Introduction to designing Microeconomic Systems*

1 Introduction

I am certain that you all have had some course in econometrics and I would like you to think of experimental economics in the same way as you do econometrics, as a methodology.[1] While there tends to be more formal rigorous analysis in econometrics (one can prove unbiasedness and consistency properties of estimators and such), one should not take the view that experiments are just games that can be thrown together simply because there is a lack of Greek symbols in discussions of the methodology of experiments. Indeed, Smith's 1982 American Economic Review article that relates microeconomic systems and experimental science contains some such Greek symbols. Like an econometrician who attempts 20 different regressions before finding a statistically significant result with the correct sign, people proceed to do experimental work poorly.[2] And doing a poor experiment is pretty much as easy as doing poor econometric work – the primary difference is that you need to involve other living beings when you run an experiment. So I ask you to consider experimental economics as you would any other methodology – it has its benefits and its drawbacks. The beauty of doing research is that one can approach a topic from all different angles – theory, empirics, experiments – in an attempt to discern the "truth". One should consider evidence and arguments from all methodologies when making a decision. While it was never going to win an Academy Award, consider this line from the movie Bloodsport:

> "You told me to use any tactic that works, never to commit yourself to one style, to keep an open mind!"

That is only my opinion about how the different methodological approaches should be viewed – take it for what it is.

2 Creating a Microeconomic System[3]

There are two essential building blocks to a microeconomic system, the Environment (e) and the Institution (I). The Environment consists of:

1. N economic agents
2. $K + 1$ commodities
3. Agent characteristics (utility functions u^i, technology endowments T^i, and commodity endowments w^i)

*Based on Vernon Smith's 1982 AER paper and Chapter 1 of Friedman and Cassar.

[1] Many people who do experimental economic research like to refer to themselves as "experimentalists" when they are asked what they do. I strongly feel it would benefit the profession to treat economic experiments as a methodology as opposed to a "field" like international trade or industrial organization. If one's research uses econometric techniques in the field of labor one does not call himself or herself an "econometrician".

[2] It is not my intention to let the theorists off lightly here. When you read a theory paper ask yourself if you truly believe the theorist set out to prove result X that is in the paper, or if he tried to prove the more interesting result Z first and failed. He then tried to prove the medium interest result Y next, failed, and then settled on proving result X because it was what he could prove and it was somewhat interesting, although not nearly as interesting or powerful as result Z or Y that he wished to prove originally.

[3] This borrows HEAVILY from the first part of Smith (1982). Microeconomic Systems as an Experimental Science. *American Economic Review, 72:5*, 923-955. One really should read the actual paper.

The Environment is these characteristics for all N agents $E = \left(e^1, ..., e^N\right)$. These features are inherently private – each agent knows his tastes and endowments but they are not directly observable by others, only outcomes are observable. These seem like reasonable assumptions for *any* microeconomic system, and have nothing to do with experimental economics in particular.

The Institution essentially consists of what property rights they agents have and do not have. The Institution might be loosely interpreted as the "rules of the game". An institution consists of:

1. A language $M = \left(M^1, ..., M^N\right)$ consisting of messages $m = \left(m^1, ..., m^N\right)$ where $m^i \in M^i$.
2. A set of allocation rules for each agent i, $H = \left(h^1(m), ..., h^N(m)\right)$, where $h^i(m)$ specifies the commodity allocation to each i as a function of the messages sent by all agents
3. A set of cost imputation rules for each agent $C = \left(c^1(m), ..., c^N(m)\right)$, where $c^i(m)$ specifies the cost to be made based on the message m.
4. A set of adjustment process rules $G\left(g^1(t_0, t, T), ..., g^N(t_0, t, T)\right)$ where:
   - starting rule: $g^i(t_0, \cdot, \cdot)$ is the time and conditions under which the exchange of messages will begin
   - transition rule: $g^i(\cdot, t, \cdot)$ that governs the sequence and exchange of messages
   - stopping rule: $g^i(\cdot, \cdot, T)$ under which the exchange of messages ends and allocations are determined

