CrossMark

Science in Context **27**(4), 631–657 (2014). © Cambridge University Press 2014
doi:10.1017/S0269889714000234

Dissolving Decision Making? Models and Their Roles in Decision-Making Processes and Policy at Large

Ragna Zeiss

Maastricht University
E-mail: r.zeiss@maastrichtuniversity.nl

Stans van Egmond

Rathenau Instituut
E-mail: s.vanegmond@rathenau.nl

Argument

This article studies the roles three science-based models play in Dutch policy and decision making processes. Key is the interaction between model construction and environment. Their political and scientific environments form contexts that shape the roles of models in policy decision making. Attention is paid to three aspects of the wider context of the models: a) the history of the construction process; b) (changes in) the political and scientific environments; and c) the use in policy processes over longer periods of time. Models are more successfully used when they are constructed in a *stable* political and scientific environment. Stability and certainty within a scientific field seems to be a key predictor for the usefulness of models for policy making. The economic model is more disputed than the ecology-based model and the model that has its theoretical foundation in physics and chemistry. The roles models play in policy processes are too complex to be considered as straightforward technocratic powers.

Introduction

This paper investigates the roles models play in policy and decision making. Some have argued that scientific models and simulations are often of limited use to policy makers (for example, Bekebrede and Bilsen 2009). Simulations and models are seen as being so complex that very few experts are able to understand and work with them. Such models become "black boxes" for policy makers (and others) and are generally mistrusted. They tend to fail when they are used to form conclusions that are translated into policy (ibid.). Often models do not capture the real situation accurately, which limits their value/utility for policy makers (van Egmond 2010). However, models are increasingly used to support policy and decision making processes (as is argued for example by Edwards 1999; Morgan and Den Butter 2000; Sundberg 2007). In addition,

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

recent calls for more evidence-based policy will lead to even more use of models and model-based information in decision making processes (van Egmond 2010).

The construction of such models and the roles they play in policy and decision making processes are not straightforward. Science and policy are intertwined within the models and within the process of methodological decision making (Shackley and Wynne 1995; Van Egmond and Bal 2011). For example, scientists' perceptions of the policy process play a role in shaping scientific practices (Shackley et al. 1999). These insights have led scholars to study models as particular cases for exploring boundary work between science and policy (for example, Van Egmond and Zeiss 2010). Studies on the use of models – such as in science and technology studies and in the philosophy of science – show how models are the result of both scientific and professional interaction (Daalen et al. 2002; Edwards 1999; Evans 2000; Morgan and Morrison 1999; Shackley and Wynne 1995). A good example is the General Circulation Model that is used to predict possible climatic changes due to human emissions of greenhouse gases. It is generally considered to be the "best science" for the study of future climate change while social and policy judgments tend to influence this consideration (Shackley et al. 1998). As the models are often publicly funded and dependent on requirements set by the commissioning bodies, they are scientific and political at the same time. Research and policy combine to shape the modeling process and are, in turn, products of the construction process that arises out of the use of models. Increasingly, models have been incorporated into both the decision making and regulatory processes governing a wide range of applied fields. This begs the following questions: How has this come about and how does it affect their roles in policy and decision making processes?

One concern about the use of models for policy making deserves special attention. The longstanding involvement of models has, in the Netherlands as well as elsewhere, led to criticism of the role of science as a technocratic power, in that science has (too) much influence and power over formal democratic decision-makers (Fischer and Forester 1993; Hilgartner 2000). As trust in models as well as their roles in policy making are more substantive in the Netherlands than in surrounding countries as is further explained below, this country can be considered a hard case through which the fear of the influence of models on policy can be investigated. The authority of the Dutch science advisory bodies developing and using the models is largely uncontested. If the influence of models on policy does not (automatically) jeopardize democracy in this Dutch context, it is likely that the criticism and fears need to be nuanced also in other countries.

Therefore we discuss three Dutch models in three different policy fields to explore these questions and this specific concern. The three models described in this article operate on the boundaries between science and policy: the ecological model LARCH addresses the field of nature policy; the PEARL model is rooted in agricultural policy with regard to pesticides; and the Care model addresses the field of health care. All three have been developed by science-based policy advisory institutions in the Netherlands.

These advisory institutes cater to the specific requirements of both the scientific and policy making fields. These institutes also provide rich opportunities for examining

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

locations where science and policy interact. They form an ideal location to study the interaction between science and policy as they allow the researcher to examine the means by which these models are constructed. In addition, the institutes and their models have an authoritative position in the Netherlands which allows us to investigate their feared technocratic power. We have studied the three models over a longer time period beginning with the initial construction phase. Models such as those described here are explicitly constructed to have a key role in the decision making process but often tend to be large and unwieldily complex. To understand the role of these models in decision making processes, we argue that these models should be addressed in the context of what we call "policy and decision making at large." We put forward the argument that it is crucial to consider model construction as an early phase of decision making which, in turn, is mediated by the changing contexts within which the models are further developed and operate. Moreover, we argue that models tend to be adopted when they are constructed in a stable political environment. It must be stressed that the level of stability of the scientific realm with respect to both epistemology *and* uncertainty seems decisive for the usefulness of models in policy making processes. The less stable the scientific field, the more difficult it is to construct a useful model to inform policy makers (and vice versa).

After introducing the context of science-based policy advisory bodies which have developed the models and their authoritative roles, we go on to outline their key roles in policy and decision making processes. To understand how models came to play these roles, we begin by exploring the political and policy context initially and then we examine the scientific context in which the models are embedded. We investigate these contexts as a series of discrete continuums in which the degree of stability of these contexts tends to shape the role a model has obtained in policy and decision making. Although the place of models on each of these continuums does not offer a formula to predict the role(s) of models in decision-making, they help to explain how the different roles come about. The wider context and background have directed their role in policy and yet these models also influence the wider political and policy context in turn. In the last sections we draw wider conclusions by stating that the analytical distinction between different contexts is helpful, although models should also be seen in the interaction between science and policy.

Three models and five science-based policy advisory bodies in the Netherlands

In this article three models take center stage. The Care model addresses the cost of healthcare and how to control it. The LARCH model assesses the impact of landscape fragmentation for the survival and development of animal populations ranging from deer to birds. Finally, the PEARL model evaluates the leaching of pesticides into the

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

groundwater. These models play a crucial role in Dutch politics and policy making processes for health care, nature, and agriculture respectively.

All three models are used for policy planning, assessment, and/or regulatory procedures. They are developed by five distinct science advisory bodies in the Netherlands. Each body represents a distinct instance of the employment of scientific knowledge in governmental policy making. Each science advisory body has a central and formalized role in science based policy assessment for the government, albeit in different policy domains. They make use of scientific knowledge and insights drawn from economic, sociological, epidemiological, and ecological disciplines and their allied models in their analysis and publications. Not surprisingly, these science advisory bodies have longstanding relations with their affiliated policy fields and respective scientific disciplines.

The Netherlands has three formal planning bureaus, the most influential being the Netherlands Bureau for Economic Policy Analysis (CPB). The CPB carries out economic policy modeling and assessments (see for example Den Butter 2003; Bogaard 1999). In addition, the Social and Cultural Planning Office of the Netherlands (SCP) addresses socio-economic issues in Dutch society (Trommel 2003). Finally, the Netherlands Environmental Assessment Agency (PBL) performs policy analysis in the fields of environment, nature, and spatial planning. It was established in 2008 and combines the former Netherlands Institute for Spatial Research (RPB) and the Netherlands Environmental Assessment Agency (MNP).

A number of other science advisory bodies perform modeling work for the government. Most of these started life as formal planning agencies but changed focus recently. The research of the National Institute for Public Health and the Environment (RIVM) is used to underpin (mainly Dutch) policy on public health, food, safety, and the environment. Alterra is the research institute for our green living environment and conducts applied and strategic research that is used for policy, management, and design of the green environment. These bodies have several features in common, such as the fact that they have monopolistic positions and have strong longstanding relations with both the policy world and the scientific world.

These institutions and their models have a particularly strong and authoritative position in the Netherlands. Unique to the Netherlands is for example the assessment of the influence of election programs put out by political parties on subsequent economic developments by the CPB since 1986. Since then, policy makers share a broad consensus that it is best to accept these assessments (Vries et al. 2010). They play an important role during election times.

