this mental model the column player T chooses between gratification (G) and punishment (P) depending on conformity of the member's behavior. In a functioning tribe each member chooses traditional cooperative behavior by predicting that it is preferable using the comparison of possible payoffs in figure 1. This is how the concept of free will in a cooperative tribe emerges – there is a choice. The subgroup of tribe members controlling cooperation works on implementing these mental models in all diverse groups of other tribe members. Control typically concerns two levels, an ideological level (e.g. religion) which aims at directly implanting a certain game (including payoff) structure, and a directly coercive level (e.g. police) which provides actual examples of punishment to reinforce the believe in the mental model. In game theoretic terms the task simply is to guarantee that

$$p^C \cdot C^M + p^F \cdot F^M > p^E \cdot E^M + p^D \cdot D^M \ ,$$

with p^C, p^F, p^E and p^D being the respective probabilities ascribed by member M_i to each of the four possible events. Expected utility from deviating from cooperative behavior must be smaller than sticking to the norm, and all measures which either concern the probabilities or the predicted utilities can be used by the tribes control instances to maintain self-control of its members[1].

Turn to conflict now. As tribes expand across areas with different fertility conflicts between tribes cannot be avoided. Again reoccurrence of battles will lead to division of labor, to a specialized subgroup within each tribe, warriors[2]. For most of human history, till the times of Napoleon, the force of a group of warriors could be directly related to the number of warriors drafted. Napoleon's rule famously stated that the higher number of soldiers in a battle between two armies will decide who wins. Complications and even possibilities for a weaker army to win a battle enter the picture as soon as internal model building of army leaders is introduced. From earliest historical sources onward military theory has emphasized the importance of knowledge of the expected battleground. Knowing where to fight and how to position the own warriors is based on the anticipation of the moves of the approaching enemy. The core of game theoretic reasoning - namely the fact that the own final outcome depends not only on my own choices but as well on the actions of another conscious player, both anticipating each other's actions – this essence of strategic decision-making immediately emerges as soon as a more detailed environment for conflicts is taken into consideration. Larger conflicts, wars, are usually spit into a set of smaller battles taking place at different locations forcing the two generals to split their armies according to these predetermined battlefields. The art of warship for several thousand years consisted to a large extent of informal game-theoretic considerations on how to deal with this issue. More than a decade before Neumann and Morgenstern published their path-breaking book (Neumann and Morgenstern, 1944) the mathematician Borel had already formalized this basic military problem as what today is known as Colonel Blotto game (Borel, 1921). In figure 2 the strategic form of a simple Colonel Blotto Game is presented. It is assumed that each of the two armies consists of six units of warriors, all with the

[1] In the Middle Ages particularly cruel forms of punishment of non-conform members could compensate for a lower probability of detection due to increasing empires; the necessary decrease in p^D was counteracted by an increase in D^M.

[2] In earlier societies specialists in exerting coercive power were just one subgroup guaranteeing internal cooperation (today police) as well as success in external conflict (today military). Till today some overlapping can be observed.

same number of soldiers. There are three battlefields and a battle at a battlefield is won by the army which has sent more soldiers to this location. If the amount of soldiers is equal, then this battle is a draw. The war is won by the army which wins more battles. The task for a General A thus is to distribute his units over the three locations to win as many battles as possible against General B. Consider the strategic form of this game in figure 2.

		General B				
	Strategy	6, 0, 0	5, 1, 0	4, 1, 1	3, 2, 1	2, 2, 2
General A	6, 0, 0	0, 0	$-\frac{1}{3}, \frac{1}{3}$	-1, 1	-1, 1	-1, 1
	5, 1, 0	$\frac{1}{3}, -\frac{1}{3}$	$\frac{1}{6}, \frac{1}{6}$	$-\frac{1}{3}, \frac{1}{3}$	$-\frac{1}{3}, \frac{1}{3}$	-1, 1
	4, 1, 1	1, -1	$\frac{1}{3}, -\frac{1}{3}$	0, 0	$-\frac{1}{3}, \frac{1}{3}$	-1, 1
	3, 2, 1	1, -1	$\frac{1}{3}, -\frac{1}{3}$	$\frac{1}{3}, -\frac{1}{3}$	$\frac{1}{6}, \frac{1}{6}$	0, 0
	2, 2, 2	1, -1	1, -1	1, -1	0, 0	0, 0

Figure 2: Conflict anticipating mental model of A

The six strategies in the table only indicate the first decision on how to split the troops; they do not concern battlefields and do not include any anticipation of the opponent's plan. Assuming that every strategy of the enemy has the same probability – this is the famous assumption about 'insufficient reason' in cases of no information – the payoff matrix of figure 2 can be constructed. The first payoff in each cell relates to general A, the second to general B. If the number is positive it shows the probability to win the war, if it is negative the probability to lose it – zeros indicate draws. A cell is shaded in grey if players can improve their chances if they know the allocations of the enemy's troops (espionage – to discover the mental model of the opponent - makes sense). Despite this oversimplified setting strategic choice is already a sophisticated enterprise[3]. The centuries' old art of warfare has produced a large amount of insights, refinements and partial solutions to the strategic games of conflict. In the last century Hitler's early success with Blitzkrieg (fast moves of tank regiments between locations) as well as terrorist and counter-terrorist strategy building by consideration of hubs in social networks, see [Barabási, 2002, pp. 109-122], are examples of extensive use of formalizations of game theoretic ideas about conflict.

Back in history, the mental models guiding actions in a game theoretic sense (i.e. by taking into account that other tribe members also act on the basis of their mental models) could only use languages available to the respective culture. But with the scientific revolution of the natural sciences a quantum jump in formalization techniques had taken place. In 1900, three years before John von Neumann was born, David Hilbert proposed his famous list of 23 problems of mathematics, the most abstract form of human language. It was due to the use of this language, of mathematics, that the continuing success of the natural sciences had been possible. Hilbert's program was thought to be a

[3] Colonel Blotto Games are still a flourishing area of game theory. Its mathematical treatment was already introduced during the first seminars with John von Neumann by John Tukey (Tukey, 1949), further enhanced by eminent scholars like Bellman (Bellman, 1969), and in certain mathematical dimensions even finalized (Roberson, 2006). But as (Kovenock and Roberson, 2008) show the interpretative power of this type of conflict models has not been exhausted at all.

pathfinder to reach the highest zenith of mathematical analysis – a point where most abstract theoretical results coincide with insights into the actual physical structure of nature. It was this presumably triumphant phase of mathematical research during which the young Hungarian mathematician John von Neumann, who later became a collaborator of Hilbert, was socialized. In the first two decades of the 20^{th} century the vision of an ultimately correct language, which has to be cleaned from all semantic references and resides only in the sphere of logic, was extremely attractive for talented young mathematicians. Alfred North Whitehead and Bertrand Russell wrote their Principia Mathematica (Whitehead and Russell, 1910), Wittgenstein produced his Tractatus (Wittgenstein, 1921), and Albert Einstein's two papers from 1905 first remained almost completely unknown (Einstein, 1905a, 1905b). This intellectual milieu within the scientific community of mathematicians for John von Neumann was additionally amplified by the outstanding historical record of the successes of Hungarian mathematicians[4]. Two other important elements should be mentioned to better understand the milieu which contributed to John von Neumann's early socialization.

