EXPERIMENTAL RECIPES

19th Herbert Simon Lectures, Part 1

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Experimental economics has an effective, or computable, core. The concept of an experimental recipe is formulated and discussed in detail. This first talk introduces students to experimental economics in a practical way: we will view the creation of an economic experiment like a short-order cook views a meal: as the creation of a simple series of steps combined in a certain order. Later, we'll fill in the theoretical blanks we left behind. Experiments in economics have gained currency in the last 40 years, culminating in the award of the 'Nobel' prize in economics to Vernon Smith in 2002. More distinguished experimenters are sure to receive the prize in coming years, particularly Prof. Charles Plott. The AIECON lab has world-renowned expertise in computational intelligence. Experimental studies of intelligence, broadly defined, and in a Simonian sense, will serve to bolster and augment the research currently being undertaken at the AIECON lab. This talk introduces students to the planning and running of a real world experiment. We'll define terms as we go. The object of the first lecture is to be as 'hands on' as possible with the material.

"The understanding of the theory of a routine may be greatly aided by providing, at the time of construction, one or two statements concerning the state of the machine at well chosen points."
—Alan Turing, Ferranti Mk 1 Manual, 1950

1. RECIPE

The 'experiment' in economics is now well established as a tool of investigation, instruction and empirical verification, though not, as yet, of theoretical falsification. Experimental economics is not yet capable of supplying what Mill called the 'experimentum crucis'[0]. Experimenters can, however, now confidently refute the claims of writers like Marshak who claim economic postulates are not, *a priori,* testable[1]. Progress has been made.

The task of computable and experimental economics is to frame the questions asked empirically by experiment in a new language, to reduce the mathematical gaps between theory, the broad corpus of which is *not* computable, and experiments, which, by necessity, are. The tool I'd like to talk about today, and in the next lecture, will be the *counter example*.

The goal of this lecture is a simple description of the foundations of experimental economics, viewed as a proper subset of computable economics. Let us begin simply, with the concept of an experimental *recipe*[2]. This notion of recipe is in strict accordance with the sense in which Knuth, in *The Art of Computer Programming,* Vol 1, pg. 6, uses the idea of a recipe to explain an algorithm:

> "Let us try to compare the concept of of algorithm with that of a cookbook recipe. A recipe presumably has the qualities of finiteness…, inputs,...and output, but it notoriously lacks definiteness. There are frequent cases in which a cook's instructions are indefinite.

[0] J. S. Mill, *Essays on Some Unsettled Questions of Political Economy,* 2nd ed, Kitchener: Batoche Books, 2000 [1874], pg 104.

[1] "The [economist] cannot emulate the engineer's dry runs...He cannot set up a laboratory experiment to study the behavioural responses of representatives of each economic group to changes that would stimulate the actions of actions of other groups or changes in the common environment."
—Jacob Marshak, On Econometric Tools, Synthese, 20(1), 483-88. (1969)

[2] recipe |ˈresəˌpē|
noun
a set of instructions for preparing a particular dish, including a list of the ingredients required; figurative: something which is likely to lead to a particular outcome

Nevertheless, a computer programmer can learn much by studying a good recipe book."

1. 1 WHAT IS AN EXPERIMENT?

We can define an experiment as a effective procedure for the discovery of, and selection between, different possible explanations that are of equivalent or greater or lesser importance to us[3]. The goal of computable and experimental economics is an increased understanding of real world phenomena by designing effective experiments to systematically break model assertions. This definition requires some explanation.

[3]"But in the last analysis [economics] reduces to this, that we can judge whether different possible explanations are of equivalent or greater or lesser importance to us" —*Lionel Robbins, The Nature and Significance of Economic Science, in An Essay on the Nature and Significance of Economic Science, London: Macmillan, 1939.*

1. *Effective procedure.* By effective we mean a well-defined, finite procedure with well-defined inputs and outputs. To work at all, this set of instructions will require what Knuth (ibid., pp. 21-22) calls 'assertions'. These are the indefinable elements of the cookbook, the dashes of salt, the pinches of spice, that serve to differentiate any economic experiment. Knuth argues "we really only understand an algorithm when we have filled in all the assertions."

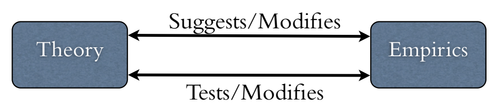


Figure. Naive positivist viewpoint: The alternation of theory and empirics as an *error-reduction* mechanism is explicitly stated.

The task of the experimenter in economics is to make clear the assertions implied within simple economic models, and to test those assertions with reference to controlled real-world data[4]. These assertions come from many places, including the experimenter's life, and give rise to the testable hypotheses of any theory's model-forms.