The economic crisis in the 1980s led politicians to seek credibility for alternative views and credibility could be found in the use of models (Keuzenkamp 2003). The authority of the CPB and its models however goes back further. In the 1930s economic planning was seen as a way to handle the economic crisis and the first director of the CPB, the Dutch economist Jan Tinbergen, saw the role of economists as advising on policy instruments that help policy makers achieve the desired outcomes (Vries et al. 2010; for more historical background on the planning bureaus, see Halffman 2009). The

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

role of the science advisory institutions can therefore be seen "as a linesman of politics: by predicting the likely outcomes of policies that are being considered, the planning bureaus define what is at stake in policy making" (Halffman and Hoppe 2005, 140).

Science-advisory institutes and the use of models for policy analysis as such are not unique to the Netherlands. For example, where the Netherlands has one institute for policy analysis, Germany has five. This means that in Germany these institutes and their models can come to different analyses which may form the basis for discussion. In the Netherlands, the science advisory organizations however hold monopolistic positions. Surrounding countries are astonished by the unquestioned acceptance of their assessments. In the Netherlands these are seen as neutral calculations and "create facts and rationales that frame and discipline political deliberation" (Halffman 2009, 59), whereas abroad these are seen as a form of technocracy that is unacceptable (Bogaard 1998). In addition to the historically grown positions of these organizations, the PEARL model will show that it is also considered important that a small country such as the Netherlands does not work with different models for the same (policy) question, especially if it wishes to strengthen its European position in a certain field.

Responding to the criticism of the role of models, science, and science advisory organizations as technocratic powers, several authors have argued for an approach in regulatory science for policy and decision making (Halffman 2003; Maasen and Weingart 2005) that better legitimizes decision-making democratically, under conditions of uncertain knowledge, and within changing political systems (for example, Fischer et al. 2007; Hajer and Wagenaar 2003; Jasanoff 2005; Stone 2007). Recent work on science and policy-making has taken up this call for further investigation of the role of science advisory bodies (for example, Bijker et al. 2009; Vries 2008; Van Egmond and Zeiss 2010). Contributing to this literature, we contend that the three models studied within this specific Dutch context form an excellent case for studying the roles of models in policy and decision making processes, with specific attention to the fear for their (perceived) technocratic roles. The Dutch models can function as a "hard case" to establish to what extent they indeed perform technocratic roles within the wider science-policy context.

The role of these science-based expert organizations as mediators between scientific knowledge and policy processes is a difficult one. They have to be close to politics while also keeping a distance so as not to become too politicized. Importantly, they have to sustain their authoritative positions and credibility to be able to perform these dual roles (Bijker et al. 2009; Hilgartner 2000; Weiss 1991). Models are usually used to assess their success in carrying out their roles with impartiality and effectiveness (for example, Edwards 1999; Jasanoff 1990; Morgan and Den Butter 2000; Sundberg 2007; Yearley et al. 2003). Models can help to depoliticize policy problems without doing away with the normative choices associated with them. As Weiss (1991) has argued, models can be used to diminish political discussion, they can be used instrumentally as data input for policy, to facilitate the development of ideas for policy making, or as arguments in disguise for political discussion. Her classification is currently used widely,

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

and underlines that the role(s) scientific models play in policy making processes is not limited to the characteristics of the models alone. Modeling can thus be considered as a complex activity on the boundary of science and policy.

It becomes clear at this point that models have come to play numerous strategic roles in policy and decision making processes. Some models can obtain a dominant position within a specific area, such as climate change (Shackley et al. 1998). In this case models encourage negotiations between model makers and policy makers on divisive issues such as "uncertainty" (Shackley and Wynne 1995). Models can be used as democratic tools amongst various groups of people (Yearley 1999), in interdisciplinary projects (Galison 1997), and in macro-economic policy (Evans 2000). Van Egmond and Zeiss (2010) have argued that models can be seen as performative boundary objects; they actively coordinate social worlds *and* contribute to changing them. The role of models in science-policy interaction has received explicit attention.

A comparison between the construction and use of the aforementioned three models offers insights into explaining how and why models gain the role they perform in decision-making processes. We now turn to the different roles the models have obtained in policy and decision processes.

Three models and their (changing) roles in policy and decision making

The three models play different roles in policy and decision making processes and these roles have, in two models, changed over time. Table 1 summarizes these roles.

These roles are further discussed in the remainder of this article, after we outline their key roles in policy and decision processes here. The PEARL model – Pesticide Emission Assessment at Regional and Local Scales – simulates pesticide leaching into the groundwater. Over the years, it has grown into the most authoritative and decisive model of the three. PEARL's outcomes have to be used in the registration process of particular pesticides. Metamodels of PEARL are now used to evaluate policies such as the EU Thematic Strategy on the Sustainable Use of Plant Protection Products. PEARL has not only become a common point of reference, but also an "obligatory regulatory point of passage" (Callon 1998) in the field. It has a legal status in pesticide registration procedures. Neither the LARCH model nor the CARE model have attained this degree of authority. The LARCH model – LAndscape ecological Rules for the Configuration of Habitat – is used to assess the viability of animal populations in fragmented landscapes and reveals the potential of biodiversity within that habitat (Sluis and Bunce 2003) it also simulates the effect of various objects such as an ecoduct (Alterra 2007). In addition to ad hoc projects, LARCH has extensively and systematically been used by the MNP, one of LARCH's largest customers (Verboom and Pouwels 2006). Increasingly, LARCH serves as an interactive tool for deliberation and group decision support in provincial and local consultative processes. LARCH produces outcomes that inform (different kinds of) decision-making rather than effectively making the decision itself. It has no

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Table 1. Models' main role(s) in policy and decision making processes.

Timeframe	PEARL	LARCH	Care
Construction phase	Coordination device between scientists	Making science usable for policy	Coordination device between scientists
	Coordination and negotiation device between science and policy makers		Legitimation device for new actor in the field
The first years	Assessments in Dutch pesticide registration	Informing ad hoc policy decisions	Not used at first
	Assessments of pesticide leaching in EU evaluation process	Structurally informing statutory Nature Outlook publications	
	Metamodels evaluate Dutch and EU policies		
	A common point of reference and an obligatory regulatory point of passage		
Currently	See above	See above, and Interactive tool for deliberation, group decision support in provincial/local consultative processes	Structural use as background model to support health sector reports

legal status. The Care model, as delivered in 1999, was initially dismissed as a mere policy tool. The model's initial goal was to be used as an assessment tool for health policies and this was not achieved. Not until the model was modified in 2005, did it gain a structural role as the background model used for publications on the health market by the CPB. To understand how these varying roles and positions of the models came about, we first discuss the importance of the political and policy context and second the importance of the scientific contexts in which the models came about.

The importance of the political context for models' role(s) in decision making

All three models were predominantly constructed by authoritative science-based policy advisory bodies with similar aims, i.e. to both assess and support policy proposals. To

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

what extent does the (changing) political context influence and explain their different roles and positions? To answer that question we ask why these models were developed, how, by whom, for what purpose and how did the political context change.

From its creation PEARL had a clearly defined purpose in the realm of politics: it had to become a good model. "If a Ministry proposes a model at European level, they have to know that there is a large possibility that it becomes successful; for that, policy-makers have to know what they propose" (Alterra interview 061019). The Netherlands has one of the most intensive farming systems in Europe which is supported by considerable use of agrochemicals (Brouwer 2001). For numerous reasons (such as trade in pesticides, quality of food, reduction of pesticides for environmental reasons) authorization of pesticides prior to use has been a key element of pesticide policy since the 1962 Pesticides Policy Act. Leaching into groundwater has become one of the key aspects in the authorization procedures of plant protection products – both at the European and the member state level (Linden et al. 2006). The modeling of pesticides in soil and groundwater has been instrumental in the development of these authorization procedures (Linden and Boesten 1989; Boesten and Linden 1991; Tiktak et al. 2002).

The first pesticide leaching models were developed and used in the Netherlands in the early seventies, but their use in pesticide registration was limited until 1989. In 1989 the model PESTLA (PESTicide Leaching and Accumulation) was launched by SC-DLO, a predecessor of Alterra, and officially incorporated in the evaluation process (Leistra et al. 2001; Tiktak et al. 2002). Initially, its use was limited to the first tier of the registration process.

