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Models as Mediators

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Scientific models have tremendous power. In physics, as in economics and biology (especially population genetics), they function as the explanatory vehicle upon which many of our actions are based; indeed they form the foundation for economic policies and for many of the technological advances that result from modern science. Both the natural and social sciences involve the manipulation of models not only in the theoretical domain but in experimental contexts as well. Hence one can think of a model as not only a manifestation of theory but also as the place where theory meets data. Consequently, models mediate between theory and data and between science and the world.

Philosophy of science has addressed the role of models in two seemingly distinct ways. On the one hand, philosophers have focused on different ways in which the notion of a model can be understood in terms of either idealising assumptions, or in terms of metaphors and analogies. The other philosophical approach emphasises the relationship between models and theories, claiming that the process of model construction is one that either involves deriving a model from a higher-level theoretical structure or building a model as a precursor to theory. Either way, much of the literature emphasises models as essentially passive hypotheses awaiting test rather than active components in the domain of knowledge production. The fact that models have this active role that has virtually gone unmentioned is a motivating factor in our research and for holding the symposium. Models indeed have a life of their own, yet their

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characterisations in the philosophical literature often bear little similarity to the ways in which models have actually worked in the history of science or to the ways they function in modern scientific practice. And, despite their enormous importance, virtually no attempt has been made to understand the nature and significance of models themselves, or the presuppositions implicit in the practice' of modelling. Models in both physics and economics seem to embody pragmatic responses to local questions and problems, yet because of their central place in various sciences one ought to be able to point to some general methodological traits that are common to different kinds of models in different fields.

The goal of the colloquium was to bring together various scholars in different disciplines, particularly economics, physics, and philosophy of science in order to get some perspective on how modelling is both conceived of and practised in different fields. By doing this we hoped to develop ways of representing models so that their central role as the chief "go-betweens" in developing scientific knowledge could be fully articulated. Both historical and contemporary examples of models and model building were examined with special attention to several themes that seem to dominate discussions on models; for example, is the realistic/heuristic distinction a fruitful way of classifying models, in what sense can abstract models provide information about the world, how do models "represent" physical systems, etc. The sessions extended over two days with five talks (one of which was the *Dienstags-Kolloquium* where Margaret Morrison presented her work on models) and two general discussion meetings.

The first speaker was Nancy Cartwright, who gave a paper entitled "How to Get Laws From Probabilities". Professor Cartwright's talk focused on the conditions necessary for the formulation of laws, emphasising that laws are not simply "read off" from nature but rather only emerge in special settings where conditions are just right. It takes special arrangements of circumstances, properly shielded, repeatedly started up, and running without a hitch to give rise to a law — conditions that Professor Cartwright characterises as a "nomological machine". Models show us where laws of nature come from and how we can produce new ones because they serve as "blueprints" for nomological machines. Hence, no laws can be represented outside the highly structured arrangements of the "machine" and it is the models that represent for us those specific situations where nature is reliable. The thesis was applied to a case where an economic model was designed to guarantee that a specific probabilistic law obtains. The model showed how loss of skill during unemployment leads to less job creation by employers which in turn leads to continuing unemployment. The talk was especially interesting in that it showed just how probabilities must be associated with special kinds of models before they are linked to the world and the special arrangements that are required before a probabilistic law can arise.

The second speaker, Marcel Boumans, discussed how a "logic of discovery" can be associated with the practice of model building and the ways in which this is intrinsically connected to a "logic of justification". One of the things that makes Boumans' work novel and interesting is that much of the discussion in philosophy of economics separates the activity of working with models from their empirical assessment. In other words, the context of justification is fully disconnected from working with the model. Boumans examined some cases from business-cycle modelling and showed how the logic of discovery involves the successful integration of various theoretical, mathematical, statistical, data and policy constraints. He then showed how the inclusion of empirical data and facts creates a kind of built-in justification for the model, thus linking discovery and justification in an intimate way.

The third talk consisted of the *Dienstags-Kolloquium* given by Margaret Morrison entitled "Mediating Models: Between Physics and the Physical World". The subject was how we use models as instruments for intervening in the world. This clearly differentiates models from theories by stressing the "active" component in modelling. For example, models define and constrain ways of acting — the liquid drop model of the nucleus tells us how to produce nuclear fission and how to manipulate nucleons in certain ways. Yet we know that it is insufficient as a true representation of the nucleus because there are many phenomena it cannot account for. The model can map onto certain aspects of physical systems in ways that allow us to manipulate them for the production of new technologies. By contrast, theories provide us with general principles that explain process by subsuming the specific under the general. But, and perhaps most importantly, models also have a representative function that is realised in part by their ability to produce simulations. These simulations allow us to directly map model predictions onto empirical level facts. Several examples from optics, nuclear physics, and gas theory were discussed as a way of illustrating how models could function autonomously as instruments for the production of knowledge and technology.

Stephan Hartmann's lecture dealt with the use of models in the application of Quantum Chromodynamics, the fundamental theory of strong interactions. He discussed two of these models, the MIT-Bag Model and the Nambu-Jona-Lasinio Model highlighting the strategies used in their construction and analyzing the arguments used for the legitimation of each within the physics community. Each model represents a different, competing condition thought to be primary for the background theory. The former stresses the importance of quark confinement while the latter emphasises chiral symmetry as the important condition. Hartmann showed how the acceptance of each model is highly dependent on whether it can support a physically plausible qualitative story about why the process dealt with in the model is more important than its competitor.

Our final speaker was Mauricio Suarez who discussed issues relating to the empirical adequacy of models of measurement in Quantum Theory. Quantum measurement tends to get modelled in an abstract mathematical language, in part because the measurement itself is already understood in highly idealised terms. Yet, important assumptions about the nature of the real measurement process and about their relation to quantum theory are built into the formulation of the more abstract models. Suarez highlighted some of the well-known results in quantum mechanics that are designed to prove that abstract models of quantum measurement are impossible. He argued that these results presuppose a notion of empirical adequacy of a model and showed how this premise could in fact be denied, yielding a successful model of abstract quantum measurement.

The colloquium ended with a general discussion of several of the issues raised in the various papers. In addition to giving us a chance to discuss our current work on models and relationships between modelling in physics and economics, the colloquium brought to the forefront new issues that will set the stage for further research in the field.