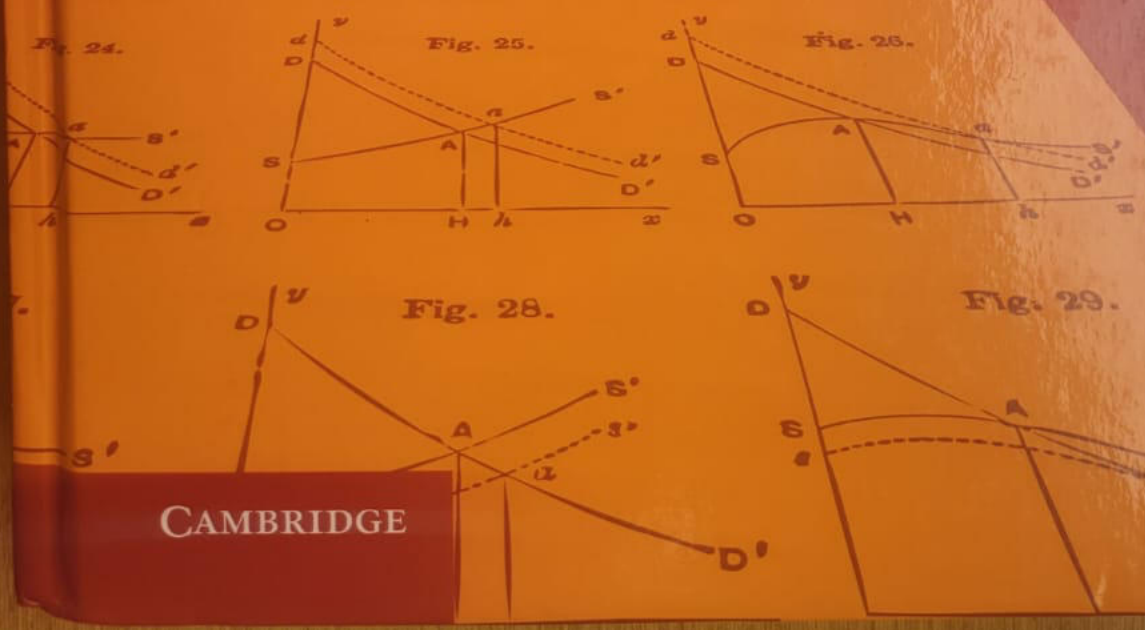
MARY S. MORGAN

THE WORLD IN THE MODEL

How Economists Work and Think



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use of a deductive mode of manipulation so that Frisch can reason mathematically about the nature of the business cycle with this version of his model.

These examples from Frisch enable us to understand not only how the reasoning rules come along with the particular model that is built, but also how necessary the resources are to provide materials to reason with. But this does not explain – in a more general way – how those model resources are used, nor to what purpose, though there are certainly hints in Frisch's example. I turn now to suggest a more general account of model reasoning.

5. Modelling as a Method of Enquiry: The World in the Model, Models of the World

It is easy enough to say that modelling constitutes an epistemic genre, but we still need to figure out how it functions as a way of doing economic science. Scott Gordon, in his history and philosophy of the social sciences, argues that "the purpose of any model is to serve as a tool or instrument of scientific investigation" (1991, p. 108).[37] This forms the starting point for my claim, in the latter half of the book, that economists use models to investigate two different domains: to enquire into the world of the model and to enquire into the world that the model represents.

