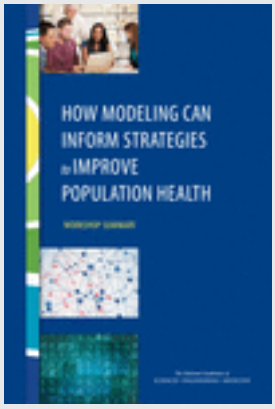

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DETAILS

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HOW MODELING CAN INFORM STRATEGIES *to* IMPROVE POPULATION HEALTH

WORKSHOP SUMMARY

Joe Alper and Amy Geller, *Rapporteurs*

Roundtable on Population Health Improvement

Board on Population Health and Public Health Practice

Institute of Medicine

The National Academies of
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This workshop summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published workshop summary as sound as possible and to ensure that the workshop summary meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process. We wish to thank the following individuals for their review of this workshop summary:

Sandro Galea, Boston University
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Tiffany Huang, National Association of County and City Health Officials
Tamar Lansky, MIE Resources

Although the reviewers listed above have provided many constructive comments and suggestions, they did not see the final draft of the workshop summary before its release. The review of this workshop summary was overseen by **Ned Calonge,** The Colorado Trust. He was responsible for making certain that an independent examination of this workshop summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this workshop summary rests entirely with the rapporteurs and the institution.

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The Roundtable wishes to express its appreciation to the following speakers and moderators at the workshop for their interesting and stimulating presentations: Rajiv Bhatia, Sharon Cooper, Ross Hammond, J. T. Lane, Nick Macchione, David Mendez, George Miller, Bobby Milstein, Karen Minyard, Pasky Pascual, Louise B. Russell, Darshak Sanghavi, Steven Teutsch, Gary VanLandingham, Michael Weisberg, and Steven Woolf.

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Acronyms and Abbreviations

ADHD	attention deficit/hyperactivity disorder
CDC	Centers for Disease Control and Prevention
CMMI	Center for Medicare & Medicaid Innovation
CMS	Centers for Medicare & Medicaid Services
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
HHS	Department of Health and Human Services
HIA	health impact assessment
IOM	Institute of Medicine
MCO	managed care organization
MIDAS	Models of Infectious Disease Agent Study
NIH	National Institutes of Health

1

Introduction[1]

The vision of the Roundtable on Population Health Improvement, said David Kindig, Professor Emeritus of Population Health Sciences and Emeritus Vice Chancellor for Health Sciences at the University of Wisconsin School of Medicine, is of a strong, healthful, and productive society that cultivates human capital and equal opportunity. This vision, he said in his introduction to the workshop on how modeling can inform strategies to improve population health, derives from the recognition that such outcomes as improved life expectancy, quality of life, and health for all are shaped by interdependent social, economic, environmental, genetic, behavioral, and health care factors and will require robust national and community-based policies and dependable resources to achieve. Given the many factors that influence population health, it can be challenging to develop strategies that will most effectively improve the health of targeted populations.

Recognizing the difficulty in addressing this challenge, the Institute of Medicine (IOM) in its 2012 report *For the Public's Health: Investing in a Healthier Future* (IOM, 2012) made a consensus recommendation calling for the Department of Health and Human Services (HHS) to coordinate the development and evaluation of and to advance the use of predictive

[1]The planning committee's role was limited to planning the workshop, and the workshop summary has been prepared by the workshop rapporteurs as a factual summary of what occurred at the workshop. Statements, recommendations, and opinions expressed are those of individual presenters and participants, and are not necessarily endorsed or verified by the Institute of Medicine, and they should not be construed as reflecting any group consensus.

and system-based simulation models in order to understand the health consequences of the underlying determinants of health and to also use modeling to assess intended and unintended outcomes associated with policy, funding, investment, and resource options. Prompted in part by this recommendation and by the interest of its members, the roundtable formed an ad hoc committee to plan and convene a workshop exploring the potential uses of simulation and other types of modeling for the purpose of selecting and refining potential strategies, ranging from interventions to investments, to improve the health of communities and the nation's health. In this context *modeling* refers to a formal representation of ideas for the purpose of problem solving. Depending on the problem to be solved, different modeling techniques, such as statistical approaches or more complex computational models, can be used to represent those ideas. For the purposes of this workshop, "a model is an idealized representation—an abstract and simplified description—of a real world situation that is to be studied and/or analyzed" (Gass and Fu, 2013). The workshop's discussions focused primarily on mathematical models.

The resulting workshop, held on April 9, 2015, in Washington, DC, included a combination of invited talks and interactive discussions with all workshop attendees. The day-long workshop included dialogue between modelers from a range of disciplines and model users, with a focus on finding practical ways to move modeling forward in population health at the local, state, and federal levels, including strategies to build modeling capacity (see Box 1-1 for the full statement of task). The objectives of the workshop objectives included

- identifying how modeling could inform population health decision makers' strategies and decision making based on lessons learned from models that have been, or have not been, used successfully;
- identifying opportunities and barriers to incorporating models into decision making; and
- identifying data needs and opportunities to leverage existing data and to collect new data for modeling.

In his introductory remarks to the workshop, IOM President Victor Dzau commented on the importance of having multiple sectors work together to create the right environment to improve health. He noted that the audience at the workshop included members of many fields, such as education, philanthropy, health care, and private industry, among others, and that there is a need for all of these sectors to work together to make healthier communities and a healthier population. Given the many impacts on health and the multiple stakeholders involved, policy

BOX 1-1
Statement of Task

An ad hoc committee will plan and convene a workshop exploring the potential uses of simulation and other types of modeling for the purpose of selecting and refining potential strategies (e.g., ranging from interventions to investments) to improve the health of communities and the nation's health. The committee will develop the agenda and identify meeting objectives, select appropriate speakers, and moderate the discussions. The workshop will include relevant examples and approaches from health and non-health settings, with a focus on work that could inform local, state, and national-level decision makers. Given the growing interest in novel ways to finance population health improvement, the workshop may include a presentation on ways that modeling could inform the uses of the so-called health dividend (savings from increasing efficiency in health care delivery) in particular and/or national investments in the determinants of health in general. A summary of the presentations and discussion at the workshop will be prepared by a designated rapporteur in accordance with institutional guidelines.

decisions hold uncertainty. Dzau said that modeling can be used as a tool to support population health decisions by communicating uncertainty to those who make decisions that can affect public health and by helping to sort out the complexity. The public health field, though, is behind many others in its use of modeling to making informed policy decisions, Dzau said. The Environmental Protection Agency (EPA), for example, does not make any policy decisions without the use of modeling as an input, he said. He also pointed to the growing role that innovative technologies are playing in improving health care and said that he believes that such technologies have promise to be part of the solution in the population health arena as well. He stressed the need to consider all the tools available when making policy decisions.

Dzau also spoke about his ideas for the IOM to be a more dynamic organization. "We have always been right in the forefront, and we have always been there asking the questions and providing the right analysis, but I will say it is time that we also broaden further along the horizon and touch on many different disciplines," he said. In particular, he said he wants to the see the IOM have more impact. As an example, he discussed an IOM report released in 2015, *Dying in America* (IOM, 2015). This report addressed many of the most important aspects of end-of-life decisions in an objective and comprehensive manner, but what was perhaps just as important, Dzau said, is that it has triggered a series of meetings with stakeholders such as Congress, the American Medical Association, the

American Association of Medical Colleges, nursing associations, and others that have focused on the message that it is time to change the way the nation deals with the end of life. It was his hope, he said, that this workshop would also trigger a broader conversation with those stakeholders that need to take action to improve public health.

ORGANIZATION OF THE WORKSHOP SUMMARY

The workshop (see Appendix A for the agenda) was organized by an independent ad hoc planning committee in accordance with the procedures of the National Academies of Sciences, Engineering, and Medicine. The planning committee consisted of Ana Diez Roux, Dean of the Drexel University School of Public Health; Marthe Gold, Visiting Scholar at the New York Academy of Medicine and Professor Emerita of Community Health and Social Medicine at the City College of New York; David Mendez, Associate Professor of Health Management and Policy in the Department of Health Management and Policy at the University of Michigan School of Public Health; Bobby Milstein, Director of ReThink Health; Pasky Pascual, an environmental scientist, lawyer, and former Director of the Council for Regulatory Environmental Modeling at EPA; Louise Russell, Distinguished Professor at the Institute for Health, Health Care Policy and Aging Research and the Department of Economics at Rutgers University; Steven Teutsch, former Chief Science Officer at the Los Angeles County Public Health; and Steven Woolf, Director of the Virginia Commonwealth University Center on Society and Health. Teutsch served as the planning committee chair.

This publication summarizes the presentations and discussions that occurred throughout the workshop, highlighting the key lessons presented and the resulting discussions among the workshop participants. Chapter 2 provides an overview of the role that modeling can play in improving population health. Chapter 3 presents three case studies that illustrated different kinds of models, how they have been used, and their effectiveness, or lack thereof, in informing decisions. Chapter 4 describes the type of information that policy makers would like to get from models and recounts the discussions that four breakout groups, each representing different stakeholders, had on this topic. Chapter 5 identifies some of the barriers and opportunities for using models to inform population health interventions and policies, and Chapter 6 discusses how the Centers for Medicare & Medicaid Services plans to use modeling to inform its population health initiatives as well as some of the lessons that the field has learned from efforts to use modeling to assess the impact of population health initiatives. Chapter 7 recounts the roundtable's discussion on

future directions and capacity building and provides a summary of some of the key ideas presented at the workshop.

In accordance with the policies of the IOM, the workshop did not attempt to establish any conclusions or recommendations about needs and future directions, focusing instead on issues identified by the speakers and workshop participants. In addition, the organizing committee's role was limited to planning the workshop. The workshop summary has been prepared by workshop rapporteurs Joe Alper and Amy Geller as a factual summary of what occurred at the workshop.

2

Setting the Context

The workshop opened with two presentations that provided the context for how modeling could be used to improve population health. Steven Teutsch, who is an adjunct professor at the Fielding School of Public Health at the University of California, Los Angeles, a senior fellow at the Public Health Institute, and a senior fellow at the University of Southern California's Leonard D. Schaeffer Center for Health Policy and Economics, first discussed why modeling matters to efforts that are aimed at improving population health. Ross Hammond, a senior fellow in economic studies at the Brookings Institution, then spoke on how models can be applied, including examples of how models have been used to inform policy and assess effectiveness. Following the two presentations was an open discussion moderated by Louise Russell, a distinguished professor at the Institute for Health, Health Care Policy, and Aging Research and the Department of Economics at Rutgers University. Box 2-1 contains highlights from these presentations.

WHY MODELING MATTERS FOR IMPROVING POPULATION HEALTH[1]

Steven Teutsch began the workshop's first presentation by displaying the framework that the County Health Rankings[2] uses to describe

[1]This section is based on the presentation by Steven Teutsch, an independent consultant; an adjunct professor at the Fielding School of Public Health, University of California, Los Angeles; a senior fellow at the Public Health Institute; and a senior fellow at the Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California, and the statements are not endorsed or verified by the Institute of Medicine.

[2]See http://www.countyhealthrankings.org (accessed September 24, 2015).

BOX 2-1
Points Highlighted by the Individual Speakers[a]

- It is important for modelers to interact with decision makers to identify the issues that are most important to them so that they can build their models to provide meaningful and useful output. (Hammond, Teutsch)
- Models have many uses, but they cannot provide definitive answers on what actions to take. (Teutsch)
- There are three ways in which models can guide policy making, intervention design, and decision making (Hammond):
  - prospectively to try to understand in advance what the intended and unintended consequences of an intervention or policy might be;
  - retrospectively to look at interventions and policies that have already been tried with the goal of better understanding how these interventions and policies work or why they do not work and to leverage that knowledge to provide insights that would be useful for replicating or scaling an intervention or policy; and
  - by focusing on etiology and reducing the uncertainty that decision makers face when developing policy.

[a]Points identified during the presentations and discussions; the presenters to whom statements are attributed are indicated in parentheses.

the many factors that drive health (see Figure 2-1). "The focus today," Teutsch said, "is to begin to understand the kind of interventions that we can bring to bear and whether programs or policies can influence these factors and how they interact to improve the health of our communities."

Interventions come in many forms, and, because of that, measuring their effectiveness can be challenging, Teutsch said. Interventions can vary in intensity and type, and they can interact in synergistic, duplicative, and complex ways with other interventions. It is important, but challenging, to make sense of those interactions and of the outcomes of interventions to begin to capitalize on those that provide the greatest value. Additional challenges in understanding the effectiveness of population health interventions arise from the long lag times between intervention and outcome, from the fact that many interventions are not amenable to randomized clinical trials, and from the fact that external factors can change over time, potentially limiting the relevance of long-term intervention studies.

Models can help address these challenges in a number of ways, Teutsch said. They can provide a way to synthesize the best available information about the many factors that contribute to health. Models

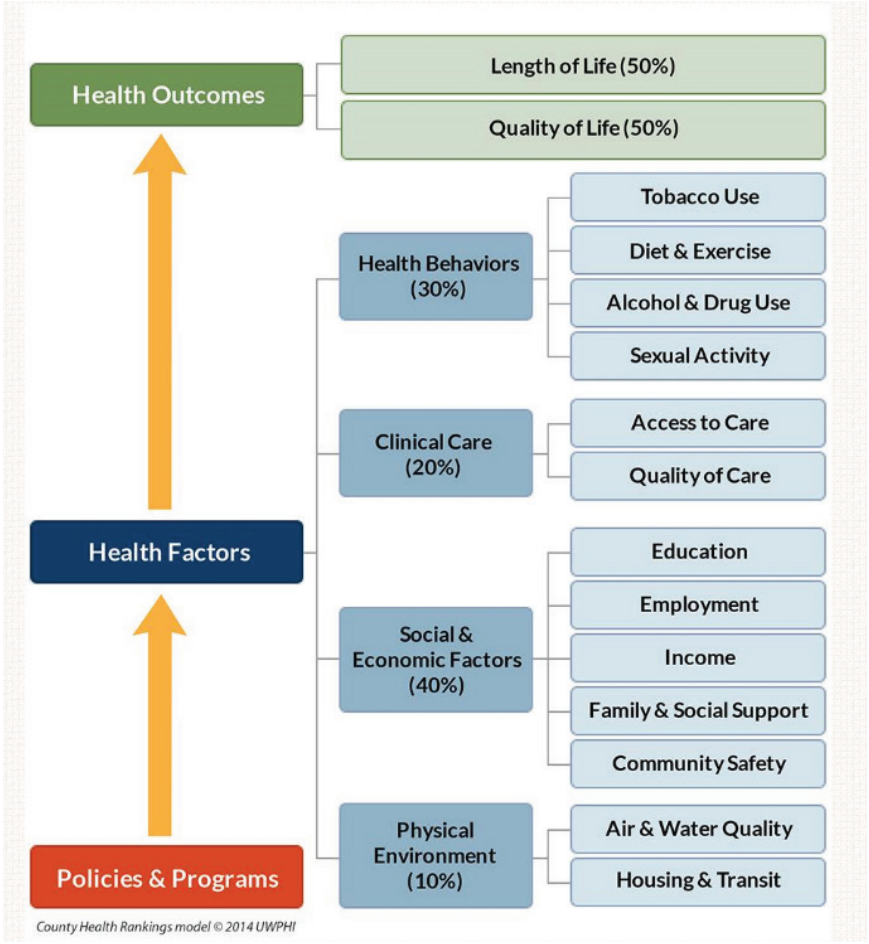

FIGURE 2-1 Framework describing the health factors used to determine county health rankings.
SOURCE: University of Wisconsin Population Health Institute (2014), presented by Teutsch on April 9, 2015.

can incorporate the primary concerns of decision makers, and, in that regard, it is important for modelers to interact with decision makers to identify the issues that are most important to them so that the models can be designed to provide meaningful and useful output. Models are often flexible and can be adapted to different situations, can incorporate the most up-to-date data and science, and can harness uncertainty. Models can also identify key research needs and answer "What if?" questions.

What models cannot do is provide definitive answers and make decisions on what to do.

The workshop planning committee had a long discussion about how to define a model, said Teutsch. The definition that resonated best with the committee came from the *Encyclopedia of Operations Research and Management* (Gass and Fu, 2013): "A model is an idealized representation—an abstract and simplified description—of a real world situation that is to be studied and/or analyzed." While models can be mental, iconic (such as an architect's model of a building), analog, or mathematical, the workshop's discussions would focus primarily on mathematical models, including those that account for economic factors, Teutsch said. "We will be talking primarily about how these models can be used to understand problems better and particularly how they can be used to influence decision makers," he said.

To conclude his presentation, Teutsch reviewed the agenda for the workshop (see Appendix A) and then asked the workshop participants to keep some questions in mind. For the decision makers at the workshop, the questions included

- What important intractable or complex problems do you have that are not being adequately addressed by current approaches?
- Can models help? What kind of model would be best suited for the purpose? How should you be involved in the process?
- Have models been readily accepted by scientists and decision makers? What factors increased their acceptability and usability?
- How can results best be communicated to you?

For the modelers in the audience, the questions were

- What would you need to answer the questions?
- Do models need to be developed anew for each purpose or can we develop some more general models that can be applied to many questions?
- What human and financial resources will be required?
- How can models elucidate unexpected effects?
- How can modeling help us find the societal and health system return on investment both in economic terms as well as more broadly where returns could include improved health or social returns?
- How can modeling move us from an emphasis on health care to an emphasis on health?
- Can modeling help to develop a system to determine how and when to pay for the improvement in outcomes?

Teutsch also asked both groups to think about the data that will be needed to inform the models and whether those data are available. If such data do exist, he asked the workshop attendees to consider if there are any barriers to the use of those data. He also asked them to think about innovative ways to collect data that are not presently available.

BENEFITS AND USES OF MODELS[3]

"Anytime you are making a projection about how something you are doing to change a system will play out, you are in effect modeling that decision," said Ross Hammond to start his presentation. In many cases, he said, these projections or models are implicit, but to inform policy it is often advantageous to turn these implicit mental models into explicit models. An explicit model, he explained, provides the ability to test the underlying assumptions that are built into the model and to explore the boundaries of when it is or is not a good representation of the system of interest. Explicit models also provide a means of exploring complex systems that are difficult to model mentally, he added.

Another reason to construct models, one that Teutsch had listed, is that they provide the ability to conduct experiments that may not be possible in the real world, Hammond said. Real experiments might be unethical or too costly to conduct, or they may take too long to complete in a meaningful period of time. Models can also address the heterogeneity across individuals, context, and time that may make it difficult to generalize from the results of a randomized controlled trial. Hammond noted that models have the potential to account for the unexpected changes to a system that can accompany an intervention or that occur in reaction to an intervention. For example, an intervention might be designed to reduce soda consumption, but if the result is that the targeted population substitutes consumption of sports beverages, it is not clear that the problem was addressed as intended. Similarly, an intervention aimed at reducing smoking could trigger an unanticipated strategic response by the tobacco industry.

Models can also help manage uncertainty and make it possible to consider alternative worlds that have not yet been observed or that cannot be observed. Examples that Hammond cited included forecasting what next year's influenza strains might be or what might happen with the implementation of a policy that has never been tried before, such as New York City's recent move to raise the legal age to purchase tobacco to 21. "Models can help us think about these possibilities that by definition we

[3]This section is based on the presentation by Ross Hammond, a senior fellow in economic studies at the Brookings Institution, and the statements are not endorsed or verified by the Institute of Medicine.

cannot think about with existing data," Hammond said. Another place that models can prove useful is in projecting how the processes of decision making or implementation of an intervention will proceed.

Policy making, intervention design, and decision making have all been guided by models, Hammond said, and there are three ways in which models have been used to do so. These methods are not mutually exclusive, and some models can serve multiple functions. The first way is to use models prospectively to try to understand in advance what the intended and unintended consequences of an intervention or policy might be. This type of application is sometimes referred to as *in silico*, as opposed to *in vivo* or *in vitro*, experimentation. In silico models can be useful for elucidating not only unintended consequences, but also potential trade-offs in terms of the synergy between different policy choices in a complex world. They can also help coordinate policy interests and policy actions across many silos in government or the policy world. These models do not eliminate uncertainty but merely help manage it, and they do not replace judgment.

