Reinhard Selten

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1994

Autobiography

I was born in Breslau on October 5th, 1930. At that time, Breslau, now called Wroclaw, belonged to Germany and only German was spoken there. After the second world war Breslau became Polish and the original German population was almost completely replaced by a Polish one. I have never visited Wroclaw after the war. Heavy fighting destroyed most of the town in which I grew up and most of the familiar places of my youth look different now.

When I was born my father owned a business called a "reading circle"; folders containing an assortment of magazines were lent to customers for one week, then recollected and lent out again. The older the folder, the lower was the fee. This was a florishing branch of industry. My father had built up his business in spite of the fact that he became blind at young years and had only three years of school education. Already in the mid-thirties he had to sell his firm because of his Jewish origin. Jews were forbidden to run a business connected to the press. My father did not belong to any religous community and my mother was a protestant. Originally my parents intended to let me grow up without any attachment to a particular religion in order to give me the opportunity to decide for myself later in my life. However, under the prevailing political circumstances it seemed to be better to have me baptized as a protestant. The ceremony is one of my early memories. Much later as a young man I left the protestant church and became unattached to any religion again. Unlike several other relatives my father did not become a victim of the holocaust, since he died after a serious illness already in 1942 before the worst of the terror began.

It was not easy for me to live as a half-Jewish boy under the Hitler regime. When I was 14 I had to leave high school and the opportunity to learn a trade was denied to me. The only career open to me was that of an unskilled worker. Fortunately it turned out that this did not matter much since after about half a year my mother, my brothers, my sister, and I left Breslau on one of the last trains before all outbound railway traffic stopped.

My situation as a member of an officially despised minority forced me to pay close attention to political matters very early in my life. Moreover I found myself in opposition to the political views shared by the vast majority of the population. I had to learn to trust my own judgment rather than
official propaganda or public opinion. This was a strong influence on my intellectual development. My continuing interest in politics and public affairs was one of the reasons why I began to be interested in economics in my last high school years.

After we left Breslau we were refugees, first in Saxonia, then in Austria and finally in Hessia. Until schools opened again in 1946 I worked as a farm boy, first in Austria and later in the village in Hessia where we lived. In 1947, we moved to Melsungen, a small town in which I went to high school until 1951. In these years I developed a strong interest in mathematics. When we still lived in the village near Melsungen, I had to walk to school which took about three and a half hours there and back. During these walks I occupied my mind with problems of elementary geometry and algebra. I still like to hike in forested hills and to think while walking.

When I finished high school, it was clear to me that I would study mathematics, even if I also considered economics and psychology. It took me relatively long to reach my master's degree in mathematics. My studies were not sufficiently concentrated on this goal. One of the reasons was that I went to many lectures which had nothing to do with my study of mathematics. However, it later turned out that some of these extracurricular activities became important for my career. I studied mathematics at the university of Frankfurt from 1951 to 1957. Until I completed my "Vordiplom", the intermediate examination which roughly corresponds to the bachelor's degree, I also had to study physics. Originally I considered to take astronomy as a minor for my master's degree and I actually spent much time trying to get some knowledge of this field but now almost everything is forgotten. What finally turned me away from astronomy was that I became more and more involved in game theory and economics. I am grateful to the Natural Science Faculty of Frankfurt University for the decision to permit mathematical economics

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as a minor for the master's degree in order to enable me to be the first one to take this choice.

My first contact with game theory was a popular article in Fortune Magazine which I read in my last high school year. I was immediately attracted to the subject matter and when I studied mathematics I found the fundamental book by von Neumann and Morgenstern in the library and studied it. Somewhat later I saw the announcement of a student seminar for economists on game theory, headed by Professor Ewald Burger who taught advanced mathematical courses but also mathematics for economists. I participated in the seminar and Ewald Burger gave me the chance to write a master's thesis in cooperative game theory. He was a man of extraordinary mathematical erudition and an excellent teacher. I owe much to his guidance and to his patient advise.

