J Econ Interact Coord (2006) 1: 21–32
DOI 10.1007/s11403-006-0006-7

REGULAR ARTICLE

Determinants of economic interaction: behavior or structure

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Published online: 9 May 2006

Abstract Experimental economics originated as examination of the behavior of aggregate phenomena, especially markets, populated by human participants motivated by their desire to attain their goals. The past two decades have brought two newer trends. One is a gradual but steady shift in the focus of the questions sought to be addressed through human experiments towards examination of micro level phenomena – individual preferences and behavior. The second is the expansion in the role of computer simulations to examine questions about aggregate level phenomena. This shift to individual behavior has accentuated the ever-present dilemma of social sciences in trying to be a science on one hand, and to understand our own self-conscious selves – human beings – on the other. To address this dilemma, it would be useful to recognize three streams of experimental economics: (1) macro stream to examine the properties of social structures, (2) micro stream to examine the behavior of individuals, and (3) agent stream to explore the links between the micro and macro phenomena using computer simulations. At least the structural stream can be firmly rooted in the tradition of sciences (bypassing the free-will dilemma of social sciences), while the agent stream can span the gap between the behavioral and structural streams.

Keywords Economic interaction · Agent-based · Aggregate outcomes · Individual behavior · Social sciences · Humanities

JEL Codes B29 · B49 · C91

The author is thankful to Dorota Dobija and Juergen Huber for their helpful comments.

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Science does not know its debt to imagination.
Ralph Waldo Emerson

Vivisection is a social evil because if it advances human knowledge, it does so at the expense of human character.
George Bernard Shaw

The theoretical broadening which comes from having many humanities subjects on the campus is offset by the general dopiness of the people who study these things.
Richard P. Feynman

Economics has an amazing capacity to summarize staggeringly complex phenomena by the application of only a handful of principles.
Charles R. Plott

Being outside and above individual and local contingencies, collective consciousness sees things only in their permanent and fundamental aspects, which it crystallizes in ideas that can be communicated.
Emile Durkheim

1 Market institutions

Experimental economics is widely believed to have originated in Edward Chamberlin's (1948) examination of a market institution under controlled conditions in his classroom. Vernon Smith was a student subject in Chamberlin's class; he (1962) redesigned Chamberlin's experiment and systematically varied the market conditions to examine their effect on prices, allocations, and extraction of surplus. Both these market implementations deviated in important ways from Walrasian tatonnement[1] – the standard abstraction of markets used in economics textbooks, and until recently, in much of the economics literature. Chamberlin and Smith fleshed out the Walrasian model with various details, using stock markets as a guide. Both used economic environment (market demand and supply conditions) and market design as independent variables to examine their consequences for the aggregate outcomes.

Economics experiments can yield a great deal of data, limited only by the interest and imagination of the experimenter, and the ingenuity in capturing the data without significantly distracting the subjects from their substantive task.

[1] Chamberlin assigned each student the role of a buyer (with a given reservation value) or a seller (with a given reservation cost), and allowed them to walk around and negotiate one-on-one with others in the room to conclude transactions, and report the completed transactions. Smith added two important features: the student traders stayed in their place submitting bids/asks by voice (subject to improvement rule). These bid/asks were recorded on the board for all to see. Second, after the students had exhausted their trading opportunities during the few minutes allowed to them, he repeated the experience several times, replenishing their endowments and starting afresh. In both these implementations each transaction was final at the moment it was negotiated, unlike the tatonnement process where price adjustments continue until the quantity demanded is equal to the quantity supplied.

Chamberlin captured three pieces of data for each transaction – price, seller cost, and buyer value – and the order of transactions. Examples of the data he might have, but did not, capture include: the clock time of transactions, details of the bargaining process (elapsed time, price proposals, number of proposals, number of counter-parties bargained with), etc.

