# Economic Models and Economic Modelling—How Economists Work and Think

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*Models and modelling have changed the science of economics, the way that economic knowledge is used in the world, and the way that economists see and understand the world. 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. This handout for students summarizes a number of hypotheses and thoughts about the use of economic models as an instrument for scientific enquiry which are taken from the book "The World in the Model: How Economists Work and Think" (Morgan, 2012).*

## I. Changing the Practice of Economic Science: From Words to Models

Two hundred years ago, political economy was overwhelmingly a verbal science, with questions, concepts, and a mode of reasoning all dependent on words. Economics is now a very different kind of activity. From the late nineteenth century, economics gradually became a more technocratic, tool-based, science, using mathematics and statistics embedded in various kinds of analytical techniques. By the late twentieth century, economics had become heavily dependent on a set of reasoning tools that economists now call "models": small mathematical, statistical, graphical, and diagrammatic objects that can be manipulated in various different ways.

Today, in the twenty-first century, if we go to an economics seminar, or read a learned scientific paper in that field, we find that economists write down some equations or maybe draw a diagram, and use those to develop solutions to their theoretical conundrums or to answer questions about the economic world. These manipulable objects are the practical starting point in economic research work: they are used for theorizing, providing hypotheses and designing laboratory experiments, they are an essential input into simulations, and they form the basis for much statistical work. Economics teaching is similarly bounded: students learn by working through a set of models: some portraying decisions by individuals and companies, others representing the behaviour of the whole economy, and for every level in between.

* This document provides a mere replication and summary of parts of the book "The World in the Model: How Economists Work and Think" by Mary S. Morgan published in Cambridge University Press in 2012. It is intended for use in class only and should not be circulated beyond class or in public as it contains copyright-protected content.

The use of economic models has become habitual in government policy making, in trading on financial markets, in company decisions, and indeed, anywhere that economic decisions are made in a more technocratic than casual way. In economics, as in many other modern sciences, models have become endemic at every level.

The significance and radical nature of this change in economics is easily overlooked. The introduction of this new kind of scientific object—models—involved not just the adoption of new languages of expression into economics (such as algebra or geometry), but also the introduction of a new way of reasoning to economics. And having moved from a verbal to a model-based science, economists no longer depicted their knowledge in terms of a few general, though unseen, laws, but expressed it in a multitude of more specific models. As models replaced more general principles and laws, so economists came to interpret the behaviour and phenomena they saw in the economic world directly in terms of those models.

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

The purpose of any model is to serve as a tool or instrument of scientific investigation. This forms the starting point for the claim 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 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 peoples economic behaviour, that they want to investigate or understand into other forms: into bits of mathematics, diagrams, 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.

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

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. 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.

### A. *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 so, for if ideas about the world can be expressed very simply, economists do not 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. 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.

### B. *Models as objects to enquire with*

The second way that economists use models is as objects to enquire with. 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.[1]

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 understand that a model stands in for their economic uni-

[1]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 mans 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. 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,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!

verse to enable them to explore certain properties of that world represented in the model.

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.[2]

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 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.

## III. Simulation: Bringing a Microscope into Economics

It is evident that one of primary places of use for models in modern sciences lies in various kinds of simulation. Economics is no exception: a distinctive culture of simulation emerged in the social sciences in the years around 1960. This sudden explosion in the use of the term "simulation" covered a very broad range of practises: a variety of types of experiments including people in role-playing experiments (known then as gaming), computation machines, probability setups, statistical data, and mathematical models.

Back in 1954, Oscar Morgensterns account of economic experimentation likened the computer, then a brand-new instrument in science, to both a telescope and microscope instruments for economists that could bring both large things from

[2]The comparison between astronomical models and economic models 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.

far away and things normally too small to be seen into focus for them to study.

The digital computer can be described to be fulfilling a double duty as laboratory equipment for economics: *"it promises to provide the economist with the means for constructing both the instruments for observation and the equipment for experimentation that have been the earmarks of the traditional sciences. Used in one way, the computer supplies a viewing equipment to the economist in a manner analogous to the microscope for biologists (however, a great amount of work goes into setting up the "specimens" to be observed)"* (Shubik, 1960, p. 908).