Born as the son of a successful Jewish banker in Budapest, who received the title of nobility, the 'von', when John was 10 years old, he was very aware of business practice and the more subtle advantages of having a higher income. Following the advice of his father John started an academic career as engineer, a down-to-earth study of chemistry. The extraordinarily talented young genius developed his mathematics as his hobby; perhaps it therefore was even more fascinating and original. Despite his outstanding ability to work on highest levels of mathematical abstraction all his life John von Neumann never shied away from using mathematics for engineering problems, used it as a tool for practical problems. This attitude seems to stem from his formative years as pupil and young student[5].

The second special characteristic of von Neumann's formation came from the peculiar cultural milieu of intellectuals interested in analysis and logic in central Europe after World War 1. After the breakdown of the feudal empires freewheeling intellectual exchange of opinions flourished, not just via research papers[6] but also in the coffeehouses of Vienna and Budapest. Debates often resembled games, challenges for competing brains looking for solutions to abstract problems, usually extremely difficult games, but nevertheless still intellectually highly rewarding competitions for the players. And parallel to serious science there was a real board game which everybody in central Europe played: chess[7]. When later in his life John von Neumann lived in the USA he still cultivated this highly cooperative central European culture for which intellectual property rights simply not existed. Knowledge was freely exchanged, voluntarily shared, sometimes copied, in principle considered as public good. The reward for outstanding achievements was mainly the admiration of the other members of the scientific circle, the authority gained within the scientific community. Of course, this authority hopefully in the end would win a position at a university. Since von Neumann never had a

[4] The legend has it that for every important mathematical proof, there seems to exist a less known Hungarian mathematician who had proved the theorem one year earlier.

[5] The sharpest contrast to von Neumann probably is the personality of a contemporary; the British mathematician G. Hardy, who insisted on the purity of the discipline (Hardy, 1940).

[6] An extremely concise reconstruction of Neumann's early years in Viennese circles can be found in (Punzo, 1989).

[7] An extremely impressive recently published book shedding light on these historical roots of game theory comes from Robert Leonard (Leonard, 2010).

problem in this respect, all his life he completely neglected intellectual property rights, cooperation of all scientists was the name of his game.

John von Neumann's reputation was surging. But then Hilbert's research program received a lethal blow: Kurt Gödel proved - using Hilbert's analytical apparatus – that any such apparatus can contain statements which necessarily cannot be evaluated as correct or incorrect (Gödel, 1931). Today 15 of Hilbert's problems from 1900 have been solved, 3 are still unsolved, but for 5 of them it is certain that they cannot be decided. The formidable research program of logical apriorism suddenly imploded. Wittgenstein turned to the concept of a diversity of 'Sprachspiele'; Russell gave up to investigate how the consistency of the mathematical apparatus can be saved from the contradictions he himself had discovered – and devoted his time to political activism. And John von Neumann turned away from pure mathematics to advance theoretical physics and economics[8]. Of course, he took his extraordinary mathematical skills with him when he directed his attention to these new fields thus becoming the prime example for successful transdisciplinarity.

In his introduction to the sixtieth-anniversary edition of the famous book by Neumann and Morgenstern Harold Kuhn notes that he agrees with Robert Leonard that 'had von Neumann and Morgenstern never met, it seems unlikely that game theory would have been developed.' The personality of Oskar Morgenstern therefore is the second, equally essential ingredient to the Neumann-Morgenstern project.

Oskar Morgenstern's career is in many respects remarkable. He often is considered to have belonged to the school of Austrian Economics, though only few economists have a clear picture of what characterizes Austrian Economics[9], or what has been produced by Morgenstern – apart of having been the co-author of John von Neumann. As many other economists socialized in central Europe during the first two decades of the 19th century, Morgenstern's vita shows a high volatility of his views, which often changed according to the intellectual milieu he just experienced. Like Joseph Schumpeter, Ludwig von Mises, Friedrich Hayek and several other less known young scientists he never really could settle down intellectually in the established circle of Vienna's economists dominated mainly by Böhm-Bawerk. The Vienna Circle, collecting so many outstanding scientists from diverse disciplines, for a short time also was a home for some of the economists whose careers in Vienna were blocked. The smallest common denominator of this group perhaps was the emphasis which they put on the combination of underlining the importance of disequilibrium and the insistence on clarity and logic. It might be speculated that this strange mix reflects the turmoil several of them had experienced in their own individual lives.

Indeed it is again the game of chess which can serve as a metaphor explaining this type of fascination. It is a game of perfect recall with all desirable clarity necessary for logical analysis. It is immediately amenable to complete analysis: both players before they start to play could agree that for all finite games with perfect information there exists a Nash equilibrium in mixed strategies, a result later provided by [Kuhn, 1953] generalizing [Zermelo, 1913]. Of course, such a game would be

[8] Leonard seems to be correct to reject Philip Mirowski's claim that von Neumann's turn to game theory was a direct reaction on Gödel's proof [Mirowski, 2002]. Indeed it is much more plausible that John von Neumann felt the immediate needs of modeling warfare from 1939 onwards were the main motivation.
[9] Moreover Austria Economics in Oskar Morgenstern's time in Vienna was radically different to what today the so-called 'Austrians' in economic circles of the USA are representing as 'Austrian Economics'.