Given the open-ended nature of the data that can possibly be gathered from an experiment, it is understandable that experimenters gather only what they need in order to answer the question(s) they wish to address on the basis of the experiment. Data capture is subject to constraints of the technology of capture, and the possibility of interaction between the capture and the subject behavior. Fortunately, the development of computer technology has eased both these constraints to some extent. In Chamberlin's experiment, asking subjects to report their transactions immediately after they successfully concluded the bargaining process served his purposes well, causing little interference with the substantive task (trading) of the subjects.

2 Shift towards micro phenomena

The focus of a great deal of work in experimental economics has gradually, but steadily, shifted from aggregate level market phenomena towards examination of the behavior of individual subjects. Three factors appear to underlie this shift: (1) the logic of analytical method, (2) incremental research designs, and (3) the empirical finding that people, acting by intuition alone, are not good at optimization, as is typically assumed in derivation of equilibria in economic theory.

2.1 Logic of analytical method

It is rare for correspondence between predictions of the relevant theory, and experimental data to be either perfect or non-existent. Most empirical findings lie somewhere between these two extremes. If the experimenter has no, or low, expectations of correspondence between the data and the theory, even a moderate correspondence is seen as a *half full* glass of water. Any explanatory power comes as a discovered surprise where little was expected.

However, conducting experiments where you expect to see no explanatory power is a difficult and expensive route to discovery. The number of such experiments is without limit, and since only a minuscule proportion of them can be expected to yield any knowledge, it is not a productive endeavor. Consequently, most experiments are designed to examine specific theories with some legitimate prior claim to have some predictive power. By definition, theories are simple models designed to capture a general tendency without claims to providing a perfect explanation for the phenomenon of interest. Before we look at the data, few theories inform us of the extent of their explanatory power; this power is usually estimated from the data, whether gathered from the field or laboratory. Accordingly, any imperfections in correspondence between data and theory are seen as a half empty, not a half full glass of water. Seeking a fuller explanation to close the gap between data and theory is a natural response of most investigators.

Following this logic, analysis and discussion of most experiments ends in a search for ways to increase the correspondence between data and theory – increasing the R-square, so to speak. Better prediction and explanation is, after all, the currency in which scientific progress is measured. We look for ways to modify the model to enhance its explanatory power through analysis – breaking the problem down into progressively smaller components. This logical pursuit shifts research question(s) to the next level of detail, causing "micronization" of economics. Analysis tends to dominate our thinking; synthesis – stepping back by discarding some chosen details – to see the big picture, is a less common reaction, especially when the data reveals the theory to be less than perfect.

For example, consider Chamberlin's and Smith's attempts to examine the basic economic theory that the point of intersection of market demand and supply determines the equilibrium price and allocations in an economy. Economists have long held deep faith in this simple theory about aggregate outcomes of the market process, although empirical evidence to support the theory was sparse. Neither Chamberlin's nor Smith's data corresponded precisely to the theory. In Fig. 1 (which reproduces Chamberlin's Fig. 3), none of the 19 transactions occurred either at the initial competitive equilibrium price of 57 or at the "moving equilibrium price" computed on the basis of un-traded units remaining in the market after each transaction. The average transaction price of 52 was considerably below these two equilibrium predictions. In Fig. 2 (which reproduces Smith's Chart 1), the first transaction at the equilibrium price occurred in the later part of the third repetition of the market. Thus neither of the two