As an example, Hammond discussed the Models of Infectious Disease Agent Study (MIDAS), funded by the National Institutes of Health. This modeling network developed multiple, independent models to inform policy choices and interventions designed prospectively, and Hammond said that it had a significant role in modeling the H1N1 influenza pandemic. The models developed by this network enabled policy makers and public health officials to consider the implications of choices made during that epidemic, such as closing schools and airports, distributing antiviral drugs, and distributing vaccine. "These are choices that had to be made in real time with high uncertainty and sometimes without a lot of data to directly guide them," Hammond said. The models were able to leverage the data that were available, including data on the global airline network, sharing of patients and doctors across large hospital chains, and social networks, social contacts, and social structure, to produce forecasts on how influenza might spread across the globe. The models can include sophisticated representations of individual behavior and even biological data about how the disease might progress in individual people and affect contagion. "What you could do with a model such as this is to systematically explore many intervention choices and to understand how the pattern of the spread of the epidemic may be altered by what you do to combat it," explained Hammond.

Another example that he discussed involved his work on models to inform decision making about point-of-sale policies for tobacco control. This model, called Tobacco Town,[4] draws on existing data to try to

[4]See http://cphss.wustl.edu/Projects/Pages/Modeling%20Retailer%20Densityaspx (accessed August 17, 2015).

understand what the consequences of retailer-based polices might be, such as how changing the spatial distribution of retailers might impact the behavior of cigarette smokers and their purchase of cigarettes over time and to explore tradeoffs between zoning strategies and licensing strategies. The model is designed to forecast the magnitude of a policy's effect and how quickly it might produce a measurable effect. It also considers unintended consequences, such as whether a policy might reduce overall access to tobacco while increasing already existing disparities, and it can help identify areas where further research is needed to better understand smokers' purchasing behavior. To provide the workshop with a flavor of how the model works, Hammond showed a simulation of a physical geography of road networks in which people were moving around the space and purchasing tobacco. Altering the features of that simulated environment generated predictions about how individual responses might change over time.

A second use of models to guide decision making is to look retrospectively at interventions and policies that have already been tried with the goal of better understanding how these interventions and policies work—or why they did not work—and to leverage that knowledge to provide insights that would be useful for replicating or scaling an intervention or policy. In this context, Hammond said, "we are trying to understand why a particular policy has the impact that it does. This is not always clear in many real-world policy situations." Successful interventions or policies can be modeled retrospectively, and results from those models can then be used in prospective models. An example of conducting a retrospective model and using the information from that model prospectively can be found in obesity prevention at the community level, an area in which significant investments in interventions are being made. Some of these interventions work well in one setting but not in others when they are replicated, and understanding why this is the case is important for designing interventions that are appropriately tailored to context and that can apply existing evidence to produce better outcomes. The model that he described is now being used prospectively to design an obesity intervention that will be tested in the field. Hammond noted that this type of modeling has also been used to better understand corruption, crime waves, retirement decisions, and childhood literacy, among other areas of study.

The third way that models are used to guide decisions involves focuses on etiology, and when used properly, this type of model can help reduce the uncertainty that decision makers face when developing policies by helping them understand the mechanisms that are at work. Such models do not explicitly model a policy but nonetheless have implications for policy and intervention design and can also help identify data

gaps. The MIDAS models that Hammond mentioned, for example, have been used to study the adaptive behavior of people during epidemics. Another modeling effort focused on the neurobiology of eating and how preferences are formed that can persist over long periods of time. Some of this work, Hammond said, has important implications for identifying windows of when to intervene, how to go about intervening, and how the same intervention might work differently for different people. Another obesity-related model examined how social norms about obesity have changed. This model, Hammond said, might provide hints about how that process could be applied to design interventions aimed at social network structure.

Hammond stressed that there are many promising ways to use models to inform policy, but with the caveat that it is not easy to do so, and, in particular, not easy to do well. The workshop, he said, would highlight some of the great successes in this area, but he also noted that there are good models that have not made a difference in decision making as well as models that did make a difference in decision making but that turned out to be flawed in important ways. "It is good to have the big picture in mind," he said, "and to know that there are best practices that need to be followed in order to do modeling well so that the results are dependable, reliable, and meaningful and that they answer the questions that policy makers and decision makers have." He said that there a number of publications available that detail those best practices. If the goal of a modeling exercise is to address policy questions, for example, one best practice is to engage early with policy makers or decision makers to determine that the question a model will answer is one that is important to answer. Best practices also exist to help modelers decide what to include and what not to include in their models and to plan testing and implementation procedures.

Another reason for engaging early with policy makers and decision makers, Hammond said, is so that they develop a deep understanding of the model and become stakeholders in the model development in a way that gives them a more intuitive sense of why the model comes up with a certain result, particularly when that result is counterintuitive. For example, one of the MIDAS models showed why closing schools during an influenza pandemic might be a bad idea—it would reduce the number of health care workers that would be available since many health care workers are single parents and would have to take time off if their children were not in school. Another counterintuitive finding was that if there is a limited supply of vaccine available and the goal is to protect the elderly, the best course of action could be to give none of the vaccine to the elderly and give all of it to school-age children, who turn out to be the primary transmission pathway. "This would be a scary result for a policy maker to act on without having confidence in the model," Hammond said.

In closing, he said it is important to keep repeating the idea that models help manage uncertainty but that they do not remove it and they do not replace judgment. For policy makers and decision makers, it is also important to think about the appropriate uses for different types of models and to get involved early on in the model-building effort.

DISCUSSION

Christine Bachrach from the University of Maryland opened the discussion by asking Hammond to comment on the issue of how certain one has to be about the causal relationships among the parameters that are included in a model. The answer, Hammond said, depends on the model's intended use, and he added that this is a particularly vexing question if the goal is to make real-world decisions that have potentially big consequences. There are, however, strategies to address this challenge. All models, he said, are essentially making causality claims, so the question is whether the causality that is implicit in a model also holds true in the real world. "To assess that," he said, "you have to use a variety of testing approaches with your model to understand what evidence is based on and what it does or does not show about what we know in the real world and what it can reproduce in the real world. That said, it is important to recognize that by design, models are simplifications, which means that they are all missing something important that is true in the real world."

George Isham from HealthPartners observed that, based on his experience as a model user and policy maker, policy makers need to be much more engaged in model development if they expect to get the kind of in-depth information that is useful in making policy. At the same time, he said, policy makers do not often have the time to engage as fully as they need to because they are making policy across a thin range of issues that do not go deep into any one area. In addition, most policy makers do not know the right questions to ask regarding the right type of model to use. He suggested that there needs to be a general primer for policy makers that they can read before engaging in any kind of modeling activity, and he wondered if the modeling field is at the point that large-scale computing was before the advent of the personal computer, where modeling is still in the hands of the experts.

Regarding the need for a primer, Hammond said that there are a number of resources, including several Institute of Medicine reports, available to help with the process of asking the right questions. He also said that many successful interactions between modelers and policy makers involve what he called translators, individuals who are conversant in the languages of the policy world and the modeling world. The MIDAS pro-

gram that he mentioned benefitted from such individuals, he said. With respect to Isham's last point, Hammond acknowledged that there is some tension in the modeling community concerning the idea of participatory modeling and how to make communities and policy makers partners in the modeling enterprise. Louise Russell added that a good model has to be the result of a conversation not just between modelers and policy makers, but also one that includes subject matter experts.

Catherine Baase from The Dow Chemical Company asked if models have confidence intervals that reflect the fact that they include assumptions when the exact information needed is not available and if there are ways of tracking the effectiveness of models over time. Hammond replied that the answer is yes to both of those questions. "There are ways to develop what you might describe as a confidence interval for the results of a model, the degree of uncertainty that is inherent in different estimates that the model is making," he said. "There are also ways to handle uncertainty about the inputs to a model by doing sensitivity analysis and exploring how much the results depend on different assumptions that you are making, which can be very important when there is unavoidable uncertainty in the real world." In his opinion, he said, an important part of modeling is to be clear about variation in the results of the model and the causes of that variability. "That is actually the most critical information in some sense for a decision maker." Russell added that this is a place to involve subject matter experts, as they can not only help to identify the best available data for a model (and the standard errors that represent the uncertainty in even the best data) but also help to develop estimates and ranges to represent uncertainty for those features of a model for which there are no good data.

James Knickman from the New York State Health Foundation asked where this type of modeling was taking place, and Hammond replied that it is widely distributed. Teutsch agreed and noted that governors' offices, in particular, are active developers and users of models for policy analysis. Knickman asked if there is an inflection point coming in the modeling world, and Hammond replied that in some ways the answer is no because much of the modeling that is done now is a natural extension of modeling approaches that have been around for a long time. He did say, though, that there are some relatively new approaches that are being developed in the modeling world, many of which are aimed at breaking down the wall between disciplines and across agencies in the policy space and that take a more systems-based approach to modeling that is new in the public health world.

Sanne Magnan from the Institute for Clinical Systems Improvement asked Hammond and Teutsch if they had any thoughts about how to marry the gaming world with the modeling world to democratize model-

ing and give consumers more power to use models to examine the effects of their decisions on their health. Teutsch replied that the tools of modeling are moving out of the sophisticated research setting and on to the Web in ways that will empower individuals to work with these models. In his view, models are intrinsically synthetic rather than reductionist, and they will move society away from medical models that are reductionist to a place where people start considering the complex interactions of the factors that influence their health and that are outside of the interventions now associated with the medical model of health. "I do think there will be empowerment that comes along with this," Teutsch said. Hammond added that models can be fabulous teachers and said that he hopes that students start learning about and using models in high school or even before rather than when they are in graduate school.

Steven Woolf from Virginia Commonwealth University's Center on Society and Health asked the speakers if they could comment on the role of big data and machine learning in modeling. Hammond replied that when he thinks about big data, the questions that he asks are "How do you know what is the right data?" and "What do you do with it once you have it?" He said that it is not immediately clear that the data collected today are the right data to collect and that, even if they are, the act of translating them to something that is policy relevant can be difficult. Machine learning, Hammond said, is another form of modeling with its own advantages and disadvantages.

Pamela Russo from the Robert Wood Johnson Foundation noted that the Foundation used to run a program called Young Epidemiology Scholars and that each year the projects selected as finalists included what she characterized as brilliant models developed by high school students. She also commented that she was involved in a project that developed a model with many assumptions that were clearly stated and transparent and which the users could change when they ran the model. She asked the panelists if that type of transparency adds to the confidence in a model. Russell replied that such transparency is a good idea and that even if the model is not set up to be easy for non-modelers to change, it should be possible for them to ask the modelers for information about the assumptions and for results that show what would happen if those assumptions were changed. "That is what sensitivity analysis is about," Russell said, "That is what policy makers, other users, and subject matter experts need to keep an eye on."

3

Case Studies of Models Used to Inform Health Policy

The workshop's second panel featured three case studies presented by long-time modelers which were offered to illustrate some of the ways in which models can be used to inform health policy. In each case, said session moderator Pamela Russo, a senior program officer at the Robert Wood Johnson Foundation, the models are nonlinear, dynamic, and interactive, and they cross multiple disciplines. (Box 3-1 contains highlights from these presentations.) David Mendez, an associate professor in the Department of Health Management and Policy at the University of Michigan School of Public Health, discussed tobacco models. Pasky Pascual, an environmental scientist, lawyer, and former director of the Council for Regulatory Environmental Modeling at the Environmental Protection Agency (EPA), described EPA's use of models to set clear air standards. Bobby Milstein, a director at ReThink Health, illustrated how communities have used models to engage in regional health reform efforts. An open discussion moderated by Russo followed the three presentations.

COMPUTATIONAL MODELS IN TOBACCO POLICY[1]

As the previous speakers had already noted, there are several good reasons to model, said David Mendez in the introduction to his presen-

[1]This section is based on the presentation by David Mendez, an associate professor in the Department of Health Management and Policy at the University of Michigan School of Public Health, and the statements are not endorsed or verified by the Institute of Medicine.

BOX 3-1
Points Highlighted by the Individual Speakers[a]

- All models are tools that are inexact representations of the real world. (Mendez, Milstein, Pascual)
- Models can provide a coherent framework to analyze a situation and integrate different datasets in a way that mental models cannot. (Mendez)
- There are uncertainties that prevent models from making perfect predictions, but there are evaluation methods that can distinguish between models that are truthful and those that merely seem true. (Pascual)
- Being transparent about the assumptions and hypotheses incorporated into models and providing an infrastructure for evaluating a model's epistemic framework and performance leads to both legal accountability and defensibility. (Pascual)
- It is rare for a model to drive change by itself, but modeling can provoke significant shifts when coupled with a sense of strong stewardship among those who come to the table. (Milstein)
- The Michigan Model of Smoking Prevalence and Health Effects was able to show that the *Healthy People 2010* goals for smoking prevalence were unreachable under any real-world circumstances, illustrating the fallacy of creating targets without thinking about the mechanisms that drive prevalence. (Mendez)
- Modeling suggests that a balanced approach to regional health reform, with investments in both downstream and upstream interventions, may be more costly in the short term but that it is the only way to generate increasingly greater returns over time in terms of lower health care costs, fewer premature deaths, greater equity, and stronger economic productivity. (Milstein)
- Though there is always a need for more data, a lack of data is not a good reason not to model. (Mendez, Milstein, Pascual)

[a]Points identified during the presentations and discussions; the presenters to whom statements are attributed are indicated in parentheses.

tation on the use of models in tobacco control efforts. One reason is to understand a problem fully, and in that context models can provide a coherent framework with which to analyze a situation and integrate different datasets in a way that mental models cannot. Models, he explained, can be used to monitor, forecast, and evaluate the consequences of policies using "What if?" scenarios that are explored in *in silico* experiments, and they can identify gaps in knowledge which can guide data collection. In the tobacco control area, models can be used to address such questions as

- If current conditions continue, what is the likely trajectory of smoking prevalence?

- If all the tobacco control measures known to be effective were fully implemented, what is the likely trajectory of smoking prevalence?
- What would be the population health impact of removing menthol cigarettes from the market?
- What would be the consequences of increasing the minimum purchasing age for tobacco products?
- What would be the impact of reducing nicotine in combustible tobacco products to nonaddictive levels?
- What is the estimated impact of tobacco control policies on avoided mortality?

One of the issues that Mendez has been exploring using the Michigan Model of Smoking Prevalence and Health Effects is the effect that tobacco control policies have on the smoking status of individuals. The model identifies individuals by gender, age, when they started smoking, and trajectory, and it tracks these individuals from birth to death. Mendez and his colleagues use these simulations to examine the probability of initiation and cessation and the way those two events interact under different policy scenarios. While the model is constructed to capture the initiation and cessations probabilities at the individual level, it actually follows groups of individuals, which is why this type of model is called an aggregate model (see Figure 3-1). One of the assumptions built into the model is that groups comprising individuals with certain characteristics behave in a homogeneous way, Mendez said.

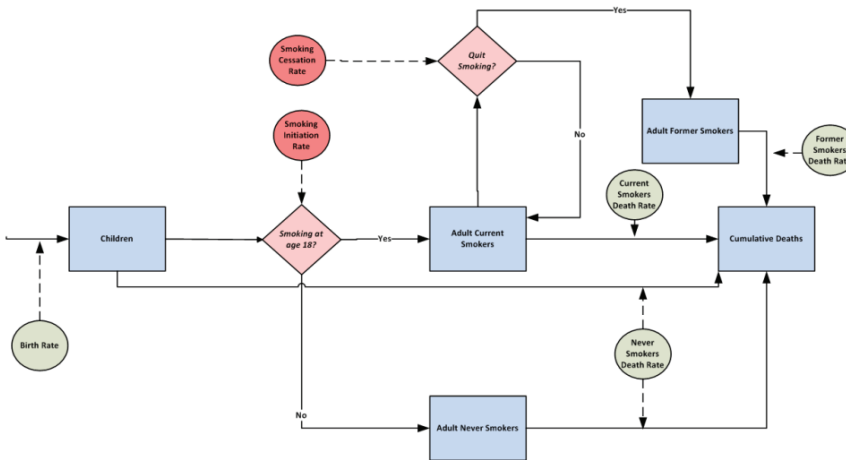

FIGURE 3-1 The basic aggregate model used to track the fate of smokers.
SOURCE: Mendez presentation, April 9, 2015.

Mendez used a bathtub analogy to explain how this model works. Water flowing into the bathtub represents individuals who initiate smoking, and the rate at which water flows out of the tap is analogous to the probability of initiation. Similarly, water flowing out of the bathtub represents individuals who quit smoking plus the number of people who die from all causes. The level of water in the bathtub represents smoking prevalence, and this is what he and his colleagues are interested in and what the model tracks over time.

When building such a model, one of the first tasks is to build confidence that the predictions that the model makes fit with the observed data (see Figures 3-2 and 3-3). "We have some theory about how the elements interact and how people start smoking and quit smoking," Mendez said, "and we want to make sure that this is a good representation of what is happening in the real world." When he and his colleagues used data from the National Health Interview Survey to test the model, they found that the fit between the model's predictions and the data was very good (Mendez and Warner, 2004). They then developed some projections of what would happen with varying initiation rates (see Figure 3-4).

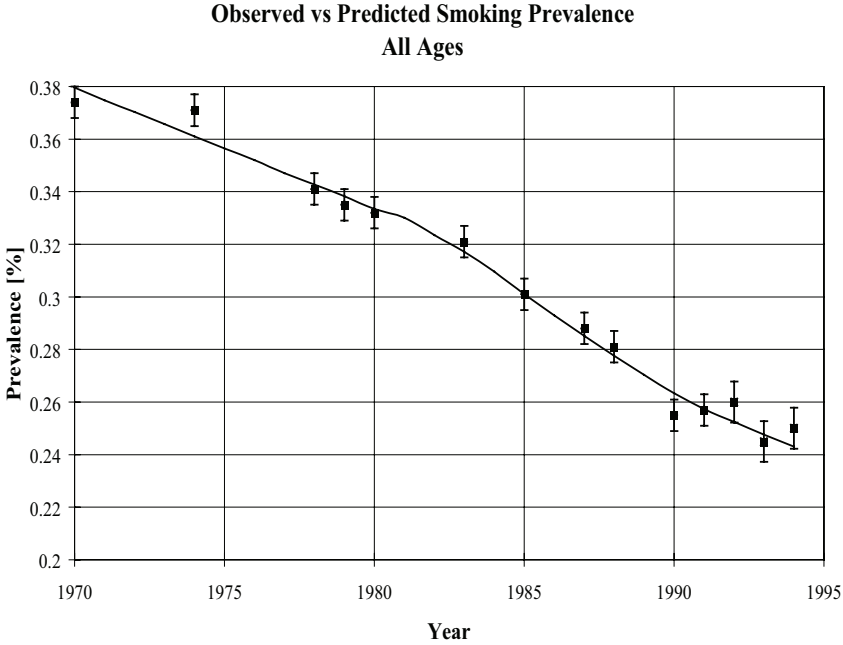

FIGURE 3-2 Observed versus predicted smoking prevalence, all ages.
SOURCES: Mendez et al., 1998; Mendez presentation, April 9, 2015.

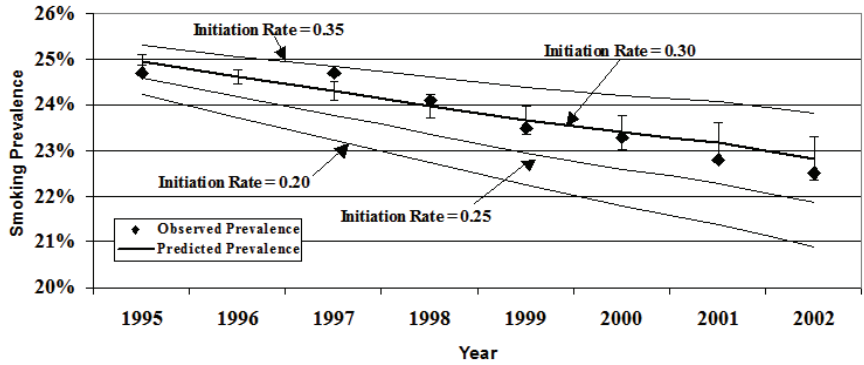

FIGURE 3-3 Observed versus predicted adult smoking prevalence in the United States.
SOURCE: Mendez and Warner, 2004.

