TI 2007-005/1
Tinbergen Institute Discussion Paper

What Simon says

Floris Heukelom

Universiteit van Amsterdam, and Tinbergen Institute.

Tinbergen Institute
The Tinbergen Institute is the institute for economic research of the Erasmus Universiteit Rotterdam, Universiteit van Amsterdam, and Vrije Universiteit Amsterdam.

Tinbergen Institute Amsterdam
Roetersstraat 31
1018 WB Amsterdam
The Netherlands
Tel.: +31(0)20 551 3500
Fax: +31(0)20 551 3555

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Most TI discussion papers can be downloaded at http://www.tinbergen.nl.

What Simon Says

Floris Heukelom
November 2006

Abstract

This paper provides an overview of the work of Herbert Simon and his ideas about rational decision making. By his own standards, Simon is an economist who works in the tradition of Adam Smith and Alfred Marshall. The central theme in Simon's research is how human beings organize themselves in different structures of distributed decision making in order to achieve a degree of rationality that is higher than which can be attained by the individual. In this realm his main preoccupation are hierarchic organizations such as the business firm and the computer. Simon sharply contrasts his views with the EUT, the dominant view on rational decision making in economics and other social sciences.

Introduction

This paper provides an overview of the different aspects of Simon's theory of rational decision making. These aspects are often closely intertwined, but an attempt is nevertheless made to distinguish the different issues involved. The first section introduces Simon's work and positions him in the scientific landscape. Rationality and irrationality are discussed in the second section, rationality and decision making in the third. The fourth section shows how Simon positions himself with respect to other theories and theorists of rational decision making. Simon's scientific tools are discussed in the fifth section. Concluding remarks end the paper.

1. Who's Simon? Is Simon an economist? What is economics?

Herbert Simon was born in 1916 and died in 2001. Although not trained as an economist, he devoted large parts of his scientific work to economics and theories of rational decision-making. As sources of intellectual influence he mentions his uncle Harold Merkel who made him familiar with the ideas of John R. Commons. Books that satisfied his curiosity in economics while still at high school included amongst others Ely' economic textbook *Outlines of Economics* (1893/1932). At the University of Chicago, Simon further explored the social sciences, especially economics and political science, and along this took extensive training in mathematics, symbolic logic, and mathematical statistics. Teachers that mostly influenced his scientific thinking include the econometrician and mathematical economist Henry Schultz, and the logician Rudolf Carnap[1].

From his first scientific publication in 1937 until the last in the year of his death, Simon has been a highly productive and diverse scientist. A count of his publications runs beyond the 650, and his contributions, as emphasized by many, "are extremely vast and diverse, ranging from philosophy and methodology of science, applied mathematics, through various aspects of economics, computer science, management science, political science, cognitive psychology to the problem of human problem-solving behaviour"[2].

[1] Simon (1978). It was not feasible to read all, or even most of what Simon has written (although I know a person who claims to have read everything Simon has ever published). I have therefore focused on what may be considered to be the main body of his research; mostly the articles that are collected in the different well-known books. For this reason, the references to these articles are references to the collected works, and not to the original article. The reader can of course obtain the original literature by consulting the collected volumes.

[2] Boumans (2001), p.75

Just how vast and diverse Simon's work is, becomes clear when we categorize and quantify his scientific publications[3]. The total number of Simon's publications is 684. When these publications are categorized along some standard scientific boundaries and publishing formats, the following table can be drawn.

	A	B	C	D
Economics	36	25	1	17
Social Psychology	4	2	0	0
Cognitive Psychology	102	114	8	24
Computer Science	28	39	1	15
Political Science	38	19	4	12
Mathematics And Statistics	9	9	0	8
Philosophy	24	19	3	6
Business and Organization	47	24	5	18
Sociology	5	1	0	6
Biology	2	2	0	0
Engineering	5	1	0	1

Table 1

A = Articles, B= Books- and proceedings-sections, C=Books, D=Other, see the appendix for more details.

Simon's contributions to these different scientific disciplines are distributed relatively equally over time, although a gradual shift can be observed from an emphasis on political science and business and organization early in his career, to a relative emphasis on cognitive psychology later in his career.

Books Simon has written or of which he was (one of) the editor(s) are the following. Between the age of twenty-two and seventy-five, Simon published a book every two and a bit years.

[3] The following numbers and figures bear on research that is described in detail in the appendix

Measuring Municipal Activities (1938)
Determining Work Loads for Professional Staff in a Public Welfare Agency (1941)
Fiscal Aspects of Metropolitan Consolidation (1943)
Administrative Behavior (1947)
Local Planning Administration (1948)
Public Administration (1950)
Centralization vs. Decentralization in Organizing the Controller's Department (1954)
Models of Man (1957)
Organizations (1958)
The new science of management decision (1960)
Planning production, inventories, and work force (1960)
Essays on the structure of social science models (1963)
The shape of Automation (1965)
The sciences of the Artificial (1969)
Human Problem Solving (1972)
Representation and meaning: experiments with information processing systems (1972)
Skew Distribution and the Size of Business Firms (1977)
Models of Discovery (1977)
Models Of Thought (vol.1) (1979)
Models of Bounded Rationality (vol. 1&2) (1982)
Reason in Human Affairs (1983)
Protocol Analysis (1984)
Scientific Discovery: Computational Explorations of the Creative Process (1987)
Models of Thought (1989)
Models of my Life (1991)

One may be tempted to assume that such a vast and diverse list of publications can only be accomplished by cooperating with many other authors. And although Simon certainly collaborated on numerous projects with other researchers, he mostly worked alone, and of most of his publications he is the sole author. When we put all the publications together and count the number of publications of which he is the sole author, and the names and numbers of co-authored publications, we obtain the following results (showing only the five most important collaborators).

	# publications
Sole author	456
Newell, A.	39
Ridley, C.E.	17
Langley, P.	11
Gobet, F.	10
Feigenbaum, E.A.	10

Table 2
See the appendix for more details

It is no exaggeration to conclude that Simon "is a bit beyond the norm", and that "none can match him"[4].

At the same time it should be noted that however vast and diverse Simon's contributions, they always have to do with one and the same theme: rational decision behavior. Indeed, Simon is the first to note that "what appear[s] to be scatteration [is] really close to monomania"[5], and that the conception of the individual decision-maker as boundedly rational guided and formed the basis of his "whole scientific output"[6]. This focus on one central topic disguised as a vast and diverse body of work has inspired some historians to understand Simon as the ultimate brain behind all that is wrong in our contemporary western societies. Thus Mirowski vehemently argues that "Herbert Simon is one of the most egregiously misunderstood figures in the history of modern economics"[7], and that "Simon has demonstrated all the talent of the successful espionage agent: he can *pass* under almost any circumstances. It is no accident he is a specialist in *intelligence* and the sciences of the artificial."[8]

Agreeing with Mirowski's enthusiasm for Simon while at the same time remaining on firmer ground, we may pose the question whether Simon in all his focused vastness is an economist, for it is intriguing that Simon has very clear ideas about what is economics and writes about economic issues throughout his entire career, yet never explicitly claims himself to be an economist. Simon is always writing about economics, but also always against economists. More on this theme will

[4] Simon (1977), Editorial Preface
[5] Simon (1957), p.viii
[6] Simon (1991), p.88
[7] Mirowski (2002), 45
[8] Mirowski (2002), p.454, his emphasis

follow below, but one explanation for this apparent paradox is the Simon's definition of economics and other sciences.

Simon's definition of what constitutes economics differs from the often-used definition of Lionel Robbins. In this definition, "Economics is a science which studies human behavior as a relationship between ends and scarce means which have alternative uses."[9] For Simon, "Broadly speaking, economics can be defined as the science that describes and predicts the behavior of several kinds of economic man – notably the consumer and the entrepreneur."[10] The difference is subtle but important. Where Robins defines economics as a specific view, a principle, of economic behavior, Simon defines economics as investigating economic behavior. At the risk of gross oversimplification, it is the difference between economics as applied political science, and economics as applied psychology. Simon is aware of the fact that his definition of economics is but one held among economists, and not necessarily the most common. His definition, as every definition, defines as much what economics is, as it defines what economics should be: "While perhaps literally correct, this definition does not reflect the principal focus in the literature of economics."[11]

With this definition of economics, Simon considers himself to stand in a tradition of Marshall[12], and considers economics thus conceived to stand in a direct relation to other sciences, both the natural, the social and the artificial sciences. Social sciences, to start with, are about human behavior. The fact that economics has economic behavior as its object of investigation makes it but one among a number of social sciences investigating human behavior. Moreover, the boundaries between the different social sciences are not clear-cut, theories or explanations that hold for one type of behavior may sometimes also be applied to others types. Indeed, such interdisciplinarity is something that should be aimed for.