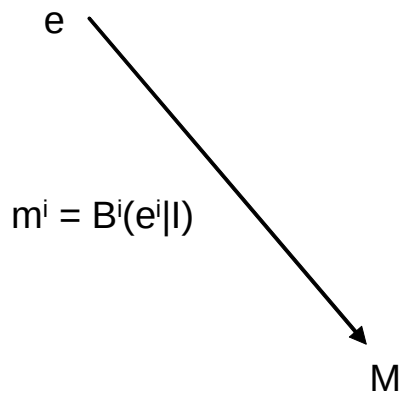
Some clarification is in order. The term "messages" seems to mean something different in today's language with the rise of instant messaging and text messaging. A message may be something nonbinding like one might receive in a text message, but I believe Smith has *binding* messages in mind. Again, to take a current example, consider EBay. A "message" using Smith's terminology is like a bid in EBay – legally, your bid/message establishes a binding contract if you end up as the current high bidder AND the seller does not have a reserve price. Allocation rules and cost imputation rules may be one and the same, but are separated because they do not need to be. Think of a 2^{nd} price sealed bid auction – the allocation rule is that the highest bidder receives the item, but the payment made by the winner is not based on his bid but the bid of the 2^{nd} highest bidder. The transition rule need not be implemented in all cases – consider a 1^{st} price sealed bid auction. There are no transitions as all bidders simply submit a bid at the beginning of the stage and then receive an allocation once all bids are submitted. The agent's property rights are defined by $I^i = \left(M^i, h^i(m), c^i(m), g^i(t_0, t, T)\right)$. An Institution is defined by $I = \left(I^1, ..., I^N\right)$.

A microeconomic system, which consists of an Environment and an Institution, is given by $S = (e, I)$.

2.1 How do agents behave?

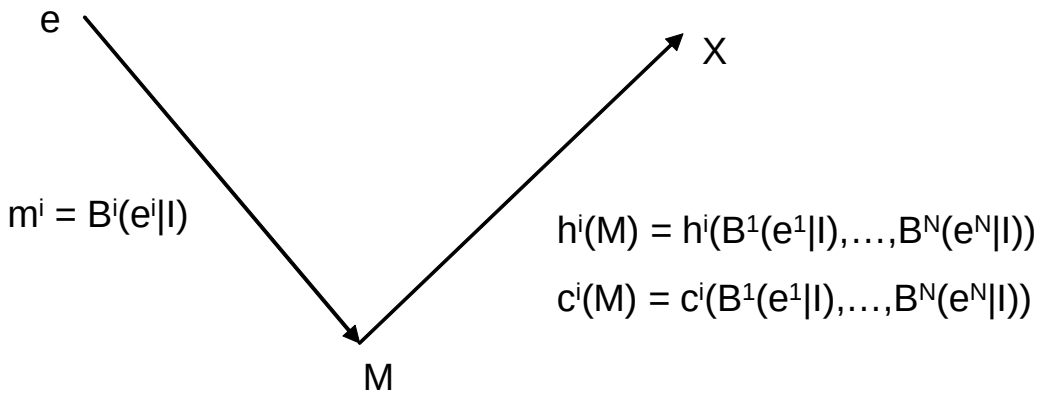
We can represent outcome behavior as $B\left(e^i | I\right) = m^i$. Outcome *behavior* is the message sent by the player, since behaviors are actions and messages are the actions in this structure. Note that the message is conditional on the institution, meaning that even when environments are the same messages may be different under different institutions. Intuitively, this should make sense. Consider a 1^{st} price sealed bid auction and a 2^{nd} price sealed bid auction. Even if the environments are exactly identical[4] the messages sent (the bids) will be different in the different institutions. Thus, we can draw a first leg of a triangle diagram.

[4] Exactly identical is redundant, but I'm trying to make the point that everything is the same in e.