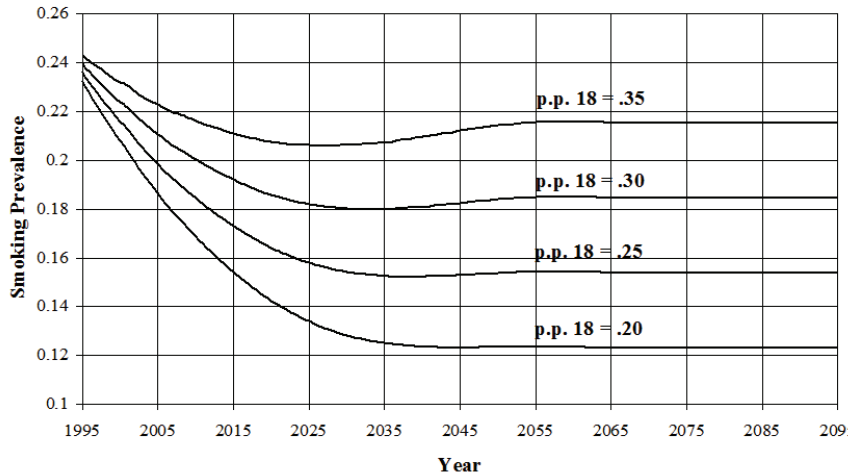

FIGURE 3-4 Forecasted overall smoking prevalence by different peak prevalence at age 18.
SOURCES: Mendez et al.,1998; Mendez presentation, April 9, 2015.

To understand the health effects of smoking, Mendez and his colleagues used data from the Cancer Prevention Study II to develop relative risks for former and current smokers, both female and male. The model predicts the relative risk of death from the time of smoking initiation and the length of time an individual smoked. He explained that the model

contains compartments that keep track of individuals by age and by when they stop smoking (see Figure 3-5) and that it explores the effects of policies that affect the initiation and cessation rates on mortality and morbidity over time on a population level.

Mendez listed some of the ways in which he and his colleagues have used this model. These included assessing smoking prevalence targets, evaluating the effect of offering smoking cessation programs in managed care organizations, evaluating the impact of menthol cigarettes on a population's health, evaluating the effectiveness of radon remediation when smoking rates are declining, and evaluating the effect of tobacco control policies on global smoking trends. In the study that evaluated the effect of offering smoking cessation programs in managed care organizations (MCOs), the question of interest was whether offering such programs were cost-beneficial for the MCOs. The answer was that they were not because of the large turnover in managed care organizations. Mendez said that this study was interesting because the presumption was that there would be a clear benefit, but the analysis showed that while the gains for society are substantial, there is no benefit that accrues to a managed health care organization.

For the radon remediation project, the goal was to examine the effectiveness of EPA guidance about remediating homes with high levels of radon. "The problem here is that there was no clear distinction between smokers and nonsmokers when this policy was put in place," Mendez

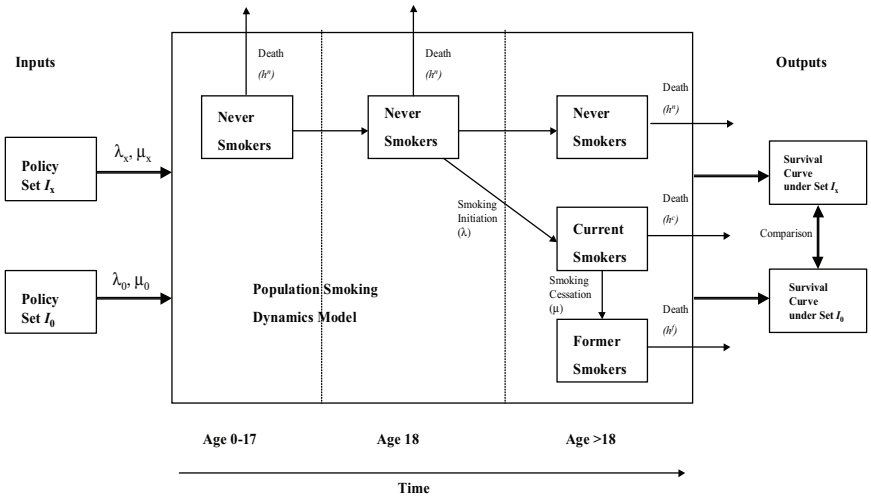

FIGURE 3-5 Compartment model of smoking prevalence and health effects.
SOURCE: Mendez presentation, April 9, 2015.

said, noting that the data show that health risks associated with radon exposure are much higher for smokers than for nonsmokers. The model's analysis showed that with declining smoking rates, the effectiveness of the EPA recommendation is questionable (Lantz et al., 2013; Mendez et al., 2011).

To evaluate the potential impact of tobacco control policies on global smoking trends, Mendez and his colleagues used data from World Health Organization databases and explored what would happen with the world prevalence of smoking if current conditions continued compared to an environment in which a comprehensive package of well-known effective tobacco control strategies was implemented. "The World Health Organization has found this information useful as it attempts to communicate the possibilities of tobacco control worldwide," Mendez said.

For the United States, Mendez and University of Michigan colleague Kenneth Warner used this model to analyze the possibility of meeting the *Healthy People 2010* goal of achieving a smoking prevalence rate of 13 percent. This analysis showed that this goal was unreachable since even if the initiation rate for smoking went to zero, the cessation rate would have to increase by more than threefold to achieve a 13 percent prevalence in 2010. If the initiation rate dropped to 15 percent by 2010, cessation rates would need to increase more than fourfold to reach the target. "The targets were made without thinking about the mechanisms that drive prevalence," Mendez said. "Our projections were that prevalence would be between 18 and 19 percent, and that is where we were in 2010, at 19.3 percent." He commented that the problem with setting unrealistic goals is that the community will get discouraged. "It is not that we fail with tobacco control policies," he said, "but because the goals were so outrageous, the public health community feels like a failure by not achieving them."

Rather than just pointing out the error of setting unrealistic goals, Mendez and Warner used their model to set a goal for 2020 that would be feasible. To do this, they chose the policies that California had enacted and that have driven the prevalence of smoking in that state to 14.7 percent (Mendez and Warner, 2008). Under the optimistic conditions that assume the nation can achieve California's initiation and cessation rate, the model found the nation would still not achieve California's current prevalence level until after the year 2020 (see Figure 3-6).

In a project commissioned by the Tobacco Product Scientific Advisory Committee of the Food and Drug Administration (FDA), Mendez modeled likely outcomes from removing menthol cigarettes from the market. The results projected that an estimated 328,000 premature deaths would be avoided over a 40-year period if menthol cigarettes did not exist and that there would be 9 million fewer new smokers over that same period. Based at least in part on this study, the advisory committee determined

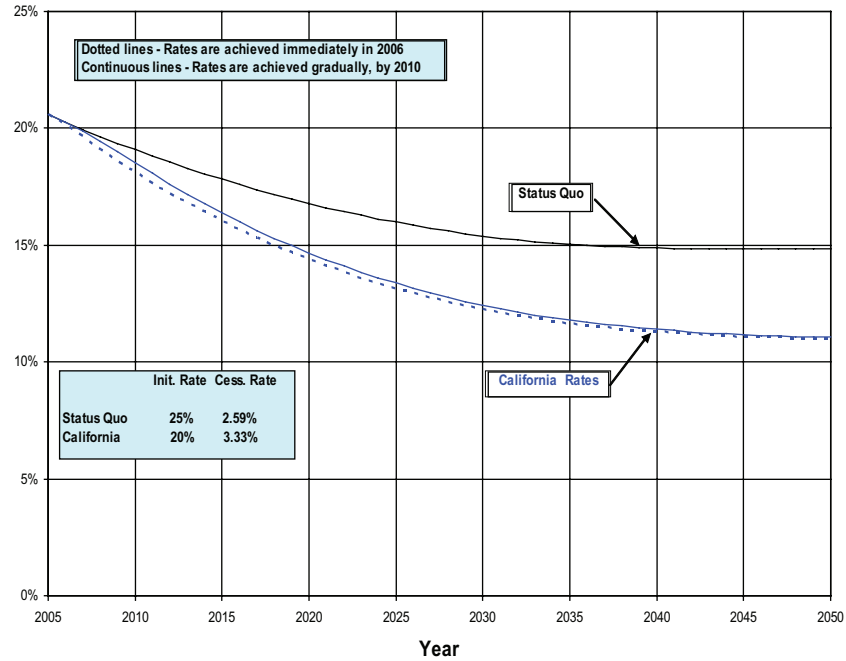

FIGURE 3-6 Projections of U.S. adult smoking prevalence under status quo and California smoking initiation and cessation rates.
SOURCES: Mendez and Warner, 2008; Mendez presentation, April 9, 2015

that removing menthol cigarettes from the market would benefit public health.

In his final comments, Mendez highlighted two modeling efforts conducted by other investigators. The SimSmoke model, developed largely by David Levy at the Georgetown University Medical Center, simulates the dynamics of smoking rates and smoking-attributed deaths in a state or nation and also the effects of policies on those outcomes. This model shows that the effects vary with the way a policy is implemented and by demographics, and it points out the dynamic, nonlinear, and interactive effects of smoking policies (Levy and Friend, 2002; Levy et al., 2013). The Cancer Intervention and Surveillance Modeling Network, funded by the National Cancer Institute, is a network of modelers looking to improve understanding of cancer control interventions. Using data from the National Health Interview Survey, this group can reproduce the history of smoking for any cohort in the U.S. population, and it has evaluated the impact on lung cancer and overall mortality of smoking control policies enacted since 1964. By the network's estimates, some 8 million pre-

mature deaths have been avoided and mean lifespan has been extended by 20 years (Holford et al., 2014).

DEFENDING PUBLIC HEALTH MODELS IN THE COURTROOM

Pasky Pascual started his presentation by talking briefly about a modeling technique that he has used, called hierarchical Bayesian modeling, to investigate the relationship between charged particles and oxygen in two streams just north of Washington, DC. The results that the model produces, he said, depend heavily on the data used to initialize the model, the variables chosen for inclusion in the model, and on the specific equations in the model that are emphasized (see Figure 3-7). "If these models remained on my laptop, they continue to be an interesting intellectual exercise," Pascual said, "but the moment I use any of these models to make a decision that affects other peoples' lives in a significant way, that is a problem."

Models are everywhere, Pascual said, and any major regulation that is issued by EPA is ultimately based on a model. With his colleagues Elizabeth Fisher from Oxford University and Wendy Wagner at the University of Texas School of Law, Pascual has written two papers discussing the use and abuse of scientific and social-scientific models in environmental policy (Fisher et al., 2010; Wagner et al., 2010). Litigants will

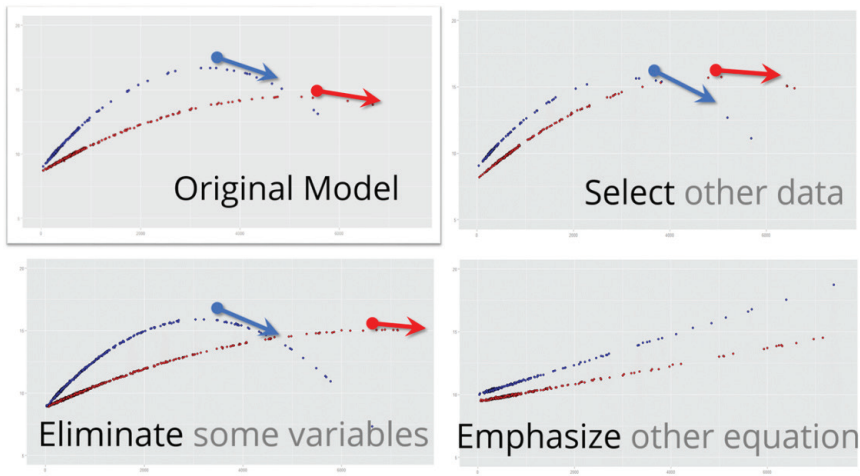

FIGURE 3-7 Model-generated predictions of the inflection point (arrows) where the oxygen concentration in two different creeks will begin falling as a function of the charged particle concentration in the streams.
SOURCE: Pascual presentation, April 9, 2015.

challenge models by mischaracterizing them as belonging to two different extremes, Pascual said. At one extreme, models are portrayed as being truth engines, which means that as soon as the model makes an error, it becomes invalid. At the other extreme, models are seen as being completely malleable and therefore should be considered arbitrary and capricious under the law.

The reality is that models fall somewhere between these two extremes, Pascual said. "There are indeed uncertainties that prevent us from making perfect predictions, but there are evaluation methods that help us distinguish between models that are truthful and those that are merely 'truthy,'" he said, borrowing that last word from the lexicon of Stephen Colbert. In reality, every modeling approach has its own intellectual foundation and its own assumptions, which Pascual and his colleagues refer to as a model's epistemic frame (Pascual et al., 2013). For example, in 1962 FDA, in responding to the thalidomide crisis, stated by way of regulation that the best scientific evidence for evaluating drug risks comes from randomized clinical trials. Implicit in that decision, Pascual said, was that FDA prescribed one particular statistical method for drawing inferences. Over the years a number of panels, including those organized by the Institute of Medicine, have been recommending that FDA take a more agnostic view of modeling, and, in fact, Congress mandated in the 2007 FDA Reauthorization Act that the agency take a more universal view of modeling. Pascual and his colleagues used the FDA Reauthorization Act to make the case that models used for regulatory decision making need to be transparent in terms of both the methods used and the epistemic framework of those methods.

In an upcoming paper, Pascual and his collaborators discuss how model transparency leads to both legal accountability and defensibility in the context of the Clean Air Act. He said that while the Clean Air Act is complex, there are four important features regarding the implementation of air quality standards that are important to know for this discussion: The standards have to protect public health, be based on the latest science, be reviewed by a science panel, and be subject to judicial review. That last feature means that if a stakeholder with established standing disagrees with the model that EPA used to make its regulatory decision, the stakeholder can force the agency to defend the model in court.

In the early years of EPA's regulation of ambient air quality standards, there were 16 court cases challenging the agency's decisions, and the court's approach to evaluating the science was, as Pascual characterized it, "very ad hoc." The court's approach was reminiscent of Justice Potter Stewart's comment on pornography in that the court seemed to say that it could not define what good science is but that it would know it when it saw it. "If you read the cases, they are rather incoherent and not very

cohesive," Pascual said. In 2008, though, EPA laid out its causal epistemic framework and challenged the court to judge its decisions against this framework. In the past courts said that controlled human exposure trials, like randomized clinical trials, engender the highest level of confidence about the causal relationship between ozone exposure and health effects. However, as Hammond pointed out earlier in the workshop, randomizing different groups and exposing them to different concentrations of toxics would not be ethical. The agency's models computationally control for other covariants that might interfere with this causal relationship. In essence, this approach to science says that given a particular level of a pollutant, the models, based on data from human and animal exposure, suggest that a particular health effect will result. If the data come from controlled human studies or from observational studies that rule out chance, the agency determines that a causal relationship exists. If the data come from observational studies with possible confounders plus animal toxicity studies, the agency considers that it is likely that a causal relationship exists between exposure to a pollutant and an adverse health effect.

In concluding his talk, Pascual offered a quote from the statistician David Box, who said, "Every model is wrong, but some are useful." No model is perfect, Pascual said, but by making a model transparent and providing a framework for evaluating a model's performance, an expert scientific panel should be able to evaluate the validity of a model to a degree that the model will hold up in court. In the end, Pascual said, modeling is nothing more than a formalized method of questioning.

MODELING REGIONAL HEALTH REFORM USING THE RETHINK HEALTH DYNAMICS MODEL

Health data show that there are regional patterns that transcend the specifics of any disease or physical exposure, said Bobby Milstein, and this is true for the way that health care is delivered and how much it costs and with regard to the social, economic, and environmental conditions that leave people vulnerable to risk and disease. The challenge of addressing health reform at a regional level is what drove Milstein and his colleagues at ReThink Health to develop a model that can be used by those working to address health reform at the regional level to ask questions about the likely health and economic consequences of their efforts under realistic regional conditions that account for local trends related to a wide range of factors. These factors include insurance expansion, demography, aging, inequities, health status, the quality and cost of health care, the demand-supply for health care resources, provider payments, among others. Nobody can keep all of these dynamic factors in mind simultaneously when making choices about what actions to take,

Milstein said. In short, the model is meant to be used by people who are immersed in systems they do not fully understand and help them make better informed decisions.

ReThink Health started its efforts in Pueblo, Colorado, when Milstein and his colleagues met with leaders who were addressing a regional health reform agenda. Together they framed an approach to look at a number of policies and actions that these leaders thought were within their capabilities to influence in the region. From that start, ReThink Health's efforts expanded to five additional sites in the first year and then three more over the next 3 years for a total of nine sites. The model is also being incorporated into an increasing number of academic curricula as future leaders are beginning to think about how the health care system works and about some of the conditions under which it might be able to change. Recently, for example, the National Association of Schools of Public Policy, Affairs, and Administration, a network of almost 300 academic institutions across the country, held its first student simulation competition on health policy. On one day, some 200 students at 93 schools sat down to think about how the health system might work and what their roles as policy makers would be.

Users of this model, Milstein said, confront a stewardship challenge as they attempt to craft strategies that will steer their health system in a new direction, not just in the short term, but in an enduring way over time. The model's logic incorporates three questions that policy makers ask in the real world, Milstein said: What shall we do, how will we pay for it, and how proud would we be of the consequences? The model provides an intentionally diverse menu of intervention options, with several dozen initiatives that policy makers could choose to change with regard to upstream and downstream initiatives and also financing within a regional health system (see Figure 3-8). For example, planners can focus on actions to cut health care costs, improve quality, or expand capacity as well as wider efforts to enable healthier behaviors, reduce environmental hazards, improve public safety, and expand socioeconomic opportunities that strongly shape health and well-being while also affecting the demand for expensive downstream health care. Every item on this menu, he explained, has been documented to make a difference in and of itself, yet there are open questions about how they might be combined to make a greater difference and how much ought to be invested in different contexts. These items can be tested alone or in combination, and Milstein presented two quick scenarios to illustrate the types of insights that users have begun to obtain with this model.