> "Economic behavior, family behavior, political behavior, and organizational behavior are all forms of human behavior. Each can be explained partly in relatively general terms that cut across these categories, and partly in terms that apply only to a particular area of behavior. The fruitfulness of the interaction between economics and other social sciences hinges on whether

[9] Robbins (1932)
[10] Simon (1982,II), p.287
[11] Simon (1982,II), p.287
[12] Simon (1987), p.

> the same mechanisms operate in all these areas of behavior, and on how far human behavior in one area is relevant for theories in others."[13]

Especially the relation between psychology and economics is interesting since both partly investigate the same behavior. Both economics and psychology investigate rational decision behavior of individuals under certainty and uncertainty. It is according to Simon no more than natural that the twain should meet where they did not for a long time. The two exist to create and stimulate one another.

> "Recent years have seen important new explorations along the boundaries between economics and psychology. For the economist, the immediate question about these developments is whether they include new advances in psychology that can fruitfully be applied to economics. But the psychologist will raise the converse question – whether there are developments in economic theory and observation that have implications for the central core of psychology"[14]

One may even go a step further and understand Simon to imply there to be a necessary relation between psychology and economics. Psychology's general theories of human behavior (should) necessarily have an impact on the specific behavior economics is interested in.

> "Psychology enters economics through the characteristics that are postulated for the several subspecies of economic man. These subspecies include (1) the buyer or seller of commodities in a market, (2) the entrepreneur or producer, (3) the consumer, and (4) the worker. In certain areas of economic theory the categories overlap, but they are convenient for classifying and examining economic man."[15]

On a higher level Simon distinguishes between the natural science and what he labels the "sciences of the artificial". Natural science is defined as "knowledge about

[13] Simon (1982), p.318
[14] Simon (1982, II), p.287
[15] Simon (1982, II), p.318

natural objects and phenomena"[16], which can roughly be understood as the common, everyday understanding of natural science. An important characteristic of natural science, according to Simon, is that natural science is only descriptive, as opposed to the artificial sciences, which are both normative and descriptive: "Natural science has found a way to exclude the normative and to concern itself solely with how things are"[17] The sciences of the artificial are, as the label suggests, sciences that investigate the artificial; that is, everything that is created by man, including computers, political ideas and Yellowstone national park. More specifically, the artefact has four characteristics: 1) it is synthesized by man (though not necessarily intentionally), 2) it may imitate natural things while lacking its "reality" (the trees in a park for instance), 3) it can be characterized in terms of functions, goals, and adaptation, and 4) it is being discussed in terms of descriptives *and* imperatives.[18] The sciences of the artificial basically comprise the social sciences and sciences concerned with "designing", such as engineering.

Thus, for Simon there is a clear and direct relation between economics, which is about economic behavior, and other social sciences, which are about other types of behavior. The relation is even stronger when one realizes that explanations of behavior may cover different types of behavior. The economist and political scientist, for instance, may and should find one another when it turns out that theories about consumer behavior are compatible, or even only related, to theories of voting behavior. Economics as a social science shares with engineering and other designing sciences the fact that apart from describing the world it also wants to build things that work in that world. Like the engineer who is not per se directly interested in the laws behind the Van der Waals-forces, but 'simply' wants his bridge to hold, the economist is not always per se directly interested in the theories behind human decision behavior, but 'simply' wants the business firm to operate successfully. By his own definitions, then, Simon certainly is an economist, by the dominant definitions of his day perhaps a little less.

2. Rationality vs. irrationality

[16] Simon (1969), p.6
[17] Simon (1969), p.7
[18] Simon (1969)

In our modern, Western societies we "discipline"[19], or "make up"[20] large parts of ourselves and the world around us in terms of rationality. We conceive of individuals, behaviors, beliefs, judgments, actions and so forth as being either rational or irrational. But not only human beings and their behavior, also human constructions such as organizations, businesses, governments, institutions, ideas, and group behavior generally is understood in terms of rationality. Even natural phenomena such as natural selection processes, designs of organisms and behavior of plants and animals is put in rationality terms.

The dichotomy of rationality and irrationality is exclusive. Something, say a specific behavior, is either rational or irrational; it cannot be both rational and irrational at the same. Either you make a rational decision, or you make an irrational decision. However, for Simon, this does not mean that we cannot distinguish between different degrees of rationality. A specific behavior may be rational for the organism in question, although we as more knowledgeable scientists may observe that with more information the organism could do better. The organism is then described as making a rational decision that is of a lower degree than it could obtain had it more information at its disposal. Thus, humans, animals, behaviors, judgments and so forth are either rational or irrational, but from a more knowledgeable perspective a distinction can be made between different degrees of rationality.

The question, then, is how broad the two sides of this dichotomy apply. If rationality according to Simon is something that is relative to the thing that has it, is there anything that is irrational? In other words, what proportion of individuals, beliefs, decisions, organizations, selection processes and animal behaviors are rational, and what proportion irrational? For Simon, there is little that can be described in terms of irrationality, behavior is "basically rational".[21] Rational behavior for Simon is rational "in so far as it selects alternatives which are conductive to the achievement of the previously selected goals."[22] The modern use of rationality according to Simon is close to Aristotle's in that it is a "calculative or deliberative intellectual virtue"[23]. Thus, behavior can only be irrational when an alternative that is *not* conductive for the achievement of the selected goal, is selected over one that is,

[19] Foucault (1976), Florence (1994)
[20] Hacking (1999)
[21] Simon (1957), p.167
[22] Simon (1945), p.5
[23] Simon (1982, II), p.406

and when this is done on purpose. So, when you have to choose between plane and car the quickest way to get from Los Angeles to New York, you only care about speed, you know the plane to be faster, but you choose the car, it is then that you act irrationally. Irrationality thus defined can probably only be applied to humans and their behavior. Although Simon nowhere makes this explicit, a hint that he thinks along these lines is that for human behavior he links rationality to intentionality[24]. When rational behavior is intentionally selecting the behavior that leads you to the goals you have set, irrational behavior is intentionally selecting the behavior that does not lead you to your goals. It is difficult to see how anything non-human could be irrational in this sense.

To sum up, Simon stands a modern, Western tradition of categorizing large parts of the world around us in terms of rationality. This includes, broadly speaking, humans, human behavior, beliefs, judgments, decisions; but also businesses, governments, political ideas, voting mechanisms, institutions; as well as natural selection processes, animal behaviors, and organism designs. For Simon, almost everything that can be conceived of in terms of rationality is rational. There is almost nothing that could be rational that is not. A precaution that has to be made is that Simon himself is not directly concerned with understanding what can be described in terms of rationality and how broadly rational and irrational as descriptions apply. Simon is interested in understanding the working, the functioning, of rationality, *given* the distinction just described. The primary focus there, as indicated above, is on rational decision behavior.

3. Rationality and decision making

What is rationality?

The question of rationality is notoriously hard. So Simon sighs, "Even the definition of what is meant by "rational" is problematic."[25] It is moreover an issue that lies at the very core of what much of Simon's work (and economics and cognitive psychology generally for that mater) is about. Indeed, to a large extent it is precisely the question of how to understand rationality that is the single most important question Simon asks. In relation to behavior, rationality for Simon, as said, is first of all something relative. To say some behavior is rational means that this behavior is rational with

[24] Simon (1957), p.200 [other references??]
[25] Simon (1982, I), p.142

respect to the environment in which the behavior is displayed, the (computational) capacitates of the decision maker displaying the behavior, and the goal(s) it wants to achieve.

> "you can only determine whether certain behavior is rational if you study behavior in the context of certain premises or assumptions about the environment in which behavior takes place, or in the light of the goals that the individual is looking to achieve, and also the means for computing or calculating how the goals can be achieved."[26]

Furthermore, rational behavior is purposive, or intentional. Simon links intentionality and rationality of behavior in what may be understood as an instrumental definition of rationality[27].