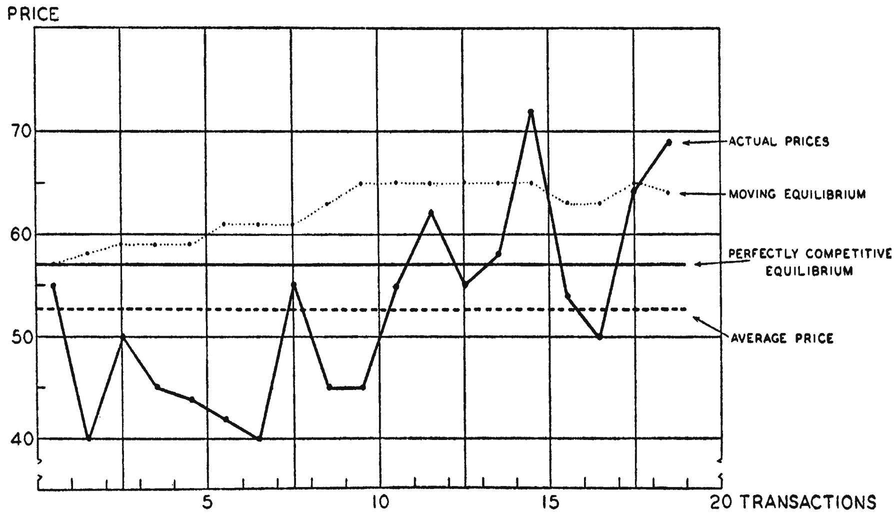

Fig. 1 Lack of correspondence between theory and data (Reproduced from Chamberlin 1948, Fig. 3)

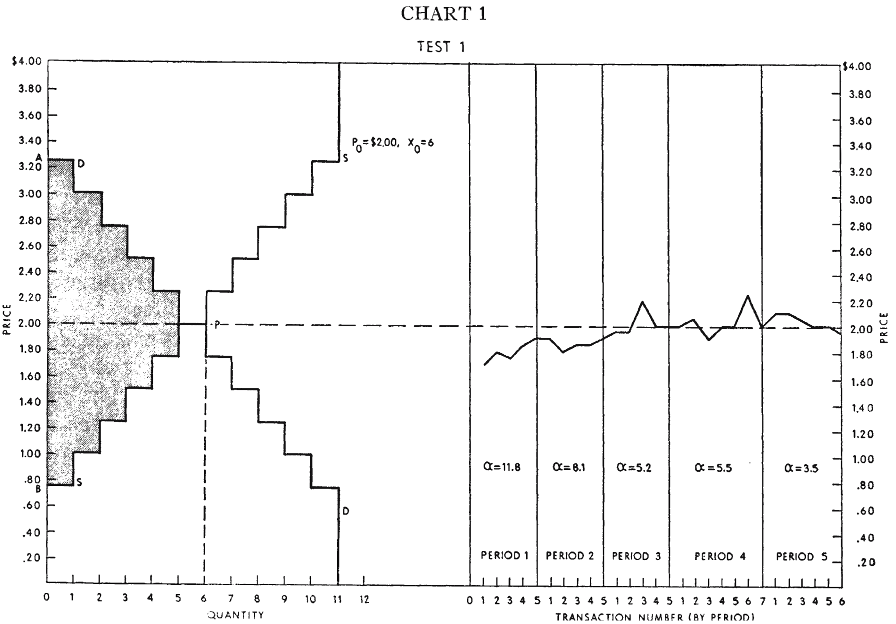

Fig. 2 Lack of correspondence between theory and data (Reproduced from Smith 1962, Chart 1)

experiments yielded results that corresponded to the predictions of Walrasian tatonnement. Given the general conceptual nature of the model, constructed to capture a common essential feature of innumerable ways in which markets are actually organized in our society, it would have been a surprise indeed if the correspondence was exact. It wasn't.

These two distinguished economists reacted to their results in very different ways. Smith saw the half full glass, and recognized the first irrefutable evidence for the significant explanatory power in a remarkably simple theory which had had little empirical support till then. Chamberlin, on the other hand, saw the half empty part and set out to build a model to better explain the residual variation left unexplained by the simple demand-supply model (instantaneous demand/supply). Perhaps it is this dominance of the analytical approach, and the logical consequence of this dominance, that has helped propel the questions addressed by the experimental method toward individual behavior and increasing detail.

2.2 Incremental research designs

A good part of research (including experimental research) is incremental, motivated by desires to (1) capture some additional uncontrolled variations in the underlying conditions that might help explain the residual variation between existing data and theory; (2) gather data about some additional aspects of behavior already observed; or (3) measure the sensitivity of observed behavior to some additional controlled variations in underlying conditions. We make conjectures about how such data or analysis might help us explain the residual variation between data and theory. Such incremental work dominates graduate seminars focused on critique and replication of extant work. It is easier to think of additional observations, motivations, and information conditions associated with individual participants, to improve the fit between data and the model.