One scenario explores a suite of strategies designed to move the health system's overdependence on tertiary care through hospitals and specialists to one that relies more on primary care combined with a greater role

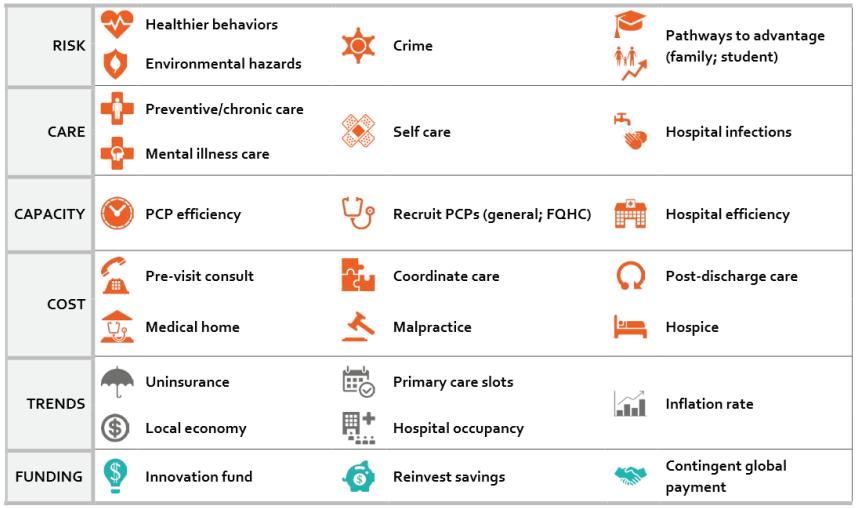

FIGURE 3-8 Initiative options in the ReThink Health model.
NOTE: FQHC = Federally Qualified Health Center; PCP = Primary Care Physician.
SOURCE: Milstein presentation, April 9, 2015.

for self-care and medical homes. This approach begins with an assumption, which can be easily varied, that start-up funds are available from a temporary innovation fund set at 1 percent of total health care spending for just 5 years. Also, it assumes that half of any savings that accrue from lower health care costs will be reinvested in the endeavor, which is similar to what many accountable care organizations are doing; furthermore, it is assumed that there will be a shift in provider payment away from fee-for-service to per capita payment. This scenario also emphasizes greater adherence to guidelines for preventive and chronic care and also serious efforts to coordinate care by eliminating unnecessary services that increase cost but do not improve health. Together, Milstein said, this combination of strategies represents an evolution toward higher-value preventive and chronic care. Simulated results show that these downstream investments can deliver relatively fast, focused impacts but that their effects tend to plateau (see Figure 3-9). Models can also have mixed results on cost and inequity. While this scenario decreases dependency on hospital inpatient stays, which in turn lowers cost, there are also fewer premature deaths, more primary care visits, more services for prevention and chronic care, and more extensive use of self-care products such as prescription drugs, all of which increase costs elsewhere in the system. "What is the balance of those? I can't do that in my head, and that is exactly why we need com-

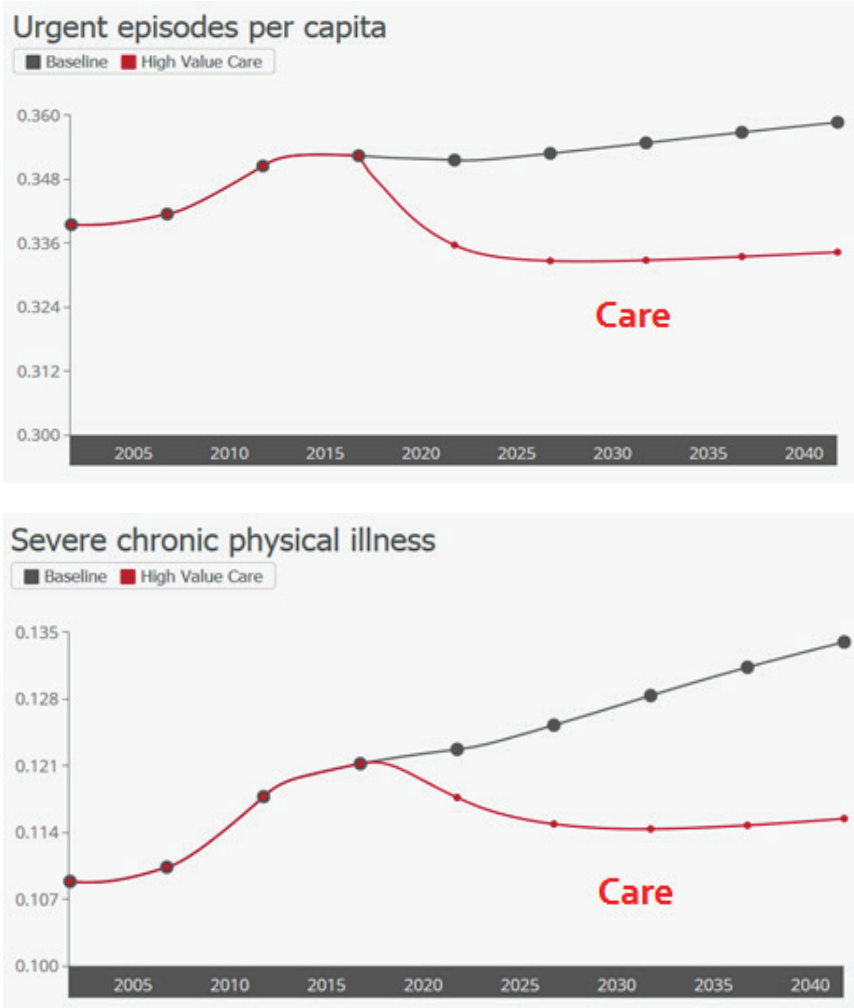

FIGURE 3-9 Downstream investments in high-value care produce relatively fast, focused impacts that plateau.
SOURCE: Milstein presentation, April 9, 2015.

puters to play this out against the other changing dynamics in a region," said Milstein.

A second scenario tested a more balanced approach, with those same downstream components now coupled with upstream investments to enable healthier behaviors and safer environments. According to that model, the added emphasis on healthier behaviors and environments

could unlock much greater health and economic potential, Milstein said, noting that the upstream elements yield broad progress on health, cost, equity, and workforce productivity (Milstein et al., 2011). The effects can be large, he added, but they accumulate gradually (see Figure 3-10).

The health consequences from the combined, balanced scenario grow stronger over time, although the distinct benefits compared to the first scenario do not become apparent until after about 8 years. The same is true for cost savings. The larger suite of initiatives is more expensive to implement, but it may still be affordable when coupled with gains from the downstream reforms. Milstein claimed that with health care costs on track to grow even larger, many regions may not be able to afford not to make these cost-saving investments. In one scenario, for example, although downstream investments save nearly $1 billion, when combined with upstream investments funded by gain-sharing agreements, the savings are 50 percent greater (see Figure 3-11). The challenge, as this scenario shows, is that there is an initial increase in spending that may make the necessary initial investments difficult to secure. "There is typically a worse before better pattern," Milstein said. "In all scenarios where you are making these investments, the question is how fast you get that yield and how happy are you with that yield." Another important insight from

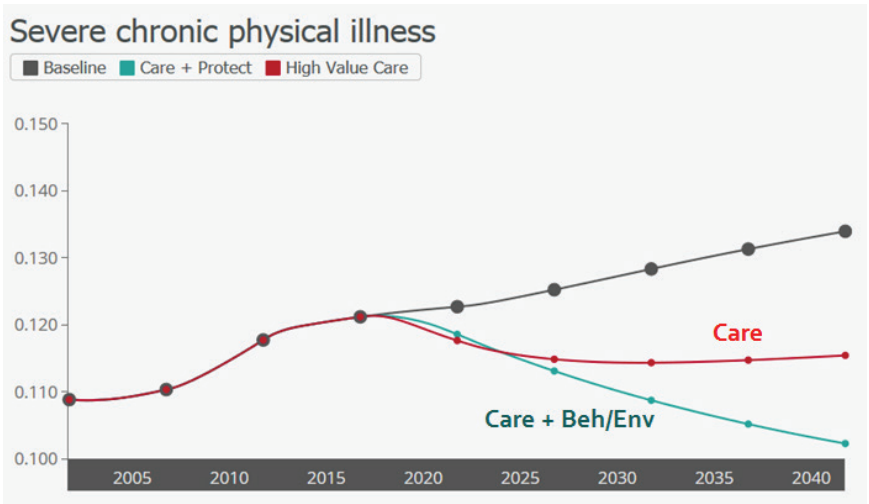

FIGURE 3-10 Balanced investments can unlock a much greater potential for health and resilience, and although the effects can be large, they accumulate gradually.
NOTE: Beh = behavior; Env = environment.
SOURCE: Milstein presentation, April 9, 2015.

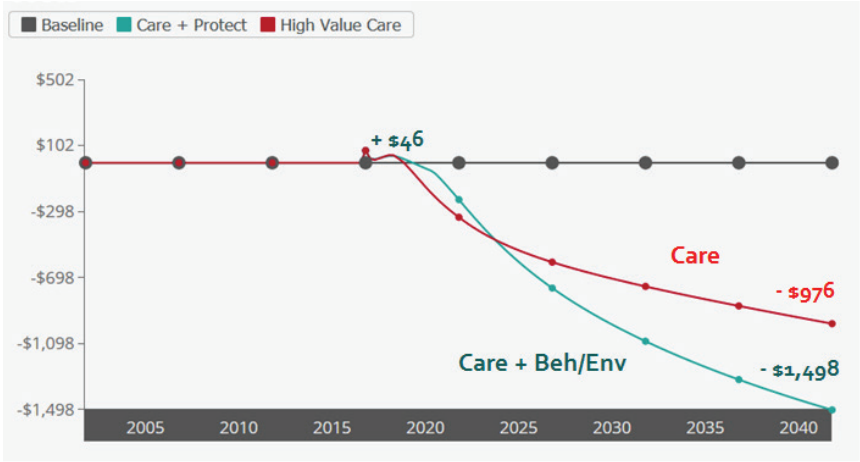

FIGURE 3-11 Spending and yield—the per capita change versus baseline in health care and program costs.
NOTE: Beh = behavior; Env = environment.
SOURCE: Milstein presentation, April 9, 2015.

these modeling exercises, he added, is that balanced strategies can drive greater economic productivity which provides a return beyond that from simply reducing health care costs.

This is a well-designed model that has been widely tested and closely matches dozens of observed times series data, Milstein said. But, like all models, it is still an inexact representation of the real world. One limitation, he added, is its 25-year time horizon, which is much shorter than a full life course, which would be needed to accurately represent the benefits of other investments, such as intervention in early childhood. The model also has a relatively high level of aggregation, which is appropriate for its focus on strategy designs, Milstein said, but if one wanted to delve into, for example, the details of *which* behaviors would make the biggest difference, that would require a different type of tool which was focused on tactics and specific program portfolios.

One of Milstein's biggest priorities is to guard against two extremes that are fraught with peril: an overreliance on an imperfect model versus an under-reliance on analytical tools to compensate for known flaws in people's mental models. Decisions made in the absence of a credible model essentially depend on people's ability to think through the complexity of a vast health system, which turns out to be notoriously difficult, if not impossible.

In his closing comments, Milstein said that he and his colleagues have examined carefully the conditions under which models can help leaders make big breakthroughs in their practice. "It is very rare for a model, in and of itself, to drive change. It really is best done when it is coupled with a sense of strong stewardship by people who come to the table thinking of themselves not as leaders of their institutions or thinking of their own narrow self-interest, but recognizing that they are part of a system upon which we all depend," said Milstein. Working through the economics of marshalling and governing common resources is a large part of this stewardship, he added. "Having a sound strategy and the muscle to enact it means very little if you can't gather the resources to direct to those priorities."

DISCUSSION

Robert Kaplan from the Agency for Healthcare Research and Quality began the discussion by asking the panelists to react to the following information. Over the past 20 years, Kaplan said, most major randomized controlled trials in preventive medicine have shown that the intervention does not make much difference, even though almost all of those trials have positive effects for surrogate outcomes. On the other hand, almost every modeling study using surrogate outcomes predicts that there should be positive effects. Both the modelers and the researchers carrying out the trials then claim that the other approach is wrong because it is too simplistic. Pasqual replied that he and his colleagues discussed this very issue in detail, using the Vioxx crisis as a starting point. One thing they found is that the design for the Vioxx randomized controlled trial screened out the very people who were most likely to experience the adverse effects that later caused trouble. In his opinion, he said, the current approach to hypothesis testing that drives trial design is flawed, and it is only recently that Bayesian methods and other analytical models that can handle distributions that are not Gaussian, binomial, or in general well-behaved and that can make use of all of the available data have become amenable to analysis in a meaningful way.

John Auerbach from the Centers for Disease Control and Prevention asked the panel to talk about the challenges associated with having nonhomogeneous populations and, in particular, with having subpopulations that may be affected differently by different interventions. Too often, he said, models that may be true for general populations are used to make extrapolations about the efficacy of an intervention in a subpopulation with different characteristics. Milstein responded that there is nothing like modeling and the need to make explicit the assumptions that go into a model to expose the fact that the data may not exist to support all of those

assumptions for all populations. If there are reasons to suspect that an intervention may be less effective in one group than in another, the model can be run over a range of scenarios, some more pessimistic and others more optimistic. What is important, he said, is to craft a research agenda that asks which interventions need to be tested more consistently across many different contexts and groups. Mendez added that models also provide a framework for understanding where assumptions are important and where they are not and where more data are needed to better understand the effects of heterogeneity. Pasqual noted that hierarchical Bayesian approaches are particularly useful for better understanding how subpopulations fit into the larger general population.

Marc Gourevitch from the New York University School of Medicine asked Milstein how the ReThink Health model makes predictions in the aggregate over time. Milstein responded that the model is not actually making predictions about the future because the world is complicated and models cannot anticipate surprises, nor are these models trying to estimate what the health of the population or the cost of health care will be in 25 years. What the models are doing, he explained, is playing out the consequences of actions taken now to see how long and how strong those effects can be and what the general trajectory of their effects might be relative to a clearly defined status quo scenario. "The purpose for building the model is to ask if it is within our latitude of influence to change present circumstances," Milstein said. From the users' perspective, these models enable them to think about the how the choices that they make today may play out over a long period of time. "My understanding is that this is a valuable perspective for leaders to have," Milstein said.

A workshop participant from the National Association of County and City Health Officials, commenting on the widespread use of data by local health departments to improve public health and the time limits of those data, asked the panel to talk about the challenges and successes they have experienced in gathering the data needed to support models at the community level. Milstein said that the issue of getting the right kind of data at a regional level in a timely manner was something that those at ReThink Health were very conscious of when they began constructing the organization's model. The discipline that goes into building such a model is intertwined with how the model represents phenomena, and that representation depends on having data. "Everything that ends up in the model has to be linked to evidence," Milstein said. It is the case, he added, that there is a great deal of information and uncertainty in the available data, including experiential data that have not been formally documented but that can provide valuable information about how these systems tend to work and how they have been changing over time. Milstein also said that the ReThink Health model maps data from more than a dozen dif-

ferent sources into a common framework, and as such, it does not rely on one dataset. For example, though the goal is to get as much local data as possible, the ReThink Health model also uses datasets from state and national sources, and it makes demographic adjustments that are subjected to uncertainty analysis to fill gaps at the local level. Fortunately, he noted, the health area is a data-rich environment. "That does not make for perfect models, but it does make for well-informed ones," he said. Having said that, Milstein added that there is a need for more consistent longitudinal data, and he said he hopes that as modeling gains more traction, it will create a demand for better longitudinal datasets.

Addressing a question from Russo about whether ReThink Health uses data from the community, Milstein said that he would never start a modeling project without access to community data, but that there is always a need to turn to other data sources for data elements that are not available locally. In California, for example, the enhanced California Health Interview Survey is a rich and valuable source of information for representing cities in that state. He added that if a region is systematically different from the state average for some reason, his team can address that using local data. As a final comment, he emphasized that the lack of data is not an excuse to not model.

Jeffrey Levi from the Trust for America's Health commented on the lack of data that are collected on the effectiveness, value, and cost of interventions and asked the panelists what type of standardized information they would like to see gathered by federally funded and philanthropically funded studies collect so that their models would be more robust. Mendez replied that one of the important data gaps in tobacco control concerns how people transmit smoking behavior and how people communicate their intent to quit or to engage in smoking. "These social networks are becoming more and more important in order to study this area of tobacco control," Mendez said. "We are looking at the landscape that is much more heterogeneous right now and is much more complex, and we don't have a good dataset that would inform how these interactions are going to play out." Milstein added that almost every part of the model and modeling process could be better informed, but that when it comes to representing initiatives and what-if scenarios, his wish list for better data would include information on the cost to implement specific innovations, the extent to which they were actually implemented, and the percentage of the population they reached.

Staying on the topic of data gaps, Robert Grist from the Institute of Social Medicine and Community Health said that one area that had not been mentioned so far was the lack of data on the political constraints that affect interventions. "I am wondering how modeling can begin to incorporate political factors that influence the kinds of interventions that

are considered politically realistic," Grist said. "In the absence of that kind of information, I am not sure we are going to get the kind of political accountability that we would need to change the system in ways that would promote public health." Pascual replied by asking if there would be a way of coding this kind of unstructured information so that it can be captured in one of his models. Mendez said that there is no formal way to incorporate the type of feedback that can influence decision making through the lens of a political agenda. What is possible is to conduct some type of sensitivity analysis with regard to possible delays in implementing a policy. Patrice Pascual from the Children's Dental Health Project spoke of a recent modeling project she was involved in that examined ways of reducing cavities early in childhood. Those running the project dealt with the political ramifications of the model's findings by taking those results to the community and letting the members of the community think about the political ramifications of the different pathways the community might take to achieving a goal. As the final comment in the discussion, she noted that this approach speaks to the comments from Victor Dzau about taking results to the community and letting the community take action.

4

What Would Public Health Decision Makers Like from Models?

This portion of the workshop first featured a context-setting presentation by Gary VanLandingham, Director of the Pew–MacArthur Results First Initiative, in which he gave an overview of that initiative. After that the workshop participants broke into four groups to discuss what modelers working in four different areas of public health would most want from models. The four areas were

- health risk factors, such as obesity and substance abuse;
- natural and built environments, including air and water quality, transit, and housing;
- social and economic conditions, including such factors as education, income, and discrimination; and
- integrated health systems, including such influences as community conditions and available clinical services.

Rapporteurs from each group presented the main points identified during the group's discussions, and an open discussion moderated by Steven Woolf, a professor of family medicine and population health and the director of the Center on Society and Health at Virginia Commonwealth University, followed the report-outs. Box 4-1 contains highlights from these presentations and discussions.

BOX 4-1
Points Highlighted by the Individual Speakers[a]

- To have the maximum impact on policy decisions, modelers need to engage in ongoing outreach and training with budget staff and legislators. (VanLandingham)
- Solving the problem of disseminating research findings is essential if the goal is to have more research available for better understanding which programs work and which ones do not. (VanLandingham)
- If a model simply tells stakeholders what they think they already know and provides no new insights, then it has not made much of a contribution to the decision-making process. (Miller)
- There is an expectation of certainty in the public sphere, and the modeling community needs to reinforce the message that models are decision helpers, not decision makers. (Lane)
- There is a need to humanize models for the policy community, to express the output of models in terms of real people and real lives in ways that can grab the hearts and minds of policy makers. (Macchione)
- Using health and wellness in all policies as a tool forces stakeholders to look at these issues through many lenses and helps identify the essential data elements that need to be collected to create models that are as robust and useful as possible. (Macchione)
- Involving community members and policy makers early in the modeling process and developing strong communication channels among all stakeholders are keys to creating trust in the models and acceptance of the findings. (Lane, Macchione, Miller, Russell)

[a]Points identified during the presentations and discussions; the presenters to whom statements are attributed are indicated in parentheses.

MODELING EVIDENCE-BASED PROGRAMS IN MULTIPLE POLICY AREAS[1]

The goal of the Pew–MacArthur Results First Initiative, a joint program of the Pew Charitable Trust and the John D. and Catherine T. MacArthur Foundation, is to bring modeling into the public arena in a way that makes sense given today's political dynamic. To do that, Gary VanLandingham said, it will be important to answer in real time the toughest questions that policy makers have covering a wide range of issues. The challenge with traditional modeling, he said, has been that it only answers pieces of a question, while policy makers want more inclu-

[1]This section is based on the presentation by Gary VanLandingham, Director of the Pew–MacArthur Results First Initiative, and the statements are not endorsed or verified by the Institute of Medicine.

sive answers because of the limited time they have to make decisions and their desire to avoid political conflict.

Once a program gets created, VanLandingham explained, it tends to go on autopilot, and little attention is paid to what it is accomplishing until some crisis develops. "When a crisis occurs," he said, "what policy makers think about is what else they can do now in addition to everything else they are doing to try to get the inflection that they want to have. "What Results First is trying to do is step back and ask the questions, 'What are we doing now?' 'Does it make sense to do these things?' 'Are there other opportunities that research has shown to be effective?'" By answering those questions, he said, Results First hopes to help policy makers make decisions in a much more informed way than they have been able to do in the past.

Results First has been focusing on states and equipping them with the ability to answer questions in a more comprehensive manner using data from real-world programs, VanLandingham said. Results First has been using data in national research clearinghouses relating to a number of policy areas as well as the work of the Washington State Institute for Public Policy, which has been developing a portfolio-based cost–benefit analysis model over the past 15 years, focusing on outcomes and return on investment. Currently, Results First can assess interventions in some areas of health care as well as interventions for adult and juvenile justice, child welfare, substance abuse, mental health, and education ranging from early education through 12th grade. Program leaders are starting to explore expanding into the public health arena to help inform decisions there as well.