> "A great deal of behavior, and particularly the behavior of individuals within administrative organizations, is purposive – oriented toward goals or objectives. [..]Behavior is purposive is so far as it is guided by general goals or objectives; it is rational in so far as it selects alternatives which are conductive to the achievement of the previously selected goals."[28]

A final element of Simon's notion of rational behavior is the evaluation of the behavior once it is displayed. For behavior to be rational the organism needs to evaluate the behavior in terms of the "goals or objectives" set. Did the selected behavior led as predicted to the chosen goal(s) or objective(s)? To sum up, "Roughly speaking, rationality is concerned with the selection of preferred behavior alternatives in terms of some system of values whereby the consequences of behavior can be evaluated."[29]

A difficulty with this broad definition of rational behavior arises when one wants to relate it to the traditional Cartesian dichotomy between reason and emotions, between rational behavior and what in social psychology is often called "affective behavior". Normally, this dichotomy is taken as exclusive; something is either

[26] Simon (1986, Int), p.19
[27] For instrumental rationality in economics see for instance Fleurbaey (2004) and Sugden (1991)
[28] Simon (1945), p.4-5
[29] Simon (1945), p.75

rational or affective. Simon agrees with this position and equates affective behavior with irrational behavior[30]. At the same time, however, Simon maintains that by far most of our behavior is rational and that large parts of what is normally classified as irrational, or affective, really is rational. Taking a culturally determined role in certain circumstance can be rational, as can be emotions. When teaching a class of undergraduates it is probably rational to act the role of teacher or professor, and when negotiating your raise in pay it may help to be offended or angry. When these affective behaviors indeed are rational in specific circumstances, Simon wants to understand them as such. But then it is on the one hand not clear why in the behavioral sciences we would still need emotional or affective behavior, and on the other hand the question whether rationality does not become an empty concept. If all behavior is rational we might as well omit the adjective. Maybe this problem is similar to the problem of natural selection in biology. However true and useful the phenomenon, if everything is natural selection there is little you can explain with it. Perhaps Simon has this in mind when he remarks that "analogous to the role played by natural selection in evolutionary biology is the role played by rationality in the sciences of human behavior."[31]

Another difficulty of rationality is that it means different things to different people. The fact that "the definition of what is meant by "rational" is problematic"[32] has as much to do with the difficulties of finding out how humans and other organisms function, as it has to do with the different ways in which the term is used (which are, of course, not entirely unrelated). Simon tries to get around this problem by adding adjectives to the noun, for instance 'bounded' or 'procedural' for his own interpretation and 'substantive' or 'global' for the rationality of the neoclassical economists. This, according to Simon, in the end is the only way to talk about rationality meaningfully.

> "Perhaps the only way to avoid, or clarify, these complexities is to use the term "rational" in conjunction with appropriate adverbs. Then a decision may be called "objectively" rational if in fact it is the correct behavior for maximizing given values in a given situation. It is "subjectively" rational if it

[30] Simon (1957), p.200
[31] Simon (1969), p.11
[32] Simon (1982, I), p.142

> maximizes attainment relative to the actual knowledge of the subject. It is "consciously" rational to the degree that the adjustment of means to ends is a conscious process. It is "deliberately" rational to the degree that the adjustment of means to ends has been deliberately brought about (by the individual or the organization). A decision is "organizationally" rational if it is oriented to the organization's goals; it is "personally" rational if it is oriented to the individual goals."[33]

Decision making

Decision making for Simon is a rational process that selects (and post hoc evaluates) a behavior that given the organism's computational capacities and knowledge of its environment is believed to best serve the goal(s) set. The major question then is how the decision maker does this. How for instance does it go about acquiring information of the environment, using its limited computational capacities and setting its goals? In principle there does not exist one best way to investigate this. One method is to observe in close detail how decisions are taken in specific circumstances by people, businesses or governments, etc.. A substantive part of Simon does just that, it carefully describes all the relevant factors of a decision problem before attempting to give some more general explanation of what is being observed in terms of rational decision behavior. The well-known Cyert, Simon and Trow (1982, II, ch. 7.5) is a good example. Another way is to take a few of what are believed to be main characteristics of a specific type of decision, simulate the process and see whether this simulation leads to (more or less) the same behavior that is observed in reality (or in experiments). If so, this then may be an indication that the characteristics defined indeed are important for the process. Although Simon concentrates his own work on these two methods – he for instance never conducts laboratory experiments – most important is that a combination of the different methods of investigation should be used. Empirical observation, simulations and experiments are all valid methods that need to be combined.

Decision making for individuals

[33] Simon (1945), p.76-77

An individual decision maker for Simon mostly means a human individual, although his analysis can also be applied to individual animals or other living organisms. With respect to other decisional units such as markets, organizations or scientists the individual in general has very little information about the environments it finds itself in. It is therefore "impossible for the behavior of a single, isolated individual to reach any high degree of rationality."[34] In fact, if we inquire the decision behavior of individuals, the idea that they make their decisions rationally is only of relatively little importance. As the computational capacities of the individual are relatively low and the information of the environment relatively overwhelming, to understand what decision the individual makes, and why, it is much more important to look at (the structure of) the information of the environment then it is to look at the specific process by which the individual reaches its decision. When analyzing individual decision behavior "the knowledge that [the individual] is rational is only a small part –almost an insignificant part- of the information that we require. His intention to be rational leads to particular behavior only in the context of conditions in which his behavior takes place."[35]

From the fact that the computational capacities of the individual are relatively small and the available information overwhelming, Simon infers that from a behavioral point of view individuals should be seen as quite simple. Despite their, from a for instance (neuro)biological point of view, very complex nature, "an ant and a man viewed as behaving system, is quite simple. The apparent complexity of its/his behavior over time is largely a reflection of the complexity of the environment in which it/he finds himself"[36] The decision behavior of individuals, then, is best described as using "heuristics" or "rules of thumb". These rules are updated on the basis of the evaluation of past decisions and new information about the environment, and are seen by Simon as a rational way of the individual to deal with its small computational capacities and overwhelming amount of information of the environment.

One may argue that these rules of thumb do not really answer the question how the individual makes its decision. To some extent it merely pushes the question away: the question now is how the individual develops and adapts its heuristics and

[34] Simon (1945), p.79
[35] Simon (1982, II) p.214
[36] Simon 1969, p.24[??]

how it selects among them, instead of how the individual decides. This is a valid criticism. Simon is mainly interested in decision making in organizations, and not so much in individuals. In recent years, the investigation of the individual decision maker has been picked up by Gigerenzer and his ABC group.[37]

Decision making for organizations

Organizations for Simon are one solution humans have found to achieve a higher degree of rationality than can be attainted by the individual. The term organization for Simon includes among others business firms, governments, and institutions. The reason that organizations exist is, as the name suggests, the fact they organize. Organizations organize the computational capacities and information acquisition of its different members in such a way that the organization in its totality can make a decision on the basis of a larger amount of information and using a larger computational capacity than the individual decision maker. Here, Simon is close to Commons, with whom he forms the main source of inspiration for New Institutional Economics (NIE), exemplified for instance by the work of one of NIE's main protagonists, and former student of Simon, Oliver Williamson[38]. For Commons[39], as later for Coase[40], the reason that firms exist is that they reduce transaction costs. Two people who make shoes together are better off working together in one firm than constantly negotiating prices and what-if contracts. They have furthermore more power negotiating sales-contracts with other parties. Simon adds that another important advantage is that the two can better use their scare capacities of computation and information acquisition. For both Simon, Commons, and Coase, firms (or more generally organizations in the case of Simon) are solutions to the limited capacities of the individual.

Simon's main concern is *how* organizations achieve higher degrees of rationality and how they may further improve this. The role of the economist/ organization theorist/political scientist is to find out both how this functions *and* how it can be improved. There could be more science at the top-level of organizations.

[37] See for instance Gigerenzer, Todd and the ABC Research Group (1999)
[38] See for instance Williamson and Winter (1993)
[39] See Commons (1924, 1934)
[40] Coase (1937)

> "The basic decisions about the design of organization structures are still made by judgment rather than science; business policy at top-management levels is still more often a matter of hunch than of calculation."[41]

> "Today several new branches of applied science assist the firm to achieve procedural rationality. One of them is operations research (alias management science); another is organization theory."[42]

How an organization achieves higher a degree of rationality first of all depends on the type of organization, the environment in which it operates and the goal(s) that are selected. For a democratically elected government that needs to achieve a myriad of often not clearly defined goals, both how the decision process takes place and how it can be improved differs from a hierarchically structured business firm that wants to maximize profit. Also here Simon often extensively describes the precise problem, the uncertainties, the structure of the organization and so forth, before coming to an analysis of what is done and what should be done. His main preoccupation among the different types of organizations are hierarchically organizations that, is his thesis, achieve higher degrees of rationality by hierarchically dividing the complex decision problem into simple parts that can be analyzed by individuals or individual departments of the firm. When the individual parts have done their job the top of the hierarchy puts the pieces back together and makes the decision.