Both the analytical logic that dominates research, as well as the incremental approach to design of experiments tend to push the model being examined towards the "micro" side. Additional variables do use up some degrees of freedom. However, observations at the micro level being far more numerous than at the macro level, this does not present a problem. A shift to the micro level also changes the research question(s) being asked. For example, the initial investigation of "Why is the price equal to x?" may soon be replaced by "Why did trader y submit a bid at price z?"

2.3 Humans as imperfect intuitive optimizers

A third driver behind the "micronization" of experimental economics is the now well-established finding that people are not good optimizers when acting on the basis of their intuition, especially when the task is an unfamiliar one. It is possible to devise laboratory tasks that, no matter how well explained to the subjects, will be performed poorly at first; a considerable amount of experience, even instruction, is often necessary before they perform the task correctly. Apparently, cognitive processes necessary for formulating and solving unfamiliar problems are no easier for laboratory subjects than for the academics who may take decades or centuries to accomplish the same.

That a paragraph or two of problem description is not necessarily sufficient for even intelligent people to comprehend and solve a problem is common sense. However, this finding from cognitive sciences, has often been juxtaposed with the "as if" argument used to defend the optimization assumption in order to derive theoretical equilibria of economic processes. This economic model, as the argument goes, assumes that individuals optimize and we have evidence from cognitive sciences that individuals are not capable of solving such optimization problems by their intuition. Therefore, the economic theory must be wrong. Widespread acceptance of this argument (to which we return later in the paper) is a third force that has driven experimental economics towards increasing preoccupation with micro level behavior. This shift towards micro behavior confronts economics with a fundamental dilemma shared among the social sciences.

3 Dilemma of social sciences

Sciences seek to identify universal laws of nature, applicable at all times and in all places. Respect granted to science arises from the universality expected of its findings. Laws that govern mechanics, light, sound, electricity and magnetism do not change, nor does our knowledge of these laws have any effect on their validity. Physics, chemistry and biology are the examples.

Humanities, in contrast to sciences, examine the human condition to find eternal truths, not laws. They celebrate the infinite variety of human behavior. Each person is unique, not subject to any constant or identifiable laws of behavior, yet driven by the same verities of human nature – sublime and base. In reading classic works of literature, whether the *Iliad, Mahabharata, Inferno*, or *Hamlet*, we see the same truths, questions, and tendencies appear in human beings everywhere. Yet no two human beings are alike, and there are no laws of human behavior. People, endowed with free will, choose in ways which are difficult to predict on the basis of their circumstances. Celebration of infinite variation in human nature lies at the heart of how humanities view the world. Indeed, it is the essence of how we distinguish ourselves from the rest of nature.

Science, then, is about eternal laws of nature valid everywhere at all times; its essence being the regularities of nature captured in known and knowable relationships among observable (including stochastic) elements. It helps us understand, explain, and predict observable phenomena: If I know X, science helps us form a better idea of whether Y was, is, or will be. Objects of science have no free will. A photon does not pause to enjoy the scenery. A marble rolling down the side of a bowl does not wonder about how hot the oil at the bottom is.

In social sciences, the irresistible force of human nature meets the immovable object of science. On one hand, the endowment of free will is essential to our concept of self as sentient beings who have the power to choose. Without the freedom to act, we would be no different than a piece of rock. Science studies rocks and other such objects without endowing them with free will. The object of study in social science is our own selves, and in order to be science, social science must look for eternal laws that apply to humanity. But stripped of the freedom to act, and subject to such laws, there is no humanity. Perfecting the scope and power of general laws of human behavior also implies squeezing out the essence of humanity – our free will. What, then, does it mean to have a science of individual human behavior?