extremely boring if it indeed would be possible to play it that way[10]. The reason why chess proved to be so fascinating in the milieu of Viennese economists like Morgenstern was that the intelligence of the players was not reduced to being good in deductive reasoning or guessing the opponents secrets – intelligence of a player consisted in the ability to produce internal models of the not-too-far future *in time*[11]. This was similar to the still valid critique of the 'Austrians' (e.g. von Wieser, Mayer, and Mises. Morgenstern's teachers) concerning Walras: The result that with certain assumptions on functional forms and market rules used by agents in a perfectly competitive society is compatible with the existence of a unique and stable price vector is formally interesting, but the real challenge clearly is to model what agents and institutions do if they build expectations based on models using limits of perception (of total complexity) and have to result in actions taken before full enumeration of consequences is possible. The quantitative overload of atomistic agents with such an extremely interdependent network leads to structuring and summarizing certain specialized features. In real economic life – Schrödinger stated this quantitative overkill as one of the characteristics of life itself (Schrödinger, 1928) – division of actions breeds further division of labor resulting in social classes. But to synthesize this divided world all internal models not only have to be built, they have to be kept consistent by communication. Morgenstern, after some 'nihilistic' years in Vienna, where in the face of these methodological difficulties he doubted any possibility of predicting overall socio-economic development at all, went to Britain where he met Edgeworth. The special twist in Oskar Morgenstern's vita is his insistence on the use of abstract language, of mathematics, to overcome mostly useless results put forward in this same language. He admired Edgeworth's ability to clean his abstract arguments from any 'normative' reference, while at the same time these models escaped the rigid framework of Walrasian economics. Already from 1928 onwards Morgenstern's desire to produce a new abstract formal language for economics became visible. It just needed his encounter with the mathematical genius of John von Neumann to take serious steps towards this goal.

The Context of the further Evolution of Game Theory

In his paper "Zur Theorie der Gesellschaftsspiele" (Neumann, 1928) John von Neumann had already developed a blueprint of what was later to become known as game theory. But for more than a decade he did not further consider the topic. Only after some fundamental changes - in his life as well as in the general state of the world - he returned to this seemingly mundane theme. In 1938 his first wife had left him, he had left Europe and had settled in Princeton, and Hitler's armies were successfully conquering Europe[12]. An enormous amount of intellectual capacity was driven out of Europe and almost exclusively found its exile in the United States. John von Neumann's world-wide reputation as a mathematical genius made him, together with Albert Einstein and Kurt Gödel to one of the key personalities at the epicenter of this exodus from Europe – Princeton University and the Institute of Advanced Studies in Princeton.

Oskar Morgenstern was attracted by John von Neumann's genius too, and during a visit to the USA managed to meet him. During the 30-ties Morgenstern had been able to achieve a well-respected

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[10] The number of possible constellations on the chess board is about 10^{47} and exceeds the number of atoms in the universe. And without a carrier system for the symbols of internal modelling no operational strategy is possible.

[11] It is interesting that many contemporaries of John von Neumann mention his *speed of thought* as the most impressive feature of his genius.

[12] For a detailed account of these crisis years in von Neumann's creativity – he only published one paper during 1938 and 1939 - see (Leonard, 2012, pp. 195-223).

status as economist in Vienna. With Mises helping him to get into contact with the Rockefeller foundation he had become director of the "Trade Cycle Research Institute" in Vienna, but in March 1938 (while Morgenstern was in the USA) Hitler's academic collaborators took over and installed Ernst Wagemann and Reinhard Kamitz as new directors cleaning the staff from all Jewish and "politically unbearable" elements. Morgenstern had never been a socialist though; quite to the contrary his early formation has had a strong anti-socialist, during school days even anti-Semitic, tendency. Like John von Neumann's family background his family background rather was characterized by a flight from the threatening communist regimes in Eastern Europe. In his student days in Vienna he had been closer to the conservative groups around Mises, Mayer, and Hayek, and he always stayed in distance to the social-democrats Otto Neurath and Otto Bauer. Only when he met Karl Menger, son of the famous father of marginalism Carl Menger, he developed an interest beyond the difficulties of modeling of complex individual decisions, an interest in theories of social justice and fairness. Karl Menger and Hans Hahn had been those members of the school of Austrian Economics who were closest to socialist thought. By the putsch of Austro-fascism in 1934 the carriers of the tradition of liberal thought of the Austrian School were forced to take a decision: Either they could transfer liberalism into a political agenda that (due to its anti-socialism) was hopefully compatible with the new political rulers, or they could take the problems of modeling liberalism to some higher methodological grounds, carefully separating theory building from normative political judgments[13]. Friedrich Hayek took the first option while Karl Menger and Oskar Morgenstern took the second alternative. As a consequence Morgenstern during the 30-ties worked through an extensive list of readings in mathematics and philosophy to acquire more knowledge on the state of the art of formal methods across all disciplines. It probably was this extraordinary broad aspiration, which made Morgenstern an ideal partner – a "necessary interlocutor" as Leonard calls it – for John von Neumann.

When Neumann and Morgenstern met the excitement they both experienced during the relatively short time it needed to produce their common book had immediately emerged. They set out to produce a new formal language for the social sciences; the deficiency of mathematical economics is best expressed in von Neumann's words: "You know, Oskar, if these books (on mathematical economics, G.H.) are unearthed sometime a few hundred years hence, people will not believe that they were written in our time. Rather they will think they are about contemporary with Newton, so primitive is their mathematics. Economics is simply still a million miles away from the state in which an advanced science is, such as physics." (Morgenstern, 1976).

A detailed discussion of the content of the masterpiece of John von Neumann and Oskar Morgenstern goes beyond the scope of this chapter; a few remarks have to suffice. First, it is important to realize that the book to a considerable extent has to be understood as a critique of political economy, of prevailing economic theory existing in 1942. It is evident that the difference to be made between models of non-living atoms and models of agents in social settings consists in the necessity to consider internal model-building of the agents. Since they use these internal models to identify variables they want to optimize (goals), variables they can control (instruments), and relations between these variables, which they have to observe (rules plus auxiliary variables) it is necessary to characterize these subsets. Chapter 1 and the appendix of the book thus contain a new theory on how to formalize goal variables, i.e. the famous Neumann-Morgenstern utility theory. As a

[13] This strict distinction between objective knowledge and subjectively determined normative issues stemmed from Max Weber and was highly influential in the interwar period (Weber, 1904).

side product of this formalization the notion of rationality is given a clear definition. Then, turning to instruments and rules instead of using the already formalized metaphor of Newtonian mechanics the authors rather take a look at social learning of goal directed action as it occurs in human societies. And they discover it as learning via games, games with which children learn, card games with which adults entertain themselves and explore their psychological interaction, games like chess where masterminds encounter the problem of 'infinite' regress[14]. As chapter 2 of the book demonstrates goals, instruments and rules can neatly be packed in a formal definition of a strategic game built on the archetype of a simple board game. In this chapter another important feature of the new formalization had to appear: Internal model-building needs assumptions describing the processing of information. Chess again proves to be a good starting point for an analysis, since the only information kept secret by each player is his or her internal model. But even this last hide-away of secret personal knowledge is hard to capture because it contains all memories and pattern recognition capabilities of a player. Neumann and Morgenstern react to this difficulty by restricting their attention to most simple settings and the structure of the theory they imply: Structure implied by the number of players, by payoffs being constant-sum or not, by decomposability. The detailed treatment of all of these cases constitutes the core of their book.