> "In fact the main advantage to be gained from hierarchic authority is identical with that gained from using prices as communicators: matters of fact can be determined at the particular loci in an organization that are best equipped by skill and information to determine them, and they can then be communicated to "collecting points" where all the facts relevant to a specific issue can be put together and a decision reached."[43]

For Simon, there is a clear link between hierarchical organizations thus conceived and the functioning of the computer and the functioning of the brain. Also the computer

[41] Simon (1982, I), p.384
[42] Simon (1982), p.34
[43] Simon (1982), p.48-49

and brain are hypothesized to function as decentralized hierarchical systems. The analogy runs both ways: hierarchical organizations are also conceived to work as computers: "business organizations, like market economies, are vast, distributed computers whose final choice processes are substantially decentralized."[44]

An organization of a different kind is the sets of behavioral rules that can be summed up under labels as 'institution' or 'culture', and which are the main province of investigation of sociology. Also behavioral rules of groups or societies are ways to achieve a collective rationality that is of a higher degree than that of the individual. A difference with the hierarchic organization is that the processes in institutions and cultures are more dynamic. Individual adaptation on the basis of new information and evaluation of past decisions influences the rules of the group.

> "The sociological terms "institution" and "role" refer to these mosaics of programmed behavior that constitute social systems. The point is much emphasized in the sociological literature that the whole system of interlocking roles constituting a society is adaptive, in the sense that it satisfices the functional requirements of the society. What is usually less emphasized is that each role is not a fixed pattern of behavior but a set of ground rules – a program, in the precise sense in which we have been using that term – on the basis of which more or less rational choice can be exercised."[45]

Finally, Simon notes that the organizations humans erect to achieve higher degrees of rationality in turn become part of the environment in which the individual has to make its decision[46]. There is a dynamic interaction between the rational behavior of the individual and that of higher order decision makers such as an organization. Both cannot be seen without the other.

Decision making for markets

[44] Simon (1982), p.49. More on Simon and computers follows below. In view of the sometimes heated debate about computers and humans it should here perhaps be noted that the alleged analogy between the functioning of computers and human brains in cognitive science has in recent years been abandoned. The human brain simply does not function as a hierarchically organized system of distributed decision-making.
[45] Simon (1982), p.384
[46] Simon (1982,II), chapters 5.1-5.8

Another mechanism to overcome the limited capacities of computation and information acquisition of the individual is the market.[47] The market mechanism is not one of Simon's main preoccupations, and in describing this mechanism he simply states to agree with theories on the functioning of markets by Friedrich Hayek. Simon agrees that "as von Hayek points out, [the market's] most striking characteristic is the way it reduces and localizes informational and computational requirements."[48] He furthermore agrees with Hayek that the market communicates information through prices. The market does not have an organizational structure like the government or the business firm. But because prices carry the relevant (economic) information, the market nevertheless achieves a higher degree of rationality than its members individually. Through prices, people know where to use their limited capacities.

A question Simon does not answer is why some decisional problems are solved through organizations such as governments and business firms, and others through the market. Are there certain types of decision problems at which the market is better? This remains unresolved question. What Simon does say, is that there is a competition between the different solutions to the bounded rationality of the individual. The market, for instance, competes with hierarchical organizations for decision problems: "markets are only one of the mechanisms that people use to achieve rational behavior above the individual level. The chief competitor of the market for this purpose is the hierarchic organization"[49] Thus, in a sense, the different solutions to limited individual rationality compete in some meta-market for the different decisions.

Normative vs. descriptive decision making

Simon considers his theory of decision making to have both normative and descriptive merits, as already briefly indicated above. The task of economists and other social scientists is both to describe how decisions are made, and to give advice to individuals, governments, business firms etc. on how to improve their decision making; how, in other words, to increase the degree of rationality of their decisions. "In normative economics, our aim is to find rules for making "good" decisions. In

[47] Along this, markets function as solution to conflicts of interest.
[48] Simon (1969), p.42
[49] Simon (1969), p.48

positive microeconomics, our aim is to explain the decision-making behavior of economic agents."[50]

The relation between the normative and descriptive (Simon uses 'descriptive' and 'positive' interchangeably) is direct for Simon. On the basis of descriptions of the decision process social scientists give normative advice on how to improve the decision process. This in turn changes the description of the process. Along this, external influences like technological progress or changes in the (institutional) rules influence the descriptive and the normative realm, making the descriptive and normative dynamic theories that change over time.

> "If human decision makers are as rational as their limited computational capabilities and their incomplete information permit them to be, then there will be a close relation between normative and descriptive decision theory. Both areas of inquiry are concerned primarily with procedural rather than substantive rationality [..]. As new mathematical tools for computing optimal and satisfactory decisions are discovered, and as computers become more and more powerful, the recommendations of normative decision theory will change. But as the new recommendations are diffused, the actual, observed, practice of decision making in business firms will also change."[51]

Simon is aware of the fact that this understanding of normative and descriptive is different from that used in economics and related parts of psychology. For Simon, neoclassical economics is normative economics. It tells us how individuals and firms should behave, not how they actually behave. In principle, there is nothing wrong with this – in Simon's view economics is both descriptive and normative – although economists could and should devote more energy to descriptive economics. What is problematic, however, is that the normative economics of neoclassical economics (including Savage) is very rigid. It gives one, universal norm that holds always and everywhere, independent of environment or actual human behavior. This is a fundamental flaw.

[50] Simon (1982, II), p.359
[51] Simon (1978), p.351

> "Economists have been relatively uninterested in descriptive microeconomics – understanding the behavior of individual economic agents – except as is necessary to provide a foundation for macroeconomics. The normative microeconomist "obviously" doesn't need a theory of human behavior: he wants to know how people *ought* to behave, not how they *do* behave."[52]

According Simon there is a direct and dynamic relation between normative and descriptive decision making, both of which are influenced by changes in the environment. Neoclassical economics (still including Savage), according to Simon, bases its theory and norm on the same loose "armchair"[53] observation of human behavior, and uses the same logic in both the descriptive and the normative domain. Because neoclassical economics "observes" people's decision behavior assuming that they make decisions in a normatively correct way, it cannot distinguish between the norm and the description.[54] When one reasons about decision making the way neoclassical economics does, there is no difference between the descriptive and the normative.

Decision making for scientists

For Simon, scientists are a special case of individual decision makers, and science a special case of decision making. "The currently accepted theory in [cognitive psychology] suggests that the processes of scientific discovery may be described as special cases of problem-solving processes."[55] Scientists investigating the process of human decision making may thus also describe and give advice to scientific decision making.

In analyzing scientific decision making, Simon starts from the distinction between the context of discovery and the context of justification. Many philosophers of science, Simon argues, have wrongly treated these two categories as independent, and moreover assumed that only meaningful statements could be made about the context of justification. As a result, the context of discovery is treated as a black box about which content nothing could be said. Simon develops his own theory in

[52] Simon (1982,II), p.254, his emphasis.
[53] Simon (1982,II), p.210
[54] Simon (1977), p.142
[55] Simon (1986), p.18

opposition to this received view of scientific methodology, and, especially, in opposition to the work of Karl Popper.

What a scientific decision maker does, according to Simon, is to look for empirical regularities in quantitative information. Subsequently, the scientist proposes a (mathematical) mechanism that can account for the empirical regularities observed. "Discovery" for Simon, in other words, is "pattern induction", and "to 'explain' an empirical regularity is to discover a set of simple mechanisms that would produce the former in any system governed by the latter."[56] The "simple mechanisms" or "hypotheses" the scientists comes up with to ' explain' the empirical regularities come from an "hypotheses generating process"[57] inside the scientific decision maker. This hypotheses generating process is a process of trying out in a smart way different mathematical functions to fit the empirical regularities. It is therefore a process also a computer could be programmed to do.[58] The final hypothesis informs the scientists how and where to gather new data. Once the scientist better understands the empirical regularity he can improve his data gathering, which will lead to ever more refined hypotheses. The 'justification' of a hypothesis is thus directly related, and cannot be seen independently of the discovery. Hypotheses come directly from the data and it is thus nonsense to again test the best hypothesis against the data.

> "Throughout this paper, considerable stress has been placed on the close interaction between hypotheses and data in the building and testing of theories. In most formal theories of induction, particularly those that belong to the genus 'hypothetico-deductive' or H-D', hypotheses spring full-blown from the head of Zeus, then are tested with data that exist timelessly and quite independently of the hypotheses. Theories as otherwise divergent as Popper's and Carnap's share this common framework.
>
> It was one of Norwood Hanson's important contributions to challenge this separation of hypothesis from data, and to demonstrate that in the history of science the retroduction of generalizations and explanations from data has been one of the central and crucial processes. [..]