Model-making – as we have already seen – is an activity of creating small worlds expressed in another medium. The economist represents his/her ideas about certain elements of the economy: the system as a whole, or people's economic behaviour, that they want to investigate or understand into other forms: into bits of mathematics, diagrams, machines, and even – sometimes – strictly defined verbal portraits. The models have certain qualities – they are smaller-scale, and it is supposed, simpler, than the real world, made of quite different materials, and their sense of representation, imitation, or similarity might be quite opaque.[38] I take up these awkward qualities of the way economists render their accounts of the world into models in Chapter 10, but for here, the point is rather that these representations – by design – contain economists' intuitions, or the things they already know, or both. That is, sometimes these small worlds in the model primarily represent speculations and theories about the economic world; the economist may be agnostic about how far they represent the workings of that world, or even deny that they do so at all (as we saw with Lucas), regarding them perhaps as parallel or imagined model worlds. At other times, models are created primarily to incorporate (in some form) features they already know, that is, to embody what the economist takes to be essential

37 Of course, I am not the first to see models as instruments of enquiry in the social sciences (arguably, Max Weber (1904, 1913) thought of his ideal types in this way – see Chapter 4), but few suggestions along these lines explore how such instruments work.

38 A nice parallel is found in the studies of geologists who built small boxes and filled them with different materials to see what happened when big physical shocks hit them as a simulation model for earthquakes (see Oreskes, 2007). On smallness see Chapter 10.

features of the relevant section of the world, how the parts relate, how the elements interact, and so forth, as with Frisch and Tinbergen. Most often, the 'world in the model' represents a combination of both economists' ideas and their knowledge.

These small objects, models, then have a stand-alone, autonomous, quality, that enables them to lead a potentially *double life* for, I argue, *models function both as objects to enquire into and as objects to enquire with*. That is, they are objects for investigation in their own right, and they help the economist-scientist investigate the real-world economy.[39] Model investigations offer economists the possibilities to speak both to their ideas and to their experience of the world at the same time, but characterizing such work as a method of enquiry, exploration, even discovery, still presents us with quite a puzzle. How do models provide such a method of enquiry that enables this double life to go on? My answer is that model reasoning, as a generic activity in economics, typically involves a *kind of experiment*.

Advancing the argument that appears later in the book, I suggest that we can characterize model reasoning as a kind of experiment in the following way. Models are made to address some particular purpose, and so working with a model typically begins with the economist asking a question related to that purpose. To answer the question, the economist makes an assumption that fixes something in the model, or changes something in the model, that is, in the diagrams or equations, or other material, that the model is made in. He or she then investigates the effect of that assumption, or change in the model, by manipulating the resources of the model in a model experiment to demonstrate an answer. That demonstration is deductively made, for it uses the reasoning rules given in the language format and in the carefully specified economic content of the model. The process of demonstration itself prompts a narrative about the economic content. This combination of *questions*, *experimental demonstrations*, and *narrative answers* forms the way in which the economist explores a particular model (see Morgan 2002 and Chapter 6). From experimenting on the model, economists investigate and come to understand, in the first instance, only the world of the model. How such experimental investigations into the model might also provide some understanding about the world that the model represents is a messier problem that I return to shortly.

Let me begin with the easy part of this double life of models: *models as objects to enquire into*. Economists investigate the world in the model using this mode of experiment to understand their economic ideas or theories. This seems odd: since they created that little world in the model, wouldn't they already understand it? Not

39 The ways that models function in these two domains in economics is not well accounted for by the standard views in philosophy of science that have tended to worry about the definition of models and to treat them either as mini-versions of theories or as efficient descriptions of data from the world. As we will find in the chapters that follow, the diagrammatic models of the Edgeworth Box, Ricardo's arithmetic chains, and Samuelson's mathematical model of the Keynesian system all function as independent forms: they embody ideas and knowledge about the economy, but are themselves neither theories or data descriptions. In Morrison and Morgan (1999), we argued such construction was responsible for the observed practical autonomy of models that enabled them to mediate between the mathematics of theory and the empirics of observation (see Chapter 2).

so, for if ideas about the world can be expressed very simply, economists don't need a model to think with. But as soon as they abstract two or three characteristics of economic man together, or isolate two or three hypothesized relationships from the economy at once, it becomes difficult to reason about what happens when they are combined. That is why economists create models in the first place, and why they need this kind of experimental approach in order to answer questions about this small person or world in the model.