When PESTLA's use was extended to higher tier assessments, and other versions of the model were developed, the RIVM developed another model. Although PESTRAS (PESTicide TRansport ASsessment) was designed for the same purpose and based on the description of pesticide behavior as used in PESTLA, the models produced slightly different results. This could mean that, if both models were used for the pesticide registration procedure in the case of a particular pesticide, the pesticide would be authorized according to one model and not the other. This was deemed unacceptable. A single model replacing the two existing ones would ensure that no different outcomes would be possible with regard to authorization of pesticides and limit potential legal and financial claims by companies producing and marketing pesticides (Jansen et al. 2004). In addition, the Dutch pesticide policy has been increasingly influenced by European policy and the Dutch government has had an interest in a strong presence at the European level from the start (Alterra interview 051010). Since the Netherlands fulfilled a prominent role in the mathematical description of pesticide leaching, it was in a position to contribute extensively. However, it was regarded as important that a small country such as the Netherlands would present one authoritative model at the European level (rather than two different models).

To strengthen the position in Europe and to prevent confusion around the registration of pesticides, the Ministries of VROM (Housing, Spatial Planning and the

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Environment) and LNV (Agriculture, Nature and Food Quality) asked the RIVM and Alterra to develop one agreed leaching model (to replace the previous two models). This was developed by Alterra and the RIVM in the late 1990s. Both institutes succeeded in this. PEARL now provides definitive, quantitative results with a legally approved status in pesticide registration. PEARL (and increasingly GeoPEARL, which is based on PEARL) is currently the official tool in Dutch pesticide registration procedures and also plays an important role in the evaluation of Dutch pesticide policy plans (such as the "Multiyear Crop Protection Plan" and the plan for "Sustainable Crop Protection") (Tiktak et al. 2003). In cooperation with the European Commission and other EU partners the so-called "FOCUS scenarios for pesticide leaching to groundwater" have been developed. These scenarios are integrated into the PEARL software package and are used for the assessment of pesticide leaching for the EU registration of pesticides.

The idea for the LARCH model was developed in the context of the 1990 Nature Policy Plan in which the notion of a "national ecological network" (NEN) was formulated. Alterra researchers had been engaged with questions concerning landscape fragmentation and the metapopulation theory from an early stage. When field studies showed that animal populations in the Netherlands were affected by nature fragmentation (and that this was a generic problem) the idea to build a model that assessed whether a population may be viable in a certain landscape was born (Alterra interview 050217). The model was developed at the department of Landscape Ecology at the State Institute for Nature Management (RIN) in the early 1990s. LARCH was thus a model initiated and developed by researchers, although at that time they were civil servants at the Ministry of LNV. Unlike the Care and PEARL models, no neatly formulated policy question lay at the basis of LARCH. At the same time, the NEN provided a broad policy framework to start from.

The LARCH was first applied in the project "Ecological networks in river rehabilitation scenarios: a case study for the Lower Rhine" (Reijnen et al. 1995), and in many ad hoc projects which were often related to quick policy recommendations and rapid assessments for the LNV and other Ministries (Verboom and Pouwels 2006). One example is its use in a project by the LNV to assess the ecological effectiveness of "corridors" between nature reserves. The Netherlands is one of the smallest and most densely populated countries in the world, and due to increasing urbanization and industrialization the landscape has progressively been fragmented. The ecological corridors that had originally been drawn by LNV had been heavily criticized due to the perceived lack of valid scientific input in assessing their ecological efficacy. These corridors, with the exception of those with legal commitments, administrative commitments, robust corridors which were ecologically sound, and those that were expected to soon be finished, were tested for ecological importance with LARCH (Alterra interview 051029). On the basis of the outcome, it was decided which corridor should be funded.

LARCH may not be perceived as a legal instrument in the vein of those of the caliber of PEARL; it does however structurally provide input into legal works such as

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

the Dutch statutory Nature Outlook publications. It has also been employed for the redrawing of boundaries of the NEN and for projects related to the European Bird- and Habitat Directive and Natura 2000, a European network of protected nature areas. One of the core aspects of the nature policy since the adoption of the Nature Policy Plan has been to create corridors between large nature reserves in order to create a national ecological network (NEN). During more recent years (and due to increasing decentralization) LARCH has also become an interactive tool for deliberation and group decision support in provincial/local stakeholder and shareholder consultative processes (Alterra 2007). A study by Van Rooij et al. (2004, 214) provides an example: "The LARCH model provided a very useful analysis of the present quality of the network of woodland habitat in Cheshire. The involvement of ecologists in the County Council and local naturalists increased the realism of the final results and acceptance of their diagnosis." Rather than developing "basic ecological knowledge," researchers would have to show the relations between nature quality gain and the necessary efforts in investments and therewith provide alternatives from which the participants in the decision making process can choose (Alterra interview 041027).

However, the LARCH model is not always to be found in written reports based on outcomes derived from the model. Despite its importance in informing the overall policy and decision making process (the process at large), its role is often not revealed in the final product. The Care model has undergone a similar transformation – towards a background model that is largely invisible.

The Care model, however, started from a much more politically divisive background. The need for a model for the care sector derived from political and economic circumstances in the 1980s that caused Dutch politicians to be faced with structurally rising costs in the healthcare sector. The economic models used by the Ministry of Health (VWS) proved to be both "insufficient in explaining why and how health care expenditures increased so quickly" and "in providing solutions what could be done about this" (VWS interview 040512). Moreover, the Ministry of Health lacked knowledge about epidemiological trends. Politically, the government shifted towards a new public management of governmental policy making, i.e. more accountability and transparency of public policy and its effects (which was a trend visible in other European countries as well) (for example Ashmore et al. 1989; Hunter 1997). These trends contributed to a framing of healthcare in more economic terms; an economization of healthcare. The succeeding Cabinets proposed market based policy programs for the financing of health care (Helderman et al. 2005). Unfortunately, these were poorly received, both politically and within the sector, sparking many heated political debates. To solve these political discussions, an interdisciplinary project was commissioned by the Minister of Health to construct an economic model for the healthcare sector. The model was expected to provide the government with clear measures, in order to set a framework of terms of references for the yearly health care budget.

In 1993 the Ministry of Health asked the CPB, the SCP, and the RIVM to develop the model further. These three science advisory institutions retain the authority to

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

dictate the use of simulation models for the assessment of policy proposals for the Dutch National Government. The decision to ask these three authoritative science advisory bodies to collaborate on one project was not self-evident. Nonetheless, the involvement of these three authoritative institutes would hopefully lead to unambiguous policy answers for the Ministry of Health in forming health care policy that could be seen to be beyond reproach. After all, the three institutes, it was thought, not only provided enough expertise to develop the model, but were deemed capable of making an integrated model for the health care sector (VWS 1994). The model needed to address three policy questions in one: a) to explain the past developments of in the use and costs of healthcare on the macro level; b) to calculate the future effects of health policies; and c) to show the effects of possible policy options on the demand and supply of health care and health care costs. The stakes were high, as all three authoritative institutions were to combine the epidemiological, socio-economic, and the macro-economic approach in one model. Take smoking, at the epidemiological level numbers are needed on the number of smokers, the illnesses smoking has caused, effects of prevention programs, and the costs involved in all this. For a macro assessment numbers are needed on demand effects of policy measures, for example to prevent smoking. The example shows how complex such a model quickly becomes, besides the fact that many numbers were lacking at the time.

The project did deliver a model in 1998. However, it failed to deliver the hoped for an "unambiguous" hybrid model. Initially, the model was not used as an assessment tool for health policies because it was thought to lack theoretical accuracy. It was also found to fail to reflect policy reality at the time; the model addressed the health sector as a regulated market, while the Dutch healthcare market at the time was budget regulated. Finally, it had become "a distribution model rather than an assessment model to predict future development" (VWS interview 040512). The collaboration between the three science advisory bodies fell apart and further model refinement was placed at the door of the CPB. The model shifted from a socio-economic model to a macro economic model. Perhaps for these reasons, the project was termed a failure by many involved at the time. However, the project's break-up merely exposed deep-rooted political and scientific differences in opinion on how to solve issues within healthcare financing. It did not lessen political discussions concerning further financial restructuring organization of the health care sector. It marked a return to the use of solely scientific points of reference.