Moreover science does not go well with personal responsibility. Objects of science can have no personal responsibility because they do not choose to *do* anything. They are merely driven by their circumstances, like a piece of paper blown by gusts of wind. We don't blame a rock rolling down the hill under the force of gravity, if it hits an oncoming car. If an abused child grows up to be an abusive parent, is he personally responsible for his behavior? Are we ever personally responsible for what we do, if we accept ourselves as subjects of study under the premises of a social science? Science and personal responsibility do not mix.

This neither-fish-nor-fowl character of social science is exemplified in the continuing attempts to build a theory of choice in economics. From the science end, we axiomatize human choice (from a given opportunity set) as a function of the innate preferences of the individual – people choose what they prefer. How do we know what they prefer? Look at what they choose. The circularity between preferences and choice might be avoided if there were permanency and consistency in preference–choice relationship across diverse contexts. One could observe choice in one context, tentatively infer the preferences from these observations, and assuming consistent preferences, predict choice in other contexts. Unfortunately, half-a-century of research has yielded little predictability of choice from inferred preferences across contexts (Friedman and Sunder, 2004). Individual human behavior appears to be unmanageably rowdy for scientists to capture in a stable set of laws. While humanists do not take delight in our discomfort, they can hardly be surprised (if they pay any attention at all to choice theory) at our failure to reduce human behavior to a fixed set of laws.

Hence we see the dilemma of social sciences. Do we abandon free will, personal responsibility, and special human identity; and treat humans like other objects of science? That is, drop the "social" qualifier, and become a plain vanilla science? Or, do we drop the "science," abandon the search for universal laws, embrace human free will and unending variation of behavior, and join the humanities? Either way, there will be no social science left. Is there a place where we can keep the "social" and the "science" together?

4 Three streams of work

There may be no general solution to this dilemma. However, there is potential value in isolating three streams of work in which this problem varies in its severity. Significant parts of social sciences, and a large part of economics, are concerned with aggregate level outcomes of socio-economic institutions. The institutions themselves being human artifacts (Sunder 2004), do not need to be ascribed intentionality or free will. Characteristics of the institutions can be analyzed by methods of science without running headlong into the problems outlined above. This leaves the analysis of individual behavior in the territory between science and humanities. Agent-based models (in economics and elsewhere) could serve the bridging function between aggregate and individual level phenomena (Mirowski 2002). Let us consider these possibilities.

I do not have much to add on the most complex problem, of examining individual behavior. It seems that we shall continue to look at ourselves and our behavior, using both humanities as well as science perspectives, without ever reconciling the two into a single logical structure. I hope there is a way out, but I do not see it.

Experimental economics started out as investigation of aggregate level outcomes of market institutions using human subjects. Three forces appear to have driven the gradual shift of attention from aggregate outcomes to micro behavior: the logic of analytical approach; incremental research designs; and behavioral interpretation of the optimization assumption made in equilibrium analysis of aggregate phenomena. Cognitive psychology showed that individuals are far from perfect at optimization by intuition. This mismatch between the optimization assumption and actual behavior at individual level has given additional impetus to the "micronization" of experimental economics. Recent developments using agent-based methods permit us to conduct the study of socio-economic institutions using methods of science.

4.1 Optimization and equilibrium

The standard approach of economic analysis has been to assume that individuals optimally choose their actions given their preferences, information and opportunity sets (Dixit 1991). Interactions of individual actions within the context of institutional rules yield outcomes (e.g., prices and allocations). Of all possible outcomes, equilibrium outcomes are of special interest. However, equilibrium predictions, derived from assuming individual optimization could be suspect when this assumption is not valid. Agent-based simulations reveal that individual optimization may be sufficient, but not necessary, for specific market institutions to yield outcomes that approximate the equilibria derived from the optimization assumption.

