THE WORKING LIFE OF MODELS

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When models live their lives, they grow up and enter working life. They leave behind the sheltered world of research where they serve as scientific instruments, measuring devices, virtual experiments or representations of the world. They enter a new domain of use, where they are no longer necessarily close to modellers, researchers or instrument makers. Rather they stand on their own to disseminate reliable and usable evidence across research communities and policy domains. This metaphorical language summarises the wealth of studies addressing the development and use of mathematical models, computer-based simulations and computational techniques, in a variety of fields – as diverse as infectious-disease epidemiology and climate research. Through these application-driven areas of research we can learn how model-based knowledge helps predict infectious outbreaks and guides our understanding of climate change.[1]

The increased popularity of modelling methods stems from their cost-effectiveness. Models are capable of producing convincing quantitative scenarios without experimental practices. Model-building itself can incorporate expertise from various fields. For example, in epidemiological modelling, experts with backgrounds in statistics, engineering and epidemiology have formed long-term collaborations.[2]

In order to understand the benefits and limitations of modelling techniques in policy contexts, I will use the metaphor of *working life*. I will explore how infectious-disease models provide predictive scenarios when they are at work for better vaccination policies or preparedness for pandemics. I will then discuss how climate models enter the debates of reliability.

Effective networking: how infectious disease models disseminate evidence across research and policy networks

Epidemiological models that are developed in infectious-disease studies function in several ways. Their primary role is to overcome the limitations faced by experimental studies. Ethical and financial considerations constrain population-level studies, and so the availability of data can become an issue in statistical analysis. Infectious-disease models can overcome some of these constraints successfully.

Figure 1. *Modelling Hib (Haemophilus influenza type b) transmission at the Institute for Health and Welfare, Helsinki, 2003.*

Their documented capacity to disseminate reliable and usable knowledge across research and policy networks is significant. In my study of models that address infectivity, transmission routes, and vaccination effects against infections caused by *Haemophilus influenzae* type b bacteria (Hib), knowledge transmission between models (i.e. where earlier built models store and distribute parameter values and estimates of transmission rates to other models) was a productive way to inform model-building within a research group. The networks were formed when evidence established in these models was used by other research groups to inform their research, providing missing parameter values or suggesting the structure and design of models. Interestingly these models may address questions related to other infections (e.g. ones caused by *Streptococcus pneumoniae* bacteria, PnC). The capacity to transfer knowledge was partly reliant on the chosen modelling style. The Hib models were built in an interdisciplinary modelling group at the National Institute for Health and Welfare, Helsinki, Finland (Figure 1). Their style evolved over time to address infectious transmission in probabilistic terms that were able to accommodate a scarcity of data and to extrapolate parameter estimates from that. When other research groups approached their

[1] E.g. G. Gramelsberger, 'Story telling with code', in A. Gleininger and G. Vrachliotis (eds), *Code: Between operation and narration* (Basel, Birkhauser, 2010), pp. 29-40; G. Kueppers and J. Lenhard, 'Simulation and a revolution in modelling style: From hierarchical to network-like integration', in J. Lenhard, G. Kueppers and T. Shinn (eds), *Simulations: Pragmatic construction of reality* (Dordrecht, Kluwer Academic Publishers, 2006); E. Mansnerus, 'Understanding and governing public health risks by modeling', in R. Hillerbrandt, M. Peterson, S. Roeser and P. Sandin (eds), *Handbook of Risk Theory* (Dordrecht, Springer, 2012).

[2] E. Mattila, 'Interdisciplinarity in the Making: Modelling Infectious Diseases', *Perspectives on Science: Historical, Philosophical, Sociological*, 13:4 (2006), 531-553.

own questions with modelling methods, the Helsinki models provided a way to address similarities between the bacterial infections, such as the lack of permanent immunity in the case of both Hib and PnC infection. These overlapping interests facilitated the dissemination of model-based evidence through the networks.[3]

But infectious-disease models are desirable not only for their ability to disseminate knowledge. Their predictive capacities and their use in scenario-building and pre-pandemic work significantly increase their popularity. Using models for their predictive functions originates in the UK from the late 1980s, when early measles models were introduced to support a revision of vaccination policies. From these experiences, facilitated by the growth of computational capacity and an acknowledgement of interdisciplinary expertise in epidemiological research, modelling methods paved the way for the most challenging uses: pandemic preparedness and prevention work. A good example is the A(H1N1) outbreak in 2009, when pandemic modelling was employed simultaneously during the development of the outbreak. Although the early predictions of the severity relied on a small sample of data, they provided a way to keep ahead of the outbreak itself. As more data became available, these estimates were reassessed.