The political continuum

Both PEARL and Care came into existence as a result of an explicitly termed policy question. In both cases, there was a political need for a model. The political question underlying the PEARL model envisaged a clear and important role being created for the model from its inception. As during the construction phase agreement was achieved about how the model should be developed and its purpose, the model became used

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

for the purpose for which it was designed, strengthening its status. In the case of Care, the model was meant to interfere in the debate on rising healthcare costs, as there was no political agreement on how to solve this issue. LARCH, on the other hand, did not have any specific policy question at the basis. It was developed within and for a specific policy context, with no explicit interest being expressed by policy makers at the time. Due to close contacts between researchers and policy makers at the Ministry, the model was adopted. However, it did not achieve the role that PEARL acquired – and that has become an obligatory regulatory point of passage. This shows that both the envisaged role for the model in policy and the groups supporting the model matter. They can ultimately define a model's role and position. The construction phase of a model is crucial in this respect. It was remarkable that the Care model did not make it as a viable concept at first.

Along with being wanted, what is of importance to the usefulness of models is the (historical) level of stability and political consensus on a matter within the policy field. This can only be established when the use of models is investigated over longer periods of time, through different political constellations. Studying a longer time span may also help to understand that models are not static, but their roles, content, and shapes may change over time.

If we regard the level of stability and consensus as a continuum, PEARL can be placed at one end. The policy field around PEARL is very stable and characterized by a high level of consensus. Agricultural policy has been a traditionally important field and remains important under all political regimes. Although pesticide policy has undergone changes, pesticide authorization has remained a stable and essential part of pesticide policy. It has not been subject to political debate at any point in the last few decades. If anything, its importance has increased with the growing awareness of the environment. The stability and increased importance of this issue has provided PEARL with a strong position within the authorization procedure. The statutory role PEARL came to play, in turn, strengthens the stability of such a procedure.

LARCH can be placed near the other end of the continuum, as the importance of nature policy continuously fluctuates with different political constellations. Nature policy has never established the same importance as agriculture and lacked a strong lobby. The significance it is given strongly depends on the specific political constellation in place.

LARCH has not obtained as strong a position as PEARL. In addition, its role in ad hoc projects (and its structural role for the MNP) is currently at risk of becoming superfluous with the changing importance, status, and organization of nature policy. The previous Cabinet Rutte-Verhagen (2010–2012) drastically decreased the size of the Nature Policy Plan (NEN), decentralized the work on the NEN, and nature corridors were no longer seen as important. The current cabinet Rutte-Asscher placed the NEN back on the agenda. However, very little is mentioned about it in the current coalition agreement. If, how, and to what extent the NEN will be carried out during the current economic crisis remains to be seen.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

It seems apparent that the changes outlined above have provided LARCH with a new space and a new role. During the last years, LARCH has been used in a changing institutional and political environment of increasing decentralization – ranging from national to regional levels – and towards decision making as a participative, multilevel, process with a number of discrete stakeholders. This view on decision making is in line with the view of some of the people involved with LARCH: "setting goals for biodiversity conservation is a cultural and social activity guided by science but done by the public" (Opdam et al. 2003). As a consequence the model is continuously being evaluated and further developed and the roles of LARCH in policy and decision making processes are changing: "Until a while ago LARCH was solely used for assessments, for calculating plans. Now a number of projects develop tools for spatial planning which is closely related to LARCH and uses the concept, the way of thinking, and the database, but not the model itself. This demand is growing!" (Verboom and Pouwels 2006). It is now clear that the LARCH concept, rather than the model itself, has become the compelling selling point of the model.

The Care model context can be placed at the far end of the continuum as it was characterized by a very low level of political consensus at the start of the project in that it did not fit the policy reality of the time. Healthcare policy, specifically the question of how to control the ever rising costs, has sparked many heated political debates in the 1990s. The Minister of Health at the time, Els Borst, was in need of an independent tool, "a clear starting point" that could support her health policies (VWS 1994). The model itself was the means to create stability in a field that was in political turmoil. The model did not change the policy line of the government at that time, which entailed an open ended payment system, the so-called "*boter bij de vis*" (payment on delivery) system. This policy was introduced after public debates about the "Stalinist" healthcare system (characterized by long access times for health services and growing complexity of the system) had led to the end of the system of "supply regulation" (Van Egmond 2010). The open ended system led to an expected increase of healthcare costs during the 1990s. A change of Cabinet in 2001 (from left-liberal to Christian-liberal) replaced this open ended policy with a regulated competition system of payments into the Dutch health system. As the Care model was built with a more competitive health system in mind (Van Egmond 2010), this led to a second round for the model. In 2005 the model was updated, in time for the new law on regulated competition in health care that was executed in 2006. However, its role has been in the background, where it is used structurally to provide input for publications on health issues by the CPB.

The importance of the scientific context for models' role(s) in decision making

A stable or unstable policy context thus influences the content, shape, and roles of models. With regard to the scientific context, often a front stage picture is presented

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

of scientific agreement and scientific truth. However, as mentioned above, the level of agreement or disagreement (and certainty or uncertainty) between the teams of researchers and within and about the underlying scientific fields may also greatly influence the role a model takes on in a policy field.

PEARL is based on long-standing equations in physics and chemistry that enjoy a high level of agreement and support in scientific circles. Uncertainties about actual pesticide concentrations and transport processes do not impact PEARL as its purpose is to see whether or not a pesticide meets a set regulatory threshold. This means that the model provides clear-cut, decisive, and quantitative answers that can be, and are, used to decide on a particular pesticide registration. In 1997, a project team was formed to develop the new model. The team contained scientists from both RIVM and Alterra, who had co-operated on several projects since 1987 to serve the needs of several discrete ministries (with regard to pesticide policy). The project team decided that PEARL should be more than a simple merger of the two precursors. The opportunity was taken to include recent scientific developments, to upgrade the computer language, and to develop a graphical user interface for ease of use of the software (Tiktak et al. 2002).

Despite the long-term relation between the RIVM and Alterra, there was no immediate consensus on the model among project members. The relation between the two organizations has been described as one of "inherent conflicts," "culture differences," and "arithmeticians versus artists" (Eggink and Wiertz 2003). Since team members working in particular ways for years suddenly had to develop a model together with others possessing contrasting working styles, it took three quarters of a year to develop a consensus about the programming style. After that, the RIVM was mainly responsible for the aspect of calculations whereas Alterra maintained the database and was responsible for the user-friendly interface. Following this initial period, the collaboration went well and the organizations themselves remained stable. This helped PEARL to establish its strong position. Its position was strengthened, not only because the RIVM and Alterra both supported it, but also due to the support reached by a broad steering committee that had been specially drawn up. This steering committee consisted of LNV (which supported the Alterra side of the project financially), VROM, the Ministry of Transport and Water,[1] the Association of Dutch Water Companies (VEWIN), the Board for the Authorization of Pesticides (CTB), and the pesticide industry. Whereas the working styles of the teams involved in PEARL differed, eventually consensus could be reached about both the underlying science and the purpose of the model.

LARCH is (largely) based on ecological theory. Ecology is the main disciplinary background amongst the group of researchers who developed the model. This stable group who were involved in the initial construction of the model is still part of the

[1] The various ministries as well as the CTB have changed names over time due to different political constellations and tasks that varied. To maintain readability, we maintain the names as indicated here.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

team fifteen years later. The disciplines, (ecological) theories, and method of working and/or data collection methods underlying the model have not created substantial scientific dissension. The main elements discussed during the construction process of LARCH were "contextual" elements such as modeling skills, computer capacity, how to model dispersion of species, and what arithmetic methods should be used. One interviewee explained, for example, that at one time it was impossible to calculate the distances between all nature areas, whereas now a table of these areas exists and there is no longer a problem (Alterra interview 041020).

The scientific thinking about nature protection in the Netherlands from the 1960s until the 1980s mainly consisted of maintaining existing nature areas and purchasing new areas. This shifted in the 1980s when ecologists, working at the LNV, were influenced by developments in theories of island biogeography and metapopulations that had become popular (MNP interview 051029; Turnhout 2009). This shift helped scientists to frame landscape fragmentation as a public policy problem. The idea is that when landscapes become more fragmented, the number of populations and the possibilities for migration decrease. Since smaller populations become extinct more easily than large populations, nature policy had to focus on creating large nature reserves that would be joined together or otherwise linked by corridors or stepping stones. Hence, scientific consensus was shown to be a powerful tool in model construction to gain policy support.