Investigating the world in the model through such experimental means is the way that economists explore their theories and intuitions.[40] By asking questions and making such investigations, they understand the implications of their intuitions, explore the limits of economic behaviour that their models imply, codify and classify the various different outcomes that some more general theory might overlook, and are prompted to develop new hypotheses about the behaviour of the elements represented in the model. For example, Samuelson wanted to know the effect of increasing government expenditure. He found by his experiments on the little mathematical model in his 1939 paper that the model could generate cyclical behaviour, explosive growth, or gradual decline in the elements of the model, according to the numerical parameters he inserted into their relations. These model explorations provided some surprising answers about certain aspects of the Keynesian account of the world as well as generating more understanding about the various extant theories of business cycles.

The second part of this double life of models is the way that economists use *models as objects to enquire with*, for it is clear, from the way economists work, that the small person or world in the model also serves as an object to investigate the aspect of the real people or real world that it is taken to represent. This aspect of model work is much more difficult to characterize than the way economists use models to investigate their ideas and theories.

Philosophers have problems at this point, and for good reasons. Their justly sceptical argument goes as follows. If the model is an accurate representation – in some way – of the relevant parts of the economic world or of economic man's behaviour, and if those elements can be treated in isolation, then it might be that the results gained from model experiments can be applied directly and unambiguously to the world, and give truthful statements and valid explanations about those things in the world.[41] These 'ifs' are big ones – for how does the economist know if they have an accurate model of the world? Or, that it can be treated in isolation? It is this ignorance that creates philosophers' worries about modelling, and,

40 Crombie assumed some kind of a one-for-one relationship: that "a model embodies a theory" (1994, Vol. II, p1087), and on this basis, that the method of models offered "a characteristically effective scientific combination of theoretical and experimental exploration." This is certainly a useful hint about experiments (which he does not expand), but the account of how models are formed in this chapter, and various examples discussed in Chapters 2–6 suggest that the relationships between theories and models are varied and not easy to characterise.

41 See, for a recent discussion, Cartwright (2009).

most especially, their concern about the status of the representation involved. But of course, it is just such problems – and this same lack of knowledge – that lead economists, like scientists in other fields, to adopt modelling as a mode of investigation in the first place!

It may help to clarify my account of modelling as a double method of enquiry in economics if we compare it with two of the other reasoning styles mentioned earlier: the method of mathematical postulation and proof and the method of laboratory experiment.

If we portray mathematical modelling as a version of the method of mathematical postulation and proof, then we could say that economists *postulate* the economic world in the model and so could quite reasonably expect to make mathematical truths about that world in the model. This account works well for *enquiries into* the world of the model: models can indeed be truth-makers about that restricted and mathematical small world. But as economists recognise, these are not truths that they can transport unconditionally to the world that the model represents. Economists (just like their astronomer forebears) understand that a model stands in for their economic universe to enable them to explore certain properties of that world represented in the model. But whether they can come to valid conclusions about the behaviour of their actual economic universe is a much more difficult problem, as they know themselves.

If we make the alternative comparison with laboratory experiments, we get an idea of how economists use a model as an object to *enquire with*. In this way of understanding modelling as an epistemic genre, economists *hypothesize* how the world is when they represent it in the model, and then experiment with that world or person in the model to see how it behaves. Then the important question of whether the results of the experiment on the model can then be transferred to the world that the model represents can be considered an inference problem. So, by treating model enquiries as a form of experiment, the question of how this mode of reasoning connects models to the world switches from a truth-making problem to an inference problem, though no less difficult to answer.[42] This is why I suggest that we view modelling as a method of investigation and enquiry more akin to the method of experiment than to the method of postulation and proof.

Of course, model experiments in economics are usually pen-and-paper, calculator, or computer, experiments on a model world or an analogical world (such as an hydraulic machine), not laboratory experiments on the real world. This has implications for the inferences that can be made. There are two issues here: one is the form of the inference arguments, and the other is the power of the inferences that can be made.