First leg of the triangle

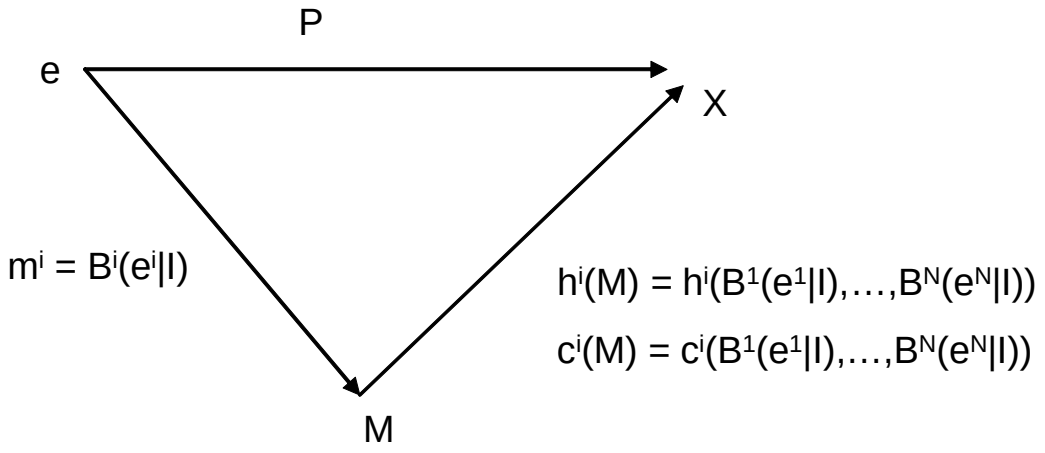
Why specify all these pieces? We specify them because agents choose messages in the "real world", not allocations. Consider the standard consumer choice problem in microeconomic theory. There is an agent with an endowment and there are some commodities with some prices and the agent chooses the optimal bundle from the feasible set of bundles. There is no mention of how the agent chooses this, or what the features of the market are (is the purchasing process bilateral bargaining, posted-price, double auction, one-sided auction, etc.). The *assumption* in the standard consumer choice problem in microeconomic theory is that the purchasing process does not matter. And with that assumption one obtains very powerful results, but the question is the assumption correct? Remember, a theory can never be falsified, but we can test the underlying assumptions of the theory. So the Institution determines allocations via the rules that carry messages into allocations. And thus we have the second leg of the triangle, that messages through the rules are turned into outcomes, where X is the final outcome.



Second leg of the triangle

2.1.1 Performance of the system

There is a missing branch to the triangle. We complete the triangle by evaluating the performance of the system, typically in terms of Pareto optimality (P). Evaluation of the system relative to some benchmark is a crucial piece of most research endeavors (consider computational work in economics, where they often set up a benchmark economy). The outcome X should be identical to the Pareto outcome, or some assumption about the system may be incorrect. The mapping from $e \longrightarrow m \longrightarrow x^i$ is generated by any microeconomy (even in the lab) if we can vary e and I and observe M and X. The complete triangle is:



Complete triangle

3 Why study this system?

It might be that we are not able to theoretically derive B^i. Why study this system in a laboratory setting, rather than a field setting? The observable variables in the field are:

1. List of agents
2. List of physical commodities and resources
3. Physical commodity and resource endowments of agents
4. The language and property right characteristics of institutions
5. Outcomes

What is not observed in the field:

1. Preferences
2. Technological (human capital, knowledge) endowments
3. Agent message behavior[5]

Typically economists will make assumptions about preferences, technology, and behavior and use the Pareto criterion to "test" the logical consistency of the assumption. The question then is where do these assumptions emanate? Typically they come from introspection on the part of the theorist, or are borrowed from another theorist's introspection. Basically, now everyone is a "philosophizer".

There are two possible outcomes that could occur from this process that may need to be investigated. One is that the outcome may be Pareto optimal in certain institutions, but it would be nice to know if the Pareto property was predicted for the right reason. The second is that the outcomes may not be Pareto optimal, which then leads to the question, Why were they not Pareto optimal?

What would we like to know? Enough about environments and behavior in particular institutions to classify the institutions – do they lead to Pareto optimal outcomes or not, under what conditions do they lead to Pareto optimal outcomes, etc. Essentially, we desire to create a dependable mapping from the environment into the outcome via the institution.

[5]Note that agent message behavior may be more observable today than it was 25 years ago. Given the availability of scanner data and institutions such as EBay, we are likely observing more agent message behavior than ever before in the field. Does this mean that laboratory experiments will soon be extinct? Probably not. In many instances it is still important to know variables that are unobservable in the field, such as values and costs, and also it is **impossible** to evaluate a proposed institution in the field without actually implementing it in the field. Thus, the lab can still be used as a testbed for proposed institutions without incurring the costs of actually implementing the institution in the real-world.

4 Why use lab experiments?

Smith's quote, which is taken from Wilde (1980), is that we want to:

> Create a manageable 'microeconomic environment in the laboratory where adequate control can be maintained and accurate measurement of relevant variables guaranteed'.