Ecology is a more recent scientific field than physics and chemistry. The theories which underlie the LARCH model are much less long-standing, stable, and robust than the equations underlying PEARL. Instead, like LARCH, they are evolving and adaptable to a diversity of problems in the actual environment. In the first place, ecologists do not address ecological issues by identifying underlying natural laws. LARCH is not a decision making instrument as such that provides definitive answers. It informs decision-makers about the consequences of various scenarios which enables decision making. It is thus more likely to be modified and adapted to the specific question asked. The use and flexibility of LARCH can be understood by investigating the underlying scientific field and theories. The flexibility of LARCH can be understood further by investigating the different ways in which it is used (ad hoc projects, statutory work, and consultative processes) and by the externalization of the in-house expertise of the Ministry of LNV (to be discussed in the next section). This led to commissioned research projects rather than freely acting independent researchers developing a specific model any way they want. These contexts influenced the development, shape, and content of the model which consists of a number of relatively stable building blocks or modules.

Finally, the Care model was not based on generally agreed upon scientific principles. The Care project started as a means of escape from political discussions about the pros and cons of market oriented financial systems for the healthcare sector in the Netherlands. This is the reason that the three science-based policy advisory organizations working on health care and with modeling expertise were brought

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

together. This was done in the belief that bringing together all knowledge would automatically synergize into a model that might transcend the boundaries of each party. The legitimization of the model building could partly be found in depoliticizing the issues of rising health care costs.

However, the Care project team struggled with the need to be simultaneously scientifically sound and policy-oriented. The challenge was first to combine three different epistemological, theoretical approaches towards health, and different positions in the political field. The second challenge was to combine micro and macro-economic traditions for the construction of a hybrid dynamic model addressing the past, the present, and the future of the healthcare sector. A project member explained that "to simultaneously connect micro level derived demand and supply with demand and supply at an aggregated macro level is extraordinarily complex and will, in practice, lead to immense practical problems" (SCP interview 040422). Outcomes on the macroeconomic level are, as of yet, very hard to derive from micro data analysis.

Scientific discussions on such issues soon turned out to be political discussions in disguise, exemplified by the data discussion. The model needed to be based in empirical data, as was formulated by the Minister of Health. However, not much data was available at the time. A solution was sought for limiting the focus of the model in order to explain past developments in healthcare costs, and to combine this with an "accurate" theoretical description of the policy field (CPB et al. 1994). This solution was endorsed by both State Secretary Simons and the project secretary from the Ministry of Health. Consequently, the public health approach became superfluous and with it ended the role of the RIVM in the project. With the RIVM's role reduced, the role of the CPB and the macro-economically oriented policymakers from the Ministry of Health became greater. This rapidly brought to the fore the difficulty of integrating a dynamic model (based on the microeconomic data and algorithms of the RIVM and SCP) with a structural model (based on macroeconomic theory of the CPB). Consequently, the scope of the model became a macroeconomic one, based on theoretical descriptions of the Dutch healthcare sector.

At this stage of the project, political discussions and scientific discussions began to intertwine more openly. For example, in discussion about the key question set before the project team – to find an accurate mathematical description of the care sector – this question turned out to be a political rather than a scientific question. For example, when the parameter "demand" was modeled, the team had several options of how to carry this out. However, each option involved a discrete political choice; the first option of the team was to not take into account the demand side of health care by treating demand as an exogenous factor. Unfortunately, this choice was not in line with political discussions on how demand can be influenced. The authors argued that:

> The not taking demand effects into account would imply that we lay on the model the fact that additional own payments for GP consults or specialist consults do not have

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

> any effect on the production of health care. Given the prominent place of the issue of additional own payments in the [political] discussion on cost containment in health care, it seems irresponsible to not build such an assumption into the model (CPB and SCP 1995, 6).

Although with hindsight it might seem typical that scientists fight over the question whether additional own payments by insurers for health services should to be built into a model, at the time of the construction, additional own payments did not exist in large parts of the health system, and heated public debates were held. However, the second and third option for modeling demand entailed a position either in favor of SCP's empirical micro-economic approach to health or in favor of CPB's theoretical macro-economic approach. As the first option was no longer an option, the choice was made for the third option, the theoretical model.

However, the example does show that the political context of the model – the political discussions in Parliament and in the media – directly influences the way a model is shaped by the developers.

The scientific continuum

The three models each assume a different position on a scientific continuum: a continuum from certainty to uncertainty on the general theories, which runs broadly from physics and chemistry through ecology to economics and political science. Although at first there were disagreements between the two teams of researchers working on PEARL, the model is characterized by consensus on the long-standing underlying scientific principles. LARCH is also based on a scientific consensus, but the underlying science is of a different nature, less long-standing and more evolving. In both cases, consensus was achieved on both method and theory during the construction phase. Care stands at the other end of the continuum. Although political disagreement did not help the scientists in the Care project to construct a coherent model, the descriptions of what took place during the initial phase and the phase of the model construction, pointed towards something else as well: the role of scientific consensus or lack of consensus as a single decisive element. Whereas there is a high degree of universal acceptance with regard to some theories in physics and chemistry, the field of ecology is in a more evolving state and the field of economics is characterized by a lack of scientific consensus. This might be illustrated by the fact that one can easily find living Noble laureates in economics that are on polar opposites with respect to health-care policy today, and no model that anyone develops can transcend this simple fact. And if one adds in the socio-economic component to the vision of a socioeconomics assessment capability for modeling health-care policy, that only adds to, rather than subtracts from, the lack of consensus.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

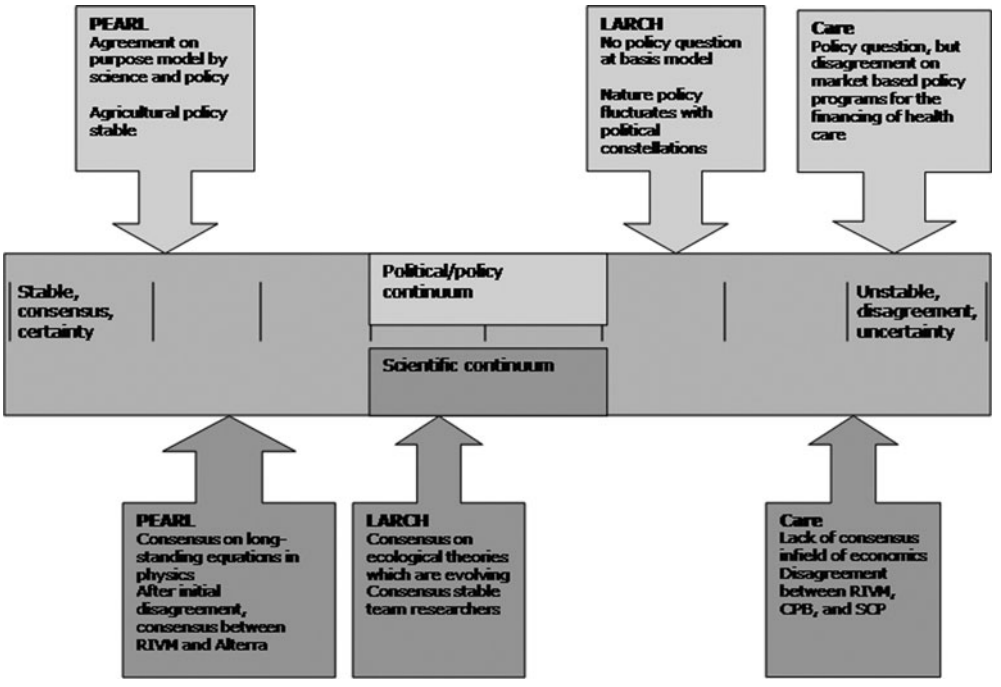


Fig. 1. Models' position on the political/policy and scientific continuum.

"Political Models" – the interconnectedness of science and policy

As we have shown, the stability of the political and the scientific context defines the shapes, contents, and the roles these models play in their policy field and in decision making. For analytical purposes it helps to distinguish the political/policy and the scientific context. Figure 1 below summarizes the place the three models occupy on the two continuums.

However, the separation between the scientific and political context does not represent, as such, the reality of modeling for policy. Constructing a model that can be employed by experts for policy assessments involves much boundary work and many actors from several social worlds – from the scientific field and the policy field (Van Egmond and Zeiss 2010). Such models have to be scientifically sound yet useful for policymakers. Being useful entails that a model meets a broad set of criteria, such as formally and a priori formulated policy aims of a model, scientific soundness, policy orientation, being broadly supported, etc. This involves tinkering with theory and data, and negotiation and coordination between several social worlds. It is the interconnectedness between science and policy with regard to such models

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

that provides the model its place and usefulness for policy makers and for scientists as well.