The digital computer, he went on, allows the economist to study masses of data at various levels of aggregation; it enables the use of more "realistic", that is, complicated, models that do not have to be solved analytically, but can be analysed by numerical methods; and it enables simulation.

*"Simulation is a general approach to the study and use of models[...]. An individual simulation run may be thought of as an experiment performed upon a model[...]. A model of something is a representation of it designed to incorporate those features deemed to be significant for one or more specific purposes."* (Orcutt, 1960, pp. 893 and 897).

It is the exploratory and investigative power of simulation, the power to make economic things observable, that is the focus for our discussions here. In this context, it is worth remembering that there is no one technology of observation in the sciences, but many different instruments working in different ways. Understanding simulation as an instrument of observation like a microscope provides us with a neat way into understanding the technology of simulation in economics.

Simulation can be a successful instrument of observation of the world in the model, even if we are unable to strictly divide up its parts and relate them to functions.

The other side of this technological problem is that faced by the economist. This suggests another caveat that follows from this analogy of the technology of simulation with microscopes, namely, that such simulation instruments are man-made and mass-produced. Like modern microscopes and imaging instruments, pre-programmed simulation packages on the computer come ready to use. They have all the features of "black boxes": that is, these simulation packages are complex enough that they require tacit knowledge and associated practical skills to get them to work, yet the economist does not need to understand how the instrument works to use these programmes to carry out simulation experiments. Economists are therefore in a strange, but not unusual, situation: they have instruments that use certain kinds of laws to manipulate their models to reveal certain aspects of those models, but they don't necessarily understand exactly how those instruments work. There are two sets of worries that arise with such a black box technology, both relate to the status of what is observed. First, simulation is a kind of experiment, and as such brings with it the problems of creating experimental artefacts, raising questions about how to distinguish genuine characteristics of behaviour from artefactual ones created by the technology

of manipulation. Second, while simulation begins as a technology of enquiry into the world in the model, an economist's purpose may be to seek insight about the real-world economy from that enquiry.

## IV. From the World in the Model to the Model in the World

Models and modelling have changed the science of economics, the way that economic knowledge is used in the world, and the way that economists see and understand the world.

If we look back two centuries again, as we did at the beginning of this document, we now have a much better view of the way in which economics has changed. Adam Smith's Wealth of Nations of 1776 covered the whole territory of what then constituted the art and science of political economy in an expansive verbal treatment. His text provided a closely sequenced set of arguments linking the laws of political economy together, and simultaneously illustrating and supporting those laws by the evidence of common experience and of history.

Modern economics is qualitatively very different. It has became a social science largely dependent on small mathematical or diagrammatic models, each separately representing different bits of the economy and each treated largely independently of the others, while its evidence base rests largely on statistical, and now experimental, methods. So the changes in economics might be found both in these new objects: models, as a way of expressing economic ideas and content, and in the new way of reasoning with them: modelling.

### *A. Models: The Working Objects of Economics*

Even though economic models form small and artefactual working objects, for economists these creations may nevertheless express sophisticated accounts of the things they want to describe and understand. At the same time, the characteristic of individual economic models to represent typical kinds of things in the economy suggests how working with models may offer more general results.

No doubt all scientists develop or adopt some objects, specific to their particular science, that form the materials for their scientific investigations—labelled "working objects". For the natural and human sciences that they were discussing, these were often naturally found objects, such as the snails and finches that Darwin worked with and that prompted his understanding of evolution. Their focus was not so much on the work that these objects did as individuals, but on the way in which they denoted something broader than their individual objectivity might suggest: *"Working objects can be atlas images, type specimens, or laboratory processes—any manageable, communal representatives of the sector of nature under investigation. No science can do without such standardized working objects, for unrefined natural objects are too quirkily particular to cooperate in generalizations and comparisons"* (Daston and Galison, 1992, p. 85).

The working objects for any science are not predetermined—rather scientists choose their working objects for their own science with two main criteria in mind.