The general approach that Results First takes, VanLandingham said, is to start with the best research from evidence-based programs that identifies what works, use econometric models to understand what happens in terms of effect sizes, and then use those results to predict the impact of a large variety of interventions, again using the same econometric modeling methods. The goal, VanLandingham said, is to give policy makers an apples-to-apples comparison of what happens if they take one course of action versus another within a given policy environment. If a policy maker is concerned about rising crime rates, for example, the model provides a comparison of different interventions that have been shown to reduce recidivism in other places in the United States and estimates what their effect might be in that policy maker's state. Results First lets policy makers identify how they will spend their money, given what is known about the possible interventions and what the possible return on investment will be. This information is supplemented by an analysis of currently funded programs that are matched against the national evidence base, recognizing that there is a continuum of evidence about a given program's effectiveness.

"Unfortunately, there are programs that we know about that make things worse, and there are homegrown programs that nobody knows anything about," VanLandingham said. "The question that we pose to policy makers is if they are happy with putting half of their money into interventions if nobody knows if they are working when there are other programs out there that we can predict will work." That is not to say that Results First advocates against homegrown programs, he said, but it does ask policy makers to test them and subject them to the same assessment that other programs with known effectiveness have gone through so that they can feel confident that they are getting the best return on their investment.

To illustrate the kind of analysis that the Results First program generates, VanLandingham discussed an assessment of community-based functional family therapy for juvenile offenders. The best research available shows that children who go through this program have a number of positive outcomes and that crime drops an average of about 22 percent after the program has been completed. Children who go through this program are more likely to graduate from high school, which in turn means that they are more likely to be employed, have health insurance, and have lower health care costs (see Table 4-1). On average, this program generates more than $37,000 in benefits per child at a cost of just more than $3,300, for an 11-fold return on investment, which VanLandingham characterized as a good deal for a state. The question, though, is how this compares with other options for dealing with youth offenders.

The Results First team looked at 10 additional programs and ranked them by their cost–benefit ratio (see Table 4-2). Some of these programs,

TABLE 4-1 Cost–Benefit Analysis for Community-Based Functional Family Therapy

Outcomes from Participation	Amount	Main Source of Benefits
Reduced crime	$29,340	Lower state and victim costs
Increased high school graduation	$9,530	Increased Earnings
Reduced health care costs	$398	Low public costs
Total benefits	$37,587	
Cost	$3,333	
Net present value	$34,254	
Benefits per dollar of cost	$11.28	

SOURCE: VanLandingham presentation, April 9, 2015, based on benefit–cost data reported by the Washington State Institute for Public Policy (see http://www.wsipp.wa.gov/BenefitCost [accessed September 25, 2015]).

TABLE 4-2 Cost–Benefit Analysis on a Portfolio of Programs Aimed at Juvenile Offenders

Programs	Cost	Long-Term Benefits	Benefit/Cost Ratio
Adult Programs			
Cognitive behavioral therapy	$419	$9,954	$24.72
Electronic monitoring	$1,093	$24,840	$22.72
Correctional education in prison	$1,149	$21,390	$19.62
Vocational education in prison	$1,599	$19,531	$13.21
Drug court	$4,276	$10,183	$3.38
Domestic violence treatment	$1,390	–$7,527	–$4.41
Juvenile Programs			
Aggression replacement training	$1,543	$55,821	$37.19
Coordination of services	$403	$6,043	$16.01
Drug court	$3,154	$11,539	$4.66
Scared Straight	$66	–$12,988	–$195.61

SOURCE: VanLandingham presentation, April 9, 2015.

such as cognitive behavioral therapy, are relatively inexpensive to implement and provide good outcomes, while others, such as Scared Straight, are relatively inexpensive and produce terrible outcomes. "Scared Straight is a very good program if you are trying to increase crime," VanLandingham said. "Research shows kids that go through that program are more likely to commit crime and more likely to commit more serious crimes than kids we leave alone." He added that the message to policy makers is that there are some programs they fund that simply do not make sense.

The model allows the users to do what-if scenario testing using Monte Carlo simulations which produce a probability distribution for achieving a positive return on investment. VanLandingham noted that sometimes there are political reasons for choosing one program over another, but the goal of the Results First program is to make a compelling case for not making bad policy decisions.

Results First has been testing its models for 3 years and is now working with 17 states and 4 California counties to build their own capacity for conducting these analyses in an ongoing manner. Over the past 2 years, five states have moved about $80 million in funding, both new money being spent on programs that have been shown to produce positive returns on investment and also money reallocated from programs that produce negative or small impacts. In at least some cases, these

poorly performing programs are not working because they have been implemented poorly. "This is trying to pay attention to the fact that implementation matters in evidence-based programs," VanLandingham said.

He reiterated that the main focus to date has been at the state level because the actions that states take have significant real-world impacts. He also noted that Results First recognizes that there are real challenges in bringing modeling into the policy process, and he said that the program's strategy is to put these models in front of the people who are actually making policy, such as those in state budget offices and state legislative research offices. He noted that the best people to work with are those who have honest broker status and who have the technical skills required to look at the results of these models and understand their implications. Another reason for working with people inside the process is one of timeliness—these reports have to be ready when policy makers are making their choices, not a week later. To have the biggest impact, VanLandingham and his colleagues have found that they have to engage in ongoing outreach and training with staff and legislators.

In his final comments, VanLandingham offered a few ideas for making modeling easier. His first suggestion was to identify what is known about these interventions and to encourage the research community to look at outcomes and not just implementation. Results of studies that are properly powered are applicable on a bigger scale. There is also the issue of dissemination. "Good outcome studies often never come to the attention of people who could use them because the results only go to funders," he said. "They do not go out to the research clearinghouses, and they are not published for a variety of reasons." Solving the dissemination problem is essential if the goal is to have more research available in order to better understand what programs work and which ones do not. Better coordination between the research and modeling communities will enable research programs to generate the data that modelers need to convince policy makers that a program is worth doing. For example, program evaluations rarely include information about implementation cost.

In response to a question from Catherine Baase about how Results First selected which states to work with, VanLandingham said that when the program started 4 years ago he and his colleagues made presentations at policy forums such as the National Conference of State Legislatures and the Council of State Governments and then asked anyone who was interested in participating in the program to get in touch. At first, he and his team worked with anyone who expressed an interest, but now there is a much more rigorous selection process which requires a formal invitation from a state that is willing to make a high-level policy commitment, such as a letter of invitation from the governor and presiding officers of the

legislature. "We think it makes more sense to have exemplar states than to be in 50 states and 400 counties," VanLandingham explained.

The long-term plan for the program is still unclear. "We think this is where the field needs to go, and we think that the technology is available now and the research is available now," VanLandingham said. What he and his team are doing now is trying to develop the best plan to move the field to embrace modeling. "My goal is at the end of the day that people will not think about putting money into a program without asking the question of what is going to happen and to make better choices on how to spend limited amounts of money to meet big needs," he said. "We are seeing our best states asking those questions now, and what we want to see is for that to happen across the country."

REPORTS FROM THE WORKING GROUPS

After VanLandingham's presentation participants broke into four working groups to explore how modeling could be used to inform population health decisions. As noted earlier in this chapter, the four working group topics were

- health risk factors, such as obesity and substance abuse;
- natural and built environments, including air and water quality, transit, and housing;
- social and economic conditions, including such factors as education, income, and discrimination; and
- integrated health systems, including such influences as community conditions and available clinical services.

The following sections recap the comments of the working group rapporteurs who summarized what they had heard from the individual working group to which they were assigned.

Before the working groups began their discussions, Steven Woolf from the Virginia Commonwealth University provided some guidance to the participants. He said that the overall objective of the discussions was to identify opportunities, barriers, and innovative approaches for using modeling to inform population health. The objective for decision makers and population health researchers was to gain a better understanding of where and how modeling could be a useful tool to inform decisions and identify data and research needs. The objective for modelers was to gain a better understanding of where models are needed in population health and of the complex nature of the priorities in the field. The groups were provided with a list of starter questions, including

For policy makers and population health researchers:

- What are the main evidence gaps you encounter? Where do you need more support to inform your decisions, and where would the results from quality modeling exercises help you, both with making decisions and with relaying to others the importance of a potential decision?
- What are your concerns about using models?
- What is intriguing to you about using models?
- If you have used models, how have they been useful to you?

For modelers:

- Based on the expressed needs of the policy makers and researchers, how do you think modeling could be helpful?
- What information would you need from policy makers and researchers?
- What types of data (both qualitative and quantitative) would you need?
- How resource intensive (in terms of both funds and human capital) should the modeling be expected to be?
- Are there models that could be developed relatively quickly for these issues, or would they be a long-term endeavor?

During his comments Woolf asked the groups to make note of data gaps and barriers, of communication requirements and challenges, of ideas on how to build trust in results and capitalize on the information from models to drive change, and of opportunities for policy makers be involved in the modeling process.

Health Risk Factors—Report Back[2]

George Miller, a fellow at the Altarum Institute's Center for Sustainable Health Spending, presented the report from the health risk factors group. He showed a "value per effort" graph (see Figure 4-1) that illustrated the idea that as models become complex, it takes more time and effort to create them and that, up to a point, the additional time and effort provides more value. At some point, however, a model becomes so complex that it loses transparency and, as a result, no longer provides what good models should—valuable insights about the modeled system rather than simply a numerical output.

[2]As summarized during the activity by participants and rapporteur George Miller, fellow, Altarum Institute.

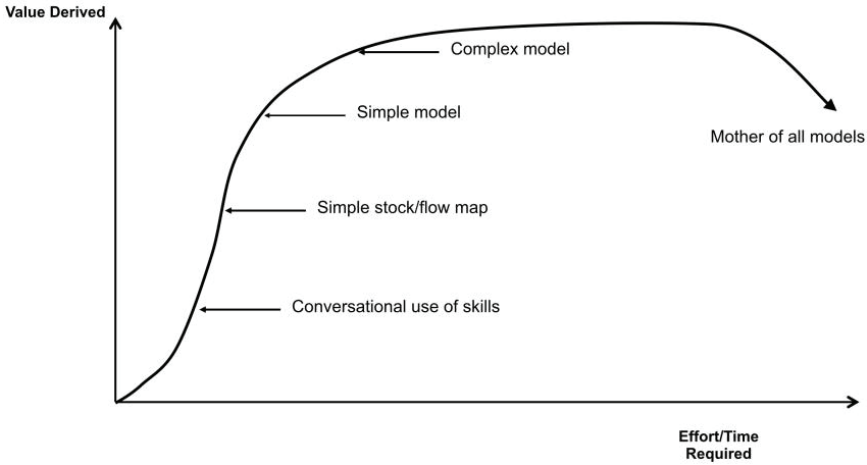

FIGURE 4-1 Value-per-effort graph for model creation.
SOURCES: Peterson, 2003, used with permission; Miller presentation, April 9, 2015.

To stimulate the group's discussion, Karen Minyard from the Georgia Health Policy Center prepared a list of guiding principles for modeling health risk factors that Miller said would also be good guiding principles for modelers to remember when working with decision makers. This list highlighted the fact that models, which are tools to enable thinking about complex systems, are most effective, accepted, and useful in catalyzing change when the following factors hold

- the purpose for using a model is clearly identified and supported by the client;
- it is developed in a collaborative process among the modeler, the stakeholders, and the subject-matter experts;
- the model is as simple as possible, but no simpler;
- it can be tailored to the readiness and level of engagement of the participants as well as to the goals and outcomes of the process;
- the modeler or facilitator has the adaptive and technical skills to use these tools; and
- the model is used as part of a larger change process.

One point made during this group's discussion about readiness and engagement was that sometimes there is no need for a model, as in the case when there is strong empirical evidence for a decision and the decision makers are onboard. At other times, there may be a great deal of information available about a potential intervention, but a model can

help organize that information and coordinate it in a way that allows the various stakeholders to share a mental model about how that information interacts. Another point raised during the discussion about models needing to be part of a larger change process was that decision makers need to be able to understand a model's output in the context of their environment and their experiences. Miller noted, too, that if a model simply tells stakeholders what they think they already know and provides no new insights, then it has not made much of a contribution to the decision-making process. "I think there is a tradeoff between making sure that the results are understandable and having the richness that will provide new knowledge as well," he said.

Several members of the group commented that modelers need to know how to talk to stakeholders and decision makers—and, in particular, to know how to translate the results of their modeling for these audiences. It is also important for modelers to be good listeners, Miller said. Solving the right problem, one that matters to stakeholders and decision makers, is important. For example, if a model shows what an intervention might do to change a risk factor, but what the decision maker wants to know is what the economic impact of that intervention will be, then the model has not gone far enough to support a decision.

When the discussion turned to changing health risk factors, the point was made that models can show decision makers how to trade off interventions in different sectors. Miller said that this is particularly true for upstream population health interventions. In part, the need to inform decision makers about these trade-offs results from the way that legislators work, which is to make decisions about where to invest in different sectors such as health, education, and transportation, but it also arises from the fact that these upstream interventions will interact with one another to affect population health in complex ways that a model might help policy makers understand.

The group engaged in some discussion about the interest and importance in understanding the longer-term impacts of some of the interventions, particularly those that operate on a population health level, where much of the value comes over the long term. There is, however, a trade-off between short-term and long-term concerns because legislators have to worry about budget cycles and therefore have a shorter-term focus, Miller said. It was noted during the group's discussion that models tend to discount the future, which is appropriate because it is more difficult to understand the distant future than the near future. One member of the group did point to an example of a legislator who used model results to have the courage to make recommendations for a long-term investment which might not have otherwise been made in the usual context of having to worry about short-term budgets. There was also some discussion

concerning diabetes prevention, with the suggestion made that modeling efforts could focus on upstream interventions that occur even before the pre-diabetes stage of disease development.

Natural and Built Environments—Report Back[3]

J. T. Lane, the assistant secretary for public health for the State of Louisiana, who served as the rapporteur for this natural and built environments work group, said that two themes had emerged from this group's discussions: (1) Modeling has proven that it is reliable for examining long-term problems and concerns, and (2) there are limitations when it is applied to more immediate needs, such as modeling an infectious disease outbreak as it occurs. Several members of this discussion group noted that the modeling community needs to develop better tools for immediate-term situations. The development of such tools could lead, for example, to a future in which American families turn on the morning news to get the day's influenza forecast, just as they now get the day's weather forecast.

Much of the group's discussion regarding barriers focused on regulatory issues, but some group members also noted that there are resource gaps in terms of trained individuals and finances for governments and organizations that still need to adopt modeling. There may be opportunities to address both of these resource gaps, Lane said, by developing partnerships between these organizations and academia. Educating the policy community and the public about the use, value, and limits of modeling is also important. Lane said that one thing he has learned as a state health official is that policy makers often want to move forward on an initiative in large part because of the projections or modeling activities that they have been privy to, but that there is still a need to spend the time to go out to the public, sell that idea, and explain what the model means and does not mean. Part of that sales job includes educating members of the public about the model so that they can understand how policy makers decided that an initiative will serve the public good and will provide a good return on investment. The last barrier identified during the discussion by several group members was one of high expectations—that is, that there is an expectation of certainty in the public sphere. To address this, some group members said, the modeling community ought to reinforce the message that models are *decision helpers*, not decision makers.

The group discussed the possibility that models may be stifling innovation because they are based on evidence accumulated from projects that have already been completed, rather than challenging convention. Even-

[3]As summarized during the activity by participants and rapporteur J. T. Lane, assistant secretary for public health for the Louisiana Department of Health and Hospitals.

tually, however, several members of the group noted that models can in fact serve as a source of innovation because once a model becomes robust enough, it becomes possible to change the model's assumptions and system features to incorporate novel ideas and test new theories. Another opportunity identified, Lane said, would be to use models to develop priorities for collective future action and benefit to communities and to explore more deeply and systematically whether it would be possible to model the effects of social and cultural values on health concerns. One example given was to examine burial rights in West Africa and the impact of that cultural practice on the spread of Ebola. Lane characterized this challenge to the modeling community in this way: How can we modify our models in a scientifically sound way to account for, quantify, and give value to cultures and beliefs in society and thus make our models more accurate and responsive?

Social and Economic Conditions—Report Back[4]

Nick Macchione, the director and deputy chief administrative officer for the County of San Diego's Health and Human Services Agency, served as the rapporteur for the social and economic conditions working group. This group first discussed data needs, he said, concerning the social and economic enablers of health, the relevant data need to be collected from many different sectors. Some participants in the group suggested that the modeling community could capitalize on opportunities for capturing and using "big data" and that the open-source data movement offers some great opportunities to address data gaps. At the same time, modeling may be able to help consolidate and make sense of data from disparate sources.

One concern that Macchione voiced from his perspective as a policy maker is that there is a need to humanize models for the policy community, to express the output of models in terms of real people and real lives that can grab the hearts and minds of policy makers. This is particularly true, he said, for the human services area which deals with emotional and life-threatening issues such as child and spousal abuse.

When the group discussed the types of models needed, several participants in the group noted that the social and economic conditions area needs models that compare interventions as well as models that look at the synergies of multiple interventions. To address this latter need, the community could involve experts in systems science. Individual partici-

[4]As summarized during the activity by participants and rapporteur Nick Macchione, director and deputy chief administrative officer for the County of San Diego's Health and Human Services Agency.

pants in the working group shared questions that could benefit stakeholders and modelers in setting goals together:

- What are models needed for in the domain of social and economic conditions, given that this is an emerging area for modelers?
- Is modeling a barrier to adopting necessary decisions in this area?
- What common features of models can be borrowed from other, more developed areas of modeling?

One of the issues that the group discussed was how to sustain a great model once it has been implemented, given the funding environment in most state and local governments. One solution, Macchione said, might be to use open-source models, something that his office and public sector policy groups across the country are currently examining. Communication is another issue, he said, particularly with regard to policy makers' expectations and their tendency to look at the short term rather than the long term. Many policy makers would like models that can be developed quickly. The fact that not all models are interactive is a problem—simply handing policy makers a model's output has limited impact—and moving toward an interactive standard would be beneficial, even though it would also be challenging.

Several members of the group commented that modeling can help bridge gaps across different professions, which generally each have their own educational background, intellectual biases, and approaches to problem solving. Modeling can also make it possible to have conversations across professional cultures, though several members of the discussion group said there is a need for translators who can move among subject matter experts, modelers, and policy makers. There was some concern within the group that the field may need to pay more attention to the core competencies of those translators in terms of how well they can translate science and communicate, convene, and influence conversations among the different constituencies.

Skepticism about modeling is a potential barrier, and addressing it will require that modeling becomes more formalized to ensure trust. The field would also benefit if modelers better communicated what they have done to ensure the quality of their models. As some of the workshop's presentations had highlighted, some members of the discussion group said that it is important to engage stakeholders early in the modeling process to increase transparency. Well-trained translators can serve an important role at this stage by helping to bridge the language gap that can work against transparency.

Concerning next steps, several participants in this group stressed the importance of starting the modeling process by engaging the policy-

making community and other stakeholders to identify the questions that need answering and to think hard about where and how modeling can have an impact in this area. Some members of the group said that using health and wellness in all policies as a tool forces stakeholders to look at these issues through many lenses and helps them identify the essential data elements that need to be collected to create the most robust and useful models. Macchione added that modeling in the domain of health and human services could also be useful in helping identify causal pathways, which might be more concrete to a policy maker.

Integrated Health Systems—Report Back[5]

The final working group's report was delivered by Louise Russell, a distinguished professor at the Institute for Health, Health Care Policy, and Aging Research and the Department of Economics at Rutgers University. Russell said that this group's discussion hit on many of the same themes as the other groups did. She recounted two examples that group members discussed which illustrated some of the challenges that come with modeling. The first example involved work on breast cancer screening by the U.S. Preventative Services Task Force. Based on simulation modeling of different screening strategies, the task force recommended a change in the guidelines for breast cancer screening. However, Russell noted, the public's reaction was almost uniformly negative, illustrating the importance of education and the need to involve all stakeholders early in the modeling process.

The second example, explained Russell, involved a model of community action, developed and funded by the Kellogg Foundation, which had some stringent requirements on community involvement. Every program that accepted funding failed except for one, and that program succeeded because, after assessing how community involvement was to take place, it decided to return the money and not even try to use the model. This group, Russell said, realized that a community organization structure already existed and that forming a new one, which was a requirement for funding, would lead to failure.