The focus now turns to *control* and *measurement*. The idea of control is exactly what one might think it is in any standard physics experiment – we desire to hold constant as many factors as possible and then vary other factors to determine the impact this variation has on behavior and outcomes. It might be that the institution is held constant, and all factors of the environment are held constant *except* the number of agents in the environment. We can then isolate the impact that the number of agents has in a particular environment.[6] Or perhaps we desire to hold everything constant except the market process, so we run some experiments using bilateral bargaining and others using posted prices. We can then examine the impact that the change from bilateral bargaining to posted prices has on outcome *and* behavior. It would be irresponsible of me to point out one thing that is different between laboratory experiments in the physical sciences and laboratory experiments in economics and other behavioral sciences. In a physics experiment an atom or molecule does not have a mind of its own – thus, we can find many identical molecules and use them in an experiment. In the behavioral sciences, it is necessary to employ humans, most of which have a mind of their own. Thus, there are some concerns with replicability – for instance, students at Cal Tech may be different than students at the local community college. Even if one uses the same subjects, so that unobservable characteristics are held as constant as possible, problems still creep in – there may be learning effects across repetitions of the same game or even across different games. The same subject may have a different emotional state, so that one day the person may be risk loving and the other risk averse. The goal *should be* to replicate experiments controlling for as much as possible, but realizing that larger numbers of observations may be needed in the behavioral sciences than in the physical sciences simply because humans are not identical to one another, whereas molecules are.

As for measurement, the goal is to measure message responses, m^i, and the outcomes h^i and c^i resulting from the messages. The reason for measuring the outcomes is to evaluate system performance – is the system Pareto optimal (or is the observed outcome the result of Nash equilibrium play in a game). The reason for measuring messages is to identify the behavior *revealed* by the agents. Observing actual behavior and modeling it is different from introspection about what such behavior might be.

4.1 Achieving control and measurement

In order to achieve control and measurement Smith sets forward 5 precepts. The choice of the word precepts is important here, as Smith does not label them as axioms, or self-evident truths. Unlike axioms, which need no verification, the precepts identified by Smith should be empirically verified. In Smith's view, these precepts are the sufficient conditions for a microeconomic *experiment*. Before discussing the precepts it is useful to discuss the concept of induced value. The proper use of a reward medium allows an experimenter to induce pre-specified characteristics in the subject so that their innate characteristics become irrelevant. The idea is that subjects come to an experiment with varying backgrounds and innate characteristics. The goal of the experimenter is to make these characteristics irrelevant. To use an extreme example, if a nun and a thief were to participate in an experiment the goal would be to design an experiment that minimizes the nun's innate characteristics (holiness, altruism, etc.) as well as the thief's (disregard for property rights, distrust, etc.) by using a suitable reward medium.

Precept 1: Nonsatiation – Induced value depends on nonsatiation, the concept that more is better in the reward medium space.

According to Smith, "Given a costless choice between two alternatives, identical except that the first yields more of a reward medium, the first will always be chosen over the second, by an autonomous individual". Essentially, the subject's utility is a monotone increasing function of the monetary reward. For example,

[6] In 1^{st} price sealed bid auctions with symmetric, independent private values uniformly distributed from $[0, 1]$ and risk-neutral bidders the Nash equilibrium bidding function is $b_i = \frac{N-1}{N} v_i$. Thus, this is one instance where holding values constant but changing the number of bidders theoretically impacts behavior. Another instance might be whether or not collusive/cooperative behavior occurs with 2, 3, 4, or 5 subjects.

suppose that an individual is offered \$3 to feed the dog or \$5 to do the exact same task. Nonsatiation requires that the individual take the \$5, if the \$5 is a proper reward medium.

It is possible to make a somewhat simple example where an individual might choose \$3 over \$5. Consider being given the choice of three \$1 bills or one \$5 bill. The location is some remote village where the denomination of the bill means nothing, but having 3 pieces of paper to start a fire with might be better than having 1, so the individual choose "\$3" over "\$5" which might seem irrational or illogical to the experimenter, but the experimenter and the subject have *different* reward spaces in mind. To the experimenter, the reward space is the total amount of money found by adding up the dollar values of the currency, while to the subject the reward space is the number of pieces of paper, regardless of what might be written on them. In experiments in the US it is assumed that \$5 is better than \$3 regardless of how many pieces of paper they are handed and that the subjects understand this.[7]

Precept 2: Saliency – rewards must be indirectly associated to messages so that rewards have motivational relevance.

Value is induced on messages by the institution in BOTH the field and the laboratory. In the field, outcomes are valuable because the agents have utility. In the laboratory, value is induced on outcomes with monetary rewards. Saliency requires that rewards are tied to outcomes through messages (or actions as we called them when discussing game theory). The idea is that in the field the message decisions of individuals are tied to some reward, be it money or utility, so in the laboratory the subjects must be motivated by the same link.