42 Others have suggested that the model-world relation might be thought of in inferential terms, but without seriously considering the nature of the inference in practical terms, or whether the inferential relation lies in the original construction of the model, or rather in its subsequent relation back to the world (see for example Suárez, 2004 and Woody, 2004; and the essays in Grüne-Yanoff, 2009).

Inference arguments from model experiments are informal: when economists talk of 'testing their models' (having already assured themselves of their internal mathematical qualities and coherence) they are interested in judging the usefulness of their model experiments by comparing the behaviour of the model world to that of the real world in a kind of matching or bench-marking process. They may compare the model experimental behaviour of their thin model of economic man with the behaviour of real economic people, or surmise how a particular policy change instituted in a model compares with the equivalent actual policy in the world. A characteristic feature of these informal inference arguments from economic models is that they often involve narratives in making inferential or explanatory accounts that serve to link results *from* the experiment made into the world in the model *to* events in the world that the model represents (discussed in various ways in Chapters 6 to 9).[43]

These informal comparisons made from model experiments to the world clearly lack the formal decision rules based on probability measures found in statistical inference, and that are used to validate and make inferences from econometric models. But it is worth remembering that inferences made from laboratory experiments also lack formal decision rules. Laboratory scientists, like modellers, depend upon both tacit and articulated knowledge in making sense of their experimental findings and judging their relevance within the laboratory.[44] And, like model work, laboratory scientists face the same question of whether their experimental results can form the basis for inference beyond the laboratory, namely the problem of external validity.[45]

But in another respect, clearly, the experiments made on models are different from the experiments made in the laboratory, and the inferences that can be made differ in principle. This has nothing to do with the formality or informality of the inference argument, but rather, as I argue in Chapter 7, it is because model experiments are less powerful as an epistemic genre. It does make a difference to the power and scope of inference that the model experiment is one carried out on a pen-and-paper representation, that is, on the world in the model, not on the world itself. While model experiments may *surprise* the economist with unexpected results, laboratory experiments may *confound* the economist-scientist by producing results that are not only unexpected but potentially unexplainable given existing knowledge.[46]

Let us look briefly at a more complicated example to see how the model is both an object to enquire *into* and an object to enquire *with*, holding these notions of questions, deductive experiments using the resources of the model, and informal inferences, in mind. The Phillips-Newlyn Machine (shown in Figure 1.7 and

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43 See Morgan (2001, 2007).

44 It is precisely this difficulty that has led Deborah Mayo to advance her framework for making inferences from experiments (see her 1996), which recognises that such inferences depend on the knowledge of the scientist in making relevant pre- and post-experimental judgements.