One quality is their typicality, or perhaps their possibilities for being representative of, or for, certain kinds of natural object. The other quality is the objects possibilities to reveal some of the secrets of the nature that they embody or represent. Both of these qualities are needed to make an object a useful working object.

Like maps, the models of economics are also manageably small worlds. Maps, like models, rely in part on omission to become small worlds: they do not represent every detail of the terrain and have more or less specific content depending upon the scale that is chosen for the representation. The scale in turn depends upon the purpose: a map good for hiking requires a large scale and lots of detail, a map designed to show the relationships of countries and continents needs a very small scale as we find in world globes. And while there is a direct relation in maps between scale and content—the larger the scale, the more detail that can be shown, and the smaller the scale, the less detail can be fitted into it—mapmakers have been ingenious in the extraordinary degree to which content can be expressed even at very small scale. Thus walking maps may include sketches of peculiar or recognisable features of the landscape to draw attention to important nodes of the route. Like map-makers, those creating economic models must pick out what they take to be the salient points of the economy so that their representations not only remain manageable but also focus on the elements and their relationships that are of particular interest to them.

### *B. Small Worlds, Miniature Worlds?*

To an outsider coming to the field of economics, one of the most striking things is the way that economists feel that they can express so much of what happens in the economy within their small worlds, within these little chunks of mathematics or puzzling diagrams. Don't they seem much too small? Surely those economists must have ignored too much, and the model descriptions be much too different from economic life as it is lived, to be the way to do science? Even some inside the field question whether models are a valid way of doing economic science because of this combination of scale reduction, simplification (to omit things), and transposition into mathematical and diagrammatical forms.

Economic models have occasionally been referred to as "toy models" (by both critics and users), conjuring up images of the scale models of farm animals and fire engines—objects of the playroom rather than the serious work of social science. And, of course, to some extent this label and these criticisms are right: economic models are—in certain respects—like those toy assembly kits that enable a child to construct and manipulate a model plane or a crane. Such constructions omit many features, even though they may capture sufficient salient details of real things to be recognisable as models of them. And as toys, they are made out of plastic perhaps, rather than the serious scale models of engineering (where, as we have seen above, the materials have to be right for the scale of the model). But economic models don't even have the virtues of those toys in as much as

their equations and diagrams do not even look like anything recognisable in the economy such as consumer goods, factories, or tax bills. Of course the economists who are committed to economic models, and know how to read them, do recognise these pieces of mathematics as accounts of economic life.

And if we understand the small worlds expressed in economic models, we can see how both offer combinations of carefully chosen and arranged ideas, succinctly expressed within a formal structure. Models for the economist are means to express accounts of life in an exact, short form, using languages that may easily abstract or analogise, and involve imaginative choices and even a certain degree of playfulness in expression, all within a structure that follows certain rules—of mathematics or of length and metre. This process of capturing and articulating the nature of economic activity provides a very neat possible way. And just as with maps for the geographer or geologist and models for the economist, understanding takes not just knowledge of the form but also considerable cognitive attention on the part of the reader to unravel the content and meanings so carefully compressed into those standardized and constraining structures.

There are two points to take from these comparisons about the nature of models and how their qualities might be regarded. First, economic models may be small, simplified, and not recognisably like the things that they depict in the world, but this does not invalidate them as working objects, for the sciences—like the humanities—rely on such objects in their search to comprehend the world. Second, economic models may be constructed and played with like toys, but for the economist-scientist who works with such objects, models can be understood as articulate artefacts–compressed accounts of things in the world expressed in an appropriately specialised form and language.

### *C. Assumptions in Practice*

If we look to the most salient difference between economics of 200 years ago and economics of today it is that the notion of "laws" has almost disappeared from economics. Historians have argued that there were few laws left over from the classical system of political economy by the mid nineteenth century, the laws of supply and demand being the most obvious remainders when models started to arrive in the late part of that century. There are also only a few general theories left over from the nineteenth and early twentieth centuries, for example, the quantity theory of money. This loss of general law-like claims and theories about how the elements of the economy behave and are related together is exemplified by the fact that, in practical terms, economists have collapsed the distinction between "theories" and "models". When pressed, economists might suggest that theories are more general than models, or that they are less conjectural, but they dont usually find the need to distinguish between them.