An example of a non-salient reward is a payment for showing up to the experiment. If there is a statement such as, "We will give you \$10 to show up and perform this task", and there is no payment for the task, then the \$10 is *not* salient relative to the task. The \$10 *is* salient for the task of showing up, although we are generally not interested in testing show up rates by varying the show up payment. What you should know is that the show up payment has increased over time, so that \$3 in the early 1980s is no longer viewed as a salient payment to get potential participants to perform the task of "showing up". At a minimum the payment is typically \$5, with some people using \$7. I once ran an experiment where I wanted to limit the subject pool by using only experienced subjects, and I used a \$10 show up payment. Of the 6 participants who replied, 5 showed up and the other emailed to say that something important came up and would be unable to make the experiment. Saliency at its finest, at least for showing up. Then, in the actual experiment, subjects were paid based on outcomes, so there was also saliency *for the task at hand*.

It is also imperative that the subjects understand how the messages are linked to the outcomes and the outcomes to rewards. If subjects are unaware of how messages and outcomes are linked to rewards, then saliency is lost.

Precept 3: Dominance – A condition sufficient to guarantee that we have not lost control over preferences.

The reward structure dominates any subjective costs (or values) associated with participation in the activities of the experiment. There are typically two ways with which to achieve dominance:

1. High payoffs – if payoffs are high, then this should dominate other costs or values. However, high is a relative concept, and what may be high to one individual may not be to another individual. This is one reason experimentalists typically use undergraduate volunteers as subjects. Undergraduates typically have a lower opportunity cost for their time than individuals who work for a living, so a high payoff to an undergraduate may be an average of \$10 per hour, whereas to a business professional that may be a low payoff.

2. Commissions for actions (or trades) – Smith has in mind his double-auction experiments, where subjects receive a small commission for making a trade *in addition to* their payment based on value minus cost for the item.

As an example for where dominance may be lost, consider the Dictator Game. Subjects arrive and are informed that they have been randomly chosen to be either a Player 1 or a Player 2. They are told that each Player 1 will be paired with a Player 2, but neither player will know the actual identity of the other player. Each Player 1 is given \$10 and must decide how much to give to the Player 2 who is paired with

[7] But imagine a choice between 3 \$1 bills and 500 pennies – while \$5 > \$3 it may be that some participants would choose the 3 \$1 bills over the 500 pennies so that they do not have to deal with the 500 pennies.

him. Player 2 makes no decision, but must simply accept Player 1's offer. The game is quite simple and the Nash equilibrium to this game is that Player 1 should keep all $10 for himself. Subjects typically do not play the Nash equilibrium. The question is why? Is it because subjects are stupid, or perhaps because the experimenter has not achieved dominance? Why might the experimenter not have achieved dominance using a set of instructions like the following:

> You will be randomly assigned as either a Player 1 or a Player 2 for this experiment. Each Player 1 will be anonymously paired with a Player 2. Neither player will know the identity of the other player. Each Player 1 receives $10. Player 1 may choose to divide the $10 in any manner deemed fair between himself and his corresponding Player 2 by giving any portion of the $10 to Player 2. Player 1 then keeps whatever remains of the $10 after he has given Player 2 his share. Player 2 makes no decision, but simply receives Player 1's offer.

There are many potential reasons, and the "stupidity of subjects" probably ranks last.

1. Preferences for "fairness" – equality is probably a better term as there are 31 different definitions of the word fair

   a Wants the other subject to think he is fair

   b Wants the experimenter to think he is fair

   c Random allocation process is unfair, so the Player 1 attempts to correct for this injustice by splitting the money equitably

2. Could be the words in the instructions – "deemed fair", "give" – that are biasing the Player 1's

There are other reasons dominance may be lost. The question to then be asked is how to regain dominance in this game. We can remove "b" by making the process double blind. We can remove "2" by changing the wording of the instructions. We can remove "c" by making the assignment depend on something other than a random draw, perhaps a quiz. When these features are added, there might still be some subjects who split the $10 evenly, but the distribution should shift towards the Nash equilibrium.