My master's thesis and later my Ph.D. thesis had the aim of axiomatizing a value for e-person games in extensive form. This work made me familiar with the extensive form, in a time when very little work on extensive games was done. This enabled me to see the perfectness problem earlier than others and to write the contributions for which I am now honored by the prize in memory of Alfred Nobel.

After I had received my master's degree in 1957, I was hired by Professor Heinz Sauermann, an economist at the University of Frankfurt am Main, who employed me for ten years in various assistant positions. It was my task to do research funded by Deutsche Forschungsgemeinschaft, the German counterpart of the National Science Foundation. At first I was supposed to apply decision theory to the theory of the firm, but soon I became involved in economic laboratory experimentation. Fortunately the referees of Sauermann's research proposals approved of this new research direction. This made it possible to finance a small group of young people doing experimental research. Sauermann had about 15 assistants and only two to four of them were involved in experiments. I became something like a foreman of this small detachment. Reinhard Tietz, Volker Haselbarth, Otwin Becker, Klaus Schuster and others belonged to it for longer or shorter periods.

Heinz Sauermann was a remarkable man. He was one of the first to propagate Keynesianism in Germany. In spite of a lack of mathematical training he encouraged his students to do work based on formal models. He always had a good feeling for the trends of the field and therefore was very successful in suggesting the right problem areas to those who did research under his supervision. Moreover he was an excellent administrator and scientific organizer, who did much for the propagation of experimental economics. I owe much to him.

In 1959, I married Elisabeth Langreiner, who for all the years since then helped me to become the person I am now. We would have liked to have children but we do not have any. We both belong to the Esperanto movement and this is how we met. The international language Esperanto has still an important influence on our life.

My first publication was a journal article with the title "Ein Oligopolexperiment" (an oligopoly experiment) written together with Heinz Sauermann and published in 1959. When we began to do experimental economics at Frankfurt, such a field had not yet existed. My attempts to learn some psychology while I studied mathematics had made me acquainted to experimental techniques. I had listened to lectures of the gestalt psychologist Edwin Rausch, who was a careful experimenter, and I had participated in psychological experiments as a subject. Therefore it seemed natural to me to try an experimental approach to oligopoly.

In 1961, I received my Ph.D. in mathematics at the University of Frankfurt am Main. Shortly afterwards Oskar Morgenstern made it possible for me to participate in a game theory conference at Princeton. In the late 50s - I do not remember the year - he had given a talk at Frankfurt and my remarks in the subsequent discussion must have impressed him. In the following years he sometimes asked me to meet him when his travels brought him to Frankfurt. He also gave me financial support for staying several weeks longer at Princeton after the game theory conference. My short visit to Princeton was important for my life since it gave me the opportunity to interact with R.J. Aumann and M. Maschler who were members of Morgenstern's research group at that time.

Around 1958, I became aware of H.A. Simon's seminal papers on bounded rationality and was immediately convinced by his arguments. I tried to construct a theory of boundedly rational multigoal decision making. Together with Heinz Sauermann, I worked out an "aspiration adaptation theory of the firm" which was published as a journal article in 1962. After the Princeton conference in 1961, I visited Pittsburgh for two days in order to establish contacts with H.A. Simon and his associates. The problem of bounded rationality has occupied my mind for a long time but unfortunately with less success than I had hoped for. More and more I came to the conclusion that purely speculative approaches like that of our paper of 1962 are of limited value. The structure of boundedly rational economic behavior cannot be invented in the armchair, it must be explored experimentally.

In the early 60's I had run experiments on an oligopoly game with demand inertia. A game theoretical analysis of this model proved to be too difficult but I was able to solve a simplified version. I found a natural equilibrium but the game has many other equilibria. In order to describe the distinguishing features of my solution, I defined subgame perfectness. My paper, *Ein Oligopolmodell mit Nachfrageträgheit* (An Oligopoly Model with Demand Inertia) was published in 1965. At that time I did not suspect that it often would be quoted, almost exlusively for the definition of subgame perfectness. Very soon it became clear to me that the perfectness problem is not completely solved by this concept. Therefore in a paper published in 1975, I defined a refined notion of perfectness, now

often referred to as trembling hand perfectness.