PEARL, for example, definitely is born from a stable scientific environment and a stable political environment, hence, the scientists involved do not have to struggle to raise their voice. Nevertheless, the model provides the scientific field with a strong scientific tool to soothe possible political discussions on the effects of pesticides. This role is supported and encouraged by the involved ministries as the following quotation shows:

> Authorization decisions have usually been taken on this scientific basis and only rarely [do] political decisions overrule these assessments. The ministries involved in pesticide policy in the Netherlands try to maintain and improve the scientific basis by continuously evaluating the adequacy of the decision system and setting out research to keep the system scientifically up to date. (Tiktak et al. 2003)

The model is updated in a structured way so users know which version to use. Through the "Homepage of PEARL and GeoPEARL models" users are kept up to date. The existing strong connections between the researchers and other parties involved (particularly the policy makers) ensures stabilization and broad support for the model in the long term. Moreover, in current contacts and collaborations a clear division of labor seems to be maintained. Although researchers may propose research and the Ministry is then likely to fund this, researchers disregard this as policy issues: "we don't come up with the policy issues, policy makers steer those" (Alterra interview 051010).

The LARCH model does not have this authoritative position in the policy world. For instance, researchers did not manage to involve policy makers in the decision making about parameters needed for the model during the construction phase. As a consequence, researchers decided that it is acceptable to lose one out of twenty species every hundred years. Such decisions inform the outcome of the model (Alterra interview 050217). The externalization of the "in-house" expertise of LNV into the then new Alterra institute in 2001 meant a greater distance between the scientists and the policy makers. It also provided LARCH with an opportunity and necessity to more consciously bridge and coordinate the scientific and policy worlds. This also raised new issues of balancing scientific and policy needs, of what needed to be represented and of the translation of politically sensitive issues. For example, uncertainty in the form of lack of available data could represent a problem for the researchers who wanted to maintain the scientific status of (the outcomes of) the model. The same uncertainty could however be irrelevant for policy makers: "small uncertainties in a model are not likely to influence for example the decision to extend the NEN with robust corridors; uncertainties in policy making and with regard to other uses of land and nature, such as recreation, are of a different scale than the uncertainties in science and in the model" (Alterra 2004 interview 041027).

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Regarding the Care model, the fact that the model had been built in what has earlier been called "a failing collaboration" between three large science advisory bodies gave the health care policy field an extra voice to listen to. The model provided the CPB with a macroeconomic description of the care sector. For the CPB this meant an expansion of their knowledge of modeling Dutch policy with healthcare. Thus, the CPB became an authoritative voice in health care debates, especially debates about the introduction of market ideas in health care. Since 1999, the CPB has begun to present more and more reports on health care and regulated competition. Also, the model was made up-to-date in the late 2000s, and it now provides more authority to CPB's reports (e.g. on the effects of marketization in healthcare). More importantly, although when the people involved in the collaboration project of the Care model looked back on the project, they saw it as difficult and problematic, these contacts laid the foundation for future contacts, and indeed the SCP and the CPB, and also the CPB and RIVM have been working together more often since the 1990s. The fact that institutes work together, and gain knowledge of a specific policy field, and the fact that this policy field is modeled in a specific way, has an effect on the direction of policy. It is not the CPB that tells politics to introduce market thinking, or regulates competition in health care, but it is the CPB that partly enables politicians to think and talk about healthcare in terms of markets and competition, because it has a tool, a model, that has captured this policy field in this specific way.

Conclusions: Models as technocratic powers in decision making at large?

Models are increasingly used to inform politics and policy makers for policy development, decision-making, and regulatory processes in a large variety of applied fields and a large number of countries and international settings. Many fields of science study the role of models in policy making processes. Many empirical studies offer descriptions of only one model. In this article, we were able to discuss and compare three science-based models. We focused on the question of how models are incorporated in policy making processes, to what consequences this leads with regard to their role in policy-making processes, and to what extent they can or should be considered as technocratic powers. To understand the role of these models in policy making processes, we argue that these models should be addressed conceptually in the context of what we call "policy and decision making at large."

Thus it is crucial to consider model construction as an early phase of policy making and to take into consideration the changing contexts within which the models are developed and operate. Investigating policy and decision making at large allowed us to study the role of models in policy and decision making processes in a more encompassing way, and to better comprehend policy and decision making processes at large. We started by outlining the roles our models play in policy and decision making processes (Table 1). We then attempted to explain the different factors that influenced

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

the roles of models while concentrating on two continuums: policy and scientific (fig. 1). We then reflected on the interconnectedness of science and policy in regard to the use of science-based models for policy, as in reality the distinction between the political context and the scientific context is difficult, if not impossible, to make.

Models can, as we have shown, play several roles as arbiters, as obligatory points of passage, as legal tools, as depoliticizing instruments, or as tools to create new knowledge and new policy fields; and their roles can change over time. During the construction phase of models, models offer space for coordination and negotiation between different research organizations and science and policy domains. They thereby bring together different social worlds, and legitimate participation in (new) policy fields. This may result in broad(er) support for the decisions made, contribute to a depoliticization of political issues, or even create "new" policy fields (health economics). Moreover, models become a common reference point and/or an obligatory point of passage for the policy field. Model construction can therefore be considered as an early phase of decision-making processes, intended as such or not. During this stage, decisions are made by both scientists and policy makers, which influence the later model outcomes, i.e. science-policy boundary work takes place, and insiders and outsiders are created.

This role of models as coordination devices takes investment, in terms of funding, time, and teams of people to develop such models. The choices made during the construction phase may influence models' later roles. Once a model is used in decision making processes, it is important to realize who made which decisions earlier in the process and how this may influence the outcome. A decision with the help of, or on the basis of, a model is therefore not "neutral," but partly depends on how and by whom the model was made. Because of the time scale of the modeling construction phase, which often takes several years, the political and sometimes organizational environments change and influence the modeling and the requirements set for the model as well as the way in which a model is used. The study of "policy and decision making at large" thus starts to problematize the question of what decision-making is, by whom it is done, and when it takes place.

This article has shown that history matters. The models' histories, constructions, contexts and their role(s) in policy and decision making and therewith the kinds of decisions that models enable, have to be discussed as interdependent. Yet, this article helps to identify common themes and issues through which these specific histories with their particular characteristics can be studied and different models and their histories can be compared, such as inclusion/exclusion of people and knowledge, investment in time and funding, and how these are organized, the purposes for the model, the negotiation processes, and the specific roles they play at various points in time. We have argued that models should be studied in the context of policy and decision making at large. This provides a much better grasp of the role(s) models play in policy making processes through insights into, for example, how these roles change and the importance of the construction phase, and the people who were involved in this.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

However, the roles models play in policy making do not solely depend on the particularities of each model. Two continuums – a policy and a scientific continuum – are more structural elements that help to study and explain the roles of models in decision making. We show that models are used more often when they are built in a stable political environment. In such an environment a model can better serve the purpose it was designed for. In the case of PEARL there was a clear purpose and PEARL was indeed given the role that was envisaged for it. This strengthened its position, both for policy makers and scientists. However, a clear purpose does not automatically lead to a model's strong position, as was shown for the Care model. Care started with a clear purpose, but the purpose itself was political: to depoliticize the discussion on health policy. Such a political start makes for a difficult role. For LARCH, a purpose was kept in mind, but it came mainly from the scientific side. The fluctuating political constellations and the weight these assign to nature policy made a strong position of the model in national policy difficult. Yet, LARCH fulfills a number of roles, including a new role as an interactive tool.

More importantly, we argue here that the level of stability of the scientific context seems decisive for the usefulness of models in policy making processes. As the cases have shown, the stability of the scientific context and collaboration between disciplines makes or breaks the usefulness of models. The less stability in the scientific field, the more difficult it is to construct a useful model to inform policy makers, and vice versa. This mechanism even counts for scientific fields that have authoritative status, such as economics.