4.1.1 Deception

There is another important factor in dominance that is not concerned with the particulars of that experiment. It concerns the area of deception in experiments. Deception is unlikely to affect dominance in the *current* experiment, so it seems like there is very little harm with respect to the collected data. However, in *future* experiments that rely on induced values and the precepts of nonsatiation, saliency, and dominance, if deception has been used in a previous experiment then it is possible that participants in the future experiments will view the link between messages and outcome to rewards skeptically. This is the reason why deception is to be avoided in economic experiments. Unfortunately, there is no good definition of deception, and there is a murky gray area for what is acceptable and what is unacceptable. One possible method is to break deception into lies of omission and lies of commission. A lie of omission may be something like not publicly revealing the supply and demand curves in a double-auction experiment, or the marginal costs of rivals in a market power experiment, or the values of other bidders in a 1^{st} price sealed bid auction. The experimenter knows these values, but does not relay them to all participants. It seems like "deception" of this type is permissible, and even encouraged (see the next precept). What would not be permissible is lying to the subject. Telling the subject that the rules were one thing when they were really something else. Telling a subject they were playing against another human when in fact they were playing against a computer program (I have seen someone skate on the edge of this issue by stating that a subject is playing against another "decision-maker" – initially the decision-maker was a human but eventually it switched to a computer program). Now, it may be that you want the subject to discover the rules of the game, so you say nothing about whether or not a particular action is allowed. Again, is this deception? If nothing is said, you have not lied to the subject, you just have not provided them with all bits of information. Like I said, deception has a large gray area. If you are uncertain about where your deception, if you have any, falls it is best to get the advice from someone more experienced.

Precept 4: Privacy – individuals may not be autonomous own-reward maximizers

This could be considered part of the gray area of deception by some. Should individuals have private costs and values? That is a normative statement, one that we cannot answer unless we wish to make judgments on the morality of private costs and values. Here are some questions we can answer: What happens if participants know the costs and values of other market participants? What happens if there is a bonus paid to the highest earning participant? Again, Smith stresses that these are *precepts*, not axioms, that need to be verified. We can verify what happens to the messages and the outcomes if we change parts of the experiment and violate privacy.

Return to the Dictator Game. Smith stresses that privacy is an important precept, but in the Dictator Game both paired participants know what the other person has received, which violates this precept. This leads to the possibility that individuals may not be autonomous own-reward maximizers *in that setting*, which opens up the door for discussions of fairness or equity. In the microeconomic system settings we have been discussing, individuals know only their own values and costs and the *messages* sent by other individuals, not their payoffs, so the precept of privacy is not violated. In the Dictator Game, the precept of privacy is violated.

Precept 5: Parallelism – Proposition about the behavior of individuals and the performance of institutions that have been tested in laboratory microeconomies apply also to nonlaboratory microeconomies where ceteris paribus conditions hold.

Nonsatiation and saliency are sufficient conditions for a microeconomy, but not for a controlled experiment. We add dominance and privacy for control. If the goal is to test theoretical models, the first 4 precepts are all that is needed. If the goal is to draw inferences from the laboratory to "real" microeconomic systems, we add the precept of parallelism. The precept of parallelism states that behavior in the laboratory and the real world are identical as long as ceteris paribus conditions hold.

5 Experiment Classification

Smith goes on to classify experiments into three broad categories.

1. Nomothetic (theory testing) experiments: Use theory to summarize the conditions needed for a result to hold, and usually the theory does this succinctly. In a sense, a simple theory forces us to remove any extraneous information from the model to determine what the important assumptions are *theoretically*. We can then use the experiment to test the validity of the assumptions in various institutions. Smith distinguishes between nomo-theoretical and nomo-empirical theory testing experiments. Nomo-theoretical experiments stem from mathematical theories (this is usually what we think of when we say "theory" in economics) while nomo-empirical experiments stem from observed empirical regularities. The key with theory testing experiments is that there should be a continual process of creating the theory, testing it, revising the theory based upon observation, testing the new theory, etc.

2. Heuristic experiments: With heuristic experiments there need be no well-developed theory. This is simply a "let's see what happens" type of experiment. Whenever I think of heuristic experiments, I think of the line from Real Genius, "Let the engineers figure out a use for it. That's not our concern." There are great moments in science where individuals did not set out to discover something, it just happened by accident.

3. Boundary experiments: Once a behavioral regularity has been established with experiments, push it to the boundary to see if the regularity still holds.

Many people now list wind tunnel/systems design experiments in lieu of boundary experiments, although they could be placed in the heuristic category or the nomothetic category depending on whether or not a theory exists. This experiment type may be of most use to policy makers, and is directly linked with the precept of parallelism. The important features of the industry or economy should also be present in the laboratory, and then a new policy can be tested to determine what type of behavior occurs under the new policy.