[4]For example, Ido Erev and Alvin Roth (1998), "Predicting How People Play Games: Reinforcement Learning in Experimental Games with Unique, Mixed-Strategy Equilibria," American Economic Review, 88, pp. 848–881.

2. *Discovery and Selection.* The efficient discovery and partition of 'good' and 'less good' models via experimental methods is not at this time clearly and well understood. One can take an existing theory–say, some aspect of risk aversion—and see to what extent the theory generated thus far explains the data gathered, and refine the theory in accordance with the experimental data gathered. This is the naive positivist view of scientific progress, and to a certain extent it operates within economics. This view has come under fire recently[5]. Tools and techniques of appropriate model selection become extremely useful in this realm.

[5]Vernon Smith, Theory and experiment: What are the questions?, Journal of Economic Behaviour and Organization, 73(1), 3-15, and references therein.

3. *Systematically breaking model assertions*. Smith[4, 5] describes experimental economics as helping to analyse the anatomy of a theory's failure. Systematically breaking a theory down, assumption by assumption, in the hopes of rebuilding it in a more useful form.

[4]As Smith writes in his Nobel Lecture: 'Markets economize on the need for virtue, but do not eliminate it.', pp. 502.

This lecture is laid out as follows. I discuss the tools, rule, and fools that make up the base of an economic experiment, highlighting their problems along the way, in section 2. I

[5]Vernon Smith, Economics in the Laboratory, *Journal of Economic Perspectives*, 8(1), 113-131.

describe the bones of an experiment recently carried out at the computable and experimental lab at the University of Limerick on electricity pricing as a practical example of the principles involved in computable and experimental economics, in section 3. I conclude with some speculations on the future of computable and experimental economics on the edge of validity, to which I will return in lecture 2.

1.2 WHY ARE EXPERIMENTS USEFUL?

Experiments in economics perform various functions[5].

1. Experiments refine theories, as in the celebrated case of Fehr and Schmidt's 1999 QJE paper on inequity aversion. I disagree with the notion of experimental economics as an engine of theory falsification--no theory can be 100% falsified by a battery of experiments. Rather, the experiment can be usefully employed in modifying, refining, and extending existing theories.

2. Experiments can construct new theories. No general theory of fairness emergence in games has yet been formulated to my knowledge, but the data currently exist in replicable, testable form, pointing to a new theory of human behaviour in economic environments, with a preference for social fairness built into that theory.

3. Experiments can help design institutions, redesign institutions, and break them. Here Roth's notion of the economist as engineer meets its apogee with markets for organs, US resident-doctor selection markets, and

4. Experiments test predictions, for example, in Smith's double auction model. Experiments have a clearly algorithmic shape, as the two figures to the right show.

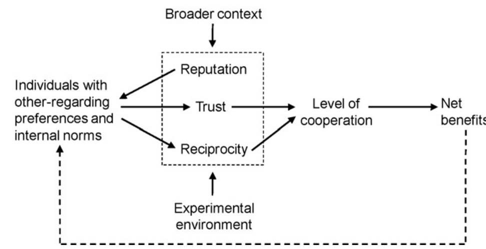


Figure. Trust feedbacks, reputation flows.

Source: Poteete, A., Janssen, M., Ostrom, E., 2010. *Working Together: Collective Action, the Commons, and Multiple Methods in Practice.* Princeton University Press, Princeton, NJ.

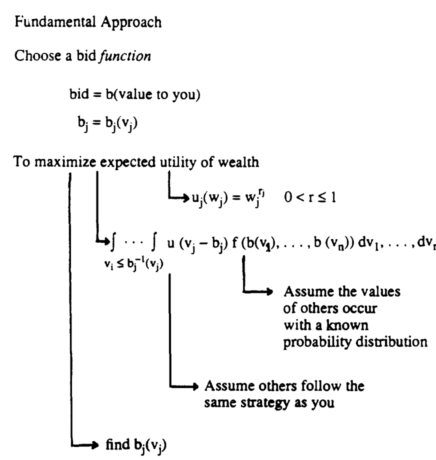


Figure. Fundamental flow chart for Individual Choice experiments. Source: Charles Plott, Will Economics become an experimental science? Southern Economic Journal, 57(4), 901-919, 1991

1.3 RECIPE FOR AN EXPERIMENT

INGREDIENTS.

- *Subjects*. Persons whose preferences are to be induced in an experimental environment.

- *Environment*. N subjects exist with an environment, and must interact with one another over a space of O+1 commodities.

- *Institution*. The environment might also be equivalent to an institution, but usually there is an institutional arrangement on top of the environment. The environment is then a set of M rules the N subjects must adhere to within the experiment for O+1 commodities. The set M can in principle be very large, and contain multiple languages, multiple property rules, adjustment and transition rules, cost and profit functions, and more. The figure to the right gives an idea of how these three ingredients 'mix' in a microeconomic system.