As Morgenstern later wrote their work was not just intended to show the capabilities of a modern mathematical treatment, neither was it just an alternative spotlight on economic processes: "The theory … deals in a new manner even with such things as substitution, complementarity, superadditivity of value, exploitation, discrimination, social 'stratification', symmetry in organizations, power and privilege of players, etc. Thus the scope of the book extends far beyond economics, reaching into political science and sociology … "(Morgenstern, 1976). When the United States were entering the war - German submarines were already near its East coast - John von Neumann became involved in war activities. Economic, political, and military strategic interaction could not be properly disentangled anymore.

Interestingly enough a certain inversion of emphasis of the two authors of the path-breaking book after its publication can be observed. John von Neumann took a turn towards operationalization, supporting the development weapons technology[15] and in the realm of modeling living agents he designed the first modern computers[16]. Oskar Morgenstern, who already had turned his back to

[14] "If he thinks that I think, what he thinks that I think …" is just the imagined mirror image of a very large decision tree of possible moves in chess. It actually is finite, but so large that it cannot be used to derive the best next move, thus providing a new meaning for "infinite", namely inoperative.

[15] This chapter ignores von Neumann's eventually occurring and irritating transformations into 'Dr. Strangelove mode' (see (Strathern, 2002)): He sometimes put forward extremely naïve and politically unacceptable suggestions. Comparable to other strange behavioral traits of his personal life (see (Macrae, 1992)) this should be delegated to a discussion on his psychology and is largely independent of the Neumann-Morgenstern project.

[16] Towards the end of his life he tried to isolate the essential elements of internal model-building by comparison with the human brain (Neumann, 1958), and worked out the necessary general rules for self-reproducing automata. Evidently returning to his early engineering background he was in a kind of search for a material correlate of a game-theoretic player's internal structure. His earlier interest in describing hydrodynamic turbulence at that time already had initiated his work on computer simulations, compare (Ulam, 1958).

‘normative’ political economy, pushed the elaboration of the mathematical generalizations of the new theory[17].

In retrospective the genesis of the Neumann-Morgenstern project to a considerable part can be understood as a coincidence of the particular biographies of the two protagonists and the conditions of a world thrown into a global war, a war the roots of which could hardly be understood by traditional political economy – not to speak of a Walrasian equilibrium theory. What is most significant for this project is that it first treats the contradictions that occurred in the real world as well as in the formalizations with an utmost extension of the existing formal apparatus. But if this apparatus proves to be insufficient then the language of this apparatus might have to be changed - at least this seems to be the implicit message of John von Neumann’s own vita leading to the invention of modern computer technology. In the end the project today appears as an enormous attempt to redesign formal modeling of human societies by including what usually is summarized by the notion of *communication*. During the last 60 years actually used communication technologies have profoundly changed our lives often in surprising ways, while the Neumann-Morgenstern project of an adequate theoretical correlate still seems to be far away from catching up with reality. Though the trigger event of their published book seemed to be a satisfactory round-up of the project at least for von Neumann, it nevertheless remained less influential for the social sciences than the immediate euphoric reviews it experienced would have indicated. Von Neumann and Morgenstern only produced one more paper together after its publication, and the further development of the theory fell completely into the hands of mathematicians.

Advantages and Dangers of Narrowing the Focus of Game Theory

In his introduction to the sixtieth anniversary edition of “Theory of Games and Economic Behavior” the mathematician Harold Kuhn contemplating the decades after its publication in 1944 writes: “A crucial fact was that von Neumann’s theory was too mathematical for the economists. … As a consequence, the theory of games was developed almost exclusively by mathematicians in this period.” (Kuhn, 2004). And then he refers to the entry on “Game Theory” written by Nobel Prize Winner Robert Aumann in the *New Palgrave Dictionary of Economics*, where the latter enumerates the following success story of mathematical results in game theory in these years: Nash, Shapley, Gillies, Milnor, Tucker, and Kuhn himself. Since Kuhn was cooperating with Neumann and Morgenstern as a young researcher, he is also truthful enough to admit that these theoretical developments ran counter the theoretical aspirations of the two original authors. He writes:

“It is important to recognize that the results that Aumann enumerated to not respond to some suggestion of von Neumann; rather they were new ideas that ran counter to von Neumann’s preferred version of the theory. In almost every instance, it was a repair of some inadequacy of the theory as presented in the TGEB (The Theory of Games and Economic Behavior, G.H.). Indeed von Neumann and Morgenstern criticized Nash’s non-cooperative theory on a number of occasions.” (Kuhn, 2004).

[17] Only late he had discovered John von Neumann’s growth model (Neumann, 1937) and was rather excited about its links to game theory. In a book published together with Gerald Thompson (Morgenstern and Thompson, 1976) he contributed to the development of the Kemeny-Morgenstern-Thompson model, a generalization of Neumann’s growth model.

