

Model Experiments and Models in Experiments

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Abstract: This paper explores how model-based reasoning might be characterized in terms of making experiments. I outline the characteristic steps of such model experiments or “experiments on models”, and apply the notions to a diagrammatic model in everyday use in economics. I compare these model experiments with two other kinds of experiments (using examples from the same economic domain): laboratory experiments and a hybrid form. This hybrid form involves simulations or “experiments with models”. The paper concludes with a comparison of the role that models play in each case.

In *Models as Mediators* (1999), Margaret Morrison and I suggested a framework for thinking about the way models were used in economics and physics. We suggested that they operated as instruments of investigation which scientists used to find out about both theories and the world. We associated this role of models with their characteristic functional autonomy in the realm of scientific argument (that is, models function partly independently of the theories or data that they involve), and linked this in turn with certain features of their construction. However, instruments come in many sizes and guises, and function in many different ways, making any more specific definition of the nature of models difficult. Magnani’s (2002) all-embracing term “epistemic mediators” nicely captures the active and various roles that models play in modern sciences, but the question of how we reason with models remains open to argument.

How can we characterize the way models work as instruments to help us to learn about our theories or the world? Should we treat the way we work

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with models as a matter of abductive logic? Or should we treat model reasoning as fundamentally analogical? And are these two, and other characterizations, antagonistic or complementary? The answer I will explore in this paper is to treat model-based reasoning as akin to extended thought experiments. This thesis is motivated by two observations about the role of models in science. First, using models necessarily involves the scientist as an active participant: not just as thinker and as cognitive instrument, but as experimenter. Second, modern science has seen a recent explosion of different epistemic mediators, hybrids wherein the two notions of experiment and model go hand in hand under the general name of simulations (see Sismondo, 1999).

The material used in this paper comes from economics. On the one hand, economists build mathematical models and experiment *on* them. On the other hand, economists undertake laboratory experiments. In between, they carry out various kinds of hybrid experiments in which they experiment *with* models. My agenda is to present the characteristic use of mathematical models as a method of experiment and to compare this with the method of laboratory experiment. The next step is to contrast these two end cases with an example of an in-between hybrid. I end the discussion by considering how economists use these model experiments to cross the inference gap and to say something about the economic world.

1. **MODEL EXPERIMENTS = EXPERIMENTS ON MODELS**

Economics is now a modeling discipline and has been for the last few decades. That is to say that economists' discourse is concerned with "models" rather than with "theories", in theoretical work, in applied work, and in giving policy advice. Economists' reasoning is centred on models which are often mathematical in form, sometimes statistical or diagrammatic, but only very rarely material or physical. But the terms "discourse" and "reasoning" do not fully capture the nature of economists' research activity in using models. The characteristic steps of modeling can be taken as follows:

1. Build a model to represent the world.
2. Ask questions about the model.
3. Manipulate the model to answer questions.
4. Relate answers to the phenomena of the world.

First, building a model in economics involves the economist in representing or denoting his/her theories and ideas about a particular aspect of the economic world into a mathematical model. Typically, these models are small in scale and the problems of accurately describing the immensely complicated

real economic world are assumed away. The typical economic model consists of a few equations or lines on a two-dimensional diagram, and the symbols used represent “agents” (people or firms) or goods or other economic elements such as prices, quantities and so forth. There are various accounts about how such models are built, and how either theories or observations about the world or both are embedded in the model, but that is not my topic here (see rather Hamminga and De Marchi, 1994, and the papers on economics in Morgan and Morrison, 1999).

My object here is to discuss how such mathematical models are *used*, and this is given in the next three steps. These might appear to be self-evident, but there are various ways in which they can be characterized. In an earlier paper (Morgan, 1999), I gave the following account: The starting point (the second step in the list above) is provided by the scientist who asks questions about the world portrayed in the model. These questions take the form: “What happens if ...?” or “Let us assume that ...?” and each question requires the model to be used to provide the answer. The questions are neither random nor general, rather they are prompted by the theoretical issues or economic events or policy agenda the model was built to address. These questions constitute the “external dynamic” or “intervention” in the model.

The third step is that the model is manipulated to provide answers to the question. The model does not manipulate itself - it requires the scientist as question-maker to determine the starting point and direction of solution, and the scientist as manipulator to deduce or derive the answer by manipulating the model. The model itself provides two resources. One is its form which in turn dictates the kind and rules of mathematical reasoning (algebraic, geometric, diagrammatic or whatever) appropriate to the case. The other is its structure, which must have sufficient flexibility and sufficient elements (variables and relations) to enable questions of interest to be answered. R.I.G. Hughes (1997) has called this internal quality the “internal dynamic”, referring to the quality of manipulability that the model must have.

The final or fourth step is to relate the answers given by the model back to the original prompt for the questions, back, that is, to the scientists’ theories and queries about the way the economic world works. In my earlier (Morgan, 1999) account, I discussed the ubiquitous use of narratives (or story-telling) in the provision of answers and in making the link between the model and the world.