[56] Simon (1977), p.31
[57] Simon (1977)
[58] Simon (1977)

> One of my principal theses here has been that hypotheses retroduced in this way are unusually highly plausible, and not highly improbable, as Popper (1961) would insist. We have already resolved part of the apparent paradox. The 'improbability' to which Popper refers is improbability of the very special state of nature described by the empirical generalization, not improbability of the generalization itself. But it remains to understand how the scientist can ever be lucky enough to discover the very special generalization that describe these a priori improbable (but actual) states of nature."[59]

This view of science and scientific discovery also holds an important message for historians of science, who should not describe science as the testing of hypotheses-from-nowhere on data, but as a continuous process of pattern induction and informed data gathering: "histories of science written in terms of the processes that discover patterns in nature would seem closer to the mark than histories that emphasize the search for data to test hypotheses created out of whole cloth."[60]

4. Simon against the world

Simon develops his theories of rationality and decision making always in opposition to other theories and scientists.[61] This makes a neutral and independent account of Simon's work, as I have tried to sketch in the previous twenty pages, relatively difficult and incomplete. Let me in this section therefore briefly sketch Simon's main complaints about the dominant theories and people of his time.

Simon against neoclassical economics

Simon's view of rationality, often labeled 'bounded' or 'procedural', differs from the dominant understanding of rationality in neoclassical economics. As rationality is crucial in theories of decision making this is a first point Simon never gets tired of attacking. Rationality, according to Simon, is closely linked to one's conception of the

[59] Simon (1977), p.41-42
[60] Simon (1977), p.43
[61] This is not very surprising as Simon's theories indeed are against the dominant grain throughout almost his entire career. Another and related explanation is that Simon developed his ideas while working among the people with whom he would so fundamentally disagree in later years. Mirowski (2002, p.453-479) notes that it was while at Cowles that Simon changed his mind from intuitive statistics to symbol/information processing and that it is Simon's rejection of neoclassical economics together with his (more nuanced) critique of von Neumann that led to his theory of bounded rationality.

working of humans. Neoclassical economics' wrong definition of rationality thus implies a wrong conception of human beings. Basically (at the risk of being tautological), Simon's critique is that neoclassical economics' rationality is not 'bounded' and that human beings are not conceived to have any limitation on capabilities of computation and information acquisition.

> "Traditional economic theory postulates an "economic man", who, in the course of being "economic" is also "rational." This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well organized and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative course of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale."[62]

Neoclassical economics, in other words, "draws a romantic, almost an heroic, picture of the human mind"[63] and the task for economics and other social scientists is "to replace the global rationality of economic man with a kind of rational behavior that is compatible with the access to information and the computational capacities that are actually possessed by organisms, including man, in the kinds of environments in which such organisms exist."[64]

On a more general level the problem with neoclassical economics' conception of rationality and human beings is that it uses an "ideal type" as the basis for the social sciences. Although there is nothing wrong with an ideal-type approach per se, it is not an appropriate starting point for sciences investigating human beings that make decisions. Differences between humans in terms of computational capacities, the information they have and the goals they want to achieve are a main concern for theories of decision making that an ideal type approach cannot account for.

> "I do not intend to dispute the usefulness of the "ideal type" of economic man for many problems of economic analysis. But the specific problems with

[62] Simon (1982, II), p.239
[63] Simon (1969), p.60
[64] Simon (1982, II), p.239

> which organization theory is concerned are of a character that generally renders this particular idealization inappropriate. As soon as we turn from very broad macroeconomic problems and wish to examine in some detail the behaviors of the individual actors, difficulties begin to arise on all sides."[65]

Looked at from a slightly different angle, the problem with neoclassical economics is that the ideal type that it does take as a staring point for its analyses is a highly unrealistic ideal type. It is a "psychological postulate", "generally contrived in the comfort of the armchair"[66] that has nothing to do with real human beings and their decisions. Following Friedman, many neoclassical economists argue that unrealism of assumptions is not a problem and perhaps even a virtue when combined with simplicity. Simon plainly disagrees: "Unreality of premises is not a virtue in scientific theory; it is a necessary evil – a concession to the finite computing capacity of the scientist that is made tolerable by the principle of continuity of approximation."[67] Elaborating on the subject, Simon argues that the distinction between realism and unrealism in science is itself flawed since both are relative concepts. Like rationality and irrationality they are not absolute standards springing from the head of Zeus, but relative concepts that directly relate to the circumstances and specification of a particular situation.

> "The term realistic is, in fact, highly ambiguous. It might be intended normatively: is it rational to define the decision problem confronting the manager in this way? But this question can only be answered if we have a larger and more comprehensive model of the decision-making program of which the decision before us comprises one part. For example, if we had taken as our starting point the classical theory of the firm, and had assumed further that the elasticity of demand for the product was not infinite, then it would not be rational for the manager to take prices as fixed. For he could presumably make maximum profits only if he regarded the quantity he would sell as a function of price. But the decision model incorporated in the classical theory of the firm is itself an heroic abstraction from reality. It is only in a relative,

[65] Simon (1957), p. 197
[66] Simon (1982, II), p.210
[67] Simon (1982, II), p.371

> and not in an absolute sense, that we can refer to a particular framework of decisions as "rational" or "nonrational." If we optimize at all, we always suboptimize. Hence, the decision problem posed in the previous paragraph, which assumes fixed prices, cannot be rejected as "unrealistic". [68]

To sum up, "neoclassical economics departs from other social sciences in three ways. It says nothing about the contents of goals and values that are assumed. It assumes uniformly consistent behavior as if there were one world, whether we are talking about the present or the future, or even as the individual moves through time, and it assumes that behavior is objectively rational."[69] Neoclassical economics is not a science that attempts to describe the world in an objective and value-free manner, but a science that wants to recreate the world after its own idea. In neoclassical economics "nature will imitate art and economic man will become as real (and as artificial) as radios and atomic piles"[70], and "if the world doesn't fit the assumptions, or you have a hard time with the regression results, so much the worse for the world."[71] In short, "how any grown-up, bright human being can go satisfied with the neoclassical theory is kind of hard to understand."[72]

Simon against von Neumann

Few, if any, who are familiar with his work deny the genius of von Neumann. Simon is no exception, and the few criticisms that he does have are posed in relatively friendly terms and presented as side remarks that do not really affect the greatness of von Neumann's contributions.

After and initial enthusiasm for *The Theory of Games and Economic Behavior* (1944)[73], Simon soon retreats to a more modest appreciation of the book. The reason is that he becomes more fully aware of his disagreement with expected utility theory (EUT) and recognizes game theory to be a part of it. Von Neumann's game theory, in Simon's final view, is a highly capable mathematical exercise that emphasizes the difficulties of approaching human decision behavior through EUT's strict definition of rationality and assumptions of unconstrained capacities of computation and

[68] Simon (1982, II), p.385
[69] Simon (1986), p.19
[70] Simon (1982,II), p.293
[71] Simon (1986), p.19
[72] Simon in Baars (1986), quoted in Mirowski (2002), p.454
[73] Simon (1945)

information acquisition.[74] Thus Simon remarks in relation to the problem of oligopolistic competition in imperfect markets:

> "A major step toward formulating this problem correctly was taken in 1944 – a century after Cournot – when von Neumann and Morgenstern published TGEB. But far from solving the problem, the theory of games demonstrated how intractable the task is to prescribe rational action in a multiperson situation where interests are opposed."[75]

Simon furthermore disagrees with von Neumann on the analogy that can be drawn between human decision making and computers. Both Simon and von Neumann think of the human decision maker as a system of information processing that can be compared to the working of the (digital) computer. For von Neumann the analogy is to be drawn on the hardware level, and the division that is made there between for instance memory and executive parts of the computer. According to Simon this analogy makes little sense. A transistor works different than a neuron, and also the functioning of the computer memory is different from that of the human memory. An analogy that can be drawn, however, is between the human decision maker and the software that operates on the basis of the computer's hardware. Both, according to Simon, are hierarchic systems of distributed decision making that work on the basis of symbol manipulation, "the significant analogy [is] not between the hardware of computer and brain, respectively, but between the hierarchic organizations of computing and thinking systems"[76] .A software program divides its work into different parts, does a number of computations simultaneously, and, when finished, brings the different pieces back together. A similar process takes place in the human brain (and in hierarchic organizations and markets). Symbolic information of the decisional problem is divided and sent to different parts of the brain to be 'solved'. When finished the information is brought back together and the decision made[77].

[74] Interestingly, both Simon and von Neumann use the chess player as a metaphor to explain their theories. As Leonard (forthcoming) shows, von Neumann conceives of decision making in situations of strategic interaction as analogous to games of chess. Simon often evokes the chess player to show that EUT cannot be applied: it is impossible to compute all the outcomes, add probabilities and maximize expected utility. Instead, chess players rely on rules of thumb.
[75] Simon (1982[??]), p.45
[76] Simon (1977), p.180
[77] As noted before, this cognitive architecture view of the working of the human brain of Simon has in recent years lost its appeal among cognitive scientists. Basically because it turns out to be wrong. An

Thus, although von Neumann and Simon both draw an analogy between the functioning of the computer and the functioning of the human decision maker, they make their analogies on different levels[78].