In predictive modelling, the scenario-building capacity of models is vital. Not that scenarios should be regarded as the whole truth, but they provide the quantitative playground to assess how well different prevention strategies (such as quarantine, school closures or travel restrictions) are functioning. Yet, in the assessment of the governmental actions during the 2009 pandemic, Dame Deidre Hine emphasises that 'modellers are not court astrologers'.[4] This metaphor captures the challenging tension when models are at work outside the research groups. Model-based evidence is not a 'crystal ball' to predict futures. Rather, we are talking about a way to communicate – accurately, reliably and numerically – particular relationships between the various factors that cause infection and which are responsible for its transmission. When modelled, these factors can be told as a story, and hence approached in a more comprehensible way.

Entering disputes: climate research

Climate research has a long history of model use. Early computer-based climate models – the massive general circulation models whose core code was written in the 1960s – are still partly in use.[5] Even before computerised

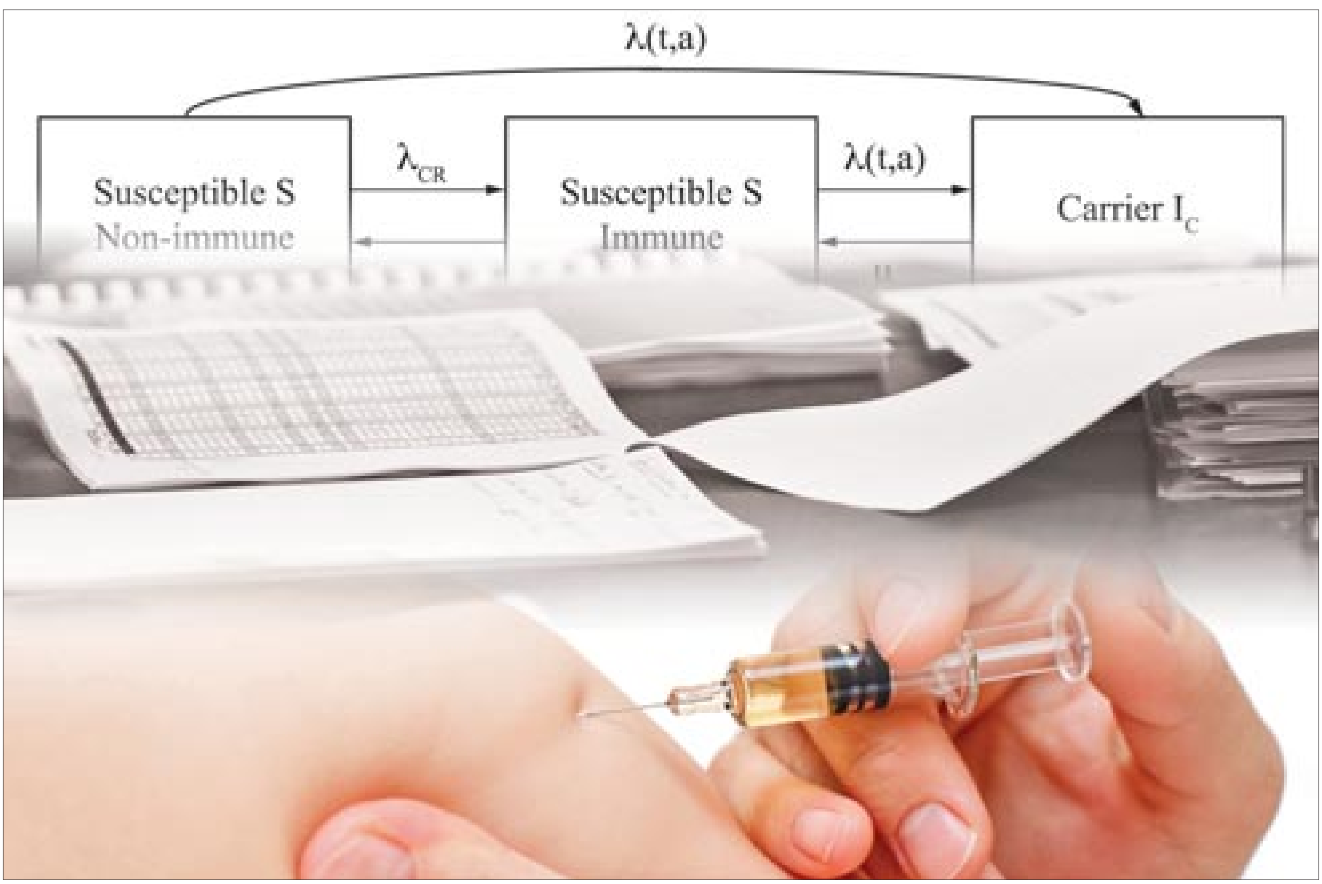

Figure 2. *From graphic model to vaccination policy.*

[3] E. Mansnerus, 'Using models to keep us healthy: The productive journeys of facts across public health research networks', in Howlett and Morgan (eds), *How well do facts travel?* pp. 376-402.

[4] D.D. Hine, *The 2009 influenza pandemic. An independent review of the UK response to the 2009 influenza pandemic* (London, 2010).

[5] Gramelsberger, 'Story telling with code'.

models, meteorological calculations of weather patterns became tools for modelling the climate. As this was one of the early steps that contributed to the mutual relationship between climate science and policy through the work of the Intergovernmental Panel on Climate Change (IPCC), it is important to assess how model-based evidence has been received in climate policy. Naomi Oreskes's study on the dispute shows how various interest groups have intentionally challenged the evidence for an anthropogenic cause of global warming. Disputes about whose facts were better finally failed to convince the American people of the seriousness of global warming.[6] Is this because the reliability of model-based evidence is difficult to establish? One factor is the potentially opaque nature of acquiring knowledge through computer-based simulations. What are the model assumptions, and how were they made? What about the instrument itself – the model? These questions can be answered when three aspects of model-building and model-functioning are taken into account.