Three panels of Fig. 3, for example, show the price paths of double auction simulations conducted with three kinds of agents (Gode and Sunder 1993a, b). The top panel shows the results obtained when agent-traders randomly pick numbers from the 0–200 range, and submit them as bids or asks. The bottom panel shows the results from the same double auction market populated by profit-motivated human traders. The middle panel shows the results from the same double auction market populated by agent-traders who are subject to budget constraints (i.e., they pick or are constrained to pick their bids randomly from the range 0 and their value, and pick their asks from the range 200 and their cost). The price paths (shown in Fig. 3), as well as allocations and efficiency (not shown), reveal that the results on the middle panel are close to the equilibrium prediction and to the results (in the bottom panel) obtained from markets populated by profit-motivated human traders.

Why do the markets populated with simple budget-constrained random bid/ask agents converge close to Walrasian prediction in price and allocative efficiency? These agents are endowed with no memory, learning, adaptation, maximization, or even bounded rationality. After the initial surprise reaction, and when the search for programming and system errors did not yield fruit, modeling and analysis supported these simulation results. Perhaps it is the structure of institutions and not the behavior of individuals that accounts for the first order magnitude of outcomes in competitive settings. At the very least, institutions appear to have stable, observable properties of their own that can be studied using methods of science (Bosch-Domenèch and Sunder 2000).

Computers and experiments with simple agents opened a new window into a previously inaccessible aspect of economics. Ironically, this discovery did not originate in computers' well-publicized and celebrated optimization capability. Instead, it became possible because computers enabled us to deconstruct human behavior. We could isolate the market-level consequences of the structure of institutions because we could observe such consequences in markets populated