45 See Chapters 7 and 8, and Guala (2005, chapter 7).

46 See discussion in Morgan (2003b, 2005).

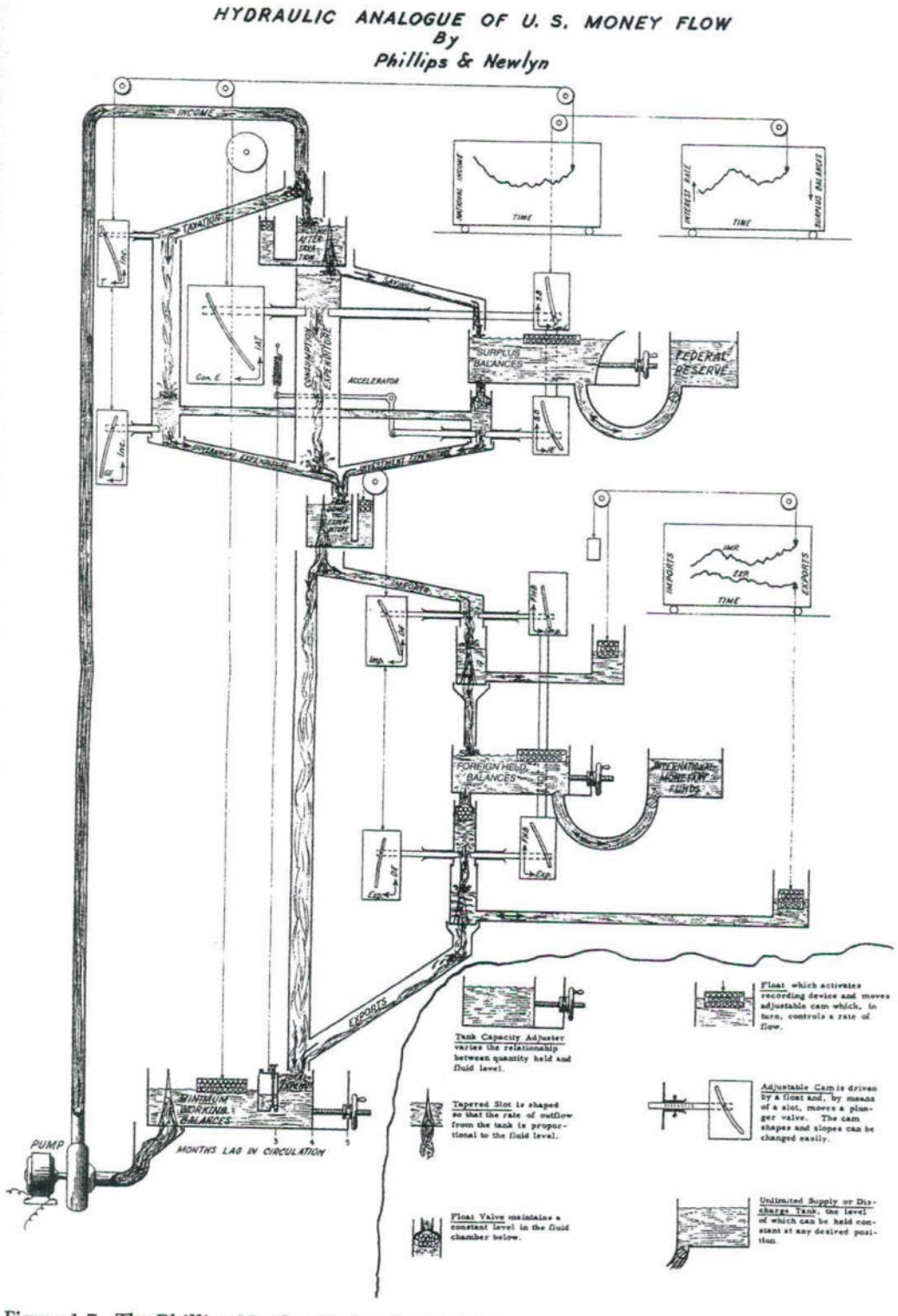

Figure 1.7. The Phillips-Newlyn Hydraulic Machine.

Source: The James Meade Archive, Box 16/3, BLPES Archives, LSE. Reproduced with permission from the estate of James Meade.

discussed fully in Chapter 5) is a big apparatus – a real hydraulic model – of which we can see here only a drawing. The physical model itself operates according to the language rules of hydraulics, with the flow of water around the machine controlled by physical valves. But the overall form and parts of the of the machine are designed to imitate the stocks and flows of money (red water) around an economy, and the behavioural functions of the economic relations are drawn into the small rectangular "slides" that can be seen on the drawing; these in their turn control the opening and closing of the valves in the hydraulic system. Despite its complexity, and even without knowing what these economic relations are, we can see how the rules of form (hydraulics) and content (monetary macroeconomics) are instantiated in the Machine.