Simon against Savage

It is only occasionally that Simon disagrees with Savage explicitly. Sometimes Savage is taken as an example of the neoclassical economics with which Simon so vehemently disagrees[79], on other occasions Savage is taken as the founding father of the intuitive statistics tradition in (mathematical/cognitive) psychology, with which Simon also disagrees, albeit less so.[80]

Savage's position on human decision making has been aptly summarized by Sugden (1991). Savage takes as point of departure the choices that people actually make. His basic, and implicit, assumption is that these choices are based on rational reasons.[81] "To suppose that a theory of rational choice is possible is to suppose that in some way, choices can be influenced by reason."[82] The task to which Savage sets himself is to construct a model that captures this rational reasoning and "to identify the restrictions that would be imposed on choices by *any* consistent set of reasons."[83] Of course, people may make mistakes in the rational reasoning that leads to the choice, for instance when the decision to be made is complicated. For this reason Savage distinguishes between a normative and a descriptive decision theory. The normative theory is the model of rational reasoning of people that leads to the choice. The descriptive theory is a theory of how people actually make their choice. This is in principle the same as the normative model but adds some situations or conditions under which people are likely to make mistakes.

Simon is not unsympathetic to Savage's approach. He agrees with the basic assumption that underneath every decision there lies a rational reasoning that can be modeled. What he does not agree with, however, is the rigidity with which Savage

example of a cognitive architecture program that still works in the spirit of Simon is John Anderson's ACT-R.

[78] Much of this paragraph draws on Mirowski (2002), p.453-479

[79] Simon (1987)

[80] Simon (1978)

[81] Unsurprisingly, Savage is sympathetic to Samuelson's revealed preference approach which he considers to be an analysis of decision making under certainty to which his own theory of decision making under uncertainty is complementary.

[82] Sugden (1991), p.753

[83] Sugden (1991), p.761

applies one model (EUT) to all rational reasoning. EUT may be a useful model to describe the rational reasoning process for some choices, but it is absurd to suppose that all choices are made on the basis of this rational reasoning. EUT may be a useful application when utilities and uncertainties are clearly and unambiguously defined, but when these are unclear the rational reasoning process is likely to be different. Directly related, Simon complains about the rigidity and absoluteness of the norm of Savage's theory of decision making. The normative, Simon argues, is a flexible thing, not a universal benchmark[84].

5. Simon's tools

Scientists use different tools for their investigations and often have clear ideas about the usefulness of each for their research. A priori there is, according to Simon, no research tool that cannot be used to investigate (human) decision making. That said, every tool has its advantages and disadvantages.

Simon and experiments

For Simon there is a close relation between empirical observation in the real world and controlled observation in the laboratory. Because his main interest is in decision making in organizations, Simon's research is mostly done on the basis of careful empirical observation of decision processes in business firms and other organizations. His often extensive and detailed account of the precise goals and environments of the decisions can be seen as a way to make up for the controlled situation of the laboratory. The only reason Simon is not engaged in laboratory experiments, is that the subject of his investigations cannot be put in a laboratory. Social scientists who do directly investigate human decision making can, and should engage in laboratory experiments. It can even be said to be a fundamental methodological flaw of mircroeconomists working on individual human decision making not to engage in laboratory experiments.

> "Economists will have to observe decision-makers in the actual process of making decisions in the real world or in laboratory experiments, or study the actors' beliefs, their expectations and their methods of calculation and

[84] Simon (1978), p.351

> reasoning. This fundamental failure in the very basic methodology means that the conclusions reached in neoclassical economics rest largely on the auxiliary assumptions that economists make in defining any given situation."[85]

As a matter of fact, empirical observation in the real world or in the laboratory is for Simon in the end the only way to make conclusive statements about the working of human decision making. However useful other methods, because the decision making, both normatively and descriptively, changes over time as a result of for instance technological or institutional changes, social scientists always have to start and in the end always have to come back to empirical observation in the real world and in laboratories. Thus Simon remarks on explanations of the phenomenon of oligopolistic competition:

> "I am at a loss to know which is the "right" one among the many competing alternatives. Nor do I have faith that more mathematical modeling, however ingenious, will solve the problem. The question will be answered only by painstaking empirical study at the level of the business firm of actual decision-making behavior in oligopolistic settings. Moreover, there may be no history-free explanation. The bargaining process and its outcomes may change significantly from one era to another."[86]

Simon on mathematics and simulation

Mathematics for Simon is a language among other languages. It is, however, a very useful language for the scientist because it forces him to order his ideas, to define the elements of his theory precisely, and to do so consistently.

> "I will simply assert, with J. Willard Gibbs, that mathematics is a language; it is a language that sometimes makes things clearer to me than do other languages, and that sometimes helps me discover things that I have been unable to discover with the use of other languages."[87]

[85] Simon (1986). p.20
[86] Simon (1982, II), p.2
[87] Simon (1982, II), p.209

Because the mathematical language as compared to other languages has properties that are especially suited for science, the scientist who is fluent in mathematics will have an important advantage over scientists who are not. "For the person who thinks in mathematics, and does not simply translate his verbal thoughts or his images into mathematics, mathematics is a language of discovery as well as a language of verification."[88]

So it seems that also in the social sciences much more mathematics could be used than is currently the practice (or at least during the time of Simon's writings). But Simon is quite cautious here. Whether it is useful to use mathematics in the social sciences depends on the possibility of representing its phenomena in mathematical terms. Not every phenomenon can be represented in mathematical form, and there exist both different ways of mathematical representation, and different mathematics in which the phenomenon can be represented.

> "If mathematics is to play an important role in the development of social science theory, then a great deal of experience must be gained as to what kinds of mathematics are likely to be useful, and as to what are some of the promising ways of imbedding fundamental psychological and sociological concepts and phenomena in mathematical models. What form shall human motives take in such models, how shall the rational and the non-rational aspects of human behavior be represented, what kind of mathematical schemes will conveniently represent the interactions of human groups, and so on?"[89]

The question whether the phenomena of social science can be represented meaningfully in mathematical terms therewith remains, for the moment at least, an open question: "What the contribution of mathematics will be to the social sciences can perhaps be more fruitfully evaluated some generations hence when that contribution –if any- has been made."[90]

In order to bring out more clearly Simon's view of mathematics it may be useful to relate it to some of the issues dealt with earlier. As the reader will recall, discovery for Simon is pattern induction. It is the attempt of the scientist to fit a

[88] Simon (1977), p.xv
[89] Simon (1982, II), p.211
[90] Simon (1982,II) p.209

mathematical mechanism to an empirical regularity. In this process it is not possible to conclusively decide which mathematical mechanism to favor. More data in the future may favor a now rejected mechanism, and it may for instance be that although a linear algebraic function better fits the data we have strong reasons to suspect that the mechanism should be of a quadratic nature. This is for Simon essentially a problem of realism. If the scientist wants to come closer to explaining the phenomena of which he has only little information, he shouldn't put all his eggs in one mathematical basket: "Realism would suggest that we attempt to construct, not a mathematical model, but a plurality of mathematical models."[91]

A way to see whether the mathematical model is a good 'explanation' of the empirical regularity observed is to run a simulation. To do a simulation the mathematical mechanism has to be constructed in such a way that simulation is possible. For one, the mechanism must be dynamic, not static. Thus there is a close relation between the building of the mathematical mechanism and running a simulation. The scientist constructs a mathematical mechanism that fits the empirical data, as described above, but makes sure to construct the mechanism in such a way that a simulation is possible. The results of the simulation can then be compared with the original data.

> "The process of simulation involves constructing a theory, or model, of a system that prescribes the system's processes. These processes can refer to macro as well as micro elements and the prescriptive detail reflects the researcher's knowledge of and interest in particular parts of the system. By carrying out the processes postulated in the theory, a hypothetical stream of behavior is generated that can be compared with the stream of behavior of the original system."[92]

Simon and computers

The relation between computers and humans is a dynamic relation and far from straightforward to analyze. Firstly, Simon recalls that the word computer draws from the invention of Charles Babbage and others in the eighteenth and nineteenth century to divide long and complicated calculation problems into simple ones that could be

[91] Simon (1982,II), p.212
[92] Simon (1982, II), p.356

computed by people who individually have comparatively little training and knowledge of the problem. These calculations were sometimes done twice in order to reduce the risk of errors and, when computed, put together by higher elements of the organization.[93] By division of labor complicated problems could be solved in relatively little time. Because division of labor is the key aspect of computing, Simon argues that "physicists and engineers had little to do with the invention of the digital computer", but "that the real inventor was Adam Smith."[94]

Builders of the digital computer in the twentieth century tried to capture the computing system in an electronic architecture. The main difficulty for the pioneers of the 1930s was that for every new computing problem a new architecture had to be designed and built. This made the electronic computer a very costly and impractical machine.[95] The great invention of von Neumann was to design an architecture that could be used for different sorts of computations. Inspired by what little was known about the working of the brain, von Neumann designed a digital computer that used one memory for storage of information *and* programs. This is still the basic architecture of the computers that we have today.[96]

As said, Simon considers distributed computation and information acquisition, and therewith division of labor, to be the basis of multi-component decision making systems. Whether we are talking about humans and their billions of neurons, markets and their millions of agents, hierarchic organizations and their different departments, or computers and their millions of transistors, the higher degree of rationality is always attained by some form of division of labor in the form of distributed computation and information acquisition. Hence, "some of the general characteristics of human thinking [..] are also, of course, the characteristics of computer thinking, since most computers that think, think in simulation of man."[97] In that sense, but only in that sense, human are computers, computers are humans, markets are computers, computers are hierarchic organizations, and so forth.