The role of science in policy making and the increasing use of models in policy processes have been criticized as technocratic. We argued that Dutch models can be considered as a hard case for investigating the technocratic powers of such models. Dutch models are developed by Dutch science advisory organizations with strong, monopolistic and authoritative positions which help them to frame and discipline political deliberation functions. In addition, one (policy) issue is often covered by one model to prevent diverging outcomes. We have shown that the level of scientific stability forms the basis on which a model can be deemed useful for policy and decision making processes. Yet, we argue that this does not automatically mean that science has (too) much influence and power over formal democratic decision processes. Our discussion of the three models in policy making provides a much more nuanced picture. Although a strong authoritative model such as PEARL may help to strengthen for example pesticide authorization procedures, the Care model shows that political discussions are difficult to silence if scientific agreement is lacking, which is also illustrated by the fierce debates concerning the models used in the climate change debate. If no scientific consensus can be achieved, it is difficult to use models and science to depoliticize certain issues. In a way, the failure to construct a useful model could be seen as an impetus or even a triumph for democratic processes. But even if scientific consensus exists, the LARCH model shows that scientific input by itself does not solve political issues or increase the importance of a policy field. Rather than

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

an increase of technocratic power of science, we notice that developments such as dependence on requirements set by commissioning bodies place scientists at a distance, literally. Scientists have to perform much work in order to get their messages across to policy makers. Even in the perceived technocratic Dutch context, many factors play a role in the way in which models enable and support policy processes. Taking these three Dutch models as a hard case implies that the conclusions that are drawn stretch beyond the Dutch cases. If, even in the Netherlands, the roles models play in policy processes are too complex to be considered as (straightforward) technocratic powers, this is probably even more the case when considering the role of models in countries where competition exists amongst different science advisory bodies using different models to assess the same issue.

This article has thus shown how the particular historical trajectories of models and their roles in policy and decision making processes, which will differ for different models and different countries, can be studied and compared through focusing on common themes. Secondly, not only particular individual histories help to understand models and their roles in policy processes. Two underlying continuums show how also more intrinsic characteristics, such as long-standing international scientific agreement, and the stability of the policy and political field help to explain these roles. Although the particular individual histories differ per model and the (national) context in which they are developed and used, both the study of common themes and of continuums can be extrapolated beyond the Dutch cases. Lastly, conclusions about the limited (technocratic) power of Dutch models can be extended to cases in other countries where the science advisory bodies constructing and using these models are less authoritative. Taking policy and decision making at large as a starting point, also has implications for the perceived technocratic influence of models. It is no longer clear where, when, and by whom policy decisions are actually made, and models cannot straightforwardly be seen as solutions for political problems in that they depoliticize policy issues.

Interviews

The interviews are coded to ensure the privacy of the interviewees. Many of them are still working within the affiliated fields. The interviews are part of the data collection that the authors have carried out. A full list of interviewees, the original audiotapes, and transcripts are available for inspection by contacting the authors. The case studies were carried out as part of the research program "Rethinking Political Judgment And Science-Based Expertise: Boundary Work at the Science/Policy Nexus of Dutch Knowledge Institutes," funded by the Netherlands Organization for Scientific Research (NWO). The numbers indicate the year, the month, and the day. Alterra interview 051029; Alterra interview 041020; Alterra interview 041027; Alterra interview 051010; Alterra

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

interview 061019; Alterra interview 050217; MNP interview 051029; SCP interview 040422; VWS interview 040512

References

Alterra. 2007. *Is Your Landscape Climate Proof? Biodiversity Analyses with Larch*. Wageningen: Alterra.

Ashmore, Malcolm, Mike Mulkay, and Trevor Pinch. 1989. *Health and Efficiency: A Sociology of Health Economics*. Milton Keynes IL: Open University Press.

Bekebrede, Geertje, and Arthur van Bilsen. 2009. "Spelen met Complexiteit: Serious Gaming voor Besluitvorming over Ruimtelijke Infrastructuren" [Playing with Complexity: Serious Gaming for Decision-Making about Spatial Infrastructures]. *Bestuurskunde* 3:24–35.

Bijker, Wiebe, Roland Bal, and Ruud Hendriks. 2009. *The Paradox of Scientific Authority*. Cambridge: MIT Press.

Boesten, Jos, and Ton van derLinden. 1991. "Modeling the Influence of Sorption and Transformation on Pesticide Leaching and Persistence." *Journal of Environmental Quality* 20:425–435.

Bogaard, Adrienne van den. 1998. *Configuring the Economy: The Emergence of a Modelling Practice in the Netherlands, 1920–1955*. Amsterdam: Thela Thesis.

Bogaard, Adrienne van den. 1999. "Past Measurement and Future Prediction." In *Models as Mediators. Perspectives on Natural and Social Science*, edited by Mary S. Morgan and Margaret Morrison, 282–325. Cambridge: Cambridge University Press.

Brouwer, Floor. 2001. "Policy-Technology Interactions for Intensive Farming Systems: Some Experiences from the Netherlands." In *Adoption of Technologies for Sustainable Farming Systems, Wageningen Workshop Proceedings*, 108–119. Paris: OECD Publications.

Callon, Michel. 1998. *The Laws of the Market, the Sociological Review*. Oxford: Blackwell Publishers.

CPB, RIVM, SCP. 1994. "Pre-Study: naar een Ramingsmodel voor de Zorgsector" [Pre-Study: Towards an Assessment Model for the Health Care Sector]. Den Haag: CPB, RIVM, SCP.

CPB, SCP. 1995. "Ramingsmodel Zorgsector. Organisatie en Planning" [Assessment Model Health Care Sector: Organization and Planning]. Den Haag: CPB and SCP.

Daalen, Els van, Leen Dresen, and Marco Janssen. 2002. "The Roles of Computer Models in the Environmental Policy Life Cycle." *Environmental Science and Policy* 5:221–31.

Den Butter, Frank. 2003. "The Dutch Miracle: Institutions, Networks, and Trust." *Journal of Institutional and Theoretical Economics* 159(2):362–91.

Edwards, Paul. 1999. "Global Climate Science, Uncertainty and Politics: Data-Laden Models, Model-Filtered Data." *Science as Culture* 8(4):437–72.

Eggink, Gert, and Jaap Wiertz. 2003. *Natuurverkenning 2: Evaluatie van Inhoud, Vorm en Proces* [Nature Exploration 2: Evaluation of Content, Form and Process]. Bilthoven: RIVM.

Evans, Robert. 2000. "Economic Models and Economic Policy: What Economic Forecasters Can Do for Government." In *Empirical Models and Policy-Making*, edited by Frank den Butter and Mary S. Morgan, 206–28. London, New York: Routledge.

Fischer, Frank, and John Forrester. 1993. *The Argumentative Turn in Policy Analysis and Planning*. Durham/London: Duke University Press.

Fischer, Frank, Gerald Miller, and Mara Sidney. 2007. *Handbook of Public Policy Analysis: Theory, Politics and Methods*. Boca Raton, London, and New York: CRC Press.

Galison, Peter. 1997. *Image and Logic: A Material Culture of Microphysics*. Chicago: University of Chicago Press.

Grin, John, and Francisca Felix. 2004. "The Praxis of Reflexive Design: Lessons from a Dutch Programme on Sustainable Live-Stock Systems." *Technikfolgenabschätzung – Theorie und Praxis* 13(4):99–107.

Hajer, Maarten, and Hendrik Wagenaar. 2003. *Deliberate Policy Analysis: Understanding Governance in the Network Society*. Cambridge: Cambridge University Press.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Halffman, Willem. 2003. *Boundaries of Regulatory Science: Eco/Toxicology and Aquatic Hazards of Chemicals in the US, England and the Netherlands, 1970–1995*. Amsterdam: University of Amsterdam.

Halffman, Willem. 2009. "Measuring the Stakes: The Dutch Planning Bureaus." In *Scientific Advice to Policy Making: International Comparison*, edited by Justus Lentsch and Peter Weingart, 41–67. Leverkusen Opladen: Barbara Budrich Publishers.

Halffman, Willem, and Rob Hoppe. 2005. "Science/Policy Boundaries: A Changing Division of Labour in Dutch Expert Policy Advice." In *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making*, edited by Sabine Maasen and Peter Weingart, 135–152. Dordrecht: Kluwer.

Helderman, Jan-Kees, Frederik Schut, Tom van derGrinten, and Wynand van de Ven. 2005. "Market-Oriented Health Care Reforms and Policy Learning in the Netherlands." *Journal of Health Policy, Politics and Law* 30(1–2):189–209.

Hilgartner, Stephen. 2000. *Science on Stage: Expert Advice as Public Drama*. Stanford: Stanford University Press.