This statement allows for an interesting interpretation of what had happened to game theory in the after war period. As many introductory textbooks on game theory today proudly state on the first pages, this discipline can be considered as a proper branch of mathematics. Having developed during the years of rapid formalization of mainstream economic theories of all sorts, during the “golden years of high theory” as some feel inclined to call this period, these mathematical improvements of many ideas of John von Neumann certainly can be considered as progress within the realm of mathematics. To some extent several seemingly new contributions of game theory could be shown to be isomorph to already existing parts of mathematics[18], in other cases game theory did provide a new vista on an already existing mathematical technique. This should not be too surprising since the formal game theoretic framework was built by a traditionally trained mathematician, and since progress in this discipline is brought about by a world-wide community of similarly educated scientists it can be expected that any seemingly new development pops up with limited time delays at different places. Till this is discovered by the scientific community some small idiosyncratic frameworks can take off and certain astonishment occurs as soon as somebody strips off the disguising nomenclature and shows that the essence of two approaches is equivalent. In a scientific discipline like mathematics, which sets itself the goal to be as free as possible from any reference outside its own language, it is not always easy to discover such an isomorphism. There is no physical outside object on which the language is applied and where different language perspectives on this same object are held together by the structure of the object as it is reflected in the different perspectives. Perhaps this is even a more general point than just a characteristic difficulty of progress in highly abstract structural disciplines: Having lost an outside point of reference and being thrown back to a self-defined criterion of consistency such sciences are prone to become quasi-religious believe systems. Standard microeconomic theory is an outstanding example of such a development. The mathematical framework that is used is a non-stochastic version of the mathematical framework that was so successfully applied in thermodynamics. And once the outside physical origin of this framework was forgotten (or even consciously deleted) the independent sprachspiel used in the new domain could sway freely[19] with an aura of eternal validity. Of course, there is always room for additional insight by deduction within the same language, the case of simple syllogisms is telling in this respect. But as Gödel to some embarrassment of von Neumann had proved, there are limits to such success in every possible analytical language[20].

At this point it has to be remembered that von Neumann – and the turn towards an interpretation of game theory as only a branch of mathematics is mainly directed against him, Morgenstern with his non-mathematical socialization was a much less critical admirer of mathematics – was also an engineer, he had studied chemistry at the ETH Zürich in Switzerland. For engineers there always exists a more or less physical object of investigation, and this feature also characterizes some of the turns in John von Neumann’s life. To complement any theoretical result by work referring and using

[18] Kuhn mentions the early success he and his young colleagues had when they showed that mathematically linear programming and the theory of two-person zero-sum games are equivalent. In other cases a difference was just a matter of naming, e.g. ‘dynamic programming’ used in operations research is the same as ‘backward induction’ in game theory.

[19] Wittgenstein’s idea of a parallelism of sprachspiele is just the over-pessimistic downside of his exaggerated and euphoric rigidity in the Tractatus. Languages used as tools can play on both pianos.

[20] Quick as he always was, John von Neumann managed to incorporate contradictions like the wave-particle problem of light, a challenge that had emerged with quantum theory, by providing an additional level of generalization (Neumann, 1996 (1932)). He also quickly had accepted Gödel’s point, though in this case he saw no contradiction there to be repaired; note again the engineering perspective.

the finite tools of the physical world was important. When Neumann encountered difficulties in the (theoretical) mathematical description of hydromechanics he turned to (practical) simulation of partial differential equations, which in turn became the catalyst for his important (theoretical) work on computers. Later, in his last book 'The Computer and the Brain', (Neumann, 2000), he (practically) compares biological processes to (theoretical) problems of the necessary elements of self-reproducing automata. Practice and theory are always intrinsically interwoven. The importance of the engineering perspective is even more pervasive if one looks beyond the monolithic contribution of the Neumann-Morgenstern project. World War 2 has not only lead to a mass emigration of Jewish intelligentsia from Europe to the USA, it also had forced all scientific workers involved in the resistance against the Nazi forces to combine theoretical and practical insights to derive operational devices. Within a short time a collective of researchers was organized not just by military leaders but also by organizations like Bell Laboratories. The most outstanding – all to some extend contributing to the Neumann-Morgenstern project of a new language for the social sciences – have to be briefly mentioned.

One of the most profound innovations for the development of the project came from an American mathematician, Claude Shannon, who surprisingly enough concentrated on stripping communication theory from any reference to semantic content. Shifting the focus from the search for a fundamental framework of essential communication concepts to the engineering perspective of quantification of goal-oriented symbol transmission opened up the exploration of a brand-new set of definitions[21]. Shannon's aspiration was to provide a far-reaching and deep general theory of communication, a historical fact often ignored by authors concentrating on his importance for practical engineering tasks, e.g. adding redundancy to overcome noise in channels[22]. In a paper presented in 1950 at the Conference of Cybernetics (in front of Von Neumann and Norbert Wiener) Shannon[23] proposed to quantify what he called 'information content', H, by a formula, which used the total number of symbols used in communication, n, and the (usually smaller) number, s, sent or received in a particular communicative signal:

$$H = n \cdot \log s$$

This formula assumed that all symbols occur with the same probability, and Shannon showed how to generalize it for a vector of different probabilities p_i :

$$H = -\sum_i p_i \cdot log_2 p_i$$

In this form the information encapsulated in a message could be measured in bits and H was dubbed Shannon entropy.

Despite the omnipresent engineering jargon, it is evident that this quantification constructs a context of purposeful transmission of selected subsets between agents sharing the same alphabet. Shannon's ignorance with respect to any further (semantic) reference leading from a signal to an element outside the symbol set should not entrap to overlook that this type of signal transmission, i.e. communication using an alphabet that is present in the consciousness of sender and receiver, is a

[21] See (Shannon, 1949).
[22] James Gleick's recent book can take the credit to readjust the image of its hero Claude Shannon. (Gleick, 2011)
[23] The formula had been developed shortly before by Nyquist and Hartley.

pivotal characteristic of tribes of living entities. Shannon's extremely rigid formalization cannot escape from being a linguistic foundation for the social sciences. These living entities might use tools to change the form of the signals they use, e.g. telegraphs or computers sending or receiving transcriptions of everyday language, nevertheless outside the context of human societies these entities would not exist – just like a hammer would not be a hammer if it were not a tool with a specified function in human work[24]. Improving the encoding for given capacity limits – bandwidth and time constraints – was the typical engineering task Shannon was trying to accomplish. And under the same stressful wartime conditions as Shannon, von Neumann and Morgenstern in parallel work were developing another piece of the puzzle of decision-making in human societies. Looking at Neumann-Morgenstern utility from the opposite perspective, namely by starting with the view that it is a theory about human individuals[25] and deriving from it the mathematical engineering problem of finding the coincidence of optimal responses explains why the mathematician John von Neumann in his famous paper from 1928 acted as an engineer for parlour games. Only more than a decade later, confronted with the harsh necessities of global warfare and after meeting Morgenstern, the Neumann-Morgenstern project took on shape. For Shannon too, wartime spurred his efforts, his first – secret and unpublished – research paper concerned cryptographic military methods and precluded many results of his famous later work (Shannon, 1949). After the war Shannon and Neumann met at a series of conferences and again the engineering perspective seemed to be the common denominator of the two mathematicians[26].