But computers do of course profoundly influence our societies and the way in which we think of ourselves. Just as markets and organizations are inventions of

[93] Simon (1969)
[94] Simon (1982, I), p.381, Simon (1969), p.22-29
[95] See among many others http://en.wikipedia.org/wiki/History_of_computing_hardware, and http://en.wikipedia.org/wiki/History_of_computing
[96] This is of course a gross simplification, see as a start http://en.wikipedia.org/wiki/Von_Neumann_architecture
[97] Simon (1977), p.282

humans to achieve a higher degree of rationality that in the course of their construction have profoundly influenced our individual decision making and more generally changed about every aspect of our lives and about the way in which we think about ourselves, so the computer not only is an invention that makes us achieve a higher degree of rationality in our decision making, but also fundamentally changes our world and the way in which we conceive of ourselves. Hence, "perhaps the most important question of all about the computer is what it has done and will do to man's view of himself and his place in the universe."[98]

Conclusion

In this paper I have tried to sketch an overview of the most important aspects of that one theme that pre-occupied Simon throughout his entire career: rational decision making. The conclusion that can be inferred is that despite the wide range of scientific fields he contributed to and the many different sorts and aspects of rational decision making he took up, the central thesis always remains the following. Individual decision makers have relatively little computational capacities and information of the environment in which they have to make their decisions. They therefore only achieve a comparatively low degree of rationality. Throughout history many solutions have been invented by individual decision makers to increase the degree of rationality of their decision making. Decision makers have invented and still invent mechanisms on the basis of a division of labor. The decision problem is divided into sub-problems that are solved by the individual decision maker and, through the mechanism, put together so that the mechanism as a whole achieves a higher degree of rationality than could be obtained by the individual parts. This general principle always holds, whether the mechanism is a business firm, market, government, computer, or ant heap. All behavior, all decision making, is basically rational. What Simon says is always about *how* it is rational.

[98] Simon (1982,I), p. 198

Appendix: Quantifying Simon

The complete bibliography of Herbert Simon has been obtained from http://www.psy.cmu.edu/psy/faculty/hsimon/hsimon.html. It is to my knowledge the most complete bibliography of Simon available.

The bibliography lists a total of 973 publications. When translations of books and articles, later editions of books, abstracts, newspaper articles, articles in small university magazines, small interviews, unpublished working papers, notes for presentations, unpublished letters to editors and hearings for governmental commissions etc, are omitted, a total of 684 publications remains.
These 684 publications include articles, books (including edited books), book sections, introductions, sections in proceedings, notes, book reviews, comments, long interviews, and published letters to editors.

To categorize Simon's publications a distinction is made between, 1) the type of publication, and 2) the scientific field of publication.

1) A distinction is made between:

A. Articles. This includes all articles in journals that can be recognized as such. When this was not clear, articles of 1 or 2 pages have been interpreted as belonging to category D, unclear proceedings of perhaps journals have been categorized under B.

B. Book- and proceedings-sections. This category includes all contributions to books and proceedings (both of journals and of conferences).

C. Books. This category includes all books of which Simon was the writer or (one of) the editor(s).

D. Other. This rest-category includes all notes, introductions, forewords, books-reviews, interviews, comments etc.

The following scientific categories have been distinguished. Especially in the case of Simon, such a distinction is highly arbitrary and easily subject to valid criticisms. It is nevertheless maintained. For each publication the categorization has been made on the basis of the title of the book, journal, or proceeding, and when this did not gave a conclusive answer, on the basis of the title of the publication. This procedure has on a few occasions led to a journal belonging to two categories, for instance *Science*. The

most important journals that are thus taken to fall in each scientific category are indicated. For book- and proceedings-sections no such list has been made because the time needed for this categorization was perceived to (far) outweigh the benefits. The categorization for book- and proceedings sections was relatively straightforward.

a. **Economics**. *Quarterly Journal of Economics, Econometrica, The Review of Economic Studies, American Economic Review, Journal of Political Economy, Economics and Business Review, The Bell Journal of Economics, Journal of Comparative Economics, Regional Science and Economics, Journal of Economic Behavior and Organization, Journal of Economics, Eastern Economic Journal, Theoria*
b. **Social Psychology**. *The American Psychologist, American Education, Mind, Culture and Activity, Journal of Applied Developmental Psychology*
c. **Cognitive Psychology**. *Psychological Review, British Journal of Statistical Psychology, Psychometrika, Operations Research, Contemporary Psychology, Science, British Journal of Psychology, Behavioral Science, Cognitive Psychology, Bulletin of the American Association of Arts and Sciences, Memory and Cognition, Artificial Intelligence, Computers in Human Behavior, Cognition and Instruction, Annual Review of Psychology, Political Psychology, Psychonomic Bulletin and Review, Minds & Machines, Korean Journal of Cognitive Science, Kognitions-Wissenschaft, Mind & Society, Current Directions in Psychological Science*
d. **Computer Science**. *IRE Transactions on Information Theory, IBM Journal of Research and Development, Journal of the Association for Computational Machinery, Science, Communications of the Association for Computational Machinery, Computer, Computational Intelligence, The World and I, ACM Transactions on Computer-Human Interaction, IEEE Intelligent Systems & Their Applications*
e. **Political Science**. *National Municipal Review, The Municipality, Public Opinion Quarterly, Public Management, Social Education, Civic Affairs, Public Administration Review, Public Personnel Review, Journal of Politics, The American Political Science Review, The*

Annals of the American Academy of Political and Social Science, Inquiry, LSE Quarterly, Policy Sciences, Political Science & Politics, State Government

f. **Mathematics and Statistics**. *Annals of Mathematical Statistics, Journal of the American Statistical Association, Quarterly of Applied Mathematics, American Mathematical Monthly, Bulletin of the American Mathematical Society*

g. **Business and Organization**. *International City Managers Association, Journal of Business, Personnel, Industrial and Labor Relations Review, Journal of operations research society of America, The Controller, Management Science, Conscience de l'homme, Advanced Management, Naval war College Review, Harvard Business Review, Public Management, FAR Horizon, Annals of Operations Research, Journal of Integrated Design and Process Science, Revue, d'économie industrielle, Computational & Mathamatical Organization Theory, Journal of management studies*

h. **Philosophy**. *The Philosophical Magazine, The Journal of Philosophy, Philosophy of Science, Ethics, Synthese*

i. **Engineering**. *Illinois Tech Engineer, Carnegie Technical, Journal of Engineering Education*

j. **Biology**. *Biometrika*

k. **Sociology**. *American Journal of Sociology, American Sociological Review, Sociometry, Social Studies of Science*

The categorization thus set up yields the following results.

	A	B	C	D
Economics	36	25	1	17
Social Psychology	4	2	0	0
Cognitive Psychology	102	114	8	24
Computer Science	28	39	1	15
Political	38	19	4	12

Science				
Mathematics And Statistics	9	9	0	8
Philosophy	24	19	3	6
Business and Organization	47	24	5	18
Sociology	5	1	0	6
Biology	2	2	0	0
Engineering	5	1	0	1

The books that Herbert Simon has written or has been (one of) the editor(s) of are the following.