Involving the community early before the modeling effort begins in a necessary step. Deciding who needs to be represented can be a challenging task, but it is an important one because if the community does not trust the process, the model is not going to have an impact. Once the stakeholders are identified, the next step is to bring them together

[5]As summarized during the activity by participants and rapporteur Louise Russell, distinguished professor in the Institute for Health, Health Care Policy and Aging Research and the Department of Economics at Rutgers University.

to help define the problem to be addressed, to settle on what the community wants to accomplish, and to identify the interventions that the community would be willing to consider implementing.

When developing systems models, it is necessary to draw boundaries about what to include in these models and, again, to involve all stakeholders in this decision. The real question, Russell said, is what the people involved want to see from a model. "Every model is a simplification," she said, "but what simplifications are they willing to live with and what are the things that stakeholders think absolutely must be in the model?"

Another key point raised by some members of this group was the importance of timing in implementing a new intervention. For example, a model may find that a particular intervention will be far more effective than the one currently being used, and both policy makers and stakeholders may agree to end the current program and start the new one. In the real world, however, programs do not suddenly end, and new programs do not begin at full speed, There is usually a period which models do not consider when a new program is being put in place and the original program is being phased out, and the existence of this period means, among other things, that funds and resources cannot be shifted immediately from one program to the other.

This group also discussed the importance of establishing good channels of communication among modelers, those who inform models, and the public, particularly with regard to the mental models that members of the public already have in their own heads, such as the public's model for breast cancer screening. In that case, the public's model assumed that early screening for breast cancer was always good and that screening was nearly perfect—ideas that experience with widespread screening had called into question. The scientific evidence about early detection and screening needed to be communicated to the public before putting that evidence into a model, Russell said. That meant, once again, sitting down early with stakeholders to determine the common knowledge base and where knowledge gaps existed. Some participants in the group did note, though, that the public is coming around to the task force's recommendation on breast cancer screening, and it is likely that putting out its recommendation based on modeling started a necessary conversation.

The last point brought up during the discussion was that it is possible to start the conversations with stakeholders in a harmonious rather than a confrontational mode. One way to do that would be to start the conversation with a conceptual model and an overview of the scientific evidence supporting the model.

DISCUSSION

Steven Woolf started the discussion session by making an observation that he said he suspected almost everyone was thinking. He had expected, he said, that the key challenges brought up by the group members would have been about technical and difficult methodological problems and complicated data infrastructure issues that need to be addressed if modeling is going to be exploited to improve population health. Thus, he said, he was surprised by the degree to which all of the groups had emphasized the need for increasing the engagement of stakeholders in the community and the importance of communication in successful modeling. "I think we often give lip service to this point," he said, "but I think part of what I'm hearing is there's a need to take this to the next level in terms of sophistication." Woolf likened this situation to that of patient engagement and patient-centered care. People talked about these issues for years, he said, but it was not until funders such as the Patient-Centered Outcomes Research Institute started taking that discussion to a new level of sophistication that serious and genuine engagement started to occur. The thesis he heard from the four working groups, Woolf said, is that efforts to use modeling to improve population health have to get serious about engaging stakeholders at the very beginning of the process, getting them to define the problems that need addressing and to decide whether a model is even needed, and then keeping them engaged throughout the process.

David Kindig from the University of Wisconsin noted that all of the discussion so far at this workshop had been about models in the public policy sector, and he said he wondered if there were any examples from the private sector, particularly from private health care organizations, that could contribute to the public health area. Russell said that she does not know much about the models that corporate America uses for health care decisions because they do not make them public. Macchione said that the Building Industry Association in San Diego—as well as the San Diego Association of Governments—has done economic modeling to identify the impacts of the construction industry's activity on the economy, job growth, and crime in the areas in which it is building. He added that he knows of many examples of modeling in the private sector but said that he has not studied those models other than to know that private sector entities use them in what they call "business engagement." Business engagement is very similar to the community engagement discussed at this workshop in that business get their end users involved in their modeling projects to make sure that they are looking at the right problems and to achieve the most efficient and effective solutions.

George Isham commented that he believes there is an opportunity with regard to community benefit investment decisions that are made by hospital boards of directors and chief executive officers to get some

estimates of returns that could then be used in models. "That would be a very specific example and tangible example of private policy making or decision making," Isham said, adding, "We use the term 'policy making' to refer typically to legislators and governmental policy making, but the premise of the roundtable is that the task of improving health in the country is so complex that it is multi-sector and it requires private policy making as well as public policy making if we are to see an impact." Along those lines, it is important, Isham noted, to educate private boards of directors that the prevailing mental model of health—which assumes that health and health care are the only two factors involved—is not correct and that health care accounts for only 20 percent of the contributors to health. Getting boards of directors to understand this reality could change the way that they construct their business models to reach beyond health care delivery into the community to form partnerships to address the other 80 percent of the factors that influence health.

Isham then wondered if there is a way to use this broader mental model to think about the research and rigor needed to model the relationships between education and health—for example, to influence investment decisions by both the private and public sectors. Rajiv Bhatia from the Civic Engine said that while the health care industry is investing a great deal of money in analytics and predictive modeling, it is notable how little of that modeling is focused on upstream population health risks. His conclusion from this situation is that the health care industry does not yet see population health to be an economic risk.

The final comment in the discussion came from Pamela Russo, who wondered if the reason that public health is "behind the curve" in using models to influence policy, other than in the area of tobacco control, is that there is a higher bar for rigorous evidence in public health policy than in other areas, such as economic modeling. Russell responded that the models used for policy making in areas other than health are reviewed just as rigorously.

5

Barriers and Opportunities for Using Models to Inform Population Health Interventions and Policies

The workshop's next panel session featured three presentations looking at some of the circumstances in which modeling is used and the kinds of barriers and opportunities that arise when people start using these tools to help make public health policies. Michael Weisberg, an associate professor and the graduate chair of philosophy at the University of Pennsylvania, spoke about the nature of evidence with regard to modeling and how models are validated for use as decision-making tools. The team of Karen Minyard, the director of the Georgia Health Policy Center at Georgia State University's Andrew Young School of Policy Studies, and Representative Sharon Cooper, the chair of Health and Human Services for the Georgia House of Representatives, then addressed the need to improve communication about the usefulness of models to policy makers. (Box 5-1 offers highlights from these presentations.) An open discussion moderated by Bobby Milstein followed the three presentations.

MODEL VALIDATION AND DECISION MAKING[1]

As previous speakers had stated, Michael Weisberg said, all models are approximate and idealized, but nonetheless the goal is to use these less-than-perfect models to generate truer theories or to produce more

[1]This section is based on the presentation by Michael Weisberg, associate professor and graduate chair of philosophy at the University of Pennsylvania, and the statements are not endorsed or verified by the Institute of Medicine.

BOX 5-1
Points Highlighted by the Individual Speakers[a]

- Models can generate interesting theories, but the key question is whether those theories tell a truth about the system, which requires that a model's output be reliable and valid. (Weisberg)
- It is important not simply to accept the results of one set of simulations on a model but rather to poke and prod a model to see where it fails. (Weisberg)
- Combining health policy content with a system dynamics–based approach to education can change the way that legislators frame issues, ask questions, build understanding, and develop and weigh solutions to complex health care issues. (Minyard)
- When working with state legislators, whose knowledge about public health issues can range from none to extensive, it is important to start with a simple example of modeling and build from there. (Cooper)
- Modeling can provide the opportunity to bring people together and give them the space to think about a problem and discover that there is a bigger area for agreement on policy issues than might have been presumed. (Milstein)

[a]Important points identified during the presentations and discussions; the presenters to whom statements are attributed are indicated in parentheses.

accurate information about the world. Weisberg said that he thinks of the practice of modeling as a form of surrogate reasoning, or an indirect representational analysis of some real-world target using a model. To illustrate how a computational model works, he discussed one of the earliest examples in which a model was used to learn something about a community—in this case, Philadelphia.

The population of Philadelphia is quite diverse, being composed of approximately 40 percent African Americans, 40 percent Caucasians, 10 percent Asians, and 10 percent Latinos. However, when looked at by individual census tract, Weisberg said, Philadelphia is not diverse at all and is actually quite segregated, as are most Northeastern cities. A demographic diagram known as an exposure index shows that in Philadelphia a Caucasian has a 75 percent chance of having Caucasian neighbors, while an African American has a 75 percent chance of having African American neighbors. A simple model called the Schelling's model of segregation can reproduce this pattern, and it was one of the first agent-based models.

One explanation of this demographic pattern is that racism is to blame, but Schelling imagined a different reason, Weisberg said. Schelling started with the assumption that people are either happy or unhappy, and if they are happy they stay put, but if they are unhappy they move. Happiness in this case is determined entirely on the basis of who a person's neighbors

are and, in particular, by whether a person's neighbor is like that person or not. Furthermore, there is some threshold—some percentage of neighbors who are like that person—that determines whether a person is happy or not and whether that person will move or stay put. Weisberg illustrated this with a grid representing Philadelphia with yellow and blue figures distributed randomly across the grid. With a threshold value set at 30 percent, the model soon produces a gird with patches of blue and patches of yellow that represent a level of segregation of 70 to 75 percent, reproducing the data from Philadelphia. If the threshold is set at 70 percent, the model produces nearly 100 percent segregation, Weisberg said.

The Schelling model was very influential in that it guided the way people think about segregation, Weisberg said, even while acknowledging its simplicity. The key question, though, is whether this model actually reveals anything true about the social dynamics of Philadelphia or any other city. In order to determine this, one has to show that a model has been validated and that it is robust. Validity, Weisberg said, comes from establishing a fit between the model and the target, while reliability relates to how believable a model is. Validation, he explained, involves understanding how well the structures that make up a model represent the system being modeled. "We want the model to truthfully describe the target," Weisberg said, working through a series of equations characterizing the validity of a model based on which features of the real system are included in the model and how they are weighted in importance in the model compared to the real system. The weights, he explained, are related to what the experimentalist or the consumer of the model most wants to understand.

To determine reliability, Weisberg said, one can employ a process called robustness analysis, which essentially consists of looking at multiple models and seeing if they produce similar results. If models, despite their different assumptions, lead to similar conclusions, the result is a robust theorem that is relatively free of the details of the model. "We're trying to find the truth at the intersection of independent lies," is the way that Weisberg explained robustness analysis. In a sense, this is sensitivity analysis taken to a new level. In sensitivity analysis, the model's parameters are changed to see how much the model's output changes. Robustness analysis involves changing the basic structural assumptions in a model—essentially creating a new model—to see how the results change. "What we're trying to figure out is what we can get away without knowing and what do we really need to know," Weisberg said.

In summary, he said, "Put your faith in the robust results of well-validated models where you've had input into the way that the fidelity criteria are set." It is important, he added, to think not only about the question to be answered, but also about the standards of fidelity that

are required. It is important to not simply accept the results of one set of simulations on a model, but instead to poke and prod a model to see where it fails.

IMPROVING COMMUNICATION WITH POLICY MAKERS ON THE USE AND USEFULNESS OF MODELS[2]

Karen Minyard, the next presenter, began by explaining that the Georgia Health Policy Center at the Andrew Young School of Policy Studies at Georgia State University, where she works, provides evidence-based research, program development, and policy guidance on local, statewide, and national levels. What drew her and her colleagues to this work, she explained, was the recognition that legislators are not faced just with routine technical problems but also with issues that are hard to define. "There are no clear solutions, and there are no experts that can say exactly what to do," she said, "so our goal is to think about how to help legislators think about the whole picture, rather than the tip of the iceberg." From interviews that the Health Policy Center staff conducted with state legislators, it became clear that the legislators have a variety of learning needs, ranging from those who need to learn about such basic information as the difference between Medicare and Medicaid to those who want to know everything about health policy.

To meet the needs of this latter group, the center developed a Health Policy Certificate Program, which uses system dynamics and system thinking to encourage broader and more systemic approaches to solving health policy challenges. Minyard said that when the program started, the expectation was that between 10 and 30 people would want this certificate, but so far more than 130 Georgia legislators and staff have taken part in this course, and 96 have received certificates. The course has been offered four times, with a fifth scheduled for late spring 2015. The course includes core sessions about thinking systematically, health status, financing, and coverage and access. These concepts are then applied to topics that each class chooses for itself, and these topics have included financing, behavioral health, and obesity. Minyard and her colleagues hypothesized that a combination of health policy content and a system dynamics–based approach to education could begin to change the way that legislators frame issues, ask questions, build understanding, and develop and weigh solutions to complex health care issues.

[2]This section is based on the presentation by Karen Minyard, director of the Georgia Health Policy Center at Georgia State University's Andrew Young School of Policy Studies, and Sharon Cooper, chair of health and human services for the Georgia House of Representatives, and the statements are not endorsed or verified by the Institute of Medicine.

As part of the course, Minyard and her team created a six-question framework that they put on pocket cards and which they encourage legislators to ask every time someone brings a bill to them to consider supporting. Minyard said that lobbyists now ask her for the six questions so that they can be prepared before meeting with legislators. The six questions are

1. What is the important (perhaps troublesome) trend related to health in Georgia? What is the shape of this trend over the past several years?
2. Who are the stakeholders concerned about the trend?
3. Why this trend (what's the cause, what is responsible)?
4. Where is there leverage (some policy) to address the underlying cause of the trend?
5. How will it work? How will it play out over time? How might unintended consequences occur? How might the policy positively or negatively impact . . .
   a. Health status?
   b. State health spending?
   c. Health care system?
   d. Health equity?
6. When would the policy create an impact on health status? When would you see an improvement in some other indicators (i.e., spending, services)?

Another concept that the course stresses is how behavior has changed over time, leading up to the current moment, and how behavior is expected to change over time, which is intended to give legislators a better perspective on an a given issue. The use of stock-and-flow maps is another important component of the course. One of the results of using these tools with legislators, Minyard said, is that they have a much stronger appreciation for the influence of prevention programs. The first session of the course also has the participants build, test, and revise a system dynamics model of childhood obesity, which contributed to legislators passing a bill on this issue. Building the model required having enough relevant data for both building and testing the model. Policy options in the model included ensuring safe routes to school, improving school food options, improving school physical education, improving nutrition and physical activity education in preschool programs, improving nutrition and physical activity education in after-school programs, and reimbursing medical nutrition therapy for obese children insured by Medicaid.

In addition to offering this course, Minyard and her colleagues have been involved in a wide range of policy modeling projects, including

one conducted using ReThink Health's model. That project, the Atlanta Regional Collaborative for Health Improvement, went in 1 day from having no strategy to having a 28-year plan and included components on teenage pregnancy and injury prevention.

Representative Sharon Cooper then spoke about the value of the certificate program from her perspective as a state legislator and chair of the Georgia Legislature's health committee. As background, she said that the Georgia Legislature has a 40-day session, and of the 236 members in the state house and senate, only eight have any hands-on experience in health care. She also said that the state leadership has backed the collaboration between the legislature and the Health Policy Center and that she is quite persistent in getting members of the legislature to take the certificate course. Participation has been bipartisan, and the 4-day course is offered when the legislature is out of session, which, she said, is a plus, given that legislators no longer have as many opportunities to get together with members of the opposing party outside of the legislative session. "This workshop gives us a chance to talk about things that we believe in on different issues in a bipartisan way," she said.

When working with state legislators, Cooper said, the key is to start with something simple. One example that she spoke about involved modeling school-based exercise programs aimed at combating obesity. In a previous session of the legislature, a bill that would have changed the way state school boards ran school physical education programs failed to pass. During the subsequent course, the participants modeled obesity prevention, and the model showed that one of the most effective was to decrease obesity in children was to have good physical education programs in schools. Out of that modeling exercise came a legislative effort to learn why current programs were not working, and the finding was that the state education department and public health department were operating in separate silos. The legislature took action, restructuring the departments to eliminate the silos, creating new school-based physical education programs, and requiring all students in Georgia's school to have their body mass index determined. This information is provided to parents along with information on obesity and the need for physical exercise. Aggregated data are provided to the schools and to the Governor, and the schools are ranked. The result is that 530 schools in Georgia have now enacted a specific, no-cost physical education program, called Power Up 30, which covers some 300,000 students. Power Up 30 was developed by one of the schools, which had accumulated 4 years of data showing that 30 minutes of activity at the beginning of a school day increased scores in math and science and decreased behavior problems.

DISCUSSION

Milstein started the discussion by saying that one message he heard from the presentations was that a real-world challenge is how to get busy people—legislators, for example—into a place where they have the space to think about a problem and perhaps discover through modeling that there is a bigger area for agreement on policy issues than might have been presumed, given today's political realities. He then asked Minyard if she could speak more about this aspect of her program. Minyard replied that building the capacity to have conversations has been one of her favorite parts of the program. As an example she told of a time when the course ran through the stock-and-flow diagram exercise around moving from being at risk to being healthy. The participants developed a list that included exercise, she said, and one of the legislators said that he was morally opposed to the government paying for weight-loss programs. One of his colleagues pointed out that the state can either pay now or pay much more later in the form of higher health care costs. That remark became the theme for the course and the subsequent legislative session, which resulted in the bill that Cooper discussed being passed. Cooper agreed that the communications piece is critically important and noted that the Health Policy Center now offers a special course for the legislators on how to communicate and listen better to their colleagues.

Pamela Russo asked Minyard how the obesity model was developed, given the time constraints of the course. The model itself was built over the 4 months preceding the course, Minyard explained, based on input from legislators obtained at a biennial gathering of legislators held at the University of Georgia prior to the legislative session. Modelers, subject experts, legislators, staff, and translators all worked on and tested the model during that 4-month period to have it ready for the course. Cooper added that the legislature was shown parts of the model and was told how it was developed, which seemed to have a positive impact on the legislature as a whole.

Rachel Ferencik, who oversaw the model's development at the Georgia Health Policy Center, noted that the six-question framework that Minyard discussed, combined with stock-and-flow maps and other information the legislators were given, allowed the legislators in the course to use the model in an efficient and productive manner.

George Isham asked Minyard if this program could be generalized to other state legislatures, and she replied that the Health Policy Center convened a meeting at which representatives from eight states came to talk to her and her colleagues about how this type of program could be implemented in their states. "We began to understand that you might design this a little differently depending on how much staff there is, what the situation is with term limits, and what the balance of power

between the administrative and the legislative body is in a particular state," Minyard said. South Carolina has since implemented a similar program, Colorado has taken a component of the program and adapted it to its needs, and Kansas has added the program to one that it already had. Minyard noted that the Health Policy Center has developed additional, abbreviated certificate programs for the Governor's Office of Budget and Policy and the state's Medicaid office. Finally, Cooper commented that legislators are hungry for knowledge and that they are only slowly discovering the resources that are available at state-funded universities.

6

Opportunities for the Future

The workshop's final panel session focused on current work that has important implications for the future of public health policies. Darshak Sanghavi, the director of the Population and Preventive Health Models Group at the Center for Medicare & Medicaid Innovation (CMMI) of the Centers for Medicare & Medicaid Services (CMS), described some of the innovative work that his group is doing to help transform the nation's health care system. Rajiv Bhatia, the founder and director of The Civic Engine, then spoke about some of the lessons he has learned from experiences in conducting health impact assessments. An open discussion moderated by Steven Teutsch followed the two presentations. See Box 6-1 for highlights from these presentations and discussions.

OPPORTUNITIES IN PREVENTION AND POPULATION HEALTH CARE MODELING[1]

According to Darshak Sanghavi, a model is a simplified representation of a real-world situation that is used to answer a specific question, and to him, he said, this represents a kind of intelligence or an ability to take something complex and make it simple. At CMMI, he said, intelligent predictive modeling is at a premium because he and his colleagues have

[1]This section is based on the presentation by Darshak Sanghavi, Director of the Population and Preventive Health Models Group at the Center for Medicare & Medicaid Innovation, and the statements are not endorsed or verified by the Institute of Medicine.