Another famous scientist present at this series of conferences was Norbert Wiener. Some of his theoretical conclusions were similar to those elaborated by Shannon, but Wiener had less modest views on the implications of his theory of cybernetics on the social evolution of mankind (Wiener, 1948, 1954). While it used to be popular to consider some processes with rigid engineering attitude as a 'black box' - to take the behaviorist position that only inputs and outputs of this black box need to be considered to understand what's going on – Wiener proposed to look into black boxes to turn them into 'white boxes'[27]. In a sense the Neumann-Morgenstern project proposes to take internal model building processes of living entities serious, to open the black box of a stimulus-response reaction pattern and to substitute it by a white box, i.e. the explicit statement of a full-fledged equation system or program[28]. Wartime needs again had been an important motive for Norbert Wiener but there also was an intrinsic methodological imperative, which enlivened Wiener. Like Morgenstern he was deeply opposed to subordinate formalization in the social sciences to the ready-made apparatus used for non-living matter. Primacy of equilibrating forces and increasing entropy had to be challenged:

"We are swimming upstream in a torrent of disorganization, which tends to reduce everything to the heat death of equilibrium and sameness. … The heat death in physics has a counterpart in the ethics

[24] In this perspective, the long-standing dispute concerning communication between computers burns down to the need to use proper definitions for ''communication' and 'tool'.

[25] Methodological individualism might be a typical inheritance brought into the cooperation by Morgenstern, who was still partially rooted in some Jevons-oriented Austrian economics.

[26] An example is the second Conference on Cybernetics: While the electro-mechanical device labeled 'Shannon's Mouse' initiated a discourse on cognition and learning on agent- and system-level, Neumann took the discourse to a broader understanding of the primacy of discrete phenomena in the context of empirically observed 'continuous' biological phenomena.

[27] For a more detailed discussion of Wiener's work see [Hanappi H. and Hanappi-Egger E., 1999].

[28] The important step from dynamic equation systems towards programs was explored by Alan Turing [Turing, 1936] and will be sketched below.

of Kierkegaard, who pointed out that we live in a chaotic moral universe. In this, our main obligation is to establish arbitrary enclaves of order and system. … Like the Red Queen, we cannot stay where we are without running as fast as we can." (Wiener cited in (Gleick, 2011, p.237)).

Norbert Wiener originally had been working in mathematics and probability theory, applying his knowledge – like Alan Turing - during wartime to cryptography. He also had graduated in zoology at Harvard and after the war became more interested in the biological foundations of cybernetics, a scientific research area he had created earlier. Like the mathematician John von Neumann the mathematician Wiener late in his life looked for inspiration in biology to see how human thought processes are conditioned by the physical constraints present in the human brain.

How much the question 'What is Life?' was in the air during the first half of the 20th century can also be seen by taking a look at Erwin Schrödinger's book with exactly that title [Schrödinger, 1944]. Schrödinger too was an outstanding mathematician and physicist and was already famous for having reframed Einstein's theory in wave equations. In this book he provided an interesting answer as to why it is possible that 'arbitrary enclaves of order and system' (see the citation of Wiener above) can be established at all. It is the sheer amount, the mass of tiny atoms in random motion, which can produce its opposite, namely order that is describable by rules[29], by (always stochastic) natural laws. According to Schrödinger order has to occur on both sides of the perception process if understanding shall be possible: on the side of the observed phenomenon as well as on the side of the observer, the human brain. Ideas how order can emerge out of randomness, a topic made prominent much later by Ilya Prigogine (Prigogine, 1984) and Stuart Kaufman (Kaufman, 1993), can be traced back to the first half of the 20th century. For the Neumann-Morgenstern project this implies that the rule set for a formal language of social interaction might mimic a large amount of heterogeneous internal models, only partly stratified by communication and mass media, which nevertheless can lead to an aggregate behavior of the system that exhibits law-like features. A theory of such emergent properties thus is possible; indeed Schrödinger proposes that all theory even in the natural sciences is of precisely this type.

The last personality of particular importance for the Neumann-Morgenstern project is Alan Turing. He had taken up a scientific research program that had been almost forgotten: The work of Charles Babbage and Ada Lovelace aiming at a machine that can carry out complicated human thought processes. Turing, a logician and mathematician, had met Claude Shannon in 1943 at Bell Laboratories when both were successful cryptanalysts, and the two men exchanged some ideas on the possibility of 'thinking machines'[30] – again a sign how important a common global political environment can be. Ten years earlier Turing had started to work on the development of what is called a 'universal machine', a thought model of a device, which should be able to encompass all possible logical deductions. His blueprint, the so-called Turing machine, decades later became

[29] This basic idea had been introduced by Ludwig Boltzmann several decades ago, though not really understood by Boltzmann's contemporaries. It constituted not only a pivotal step in theoretical physics but also advanced probability theory proper. In 1906 - feeling completely misunderstood by his contemporary researchers - Ludwig Boltzmann had committed suicide.

[30] Andrew Hodges, Turing's biographer, writes: "They (Shannon and Turing) found their outlook to be the same: there was nothing sacred about the brain, and that if a machine could do as well as a brain, then it *would* be thinking … This was a back-room Casablanca, planning an assault not on Europe, but on inner space." [Hodgson, 1983, p. 251].

famous[31]. Long before programming became ubiquitous Turing's thought machine already enabled sets of instructions[32], which transformed the state of the machine in discrete steps by a finite set of pre-defined actions. To write down programs, instead of using equation systems as a metaphor for internal model-building is an important ingredient of the Neumann-Morgenstern project, despite the fact that John von Neumann only late in his life seemed to recognize the significance of this turn of style. Even much later, when cellular automata (CA) like 'game of life' became popular, many mathematicians underlined the fact that it has been proven that any CA is equivalent to a traditional dynamic system – the new gadget CA thus being of minor importance for the development of formalisms. John von Neumann, on the one hand turning to computer science and on the other hand recognizing the severe impact, which quantum theory has on the prevailing mathematical apparatus (Neumann, 1996 (1932)) was looking for the evolution of formalisms.

Perhaps this daring great leap towards the future of scientific development can explain somewhat why after the generation of the founding fathers of game theory had disappeared a period of stagnation set in. What had been envisaged entailed a fundamental overhaul of how to do science in the area of social sciences. Since doing science always predominantly involves the use of a scientific language (often including rigid formal elements) the reformulation of this language – the Neumann-Morgenstern project – was amidst a broad and radical scientific reformation project. Though the brightest minds of this wave of scientific revolution produced prophetic vistas on what might be its future, there was no mass movement in 'normal science' (see (Kuhn T., 1962, chapter 2)) that could backup this burst of intellectual energy once its leaders were gone.