Measuring Municipal Activities (1938)
Determining Work Loads for Professional Staff in a Public Welfare Agency (1941)
Fiscal Aspects of Metropolitan Consolidation (1943)
Administrative Behavior (1st ed 1947)
Local Planning Administration (1948)
Public Administration (1950)
Centralization vs. Decentralization in Organizing the Controller's Department (1954)
Models of Man (1957)
Organizations (1958)
The new science of management decision (1960)
Planning production, inventories, and work force (1960)
Essays on the structure of social science models (1963)
The shape of Automation (1965)
The sciences of the Artificial (1969)
Human Problem Solving (1972)
Representation and meaning: experiments with information processing systems (1972)
Skew Distribution and the Size of Business Firms (1977)
Models of Discovery (1977)
Models Of Thought (vol.1) (1979)
Models of Bounded Rationality (vol. 1&2) (1982)
Reason in Human Affairs (1983)
Protocol Analysis (1984)
Scientific Discovery: Computational Explorations of the Creative Process (1987)
Models of Thought (1989)
Models of my Life (1991)

Most of the time, Herbert Simon has been the sole author of his publications. However, he has also collaborated with numerous other scientists. The following is a list of Simon's co-authors, and the number of publications on which they have collaborated with Simon. Added in the first row are the number of publications of which Simon is the sole author. For this count, the categories A (Articles), B (Book- and proceedings-sections), and D (Other), have been lumped together.

	A + B + D	C
Sole author	443	13
Newell, A.	38	1
Ridley, C.E.	17	
Gobet, F.	10	
Langley, P.	10	1
Feigenbaum, E.A.	10	
Bradshaw, G.	8	1
Shaw, J.C.	8	
Simon, D.P.	7	
Zytkow, J.	6	1
Hayes, J.R.	6	
Ijiri, Y	6	
Kotovsky, K.	5	
Ericson, K.A.	5	1
Iwasaki, Y.	5	
Qin, Y.	5	
Tabachneck, H.J.M.	5	
Anderson, J.R.	4	
Reder, L.M.	4	
Vera, A.H.	4	
Chase, W.G.	4	
Holt, C.C.	4	1
Guetzkow, M.	4	1
Divine, W.R.	4	1
Cooper, E.M.	3	1
Chernin, M.	3	1
Modigliani, F.	3	1
Gregg, L.W.	3	
Greeno, J.G.	3	
Larkin, J.H.	3	
Kulkarni, D.	3	
Leonardo, A.M.	3	
Richman, H.B.	3	
Staszewski, J.J.	3	
Okada, T.	3	
Klahr, D.	2	
Eisenstadt, S.A.	2	
Kim, J.	2	

Valdez-Perez, R.	2	
Chang, P.C-M.	2	
Bhandari, I.S	2	
Siewiorek, D.P.	2	
Shen, W.	2	
Kaplan, C.A.	2	
Zhu, X.	2	
Zhang, G.	2	
McDermott, J.	2	
Bhaskar, R.	2	
Kadane, J.R.	2	
Perlis, A.J.	2	
Bonini, C.P.	2	
Cyert, R.M.	2	
Cooper, W.W.	2	
Sharp, F.N.	2	
Ridley, H.A.	1	
Shepard, R.W.	1	
Hawking, D.	1	
Smithburg, D.W.		1
Thompson, V.A.		1
Kozmetsky, G.	1	1
Tyndall, G.	1	1
Stern, F.	1	
Trow, D.P	1	
Anshen, M.	1	
Muth, J.F.	1	1
Dearborn, D.C.	1	
Simon, P.A.	1	
Ando, A.	1	
March, J.G.	1	1
Ellis, T.O.	1	
Clarkson, G.P.E.	1	
Van Wormer	1	
Fisher, F		1
Levy, F.K	1	
Holtzinger, J.E.	1	
Miller, F.K.	1	
Paige, J.M.	1	
Roscher, N.	1	
Summer, R.K	1	
Stedry, A.C.	1	
Siklossy, L.	1	1
Cheatham, T.E	1	
Clark, W.A.	1	
Holt, A.W.	1	
Ornstein, S.M.	1	
Perlis, A.J.	1	

Green, G.J.	1	
Lea, G.	1	
Farnham-Diggory, S.	1	
Reed, S.K.	1	
Gilmartin, K.J.	1	
Rosenburg, S.	1	
Crecine, J.P.	1	
Yu, B.	1	
Zhang, W.	1	
Jing, Q.	1	
Peng, R.	1	
Prietula, M.	1	
Mitchell, T.M.	1	
Pinheiro, V.D.E.	1	
Egidi, M.	1	
Marris, R.	1	
Viale, R.	1	
Kalagnamam, J.A.	1	
Schaeffer, J.	1	
Drudzel, M.J.	1	
Ishida, Y.	1	
Lee, Y.	1	
Zhu, D.	1	
Sleeman, D.H.	1	
Munakata, T.	1	
Lerch, J.	1	
Sarasvathy, D.K.	1	
Fernandes, R.	1	
Best, B.J.	1	
Cagan, J.	1	
Lave, L.	1	
Miwa, K	1	

References

Baars, B. J. (1986). The Cognitive Revolution in Psychology. New York, The Guilford Press.

Boumans, M. (2001). A macroeconomic approach to complexity. Simplicity, Inference and Modeling. Keeping It Sophisticatedly Simple. A. Zellner, H. A. Keuzenkamp and M. McAleer. Cambridge, Cambridge University Press.

Coase, R. (1937). "The Nature of the Firm." Economica **4**(16): 386-405.

Commons, J. R. (1924). Legal Foundations of Capitalism. New York, [unknown].

Commons, J. R. (1934). Institutional economics : its place in political economy. New York, Macmillan.

Fleurbaey, M. (2004). Normative Economics and theories of distributive justice. The Elgar Companion to Economics and Philosophy. J. B. Davis, A. Marciano and J. Runde. Northampton, Edward Elgar.

Florence, M. (1994). Foucault, Michel, 1926-. The Cambridge companion to Foucault. G. Gutting. Cambridge, Cambridge University Press.

Foucault, M. (1976). Surveiller et punir : naissance de la prison. Paris, Gallimard.

Gigerenzer, G., P. M. Todd, et al., Eds. (1999). Simple Heuristics That Make Us Smart. Oxford, Oxford University Press.

Hacking, I. (1986/1999). Making up People. the Science Studies reader. M. Biagioli. London, Routledge**:** 161-172.

Hands, D. W. (2001). Reflection without Rules, Economic Methodology and Contemporary Science Theory. Cambridge, Cambridge University Press.

Leonard, R. (forthcoming). From Chess to Catastrophe: Psychology and the Genesis of Von Neumann's Game Thoery. From Red Vienna to Santa Monica, von Neumann, Morgenstern, and Social Science, 1925-1960,. R. Leonard. New York, Cambridge University Press.

Mirowski, P. (2002). Machine Dreams, Economics Becomes a Cyborg Science. Cambridge, Cambridge University Press.

Neumann, J. v. and O. Morgenstern (1947). Theory of Games and Economic Behavior. Princeton, Princeton University Press.

Robbins, L. (1932). An essay on the nature & significance of economic science. London, Macmillan.

Simon, H. S. (1945). Administrative Behavior, A study of Decision-Making Processes in Administrative Organization. New York, The Free Press.

Simon, H. S. (1945). "Theory of Games and Economic Behavior." The American Sociological Review **50**(6): 558-560.

Simon, H. S., Ed. (1957). Models of Man, Social and Rational - Mathematical Essays on Rational Human Behavior in a Social Setting. New York, John Wiley & Sons.

Simon, H. S. (1969). The Sciences of the Artificial. Cambridge, The MIT Press.

Simon, H. S., Ed. (1977). Models of Discovery. Dordrecht, D. Reidel Publishing Company.

Simon, H. S. (1978). Autobiography, www.Nobelprize.org, http://nobelprize.org/nobel_prizes/economics/laureates/1978/simon-autobio.html. **2006**.

Simon, H. S., Ed. (1982). Models of Bounded Rationality, Vol. 1. Cambridge, The MIT Press.

Simon, H. S., Ed. (1982). Models of Bounded Rationality, Vol. 2. Cambridge, The MIT Press.

Simon, H. S. (1986). "The Behavioral Foundations of Economic Theory." The Journal of Business **59**(4): S209-S224.

Simon, H. S. (1986). "Interview: The Failure of Armchair Economics." Challenger **November-December**: 18-25.

Simon, H. S. (1987). Behavioural Economics. The New Palgrave Fictionary of Economics. J. Eatwell, M. Milgate and O. Newman. London, Macmillan.

Simon, H. S. (1991). Models of My Life. New York, Basic Books.

Simon, H. S. (1992). Rational Decision-Making in Business Organizations. Nobel Lectures, Economics 1969-1980. A. Lindbeck. Singapore, World Scientific Publishing.

Sugden, R. (1991). "Rational Choice: A Survey of Contributions from Economics and Philosophy." The Economic Journal **101**(407): 751-785.

Wikipedia (30/10/2006). Von Neumann Architecture, Wikipedia.

Wkipedia (30/10/2006). History of Computing, Wikipedia.

Wkipedia (30/10/2006). History of Computing Hardware, Wikipedia.

Wlliamson, O. and S. Winter, Eds. (1993). The nature of the firm : origins, evolution and development. New York, Oxford University Press.