As factors for establishing the reliability of a model, we can clarify the quality of the model itself, how well it has been built, and how strong the modellers' expertise is. Perhaps the disputes over the causes of climate change reflect misunderstandings about the nature of model-based evidence. Yet the quality of the model itself is not easily assessed. By analysing the 'inner life' of the large-scale climate models, we can find one way of responding to the criticism of model reliability. Together with Gabriele Gramelsberger, I have contrasted climate models and epidemiological models and analysed them in terms of their computational capacities.[7] Despite the apparent differences in their scale and magnitude, we showed that in both cases the model assumptions were translated into calculable statements with the help of mathematical algorithms. When this process is grounded in available data, the models function well and can be assessed as reliable. Yet the challenge is to keep these technical stages of model-building transparent when large-scale climate simulations enter the policy domain as sources of information. In the policy world, model evidence is readily used, because quantitative scenarios are clear and attractive.

Understanding the life of models

The working life of models may turn into a success story, as the current trends for relying on quantified evidence suggest. But the evidence-base that models provide may be disputed equally well, as is shown by the delayed acceptance of the results of climate research. The metaphor itself emphasises how the boundary between model development and model use becomes more flexible when models provide evidence for policy, whether it be health, or climate policy. This is when model transparency, accessibility to the process of model-building, and an understanding of the model assumptions become central. What has been captured in the model remains opaque if the modellers are not able to clarify the assumptions made or the restrictions given by the data. Hence, we can conclude that working life revises the dual function of models. On the one hand, it sets a requirement for transparency in model building. On the other, it asks for understanding of the specific policy process. Complex policy-initiated models find their place – not as new oracles of Delphi – but as valuable tools for prediction.

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[6] N. Oreskes, 'My facts are better than your facts: Spreading goodnews about global warming', in P. Howlett and M. Morgan (eds), *How well do facts travel? The dissemination of reliable knowledge* (Cambridge MA, Cambridge University Press, 2011), pp. 136-66.

[7] G. Gramelsberger and E. Mansnerus, 'The inner world of models: Case of climate and infectious disease modelling', in C. Bissell and C. Dillon (eds), *Ways of thinking, ways of seeing* (Milton Keynes, Open University Press, 2012).