BOX 6-1
Points Highlighted by the Individual Speakers[a]

- At the Center for Medicare & Medicaid Innovation, intelligent predictive modeling is at a premium, given the need to engage a variety of different stakeholders, including patients and policy makers, in a way that resonates, is understandable, and remains true to the facts. (Sanghavi)
- Data for predictive modeling can come from many sources, and the key is to use that data to provide feedback that will change behavior. (Sanghavi)
- Few epidemiological studies examine public policies as risk factors directly, which limits the evidence available for modeling how policies affect health. (Bhatia)
- The public health sector looks at and acts on community-level data on conditions, while the health care sector looks at and acts on individual-level data on clinical outcomes. Models for prevention and public policy could benefit from population health information systems that integrate clinical outcomes collected routinely by health care systems with individual-level social, economic, and environmental factors. (Bhatia)
- There are many areas that need attention in order to fully realize the value of models, including at the research level, where more studies are needed on the value and cost-effectiveness of interventions so that those data can be used to produce more reliable models. (Kindig)
- There is a need to catalyze culture change in health care and public health so that modeling becomes accepted, so that these communities understand how and what modeling can be used for, and so that they embrace its use. (Baxter)

[a]Points identified during the presentations and discussions; the presenters to whom statements are attributed are indicated in parentheses.

to engage with a variety of different stakeholders, including patients and policy makers, in a way that resonates, is understandable, and remains true to the facts.

One of the central themes in the workshop discussion about health care and predictive modeling was the need to make decisions based on limited information which may or not be related to the outcome of interest. Sanghavi used reality competitions on television to illustrate this point. In such competitions, the ostensible goal is to identify the most talented performer, and that is done by popular vote, but the real goal, he said, is to win advertising dollars and television viewers. In a drug trial, the ostensible goal is to help a hyperactive first-grader grow into a productive, job-holding adult, while the real goal is to find a drug that leads to improved scores on an attention deficit/hyperactivity disorder (ADHD) symptom assessment. In both cases, Sanghavi said, there is

limited information at first, but the hope is that this limited amount of information will help provide a useful prediction of what will happen at some point in the future.

This is important, he explained, because of the need to use predictive analytics to identify new incentives to move toward better health care that focuses on value and performance. Performance, Sanghavi said, is judged on the basis of meeting surrogate endpoints. For example, the real goal may be to reduce heart attacks in middle-aged men a few decades in the future, but performance is judged based on reductions in cholesterol levels. Similarly, the real goal may be for a hyperactive first-grader to be able to hold down a good job as an adult, but performance is judged based on improved scores on a symptom checklist, or the real goal is to prevent hip fractures in an elderly woman, but performance is judged according to bone density scans in perimenopausal women.

Sanghavi and his colleagues are trying to determine if judging performance on the basis of surrogate endpoints is a good strategy, given that the relation of a surrogate endpoint to the actual desired outcome may be weak or nonexistent and that an intervention can improve the surrogate outcome but also have adverse side effects. "One thing I always think about with predictive modeling is how in actual clinical care the amount of uncertainty is vast," Sanghavi said. "Given all this uncertainty, how should CMS or any major payer, deal with it in ways that enhance value through the smarter use of predictive modeling?"

One predictive model that he and his colleagues are developing—which Sanghavi said he hopes will soon be cleared for public release—is called the Million Hearts Preventive Cardiac Model, and it represents what Sanghavi called a new way of thinking about prevention. This model was developed with the aim of reducing the number of heart attacks and strokes, a goal that society has deemed important. In the past, efforts to reach this goal have relied on setting and hitting targets for blood pressure, smoking, and cholesterol, but these may not have been the best surrogates to target, Sanghavi said. For example, several different pharmaceutical therapies have been shown to reduce cholesterol levels but increase the number of heart attacks, which suggests that cholesterol level alone is not a good surrogate for heart attack prevention.

A better strategy for preventive cardiology would take into account a number of surrogates, and Sanghavi used an iPhone app, the atherosclerotic cardiovascular disease (ASCVD) Risk Estimator from the American Heart Association and the American College of Cardiology, as an example. The app uses cholesterol, high-density lipoprotein (HDL) cholesterol, systolic blood pressure, sex, age, ethnicity, smoking status, and whether an individual is being treated for hypertension or diabetes to calculate a 10-year risk for atherosclerotic cardiovascular disease. To show

how it worked, Sanghavi displayed the score for a hypothetical individual with a 60 percent 10-year risk of heart attack, and he explained that the incentive would be based on reducing that aggregate risk score, not on any of the specific risk factors that were used to calculate that score. "And because we know this is a predictive analytical model," Sanghavi said, "we know that this will correlate to the endpoint of interest over the long term. This is one of the first times that we believe that we can start to incentivize prevention in a whole different way using a predictive modeling algorithm." The strength of this model, he added, comes from the fact that cardiology is a field rich in data from extensive, well-run clinical trials, but it is his hope that this type of model will pave the way for other analytical models.

Data for predictive modeling can come from many sources, and the key is to use those data to provide feedback that will change behavior, Sanghavi said. For example, pediatric obesity is tied to inactivity, and as an illustration Sanghavi showed the data from a pedometer that his 4-year-old son wore on a trip to Disneyland and in daycare (see Figure 6-1). Seeing this data convinced Sanghavi to create more activity opportunities for his son.

Similarly, seeing the data from the ASCVD Risk Estimator provides feedback that a patient and physician can use to change behavior and lower the risk score. Having said that, Sanghavi was critical of the claims being made for the ability of statins to reduce the risk of heart attack by as much as 36 percent, when the important number to convey to patients, he said, is their absolute risk of having a heart attack (see Figure 6-2).

In his brief closing comments, Sanghavi said that he and his colleagues are developing a model that will be used to determine how best to structure accountable health communities to address problems while efficiently using resources. He also provided a link to an interactive and predictive analytical model that evaluates the spread of HIV and cost per HIV infection averted for various interventions and public health strategies in two settings, New York City and East Africa.[2]

LESSONS FROM MODELS FOR POPULATION HEALTH[3]

In the workshop's final presentation, Rajiv Bhatia discussed some of the experiences that he has had over the past 15 years of conducting health impact assessments (HIAs), which he described as a transdisciplinary decision-support practice that anticipates the health effect of

[2]See http://torchresearch.org.

[3]This section is based on the presentation Rajiv Bhatia, founder and director of The Civic Engine, and the statements are not endorsed or verified by the Institute of Medicine.

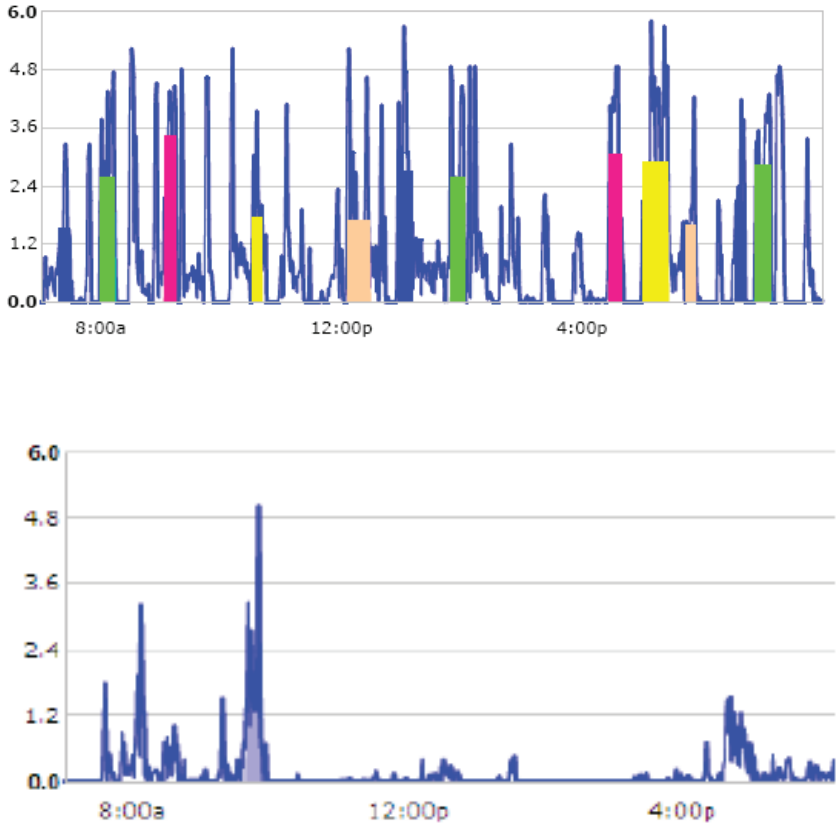

FIGURE 6-1 Pedometer data from a 4-year-old at DisneyWorld (above) and at day care (below).
SOURCE: Sanghavi presentation, April 9, 2015.

a decision prospectively. HIAs, which were started in European countries in the 1990s and brought to the United States in 1999, are intended to serve the knowledge needs of democratic decision making using a few different types of models. They use conceptual models to explain the nexus between policy and health, and they use quantitative models to quantify the effects of decision on health determinants and outcomes.

As an example of a model used in HIAs, Bhatia showed a map of areas of San Francisco with an unacceptable air pollution health risk based on the levels of airborne particulate matter found there—levels that are known to be associated with an unacceptable mortality risk—and also on the levels of airborne carcinogens, which are associated with a separate

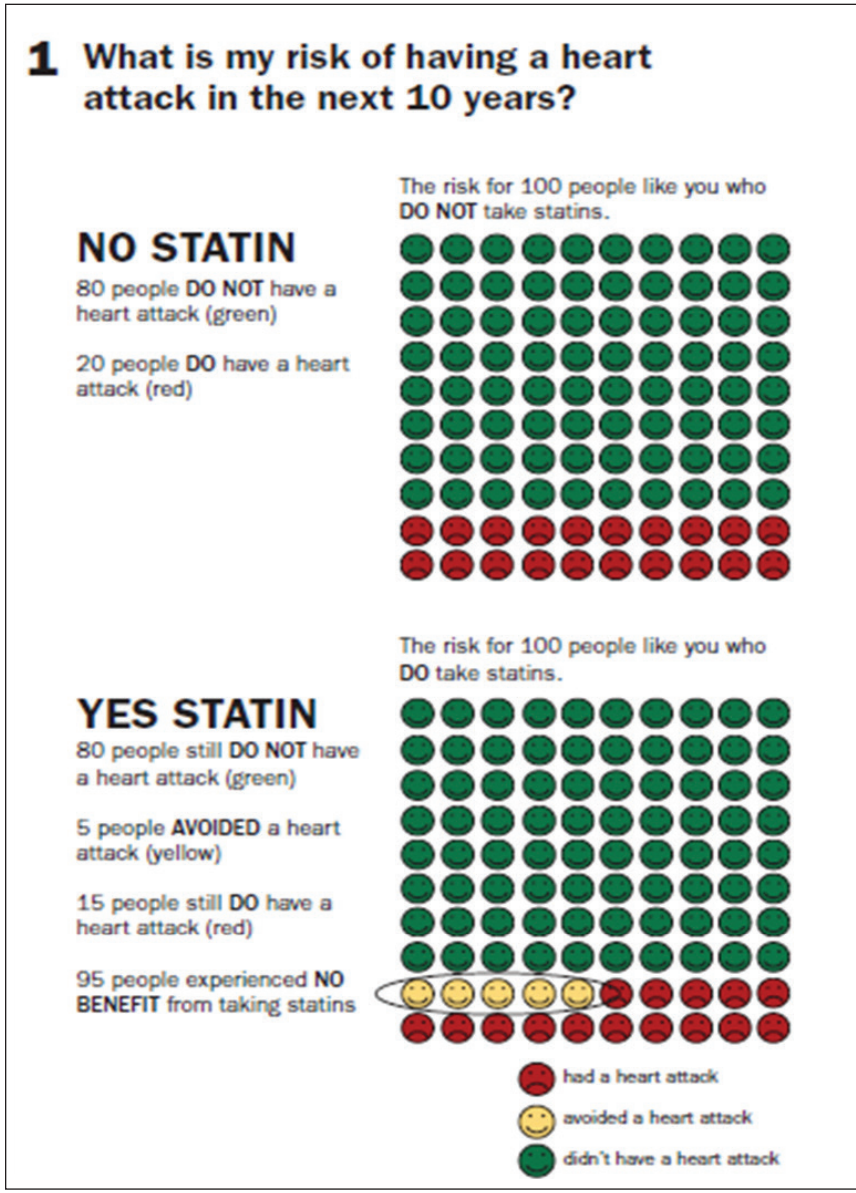

FIGURE 6-2 Information for patients showing the benefit of statin therapy on the absolute risk of having a heart attack.
SOURCES: Mayo Clinic, 2015; Sanghavi presentation, April 9, 2015.

unacceptable risk (see Figure 6-3). The model used to calculate air pollution health risks was produced by combining two off-the-shelf models, one to model air pollution and the other to translate air pollution levels into health risks. The problem that this HIA was trying to address was that in San Francisco, as in most cities, there is one air pollution monitoring station that is located far from any significant air pollution sources and that therefore cannot identify pollution hot spots. Using a model that had been developed to identify areas in San Francisco that exceeded federal and state pollution levels, Bhatia and his collaborators helped the city's planning office justify and craft a policy to prevent poor indoor air quality in new housing. With the help of the model's output, San Francisco passed the first ordinance in the country that imposed a higher standard for ven-

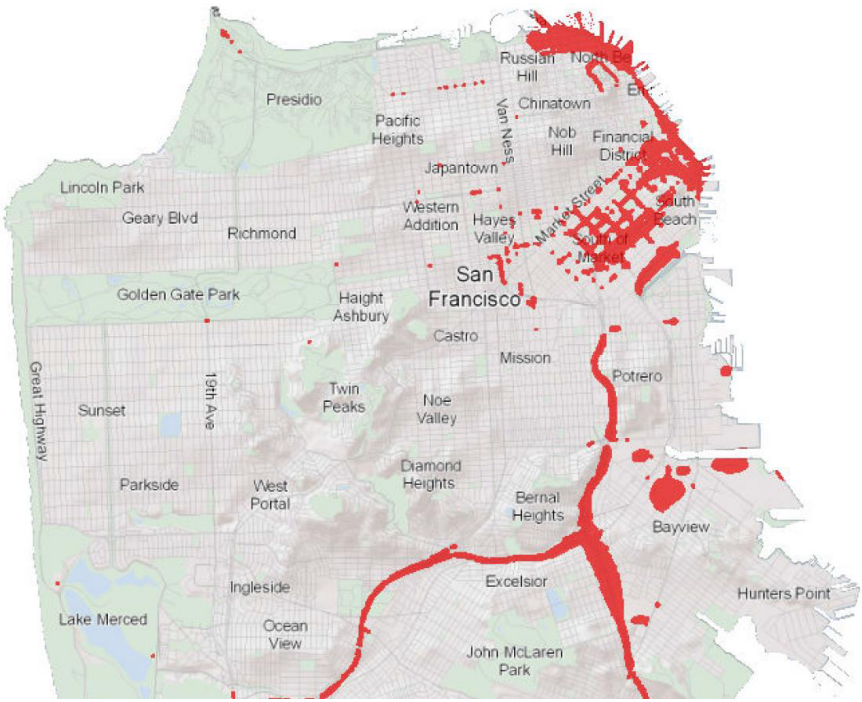

FIGURE 6-3 Air pollution health risks in San Francisco.
NOTE: Locations exceeding health standards marked in red. Health Based Standards: Fine particulate matter ($PM_{2.5}$) concentrations greater than 10 micrograms per cubic meter (including background levels) and excess cancer risk greater than 100 per 1 million people exposed.
SOURCE: Bhatia presentation, April 9, 2015.

tilation in buildings erected near air pollution hotspots, and the city later imposed a transportation impact fee for those hot spot regions. The health outcomes and costs associated with traffic air pollution were added to the total costs of adding an additional vehicle to the city, which were then used to justify a fee that developers would pay for every additional vehicle that they would be causing to be brought into the city, Bhatia said. He added that this model was also used to examine how targeting weatherization programs to pollution hotspots could have additional social benefits.

Another use of HIAs was to identify hotspots for pedestrian injuries and fatalities in San Francisco. The object of this modeling exercise was to examine how the patterns of pedestrian injuries related to the design and operation of city streets. Using a binomial regression model that took as its inputs vehicle and pedestrian volumes, traffic speed, road and intersection characteristics, and area population characteristics, the model explained about three-quarters of the variance in pedestrian injury density among city census tracts and produced risk information to inform city planning decisions. Traffic volume accounted for a third of the explained variation, Bhatia said, and quantifying the pedestrian injury risk attributable to traffic volume has contributed to policy solutions, including the imposition of the aforementioned traffic impact fee on new development as well as changes in the focus of police enforcement and in the approach of the city's traffic engineers to pedestrian safety. In fact, Bhatia said, the results of the model triggered a new focus on calming traffic on busy arterial streets.

One of the first HIAs that Bhatia and his colleagues performed looked at the health impact of changing the minimum wage in California. Again, this effort required combining two models, one that related the minimum wage to the distribution of income per household, and the other that related income to mortality (see Figure 6-4).

Bhatia said that each of these models had tremendous limitations and involved making numerous assumptions, but that they were good enough for the purposes they needed to serve. Health data and science do not usually have leading roles in public policy beyond the health care and environmental sectors. "The uses of HIA and modeling were highly selective and opportunistic and focused on timely policy issues where we already had constituents engaged in the issues and constituents that we anticipated to be ready users of the information generated," Bhatia said. He also noted that modeling in HIA is purpose driven. In the case of the examples he presented, for instance, the modeling was done to solve a defined problem for which specific gaps in knowledge were limiting factors in developing a policy solution. "The models were directed toward finding a particular piece of information: Where are the areas with air pollution above a certain standard, and what was the attributable risk

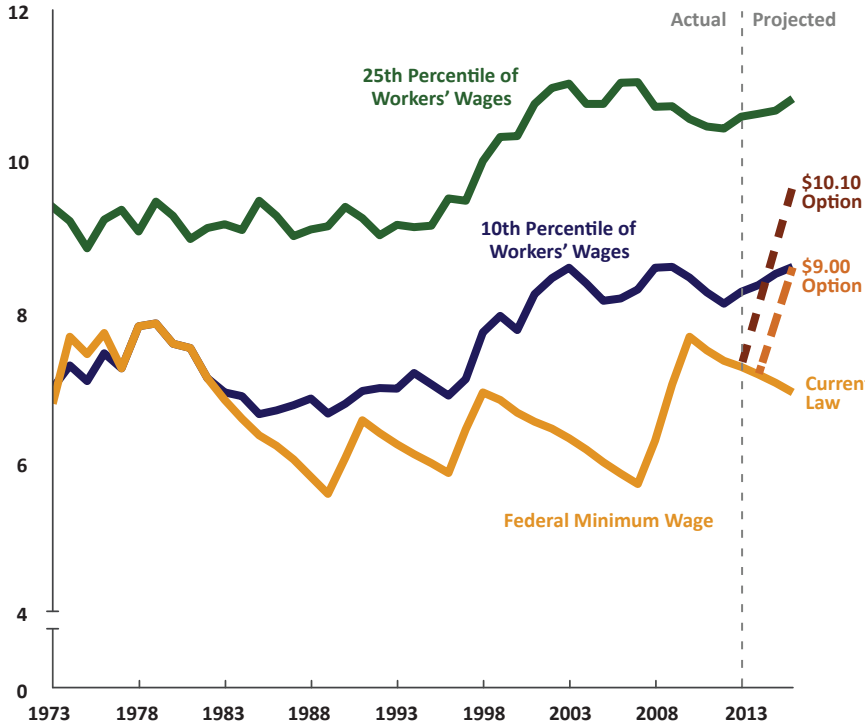

FIGURE 6-4 Minimum wage health impacts.
SOURCE: Bhatia presentation, April 9, 2015.

of pedestrian injuries to differences in traffic volume or traffic speed?" Bhatia added that he expects that policy systems will respond to the new information based on an understanding of existing regulatory systems and stakeholder and agency interests. A primary audience for the models and the information they generated were community constituencies, which then used the information from the models as evidence for their arguments in the policy process.

Bhatia said that one of the most interesting and innovative aspects of this work was that he did not have to create a model but was able to use models that had already been built. He did have to find these models, but after that it was a matter of getting local data to apply to the model. For example, a prototype for the pedestrian injury model had been developed and validated by the Federal Highway Administration, and Bhatia and his colleagues took that best practice model and replicated it in San Francisco. Similarly, the air quality models were approved and used by

environmental agencies but had not been applied to looking at street-by-street differences in air pollution levels. In the case of the impact of wages on health outcomes, there were well-described models linking income and health outcomes, but there was no model linking wages and health outcomes, which required Bhatia and his colleagues to join up models that linked wages with income and income with health outcomes.