The breakpoint to the following epoch of oblivion of the Neumann-Morgenstern project seems to be close to the occupation of the intellectual terrain of game theory by a new cohort of devoted – but differently inspired – young mathematicians. As Robert Leonard insightfully reports, Neumann disliked John Nash (Leonard, 1994). Not just as a matter of personal antipathy but due to a profoundly different methodological approach to the tenets of game theory:

'By the same token (Neumann's refusal to Kuhn's proposal of experimental study of stable sets[33], H.H.), we can understand von Neumann's dismissal of John Nash's 1950 proof of existence of an equilibrium point in a game without coalitions. Given everything we have observed about him, it seems that to von Neumann, the formation of alliances and coalitions was *sine qua non* in any theory of social organization. It is easy to understand why the idea of noncooperation would have appeared artificial to him, … At a Princeton conference in 1955, he defended, against the criticism of Nash himself, the multiplicity of solutions permitted by the stable set: "[T]his result", he said, "was not surprising in view of the correspondingly enormous variety of observed stable social structures; many different conventions can endure, existing today for no better reason than that they were here yesterday.' (Leonard, 2010, p. 245)

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[31] Turing, after being prosecuted and convicted for homosexuality in 1952, committed suicide in 1954 at the age of 42. Like Boltzmann's death, this was an enormous loss for science.

[32] Turing used different words for programming: In a (finite) state table each state was related to instructions that lead to another state. Like Babbage's machine his thought model had memory (a 'tape') and used symbols. With this setting he was able to reproduce, and even to generalize, Kurt Gödel's famous answer to the 'Entscheidungsproblem' mentioned earlier.

[33] Neumann's argument against Kuhn's attempt of what today is called *experimental economics* is interesting – and still true: 'I think that nothing smaller than a complete social system will give a reasonable "empirical" picture [of the stable set solution].' (Leonard, 2010, p. 244)

The project to produce a theory that was able to reveal and to understand the structures existing outside the realm of the formal language (game theory for social structures[34]) was different from what Nash, Kuhn, Shapely, and their colleagues were focusing on. Indeed the following decades saw the development of a type of game theory, which in general immunized itself from all impure influences of empirically observed phenomena[35]. To establish this newly defined discipline as a proper branch of mathematics implied that the two age-old ethical tenets of mathematics - namely to clean its language from any reference outside itself and to reduce its core to the smallest number of statements – became the goals of this type of game theory too.

A comparable development took place in economic theory. Starting with Paul Samuelson's PhD thesis that appeared as a book with the modest title 'Foundations of Economic Analysis' (Samuelson, 1947) the style of mathematics for Newtonian physics, i.e. calculus, started to reign over economic content – Neumann's cynic statement ' There's no sense in being precise when you don't even know what you're talking about.' was forgotten. What the proponents of the new era later proudly proclaimed as the Golden Age overcoming the Keynesian 'years of high theory' (see (Shackle, 1967)), for economic theory from the perspective of the Neumann-Morgenstern project has been a dark age. But it has to be noted that the retreat of economic theory-building into an ivory tower of mislead, self-referring dream-worlds had been possible – even necessary – because of the pragmatic take-over of the decision-making process in Western economies by political business men. In the tremendous capitalist growth process, the reconstruction possible after WW2, not much advice from outside the business community was needed. At best, economic theory should legitimize ex post what was in the interest of the business community anyway, or at least it should involve bright but potentially critical social scientists in tedious – but economically void – theoretical disputes. In hindsight it is thus not surprising that until the late 70-ties John von Neumann's and Oskar Morgenstern's epochal project became a Sleeping Beauty[36].

Renaissance of the Neumann - Morgenstern – Project

It is a rather revealing coincidence that the renaissance of the Neumann-Morgenstern project started just a few years after the first severe and synchronized crisis in Western economies since the end of WW2 – at the beginning of the 80-ties. With the breakdown of the fixed-exchange rate system in 1971 and the two oil price crises induced by this event the world economy went into troubled waters again. A more pronounced economic policy stance was needed, and as the largest Western countries just had elected conservative leaders – Margaret Thatcher, Helmut Kohl, and Ronald Reagan – economic theory mainly should prove that policy has only to assure that the free interplay of market

[34] For an engineer – von Neumann's alter ego - this outside reference of theoretical work might be any material object of investigation.

[35] The history of game theory was re-interpreted as the history of theories resembling the Nash-equilibrium. Till today the respective parts of most textbooks use this distorted perspective, e.g. (McCain, 2009). This looks even stranger if one is aware that competing equilibrium concepts like Steven Bram's 'Theory of Moves' (Brams, 1994, 2011) are in no respect inferior to Nash's equilibrium view.

[36] If a scientific field is in deep crisis, as is the case in the social sciences now, the theoretical revolution that forms a new consensus usually consists of a set of different lines of attack on the old paradigm. Some of these lines - before entering a coalition with another line to produce what Schumpeter called a *new combination* – are able to refer back in history to an already existing piece of theory that just has to be updated, awakened. This is why the metaphor of the Sleeping Beauty occurs repeatedly in recent literature (see (Kurz, 2011)).

forces suffices to establish maximum welfare. The *neoclassical synthesis*[37], which accompanied the first decades of growth after 1945, was augmented by an element of hyper-rationality: the rational expectations (RE) hypothesis. Macroeconomic dynamics on the basis of RE move even further away from any possible relation to actually observable economic processes. Culminating in Nobel Prize winner Thomas Sergeant's famous textbook on macroeconomic theory (Sargent, 1980) this 'New Classical Macroeconomics' as he prefers to call it, is characterized by the inclusion of a full-fledged internal model-building process that takes place – or better: in equilibrium always has already taken place – in an infinite number of microeconomic units. It clearly is a step towards game theory. The assumptions that (1) all these internal models are identical, are (2) also equivalent to the actual working of the economy, and that (3) every micro agent knows about the first two properties, constitute the RE hypothesis. It evidently is an extremely degenerated case of what John von Neumann had in mind when he talked about modeling stable social constellations. The usual excuse for the 'heroic assumptions'[38] of RE is that less primitive assumptions would lead to insurmountable technical difficulties. This argument barely could hide the fact that popularity and worldwide streamlining of economic theory along the lines of RE was due to its applicability as underpinning for conservative economic policy in the early eighties[39]. In the end, the analytical apparatus had become more cumbersome, attracted (and partly destroyed) more intellectual capacity of potentially creative economists, and was even less in danger to interfere with any actual policy measure[40] – except the permanent unspecified call for more privatization.