This paper provides a complementary characterization of these three latter steps of model usage as a kind of glorified thought experiment. I call them “glorified” only in that such thought experiments are too complicated to be done in the head - they are rather pen-and-paper experiments. The term experiment refers here to the combination of the external and internal dynamics, the activity of asking questions about a circumscribed and limited model world and deriving answers about that world. This is a process in which sci-

entist and model are jointly active participants, neither is passive. The final step of relating the answers back to the real world, I treat as an inference problem.

I take as my exemplar for the model experiment one of the most common and well-used models in economics, namely the supply and demand model, which appears either as a diagram with supply and demand curves or as a set of three equations (the two functions and an equilibrium condition). The effective use of this model is associated with Alfred Marshall, an English economist of the late XIX and early XX centuries, who was famous for his writings about the nature and workings of industry. In the chapter that I analyze here, Marshall (1930, book 5, chapter 13) used the standard supply and demand diagram shown in Figure 1, in which the DD' curve represents the potential demand by consumers for a good at various prices and the SS' curve the potential supply by producers over the same price range (by convention, prices are given on the vertical axis, and quantities on the horizontal). In an analysis which was typical for him (the argument went on in the text, and the model manipulations were shown in footnotes), Marshall asked four questions, conducted nine model experiments and three thought experiments (all in less than ten pages) and then used the answers to provide a commentary on both policy and theoretical implications of the answers.

The first question Marshall asked is: What happens in an industry if there is some “great or lasting” change in normal demand? To answer this, the model is manipulated as follows: an increase in demand at all prices means that the demand curve shifts upwards to the right to the position dd' (see the left-hand diagram (a) in Figure 1). The experiment shows that at the curves' new intersection point (the point at which all exchanges are believed to take place, or the “equilibrium point”): e^* , compared to the old intersection point: e , quantity has risen (q to q^*) and price has risen too (p to p^*). However, according to Marshall's text, there are two alternative shapes which the supply schedule can take: either horizontal or downward sloping like the demand curve (neither are shown here - the reader will have to imagine them or draw the model). In the former case, the experiment shows that equilibrium quantity rises but price does not change and in the latter case that quantity rises but price falls. Thus, one question and three similar experiments with diagrammatic models reveals that equilibrium quantity always rises, but that price changes depend on the shape of the supply function. The first two of these three experiments could have been done mentally as thought experiments, but only if the model diagram was already known to the economist and its rules for manipulation understood. But, as Marshall remarked, the third case is difficult to treat without the actual diagram and its manipulation.

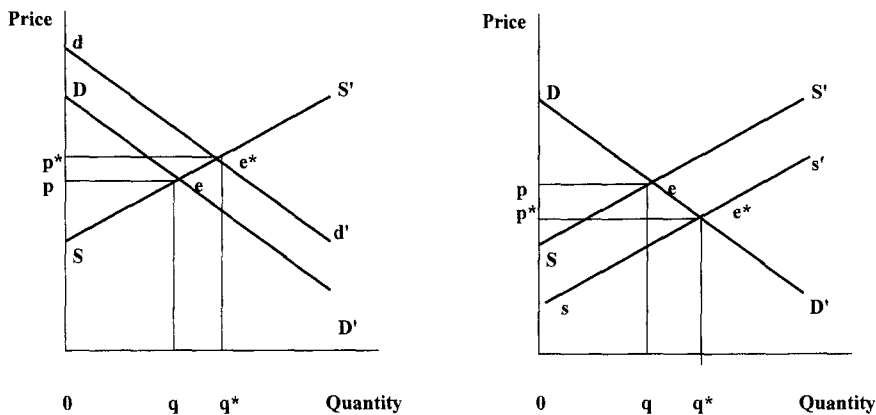


Figure 1. Marshall's model experiments to explore effects of (a) change in normal demand and (b) change in facilities of supply.

Marshall then asks: What happens if there is a decrease in normal demand? He does no model experiments here; knowing the answers to the first question provides immediate answers to thought experiments for each case.

The third question Marshall asked was: What happens if there is an increase in the facilities of supply? This question prompts a further three model experiments in which there is a shift to the right or downwards of the supply curve from SS' to ss' (as shown in the right-hand diagram (b) of Figure 1). These model experiments allow him to answer that regardless of the shape of the supply curve, equilibrium price falls and quantity rises, though there is a range of price changes in the three cases.

His fourth question is: What happens if a tax is placed on the price of the good? Here the reasoning necessary to follow through the answers to the question requires quite a complicated model experiment, but using exactly the same set of diagrams. The answer hinges on what happens to something called the "consumers' surplus" which is the triangle defined by the points Dpe on Figure 1. If a tax is placed on a good, the price paid by consumers will rise, and their share of this "surplus" (the difference consumers would have been willing to pay and the amount they actually pay at the market equilibrium price, p) will consequently fall. The answers given by the model experiments lead to two further sets of observations in which Marshall relates the findings to wider issues. On the one hand, the experiments prompt a discussion of the principles of taxation in relation to the model outcomes and in relation to the indirect changes in elements in the model revealed by the experimental manipulations. On the other hand, the model work leads to theoretical discussions on the validity of general claims about the nature of the equilibria involved and to certain general issues of ethics and distributive justice.



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