Modelling, as we have seen, provides economic science with lots of "middle level stuff": in-between, generic-level accounts of what economists take to be typical in economic life rather than descriptions of particulars or very general accounts.

Models result both from dividing general accounts and gathering particular empirical cases together. So what then holds economic ideas together? One could argue that it is those two general assumptions that modern economists came to share and use: the *individual utility maximization* of economic man, and the *equilibrium tendency* in the aggregate system models, and their combination which proved so important to the arguments inherent in game theory/models.

### *D. Network of Models*

While the practices of modelling did not create a united empire across the subject domain of economics, they did create a network of connections between different types of models.

Models stitch certain elements of economics together. For example, the models of returns to scale in production directly inter-relate with the modelled shapes of supply curves, while the utility maps of Edgeworth and Pareto can be pieced together to create demand curves; so these two curves that form the supply and demand cross in Marshall's market model rely on independent causes—one side of the cross is about the behaviour of consumers and the other of producers.

More often, models link subfields together by being transferred across subfields because of their considerable flexibility to fit into different theoretical domains. The model of rational economic man is obviously the most well travelled and well used model endemic to microeconomics. In fact it lurks inside every micro-model for it embodies one of the principled constraints of individuals' utility maximization. Economists also find the model of supply and demand flexible enough to fit onto anything that can be classified as a "good'" in economic terms, that is, to any object that is not freely available, or can be made not free: from consumer goods, to children, to wage labour, to money, to clean air and water as much as to waste products.

Other models form the exemplar case most widely used to refer to particular results that have important implications. For example, the Prisoners Dilemma case gained its exemplary status because of the way in which it shows how the usually unspoken but deeply held belief of neoclassical economics (inherited from Adam Smith) that self-interest will lead to the best outcome for all is subverted into the claim that this does not necessarily hold. The model embeds both the neoclassical assumptions of rationality and equilibrium, but in ways that show how those rules may be curiously at odds with each other.

### *E. Models in the World: Seeing Small Worlds in the Big World*

Economics as a discipline has always been considered both a science and an art: an investigation into how the economic world works and an associated set of recipes for shaping it to work better in some way or other, so carrying a moral or normative element.

Economists began by expressing small worlds in their models, but by and by, those models came be the things that economists found or saw directly at work

in the world. This has heralded a change in economists' view of the world, and that change came not just from the new form of expression, but from working with these objects.

We know historically, that modelling involved a change in language and format of expression to create new working objects that represented the economy in models that held certain qualities of smallness, typicality, manageability, and expressiveness. The modelling revolution meant not just that claims were more closely specified and argument was more rigorous, but rather that economists made new versions of the economic world for themselves, and regardless of how these models were created, it was through working and arguing with these new versions of the world that economists came to their new understanding of the economy and how it worked. So, when economists came to talk about some phenomena or puzzle in the economic world they used the conceptual elements of their models, and the investigative resources of those models, to explain them.

Economists looking at the world make an account of it in their small-world models. These accounts then function as an instrument: by analysing those models and experimenting with them, that is, by working with them, economists come to see new things in the world that were previously hidden to their view. As time goes on, these newfound things become so familiar that the model moves from being the lens that enables economics to interpret the world in this new way, to being the things they find and see in the world. So, economists begin by positing rational economic man or supply and demand curves as their way of depicting the world and the things in it. Investigating these workable objects then leads them to interpret economic things in the world in terms of these models. Finally, they move to a point where they no longer use those models to interpret the world, but they see those models at work in the world—the point at which model-designed interventions seem natural.

For economists over the past century, their small worlds offered accounts of sufficient coherence with their experience of the economy as to be usable and useful working objects to explore and gain an understanding of the economic world. In the process, those small-world models of their science became so familiar to economists that now, when economists look at their small mathematical models they see the real world, and when they look at that big real world they see it as a sequence of their small models.

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