It is not surprising that the impetus for a revival of the Neumann-Morgenstern project came from a completely different side, from more engineering inclined areas. The first area was biology, in particular the work done by John Maynard-Smith on evolutionary game theory (Maynard-Smith, 1982, 1988). Experiments in biology had lead researchers to find stable constellations of different behavioral traits within and across species, which allowed for a game-theoretic explanation. It seemed that certain animal populations, like some spiders, as a whole act like a (fictitious) conscious brain of the species would do if it was aiming at maximum reproductive success. Once biologists had jumped on the train of game-theoretic modeling they brought a lot of new ideas on how to extend the narrowed down perspective of standard mathematical treatment.

The second interesting impact on the topics addressed by the Neumann-Morgenstern project came from chemistry and concerned the equilibrium concept. As Ilya Prigogine showed, living systems building-up ordered structures are characterized by processes far away from thermodynamic equilibrium (Prigogine, 1984). Social science as a theory of the particular living system of the human species thus should be based on models that account for such non-equilibrium processes. The general time-profile of the evolution of living structures therefore rather resembles a sequence of diverging trajectories held together for some time by in-built stabilizers (e.g. institutions), intermitted by substantially shorter periods of revolutionary metamorphosis during which relations and elements

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[37] The proclaimed *synthesis* was always a misnomer. The project of a micro-foundation of a neo-classical macroeconomics had failed dramatically.

[38] Why a theorist shall be considered as a hero if he/she makes assumptions that inhibit their testing remains hidden in what some mathematical circles consider to be their sense of humor.

[39] In 1980 the original idea of RE was already 20 years old and can be found in a paper by John Muth (Muth, 1961).

[40] Policy was left to 'Practical men, who believe themselves to be quite exempt from any intellectual influences …. Madmen in authority, who hear voices in the air …', as Keynes had put it so aptly in 1936 (Keynes, 1936, p. 383).

vanish and emerge (e.g. by coalitions leading to *new combinations*). This time-profile of living structures, which describes the temporary and spatially limited build-up of neg-entropy, takes place in front of, even opposing, the non-living environment, which is governed by thermodynamic convergence towards maximum entropy. The language of the human species - and game theory can just be a specialized scientific language – has to follow the time-profile of living structures and will not follow the monotone convergence to equilibrium of non-living matter. John von Neumann seemed to have had in mind just the first step of this evolutionary process[41], the production of variety, when he insisted on the importance of his stable set concept and refused the search of a unique equilibrium point. Instead of going for a quest to discover a 'true' solution he turned to the invention of new methods to explore variety, he turned to computer simulation. Today the new discipline of econophysics offers a rich set of knowledge that might help study the evolution of living systems right from analogues to their emergence at bio-chemical roots: Spirals of emergence of variety, selection and extinction of some elements, then emergence of variety at the next level again; all that in parallel and in different (fractal) time scales and spatial dimensions[42]. This is the new methodological background that has emerged, and now waits to challenge those who try to revive and to expand the Neumann-Morgenstern project. It is becoming part of a broader social science, of evolutionary theory[43]. In this broader project the original vision of early game theorists of a new combination of cooperation and conflict will be an important guidance[44].

Finally computer science itself contributes substantially to the new appeal of the Neumann-Morgenstern project. Computer simulation had been crucial for the re-emergence of evolutionary economics in 1982, when Richard Nelson and Sidney Winter published their now famous book on the subject (Nelson and Winter, 1982). Simulation made it possible to 'formalize' heterogeneous micro- and meso-agents in an economy; finally the straight-jacket of mathematical treatability could be disposed of. Experiment by simulation became the correlate to the successful experimental methods in the natural sciences[45], an area not to be confused with the type of experimental economics, which uses observations of reactions of human individuals in test laboratories to produce hypothesis on innate economic traits. But computer simulation methods had an even wider impact on the new Neumann-Morgenstern project. To mention a further area that really exploded due to increased computation capabilities a look at network theory is mandatory (see (Newman, 2010)). 'Games on networks' as well as the evolution of networks in the form of dynamic games are part of a scientific sub-discipline that attracts an ever growing community of researchers. Finally it is remarkable that computer support today is providing an enormous amount of socioeconomic data right to the fingertips of social scientists, a working environment that at the times of Neumann and Morgenstern simply did not exist. The missing centuries of works of a Tycho de Brahe and his colleagues who

[41] Following Herbert Simon an evolutionary process can simply be summarized as consisting of two elements: (1) the generator of variety, and (2) a test selecting the survivors. (Simon, 1969, p. 52)

[42] Fractal analysis in the social sciences promises to improve the understanding of the build-up of self-similar structures (see (Mandelbrot, 1983), (Brown, 2010)).

[43] Evolutionary theories for the social sciences are themselves a heterogeneous variety, often using slightly different names for similar concepts. E.g. Kurt Dopfer and Jason Potts propose a general theory of economic evolution based on 'a process of coordination and change in rules.' (Dopfer and Potts, 2008, p. xii). The ideas of cooperation, conflict, and algorithmic formulations are shining through, but details how to model them are still a matter of controversy among evolutionary economists.

[44] The focus on cooperative aspects had been lost not only by those following John Nash (compare (Strathern, 2002, pp. 293-327)) but also by some biologists, e.g. Richard Dawkins, producing some semi-economic metaphors of 'selfish genes'.

[45] Compare (Hanappi, 1994, p. 171 -175) and (Hanappi, 2011) for a discussion of simulation methods.

prepared the ground for theoretical physics (as explained in the introductory chapter of (Neumann and Morgenstern, 1944)) can certainly not be replaced by these technical facilities - but they can be shortened.

To enumerate all the different currents of thought and scientific sub-disciplines, which will in the near future lead to an even more visible renaissance of the Neumann-Morgenstern project goes beyond the aspirations of this author – and surely beyond the scope of this chapter. John von Neumann died in 1957, Oskar Morgenstern in 1977, approximately half a century after they left the active debate of their project, and after many decades of more or less subconscious influences of their masterpiece on the general intellectual climate, the current crisis in the social sciences seems to be prepared for a fulminate comeback of the Neumann-Morgenstern project.

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