In 1965, I was invited to a game theory workshop at Jerusalem which lasted for three weeks and had only 17 participants, but among them all the important researchers in game theory, with few exceptions. Game theory was still a small field. We had heated discussions about Harsanyi's new theory of games with incomplete information. This was the beginning of my long cooperation with John C. Harsanyi. Not long after the conference I became a member of a group of game theorists hired by the research firm MATHEMATICA to work on projects for the Arms Control and Disarmament Agency. The group often met for several days near Washington D.C.. I cooperated with John C. Harsanyi on bargaining under incomplete information, but I also did other work on models of nuclear deterrence. The group did not produce anything of practical value for the Arms Control and Disarmament Agency, but nevertheless it was very successful because important theoretical advances, e.g. in the analysis of repeated games of incomplete information by Aumann, Maschler, and Stearns were made there.

In Germany the Ph. D. is not yet the last formal requirement for a career as a university teacher. In addition to this, one is expected to work towards a "habilitation". For this purpose one presents a habilitation thesis, often a monography of an area of research. The habilitation is a permission to lecture independently. In my case the habilitation thesis was a monography on multiproduct pricing. In the academic year of 1967/68 I was visiting full professor at the business school of the University of California, Berkeley. I had completed my habilitation thesis shortly before I left to Berkeley and was habilitated when I came back. In 1970 my habilitation thesis was published as a book.

In 1969, I accepted an offer of the Free University of Berlin, where I was a full professor of economics until 1972. My wife and I liked to live in West Berlin. In these years Germany experienced a period of student unrest, which made teaching difficult and sometimes impossible. The student movement was especially strong at the Free University, but this was not the reason why I moved to the University of Bielefeld in 1972. I was attracted by plans to create a big Institute of Mathematical Economics. However, these plans could not be realized since it finally turned out that the money was not available. Eventually a small institute with only three professors was established. I was not unhappy with this solution since I succeeded to convince the appointment committee that all positions should be held by game theorists. The positions were filled by Joachim Rosenmuller, Wulf Albers, and myself. The concentration on game theory gave us a chance to get some international reputation.

My years at the University of Bielefeld were a productive time. My experimental research continued but I mainly worked on game theory and its application to industrial organization and other areas. After John Harsanyi and I had completed our work on bargaining under incomplete information we decided to attack the problem of selecting a unique equilibrium for every game. He twice came to Bielefeld for a year and I often visited Berkeley for short periods of one or two months. It took us about 18 years to construct a reasonable general theory of equilibrium selection in games. In this time we considered many ideas and rejected two fairly well worked out approaches. Our book of 1988 only describes the theory we finally agreed upon.

On my frequent visits to Berkeley I also had a cooperation with Tom Marschak which resulted in a book on multiproduct pricing published in 1974. I also did experimental work on bargaining under incomplete information together with Austin Hoggatt and his younger associates. In the basement of Barrows Hall at the University of California, Berkeley, Austin Hoggatt had built up the first computerized laboratory for experimental economics. There our experiments were run.

In the twelve years I spent at Bielefeld, I began a close cooperation with Werner Guth, who in some sense is one of my students, even if we never held positions at the same university. We worked on applications of the equilibrium selection theory by John Harsanyi and myself, long before it had reached a final form, but we also did research on other problems like wage bargaining in the framework of a business cycle model. Also other people who later became university professors sometimes came to Bielefeld to seek my advise, namely Ulrike Leopold from Graz, Joel Moulen from Lyon, and Eric van Damme from Eindhoven. Ulrike Leopold also worked on the application of equilibrium selection theory and I wrote some papers together with her. Joel Moulen did Ph.D. work on cooperative game theory and became a professor of mathematics at Jaounde, Kameroun. Eric van Damme needed very little advise and is now a well known game theorist.