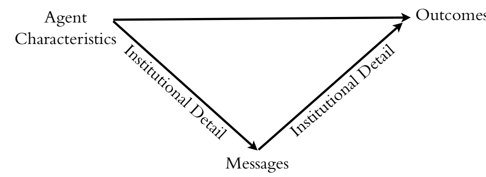
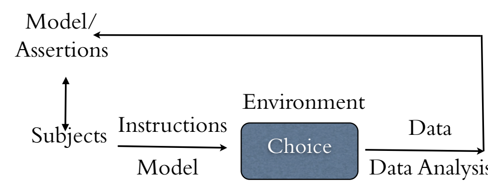


Figure. A Microeconomic system. Adapted from Vernon Smith, Microeconomic Systems as an Experimental Science, *American Economic Review*, 72(5), 923-955, 1982

DIRECTIONS

The design of the experiment takes time, and normally comes first from the literature. Following a pilot, where the rules of the experiment are ironed out and revised, the experimental subjects must be instructed on what to do after registering for the session. These instructions should be as clear as possible to avoid confusion. Ideally the lab session should be run with Ztree or an equivalent software. The results of the experiment are then saved automatically on an excel spreadsheet for statistical analysis. Following simple descriptive statistics, inferential data analysis can be applied to test different hypotheses (or assertions) statistically, as the figure to the right shows.



It should be clear that though the preceding section is in fact a recipe, there are many hidden 'assertions' within the recipe which need to be cleared up. And for that, we need more information on the specific nature of the question being asked, the theory being tested, and the type of mathematics being employed[6].

6. Lewis, D. K. 1969. Convention: A Philosophical Study. Cambridge, MA: Harvard University Press and Aumann, R. J. (1976), Agreeing to Disagree, Annals of Statistics 4, 1236-1239

2. TOOLS, RULES, AND FOOLS

2.1 TOOLS

The recent history of experimental economics has been its confirmation, refutation, or extension of game theoretic concepts and models. For example, Smith[4,5] describes the knowledge gleaned from examining the double auction model via experimental methods over a 50 year period, and, in addition to broadly confirming the double auction's theoretical results, Smith also marvels at how "the theory failed to predict the weak conditions under which these outcomes would prevail." Smith is clearly pleased with the success of experimental economics to date, and yet concerned that the results of the theory do not exactly accord with what happens in the lab setting. This is because the lab setting is capable of revealing more information about economic reality—however caricatured by the experimental design—than the theory!

The double-auction market, for example, is capable, in a lab setting, of solving for price and quantity in the presence of incomplete information. It is also capable of finding prices in a dynamic process: the theory of equilibrium formation in double auction models is static. So the experimental design is ahead of the theory in many respects. The game-theoretic form of the double auction, as designed by experimenters is in reality simpler and more complex than the theory it purports to test: something is going on here. The experiment is capable of throwing up paradoxes, counterexamples, and even refinements to the theory.

Simple economic models have, at their core, a set of assumptions about individual behaviour under certain institutional conditions. Theory identifies one–or a few–critical variables that may help us gain a partially satisfactory understanding of some phenomena. Instead of thinking of a theory as being right or wrong to some degree when passed through the filter of real-world data, I think it is better to use experiments to assess a theory by how useful it is for understanding the real phenomena of interest: risk aversion, or trust formation, or behaviour under uncertainty, say. When there are two or more theories of the same phenomena, one may compare them on the basis of their usefulness in understanding the real phenomena, but as I have written above, there currently exists no procedure to perform this function of model selection in experimental data. The tools are currently not up to scratch.

[7]Binmore, K., 1987/1988. Modeling rational players I&II. Economic Philosophy. 3&4, 179–214 & 9–55.

To be concrete, our recipe for an economic experiment needs certain tools. The tools of an economic experiment are:

2.2 Rules

Smith's[8] landmark 1976 paper introduced induced value theory to experimental economics. Induced value theory basically lists sufficient conditions, or precepts, for controlling the preferences of human subjects. The objective is to make subjects focus on their personal cash payoffs, and this focusing will induce value on intrinsically worthless objects by redeeming them for cash according to a utility function chosen by the experimenter. It is fair to say induced value theory is the core of experimental economics. If one believes the theory, then it is clear that once one controls for salience, dominance, and monotonicity, as described below, the experimental protocol can map from the laboratory into the real world, that is, the experimental protocol has *external validity*. These assumptions[8] are fundamental to experimental control over subjects' preferences, and so I reproduce them below.

[8]See Vernon Smith, Microeconomic Systems as an Experimental Science, *American Economic Review*, 72(5), 923-955, 1982

1. *Monotonicity*. Given a choice between two amounts A and B, when A > B, subjects will choose B.

2. *Salience*. The reward received by the subject depends on their actions within the experiment.

3. *Dominance*. Actions of subjects are primarily driven by the details of the experiment, not external forces.