The next point to see is how the Machine's resources are reasoned with in an experimental mode of investigations by using the rules of language and content. The economist sets up the model to answer a particular question, such as: What will happen if I increase the money in this system by increasing the liquid in the "money tank" fed by "the central bank" (at the top right)? This is the experimental intervention (or manipulation) into the world of the model. The pump circulates this increased liquid through the machine, the valves control the flows according to the economic relations ascribed in the model, and the model demonstration churns out a set of outcomes of this experiment: the effects of this change in the amount of money on the income in the economy is automatically charted in one of the top right-hand corner graphs.

The Machine model has tremendous resources: it can be set up to answer any number of questions – and thus associated model experiments. With some of these questions the economist can *enquire into* abstruse points in economic theory, for example, as to whether the interest rate is determined by the stock or flow of investment funds. Such questions and experiments about the world in the model make demonstrations that enable those theories to be compared with each other. And once economists have discovered how their world in the model works, they use this knowledge to generate further questions about those theories. Another set of questions are prompted by different historical or current situations that turn up such as financial crises or great depressions. These deliver experimental outcomes for the world in the model that economists will compare with the events that they observe in the world. That is, with these questions, economists *enquire with* the model into the world that the model represents. Economists may come to explain or reinterpret or find a new understanding about some aspects of the real-world behaviour through these experimental means.[47] That is how, by experimenting with the model, economists can gain understanding and provide explanations of *how the*

47 Economists also use this model-generated knowledge to teach others their insights, for example, economists used the Phillips-Newlyn Machine to demonstrate and explain the UK Government policy changes (an experiment with the Machine screened by the BBC and visible now on a video in the London Science Museum next to the Machine).

economic world in the model works and use these in an informal way to *reflect on the workings of the real economy* that the model is taken to represent (see Morgan and Boumans 2004, and Chapter 5).

So, modelling as a style of reasoning in economics works as a method of enquiry comprising probing questions, manipulations to provide demonstrations that are both deductive and experimental, and informal inference arguments involving elements of narrative that offer explanatory or interpretative services. These characteristics are explored in a nutshell format for Ricardo's model farming experiments in the next chapter. And, with a wider gaze, these characteristics of the style of practical reasoning of modelling are explored in different ways, and at much greater depth, in the second half of the book.

6. Conclusion

Reasoning with models enables economists to enquire directly into their theories or ideas about the world, and enables them to enquire indirectly into the nature of the economic world. They reason about the small world in the model and reason about the big economic world with the model; they reason about the thin economic man in the model and reason about real people with the model man. Yet, critically, these two spaces of exploration are not always clearly demarcated: in working with models economists often simultaneously investigate the world in the model and the world their model represents. In this sense, reasoning with economic models is like reasoning with astronomical models. Those models exemplified astronomers' theories about the arrangements of the heavens, and could be used to explore the full implications about those ideas at the very same time as being used to offer explanations or accounts for particular observed events or patterns in the behaviour of the heavenly bodies. Economic models, like those models of the planetary system, are objects to enquire into and argue over, but *at the same time* ones to take to the world and explore it to gain understanding, insight, or explanations from doing so.

The comparison between astronomical models and economic models that has woven its way through this chapter is not just an heuristic comparison that helps us see how economists use models, but reminds us that the modelling style of reasoning has an illustrious history. Indeed, the scientific revolution of the sixteenth and seventeenth centuries was not just one of content, but of styles of reasoning. Modelling has been portrayed as the working method of Galileo no less, and continues to be prevalent in modern natural sciences.[48] Despite this ancestry, economists are not quite sure that the method has a credible scientific respectability. Models are relatively small and simple compared to the economic world, they are made of different materials, and cannot well be applied directly to that world. Even so, like those

48 Hacking, for example, recognises it as the basic method of "cosmology and cognitive science – none other than the chief modern instances of the Galilean style..." (Hacking, 1992a, p. 7).

models of the universe of earlier days, economic models may capture the heart of the problems that economists seek to understand. Modelling is not an easy way to find truths about the economy, but rather a practical form of reasoning for economists, a method of exploration, of enquiry, into both their ideas and their world. That is the thesis of this book.

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