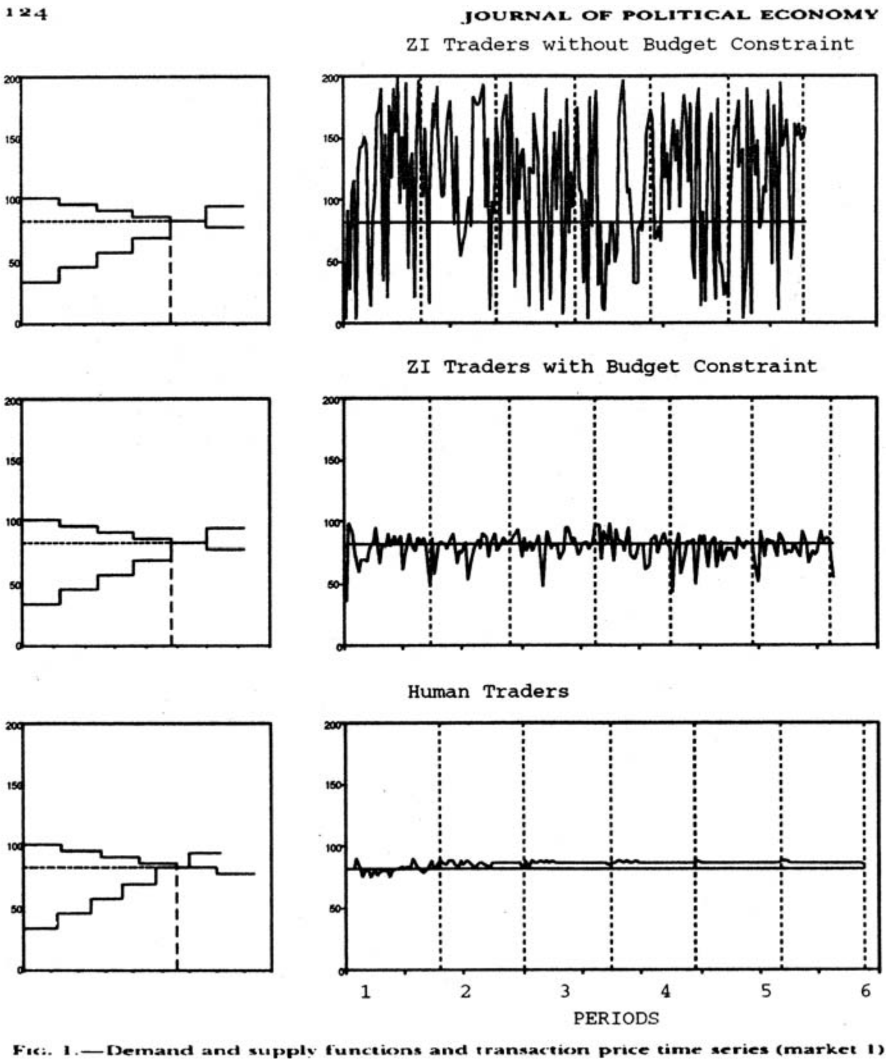

Fig. 3 Structural properties of markets as a science (Reproduced from Gode and Sunder 1993a, Fig. 1)

by software agents which modeled simple or arbitrarily chosen classes of individual behavior.

In physics marbles and photons "behave" but are not attributed intent or purpose. Yet, the optimization principle has proved to be an excellent guide to the general tendencies of physical and biological systems. For example,

> At multiple hierarchical levels – brains, ganglion, and individual cell – physical placement of neural components appears consistent with a single, simple goal: minimize the cost of connections among the components.

> The most dramatic instance of this "save wire" organizing principle is reported for adjacencies among ganglia in the nematode nervous system; among about 40,000,000 alternative layout orderings, the actual ganglion placement in fact requires the least total connection length. In addition, evidence supports a component placement optimization hypothesis for positioning of individual neurons in the nematode, and also for positioning of mammalian cortical areas (Cherniak 1994).

These observations from biology make one wonder how human cognition, with all its biases and incompetence, could have gone so wrong. Is it possible that such studies of cognition use an inappropriate benchmark to arrive at their conclusions? Or, perhaps we focus on the trees, losing sight of the forest?

Economics imported the optimization principle from science. Given the inanimate nature of its subjects, science used optimization principle as an organizing principle of nature. In economics, we humans and our systems are the objects of analysis. Mechanical application of the optimization principle to ourselves offends our self-esteem, and negates our free will. It may have been for this reason that the optimization principle, when imported into economics, was reinterpreted as a behavioral principle. It is not surprising that the switch from structural to behavioral principle was soon followed by a shift in focus from aggregate to individual behavior. Since cognitive sciences established that we are not very good intuitive optimizers, an increasing number of economists have been willing to abandon the optimization principle labeling it the "infinite faculties" assumption (Conlisk 1996).

5 Concluding remarks

Recognizing the tendency of analytical method towards reductionism, Simon (1996) wrote in the third edition of *The Sciences of the Artificial*:

> This skyhook-skyscraper construction of science from the roof down to the yet unconstructed foundations was possible because the behavior of the system at each level depended on only a very approximate, simplified, abstracted characterization of the system at the level next beneath. This is lucky, else the safety of bridges and airplanes might depend on the correctness of the 'Eightfold Way' of looking at elementary particles.

Indeed, the powerful results of economic theory were derived from "a very approximate, simplified, abstracted characterization of the system at the level next beneath," – the economic man so maligned, and its scientific purpose and role so misunderstood, by many who claim to be followers of Simon.

Economics can be usefully thought of as a behavioral science in the sense physicists study the "behavior" of marbles and photons. Given the pride we take in attributing the endowment of free will to ourselves, this interpretation of behavior is a hard sell in social sciences. To build on the achievements of theory, it may be better if we think of optimization in economics as a structural principle, as scientists do.

This will allow us to focus on the structural stream of economics in the tradition of sciences. Individual behavior is likely to remain as a shared domain of humanities and sciences. Modeling specific behaviors as software agents in the context of specific economic institutions allows us to make conditional statements about the links between individual and aggregate level phenomena.

Acknowledgements A preliminary draft of this paper was presented at the FINEXE Workshop, University of Joensuu, Finland, June 10, 2005, and at the Tenth Workshop on Economic Heterogeneous Interacting Agents (WEHIA 10) at the University of Essex, June 13–15, 2005. I am grateful for the comments received from the participants at the conference and the editors.

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