4. *Privacy*. Each subject must have information about only their own payoffs and alternatives.

5. *Parallelism*. If conditions 1-4 are fully satisfied, the results of the laboratory should map to non laboratory settings where the same conditions hold, *ceteris paribus*.

These assumptions help one achieve 'control', meaning that most factors which influence behavior are held constant and only one factor of interest (the 'treatment') is varied at a time. This controlled variation of factors is crucial for being able to draw causal inferences from various treatments.

2.3 FOOLS

Game theory as an imperfect ideal. Binmore[7] modeled his rational players as conforming to an 'ideal' theory of strategic interaction. More useful in 2010 would be a behavioural--in the Simonian sense—theory of strategic interaction, emphasizing, inter alia, heuristics, norms, computational complexity, information, institutions, and dynamics. The development of such a theory is underway all over the globe. Right now, however, the core of economic theory still assumes what Amartya Sen calls 'rational fools' in place of more meaningful and behaviourally motivated description of economic actors. Lowenstein, in calling for a more behavioural economics in the Economic Journal, asks why it has taken so long for economics to reach a behavioural description of economic agents. Ironically, Binmore, in the same issue, considers the job done.

2.4 TESTING THEORIES COMPUTABLY

Logic. Respecting the logic of the model is key. When an experiment does not follow the logic of the model it is testing, the outcome is not well defined.

Model Selection. If the experimental results confirm the theory we can alter the parameters of the experiment to identify the robustness of the model ("stress-testing"), or use the experimental results to estimate parameters of the model. The concept of 'model' needs a little consideration here. Let us view a model of an event (or a phenomenon) as a 'list' of the essential features that characterise it.

For instance, to model a traffic jam, we try to identify the essential characteristics of a traffic jam. Overcrowding is one principal feature of traffic jams. Another feature is the lack of any movement of the vehicles trapped in a jam. To avoid traffic jams we need to study it and develop solutions---perhaps in the form of new traffic rules. However, it would not be feasible to study a jam by actually trying to create it on a road. Either we study jams that occur by themselves 'naturally', or we can try to simulate them on a computer or in an experimental lab setting.

The former gives us 'live' information, but we have no way of knowing if the information has a 'universal' applicability–all we know is that it is applicable to at least one real life situation. The latter approach–simulation–permits us to experiment with the assumptions and collate information from a number of live observations so that good general, universal 'principles' may be inferred. When we infer such principles, we gain knowledge of the issues that cause a traffic jam and we can then evolve a list of traffic rules that can avoid traffic jams. That is the promise of simulation, and experimental study, simultaneously.

To simulate, we need a model of the phenomenon under study. We also need another well known system which can incorporate the model.

Continuing the traffic jam example, we can create a simulation using the principles of mechanical engineering (with a few more from other branches like electrical and chemical engineering thrown in if needed). We could create a sufficient number of toy vehicles. If our traffic jam model characterizes the vehicles in terms of their speed and size, we must ensure that our toy vehicles can have varying masses, dimensions and speeds. The model might specify a few properties of the road, or the junction - for example the length and width of the road, the number of roads at the junction etc.

Computational intelligence is one such simulation (or agent-based) tool, where experiments can define the upper bound of behaviour for subjects to approximate in laboratory settings. Computational intelligence methods have been applied to the design of autonomous agents, in particular, their adaptive schemes and rule representations in financial settings. In particular, computational intelligence studies on the cognitive capacities of different agent types within various environments could be extremely valuable, as experimental studies typically cannot vary the intelligence of their subjects, a major criticism of the experimental method. Also, computational intelligence can study (and perhaps discover) alternative filters for assertions within a model schema, taking the model to its *edge of validity* as Smith proposes.

CONCLUSION TO LECTURE 1: EXPLORING THE MARKET AS AN ALGORITHMIC PROCESS

Smith finishes his Nobel lecture (pg. 552, italics my emphasis) with an appeal to computability and to the usefulness of thinking of just what the market produces by dint of the self-interested activities of its participants:

1. Markets constitute an engine of productivity by supporting resource specialization through trade and creating a diverse wealth of goods and services.

2. Markets are rule-governed institutions *providing algorithms* that select, process and order the exploratory messages of agents who are better in-formed as to their personal circumstances than that of

> others. As precautionary probes by agents yield to contracts, each becomes more certain of what must be given in order to receive. Out of this interaction between minds through the intermediary of rules the process aggregates the dispersed asymmetric information, converging more-or-less rapidly to competitive equilibria if they exist. Each experimental market carries its own unique mark with a different dynamic path.

Clearly the task of computable and experimental economics is to discover which algorithms are being provided by these institutions, which affects the market's behaviour, and thus the outcomes of the market for its various participants.

Now we'll look at a practical example of an experiment in action.