Huitema, Dave, and Esther Turnhout. 2009. "Working at the Science–Policy Interface: A Discursive Analysis of Boundary Work at the Netherlands Environmental Assessment Agency." *Environmental Politics* 18(4):576–594.

Hunter, David. 1997. *Desperately Seeking Solutions: Rationing Health Care*. Harlow: Pearson Education Limited.

Jansen, Jacques, Junt Halbertsma, Hans Heesterbeek, Harm Houweling, and Michiel Jansen. 2004. *Kwaliteitsborging Databestanden en Modellen. Balanceren tussen Chaotische Dynamiek en Geordende Stilstand* [Quality Assurance Databanks and Models. Balancing Chaotic Dynamics and Ordered Stagnation]. Wageningen: Alterra.

Jasanoff, Sheila. 1990. *The Fifth Branch: Science Advisors as Policy Makers*. Cambridge MA and London: Harvard University Press.

Jasanoff, Sheila. 2005. *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton: Princeton University Press.

Keuzenkamp, Hugo A. 2003. "A Day of Reckoning for Politicians – or Economists?" In *Economic Assessment of Election Programmes: Does It Make Sense?* edited by John F. Graafland and Arie P. Ros, 3–7. Boston: Kluwer Academic Publishers.

Leistra, Minze, Ton van derLinden, Jos Boesten, Aaldrik Tiktak, and Erik van denBerg. 2001. *PEARL Model for Pesticide Behaviour and Emissions in Soil-plant System; Description of the Processes in FOCUS PEARL v 1.1.1*. Alterra-rapport 013 / RIVM Rep. 711401009. Bilthoven: Alterra, RIVM.

Linden, Ton van der, and Jos Boesten. 1989. *Berekening van de Mate van Uitspoeling en Accumulatie van Bestrijdingsmiddelen als Functie van hun Sorptiecoefficient en Omzettingssnelheid in Bouwvoormateriaal* [Calculation of the Degree of the Washing Out and Accumulation of Pesticides as Function of Their Sorption Coefficient and Rate of Turnover in Upper Layer of Soil]. RIVM rapport 728800003. Bilthoven: RIVM.

Linden, Ton van der, Aaldrik Tiktak, Gerard Heuvelink, and Toon Leijnse. 2006. "Spatial Uncertainty Analysis of Pesticide Leaching Using a Metamodel of PEARL." In *Proceedings of the 7th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences, 5 – 7 July 2006, edited by Mario Caetano and Marco Painho, 359–366. Lisbon: Instituto Geográfico Português.*

Maasen, Sabine, and Peter Weingart. 2005. *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making*. Dordrecht: Springer.

Morgan, Mary, and Frank den Butter. 2000. *Empirical Models and Policy-Making: Interaction and Institutions*. London and New York: Routledge.

Morgan, Mary, and Margaret Morrison, eds. 1999. *Models as Mediators: Perspectives on Natural and Social Science*. Cambridge: Cambridge University Press.

Opdam, Paul, Jana Verboom, and Rogier Pouwels. 2003. "Landscape Cohesion: An Index for the Conservation of Landscapes for Biodiversity." *Landscape Ecology* 18(2):113–26.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Reijnen, Rien, Bert Harms, Ruud Foppen, R. de Visser, and Henk Wolfert. 1995. *Rhine-Econet. Ecological Networks in River Rehabilitation Scenario's: A Case Study for the Lower Rhine*. Lelystad: RIZA, Institute for Inland Water Management and Waste Water Treatment.

Shackley, Simon, James Risbey, Peter Stone, and Brian Wynne. 1999. "Adjusting to Policy Expectations in Climate Change Modeling." *Climatic Change* 43(2):413–454.

Shackley, Simon, and Brian Wynne. 1995. "Global Climate Change: The Mutual Construction of an Emergent Science-Policy Domain." *Science and Public Policy* 22(4):218–30.

Shackley, Simon, Peter Young, Stuart Parkinson, and Brian Wynne. 1998. "Uncertainty, Complexity and Concepts of Good Science in Climate Change Modelling: Are GCMs the Best Tools?" *Climatic Change* 38:155–201.

Sluis, Theo van der, and Robert Bunce. 2003. *Corridors for Life: Ecological Network Analysis for Cheshire County UK*. Wageningen: Alterra.

Stone, Diane. 2007. "Recycle Bins, Garbage Cans or Think Tanks? Three Myths Regarding Policy Analysis Institutes." *Public Administration* 85(2):259–78.

Sundberg, Mikaela. 2007. "Credulous Modellers and Suspicious Experimentalists? Comparison of Model Output and Data in Meteorological Simulation Modelling." *Science Studies* 19(1):52–68.

Tiktak, Aaldrik, Erik van denBerg, Jos Boesten, Daniel van Kraalingen, Minze Leistra, and Ton van derLinden. 2002. *Manual of FOCUS PEARL Version 1.1.1*. RIVM report 711401008/2000. Bilthoven: RIVM.

Tiktak, Aaldrik, Ton van derLinden, and Jos Boesten. 2003. *The GeoPEARL Model – Description, Applications and Manual*. RIVM report 716601007/2003. Bilthoven: RIVM.

Trommel, Willem. 2003. "De Onderzoeksmethode van het Sociaal en Cultureel Planbureau" [The Research Method of the Netherlands Institute for Social Research]. *Beleid en Maatschappij* 30(1): 42–54.

Turnhout, Esther. 2009. "The Rise and Fall of a Policy: Policy Succession and the Attempted Termination of Ecological Corridors Policy in the Netherlands." *Policy Sciences* 42(1):57–72.

Van Egmond, Stans. 2010. "Science and Policy in Interaction. On Practices of Science Policy Interactions for Policy-Making in Health Care." Ph.D. diss., Erasmus University Rotterdam.

Van Egmond, Stans, and Ragna Zeiss. 2010. "Modeling for Policy – Science-Based Models as Performative Boundary Objects for Dutch Policy Making." *Science Studies* 23(1):58–78.

Van Egmond, Stans, and Roland Bal. 2011. "Boundary Configurations in Science Policy, Modeling Practices in Health Care." *Science, Technology and Human Values* 36(1):108–130.

Van Rooij, Sabine van, Theo van der Sluis, Eveline G. Steingrover, and Steve Clarke. 2004. "Applying Landscape Ecological Methods to Analyse and Design Ecological Networks." In *Landscape Ecology of Trees and Forests*. Proceedings of the Woodland Trust and International Association of Landscape Ecology (IALE), 208–215. Gloucestershire: IALE.

Verboom, Jana, Ruud Foppen, Paul Chardon, Paul Opdam, and Pieternella Luttikhuizen. 2001. "Introducing the Key Patch Approach for Habitat Networks with Persistent Populations: An Example for Marchland Birds." *Biological Conservation* 100:89–101.

Verboom, Jana, and Rogier Pouwels. 2006. *Strategisch Plan Larch: Van Strategische Visie naar Plan van Aanpak* [Strategic Plan Larch: From Strategic Vision to Action Plan]. Wageningen: Alterra.

Vries, Annick de. 2008. "Uncertainty in Scientific Policy Advice and Decision Making, 2004–2008." Ph.D. diss., Twente University.

Vries, Annick de., Willem Halffman, and Rob Hoppe. 2010. "Policy Workers Tinkering with Uncertainty: Dutch Econometric Policy Advice in Action." In *Working for Policy*, edited by Hal Colebatch, Robert Hoppe, and Mirko Noordegraaf, 91–115. Amsterdam: Amsterdam University Press.

WVC, Ministry of Welfare, Health and Culture. 1994. "Brief betreffende Toekomstverkenning Volume en Kosten van de Gezondheidszorg. 2" [Archival Letter Concerning Future Predictions of Volume and Costs of Health Care]. Rijswijk: Ministerie WVC, January 1994.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press

Weiss, Carol H. 1991. "Policy Research: Data, Ideas, or Arguments?" In *Social Sciences and Modern States*, edited by Peter Wagner, 307–32. Cambridge: Cambridge University Press.

Yearley, Steve. 1999. "Computer Models and the Public's Understanding of Science." *Social Studies of Science* 29(6):845–66.

Yearley, Steve, Steve Cinderby, John Forrester, Peter Bailey, and Paul Rosen. 2003. "Participatory Modelling and the Local Governance of the Politics and UK Air Pollution: A Three-City Case Study." *Environmental Values* 12:247–62.

https://doi.org/10.1017/S0269889714000234 Published online by Cambridge University Press