One of my students, Jon-ren-Chen, a Taiwanese who was my assistent for many years, has never worked on game theory. He does applied econometric research on international trade and development. He was habilitated at Bielefeld and is now a Professor of Economics at Innsbruck. A student of mine, Rolf Stoecker, who was a promising young experimentalist left me after his Ph.D., joined an insurance company and became its chief executive after 5 years. Later something similar happened to me again in Bonn. My assistent Gerald Uhlich who had done important experimental work on coalition bargaining left the university after his Ph.D. and became the second man in a furniture textile factory. Nevertheless I still nourish the hope that some of the students who now work on experimental economics under my guidance will become university teachers.

At the University of Bielefeld, cross fertilization between different fields is favored by the existence of a unique institution, the center for interdisciplinary research. Talks given there brought me into contact with biologists who made me aware of applications of game theory to biology. A young mathematician, Peter Hammerstein, who had a junior position as a statistical advisor in the biology department made me accquainted with the notion of evolutionary stability. From that time on I developed a strong interest in biological game

theory. One of my contributions to this field is the investigation of evolutionary stability in extensive games. However, I also wrote other papers in this area, some with Peter Hammerstein and others with Avi Shmida, a botanist at the Hebrew University of Jerusalem, with whom I cooperate on theoretical models of pollination of flowers by bees. Peter Hammerstein is now a well established theoretical biologist. Another student of mine, Franz Weissing, also started a career as a university teacher of biology.

I find it very interesting to cooperate with scientists in different fields who have little mathematical training but much substantial knowledge. My first experience of this kind was my cooperation with the political scientist Amos Perlmutter with whom I developed the scenario bundle method, a systematic way of constructing simple game models of concrete international conflicts. Unfortunately the results of our research have never been formally published. It is the advantage of this kind of interaction that the judgement of the expert on the empirical facts is not yet contaminated by mathematical models. I had a similar experience with Avi Shmida, even if he as a natural scientist is not quite as unmathematical.

I am grateful to Avi Shmida, not only for his scientific cooperation but also for another reason. Before I came into contact with theoretical problems in botany I hardly could distinguish any flower from any other one. However, I felt that I could not really do work on pollination problems without learning at least a little of the art of recognizing wild flowers. Since then I always carry a flower book on my hikes, except in the winter. I enjoy my often frustrated efforts to identify wild flowers. This activity has opened my eyes to the astonishing diversity and the marvelous beauty of flowering plants.

In 1984, I moved to the University of Bonn, where I am a Professor of Economics since then. I liked the interdisciplinary atmosphere at the University of Bielefeld, but I wanted to build up a computerized laboratory for experimental economics and Bonn was willing to offer me much better conditions in this respect. I came back to Bielefeld for the time from October 1, 1987, to September 30, 1988, in order to act as the organizer of a research year on "game theory in the behavioral sciences" at the center for interdisciplinary research. The cooperation of an international group of participants with backgrounds in economics, biology, mathematics, political science, psychology, and philosophy finally resulted in four volumes on "game equilibrium models" published in 1991.

At the University of Bonn my work and that of most of my assistants is concentrated on experimental economics. It is our goal to help to build up a descriptive branch of decision and game theory which takes the limited rationality of human behavior seriously. The financial support of the Deutsche Forschungsgemeinschaft in the framework of the Sonderforschungsbereich (special research unit) 303 enables us to work in this direction.

In 1991, it was discovered that both, I and my wife, suffer from diabetes. Probably we had this disease for some time without knowing it. As as consequence of diabetes my wife lost both legs up to the knee. Therefore she is now bound to the wheelchair. Moreover her eyesight has become very bad. Nevertheless she does many things in the house, even if everything takes much longer than it used to. She cooks and takes care of our three cats and, what is most important, she maintains a cheerful attitude towards life. We have learnt to adjust to our situation.

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This autobiography/biography was written at the time of the award and later published in the book series *Les Prix Nobel*/*Nobel Lectures*. The information is sometimes updated with an addendum submitted by the Laureate. To cite this document, always state the source as shown above.