One conclusion that Bhatia said he drew from his experience is that simpler and easier-to-explain models work best. "The models did not represent the whole world," he said, "but they represented important pathways that we could use convincingly to influence decisions." He also said that the low specificity and long latency of the determinant–outcome relationship hampers the credibility of models in public policy. For example, mortality is a powerful and motivating outcome, yet it is affected by multiple factors over a lifespan. Another lesson he has learned is that information value comes from explicitly linking policy endpoints (e.g., wages) and health outcomes, legitimizing community arguments, attributing and localizing risks, and supporting policy implementation.

Looking to the future, Bhatia said that the field is very far from modeling the social production of health over the lifespan and that the current research on population health determinants is often disconnected from public policy research. For example, in 2008, when he was looking at the health impact of paid sick days, he could find only four studies on the impact of paid sick days on overall health, the best of which was in the economics literature. Few health researchers thought of paid sick days as a determinant worthy of study, which Bhatia thought was striking.

In his opinion, too few epidemiological studies examine public policies as risk factors directly, which limits the evidence available for modeling how policy affects health. The public health sector looks at and acts on community-level data on conditions, while the health care sector looks at and acts on individual-level data on clinical outcomes, which creates a disconnect among sources of evidence. Models that would be useful for prevention and public policy could benefit from population health information systems that integrate clinical outcomes collected routinely by health care systems with individual-level social, economic, and environmental factors.

The last point Bhatia made was that model building is a technical process, and technical research is usually the easiest element of a successful policy process. You can find a way to model a relationship well if there is motivation to do so, Bhatia said. "The more important questions are what information do we need to make better decisions, who wants the information, and how will they use it." The answers to those questions lead to design criteria for an initial modeling exercise, but ultimately

model building is an interactive and collaborative process that will also involve the users who have to apply a model and see if it works for the purpose at hand.

DISCUSSION

Sharon Cooper opened the discussion by asking Sanghavi if CMS considers unintended consequences when it models the impacts of potential policy changes, particularly with regard to reimbursement, given the challenges of states such as Georgia that are largely rural and that are already experiencing a shortage of physicians. Sanghavi replied that this is a problem that needs to be addressed through risk adjustment, whereby physicians are paid more for treating higher risk patients, and that CMS is working through the challenges of addressing this issue.

David Kindig then asked Sanghavi if his group at CMMI is thinking about how to model making reimbursements for improvements in the short term but also reward physicians for gains that may come from downstream factors that require longer time frames to show their effects. Sanghavi's response was that in the switch from a fee-for-service to a pay-for-performance reimbursement model, the goal is to first demonstrate near-term benefits and savings before trying to tackle longer-term effects. Pasky Pascual said that he has a mental model of how a modeling process should go and that when he considers the future of modeling, he thinks about two important points in a model's life cycle. When a model is given to the users, he would like to see it reduced to the level of an app and at the beginning of the lifecycle, all data should be available in a structured format, such as XML, that anyone can download and use in whatever application they desire. He cited Major League Baseball as an exemplar for providing years of data that can be downloaded from its website in a standard, machine-readable format. In contrast, Pascual said, every government website that he has accessed data flunks this data format test. Bhatia agreed that there are many encumbrances to accessing the data needed to understand population health dynamics and that more needs to be done to link datasets representing determinants and outcomes. Sanghavi agreed that the current status of data availability from many sources is poor, but that CMS has taken the first step by simply making the data available and is working to do better.

Sanne Magnan said that she was excited by the work being done with the cardiovascular risk calculator because it could be laying the groundwork for providers to build bridges with those working in the community and those working on public health, and she suggested that CMS encourage that trend. She also wondered if CMS was thinking about how to incentivize accountable health communities to invest some of the cost sav-

ings that they will realize in both population health and the social determinants of health. Bhatia made the point that while the health system is responsible for collecting information on community risk factors and health outcomes, it is not the lead actor for fixing those parts of the social system that result in externalities on human health. "One of the challenges in talking to the people in health systems about considering the social determinants of health is that they do not think they can fix those problems and so they are reluctant to collect the information," Bhatia said. There needs to be a mechanism by which information on socially attributable health risks is used to send a signal to other systems that have the responsibility for solving these problems, he said.

Mary Pittman, of the Public Health Institute, said that she had not heard much during the workshop about the wildcards of technology and other sources of innovation. Telemedicine, for example, could play an important role in alleviating access problems, while crowdsourcing could serve as an efficient method for gathering information quickly. She asked the panelists if they could talk about how they consider wildcards in their modeling activities and how to address getting input through crowdsourcing and other forms of social media. Sanghavi said that the way CMMI is thinking about wildcards is to build flexibility into the methods used to incentivize care. He cited diabetes prevention as an example. The proven way of reducing the risk that prediabetes will progress to full-blown type II diabetes in adults of all ages is via 16 weeks of twice-weekly visits to the doctor, but that is not scalable. However, the Centers for Disease Control and Prevention (CDC) has developed remote technologies that perhaps could deliver the same intervention with equal effectiveness, and the way to model this would be to identify specific outcomes, such as maintaining weight loss for 1 year, while using broad parameters to represent interventions.

Bhatia then addressed Pittman's question about abundant new forms of information. The challenge, he said, will be for population health interests to guide the information that will be collected. He cited the Apple Research Kit as an example of the willingness of individuals to contribute health data for the public good, and he said it is now up to the public health community to decide what kind of information it wants from this willing population of individuals.

George Isham asked Bhatia if he could comment further on the idea of collecting data on the social determinants of health at the individual level. Bhatia replied that some health care providers will routinely ask patients about nonclinical risks such as food insecurity or housing instability and will help their patients navigate access to community services that they need. However, he added, collecting the information only in vulnerable populations at the point of care will not provide knowledge of such things

as what the total cost of food insecurity is to the health system. "The only way to get the answer to that question is to collect risk factor information systematically on the entire population, from those that are experiencing problems and those that are not," Bhatia said. He suggested that payers and insurance plans could lead such an effort. He added that Medicaid in particular would benefit from collecting nonclinical risk factors identified from epidemiological social determinants research at enrollment and using this data to shed light on what the differential cost and utilization of these risk factors are. In an ideal policy system, policy makers and legislators would use this information to make investments in programs that address social and economic needs to reduce health care spending. It will be important, Bhatia said, to develop a more immediate use case for private payers and insurers to get them involved in this effort. One could argue, for instance, that the data could be used in predictive modeling for high-risk events. The data could also be used to support care management and to develop new programs to address some of the social determinants of health.

Isham also commented that Sanghavi's presentation raised the idea of using modeling as an operations tool for practicing medicine in a sophisticated large-scale environment. Over the past several decades, for example, his organization has looked at preventive care in physician's offices across Minnesota as a suite of activities that have an evidence base that can be used to build an algorithm for the physician to use to recommend the best set of actions for each patient. With a good corresponding metric, that algorithm can be evaluated over time. To be most useful, Isham noted, the federal government needs to be organized so that it consistently convenes experts to do the science in the rigorous way that the U.S. Preventive Services Task Force does its studies. Today, however, those efforts are scattered across the government, with CDC issuing some recommendations and the Health Resources and Services Administration issuing others, and there is little consistency across these recommendations. Isham suggested that it would be useful for the government to think about the larger systems organizations and pressure points as it begins to look at these composite measures and models. He also noted that there are opportunities to use these data to create predictive analytics for physicians to use at the point of care as well as apps that would engage the public.

Sanghavi agreed with Isham that there is clinical medicine being done at the population level today, and as an example he noted that a hospital might examine its patients census to identify those at highest risk of readmission based on a predictive analytic score and then target those patients for special outreach so that they do not become readmitted. Accountable care organizations also incentivize hospital system clinicians

to take a population-wide view of patients, identify those who are potentially at highest risk of bad outcomes or becoming high-cost patients, and then intervene appropriately. Sanghavi characterized that as a high-level policy decision and said that CMS hesitates to become prescriptive about the actions that hospitals and clinicians should take to address those high-risk patients because that just recapitulates the fee-for-service system.

Having said that, Sanghavi added that there is still a great deal to learn to get to the personal aspect of decision making and the reach the app level that Isham proposed. The challenge is to encourage innovation that will address all areas of health care, not just the "big money" areas such as cardiology. Pediatrics, for example, is not an area where there are big savings to realize today, and in caring for the elderly there are many conditions that affect the quality of life but are not high-cost items. These are areas that CMMI is targeting, Sanghavi said, "so that clinical leaders can approach their chief executive officers and say, 'This pilot test showed that paying for this value-oriented service, whether it is preventive cardiology or treating ADHD, makes financial sense, so why don't we build this into our framework?' That is where we hope innovation can occur."

A workshop participant asked if it would be possible to develop risk-adjustment measures for social determinants in the Medicaid payment model, and Sanghavi answered that this is an issue that CMS struggles with because it means that if some Medicaid agencies pay more for complex patients, they might choose to pay less for some other group of patients. He added that CMMI can build models to address complexity, but such efforts are multifaceted. Jeffrey Levi commented that it is incorrect to say that the Medicaid system is a zero sum game. "One should not assume that because you are paying more for socially complex patients that there may not in the end be savings from managing that patient in a better way," he said.

7

Final Thoughts: Ideas for the Future

As an introduction to a discussion on future directions, Teutsch noted that the workshop had already addressed what is needed to strengthen the field of modeling. "We have talked about the data issues, about how to enhance communications, how to help decision makers use these model differently, and how to capitalize on technology," Teutsch said. He added that the field needs more people, particularly those who can help potential users access data and the models that are being developed. "We clearly need communicators to build bridges so that modeling is not just an academic exercise," he said. At the same time, he continued, the field needs to build systems and incentives that link the clinical care system with community-based activities and policies that should drive both health improvements and savings.

Kindig agreed that if the value of modeling is to be fully realized, there are many areas that need attention, including at the research level where more studies are needed to understand the value and cost-effectiveness of interventions so that those data can be used to produce more reliable models. "That is an under-invested part of our academic research world, so there is a place for government and foundations to step up," Kindig said. He also proposed that the government consider creating a model such as the one it uses for calculating the gross domestic product as a metric for national health outcomes.

Raymond Baxter from Kaiser Permanente said that one issue that needs to be considered is how to catalyze the culture change that will be required across many areas of health care and public health if stake-

holders are to accept modeling, to understand how and what it can be used for, and, eventually, to embrace it. "I suspect that modeling needs a public relations agent," Baxter said. He agreed with Bobby Milstein and Pasky Pascual that the complexity of issues that modeling can address means that the community needs to move from mental models to formal models, even though he believes that most potential users of models still think they can integrate the growing amount of data and do these analyses in their heads. "Most of the people in this room are here because we are excited by models, we see the potential of how they can be used," Baxter said. "But the challenge is that there is a variety of professions where the understanding of how to use models is simply not there, and it results in a kind of dismissal of models as black boxes." Teutsch agreed with this last statement and noted that even good science gets dismissed by people who know how to use scientific uncertainty to cast doubt on topics where the science is actually compelling, such as the dangers of smoking, acid rain, and climate change.

Continuing on that theme, John Auerbach said that how to gain acceptance of modeling as a core tool is an important discussion to have in the context of other national discussions about what foundational public health is at the local, state, and federal levels. He said that people working at the community level need technical assistance and support in understanding how to do modeling and how to use it to shape discussions about public health and to add value to the models. "We need to build awareness that models can work," Auerbach said, adding, "I would not have a clue on how to find someone who had expertise in modeling at a local level, and so I might find someone who was not good at it, and that might make for a bad experience." The modeling community needs to provide guidance on how to find the right collaborators and the right model that can be plugged into a community organizing process, Auerbach said, and it needs to provide training and technical assistance.

Pascual said that while the centralized government approach and the distributed community-based approach to modeling go hand in hand, he does not believe that government should try to solve the health care sector's modeling problems. He also said that the modeling community is adept at writing computer code that can go out to the cloud, find data, and "scrape" it down into the model, and it is also good at writing code that can parse data, or convert data into a form that one particular model can use. Because of these two abilities, he said, he does not believe that a centralized approach to data gathering and model making is necessary. "If we just subscribe to the notion that you should describe your data, make it machine readable, and make it available, there is so much to be gained," Pascual said.

Michael Weisberg said that as a modeler who works outside of the health community, he wanted the workshop participants to be aware of what members of other modeling communities, such as the social sciences modeling community, have done over the past couple of years that has been effective in making models more accessible. "They have developed a standard format for the presentation of the model so that people who do not choose to take time to understand the computational or mathematical detail have a sense of the assumptions in the model, the intended scope of the model, and the data that it relies on," Weisberg said. He suggested that the roundtable could think about the needs of policy makers, physicians, and public health officials in terms of the inputs, outputs, design, and scope of models and set standards for characterizing models in those terms. He also expressed hope that the roundtable would continue to stress the importance of thinking of models as tools that can support policy decisions, not make them.

The final comment from the discussion came from a workshop participant who said that it seemed to him that the discussions of the day hinted at trying to reinvent community health planning while losing sight of the community stakeholders in the process. He called on the government to play a crucial role in ensuring that different actors in the system have input into the process, something that he did not hear happening in the modeling examples that were presented.

REFLECTIONS ON THE DAY[1]

In the workshop's final discussion, roundtable members were given the opportunity to reflect on the key messages that they heard during the day's proceedings and to offer any comments they had that were relevant to the topic of how modeling can inform strategies to improve population health. George Isham started the discussion with the comment that, with regard to government policy on the formation of accountable care organizations and the shift in payment models from fee-for-service, information and analytics are two of the capabilities that are most commonly identified as needs of health care systems. Isham noted that there are operational models that have a long track record in some of the leading health care organizations, such as Kaiser Permanente and HealthPartners, and he wondered what lessons can be learned from those operational models that can be applied to the larger task of improving health in populations and in communities larger than health care systems.

[1]Unless otherwise noted, the comments noted in this chapter were made by members of the Roundtable on Population Health Improvement, and the statements are not endorsed or verified by the Institute of Medicine.

James Knickman said that one encouraging piece of information he heard is that models may be able to simulate some of the changes in population health that may occur over a long time frame and, by doing so, address the important challenge associated with how long it takes to accumulate actual evidence of change produced by an intervention. While acknowledging the limitations of models compared to research-derived evidence, he said that models may represent the only way for society to reach decisions to invest in long-term interventions. He also said that models can be useful tools for presenting information clearly to decision makers.

Mary Pittman first commented that the ReThink Health model has improved and become more refined each time she hears a presentation about it. She then noted that an important theme that she heard in her working group was the need to humanize data in order for it to have an impact on policy making. "You can have harmonized data and not know how to apply it in a way that it will be a good input into a model," she said, "or it could be data that is not relevant to the policy at hand." It is also important to humanize data, she said, in order to get community inputs and to ensure that a model is accounting for the populations that need to be served, both by the data and the policy being modeled.

Catherine Baase reflected on the fact that each of the roundtable's workshops she has attended has identified issues that have a big impact on population health, but the question that continues to hang over these workshops is how to amalgamate these issues and distill them into a path forward. One of her takeaways from the workshop, she said, is that modeling could be the vehicle or tool that can help with this necessary amalgamation and distillation and perhaps address one of the greatest challenges facing the roundtable, which is to create a path forward out of all of the information these workshops have produced. Yes, she said, modeling is a tool to support decision making, but it can also be a tool that is useful for convening and for shared learning.

Raymond Baxter agreed with Baase's ideas that modeling could be an important vehicle for integrating ideas and that it could also help with communication, given that the roundtable has often heard how difficult it is to explain what population health is. One of the benefits of a model is that by examining its assumptions and tradeoffs, it is possible to see how taking one action plays itself out in other ways, Baxter said.

In response to a question from Isham about how modeling might be useful to employers interested in improving productivity, Baase said that the business sectors uses models all the time in that way and that they are very effective tools. Modeling is also a language that is very well understood in the private sector, and it could serve as a bridge between the private and public sectors and the community at large. Baxter added that

modeling can help any type of organization, private or public, understand the varied impacts it has on health by the way in which they do their business. Kaiser Permanente, for example, is in the process of measuring what it calls its Total Health Impact, which is the effect of everything that the organization does, including the pensions and wages it offers, the toxics that are used in the delivery of health care, the energy that it uses, and so on. Modeling is playing an important part of this effort and will provide Kaiser with a better picture of how its actions as an organization affect the health of the communities in which it operates.

The last comment came from Sanne Magnan, who remarked that one of the objectives for the workshop was to show how modeling could help decision makers, which the workshop did accomplish, but the presentations also highlighted how helpful modeling can be in creating conversations between the decision makers and communities, or, as she put it, between the treetops and the grass roots. This idea was reinforced throughout the workshop, she said, and it points to how important it is to engage and empower communities and respect the role that they have to play in population health.

After thanking the planning committee and the Institute of Medicine staff for putting together a workshop that generated thoughtful discussions and information that will be useful to the roundtable, Isham adjourned the workshop.

A

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B

Workshop Agenda

Roundtable on Population Health Improvement
Workshop: How Modeling Can Inform Strategies to Improve Population Health
April 9, 2015

National Academy of Sciences, Lecture Room
2101 Constitution Avenue NW, Washington, DC

WORKSHOP OBJECTIVES

1. Identify how modeling could inform population health decision makers' strategies and decision making based on lessons learned from models that been used successfully (or not)
2. Identify opportunities and barriers to incorporating models into decision making
3. Identify data needs and opportunities to leverage existing and collecting new data for modeling

8:15 a.m. **Welcome and overview of the day**
David Kindig, professor emeritus of population health sciences, emeritus vice chancellor for health sciences, University of Wisconsin School of Medicine and Public Health; co-chair, Roundtable on Population Health Improvement

8:25 a.m. **Context-setting presentations**
Moderator: Louise Russell, distinguished professor, Institute for Health, Health Care Policy and Aging Research and Department of Economics, Rutgers University

Why modeling matters in improving population health
Steven Teutsch, planning committee chair, former chief science officer, Los Angeles County Public Health

Why do we need models, and how have they been used?
Ross Hammond, senior fellow, economic studies, and director, Center on Social Dynamics and Policy, Brookings Institution

9:05 a.m. **Q&A/Discussion**

9:20 a.m. **Case studies of models used to inform health policy**

Case studies will illustrate (a) different kinds of models, (b) how they have been used, (c) effectiveness (or lack thereof) in informing decisions.
Moderator: Marthe Gold, professor emerita of community health and social medicine, Sophie Davis School of Biomedical Sciences, City College of New York; visiting scholar, New York Academy of Medicine

Case study 1: Tobacco models
David Mendez, associate professor of health management and policy, University of Michigan

Case study 2: EPA air standards
Pasky Pascual, former director, Council for Regulatory Environmental Modeling, Environmental Protection Agency (EPA)

Case study 3: Regional health reform
Bobby Milstein, director, ReThink Health

10:20 a.m. **Break**

10:35 a.m. **Discussion of case studies**

11:05 a.m. **Remarks from the IOM president**
Victor Dzau, president, Institute of Medicine

11:20 a.m. **What would population health decision makers like from models?**
Gary VanLandingham, director, Pew–MacArthur Results First Initiative

Instructions for discussion groups
Steven Woolf, professor of family medicine and population health, and director, Center on Society and Health, Virginia Commonwealth University

11:45 a.m. **What would population health decision makers like from models?**

Group 1: Health risk factors (e.g., obesity, substance abuse)
Facilitator: Karen Minyard, Georgia Health Policy Center

Group 2: Natural and built environments (e.g., air, water, transit, housing)
Facilitator: Pasky Pascual, EPA

Group 3: Social and economic conditions (e.g., education, income, discrimination)
Facilitator: Gary VanLandingham, Results First

Group 4: Integrated health systems (e.g., community conditions and clinical services)
Facilitator: Bobby Milstein, ReThink Health

12:45 p.m. **Lunch**

1:15 p.m. **Discussion groups report back** (followed by discussion to explore action items for future model development)
Rapporteurs:
Group 1: *George Miller, fellow, Altarum Institute*
Group 2: *J. T. Lane, assistant secretary, Louisiana Department of Health and Hospitals*
Group 3: *Nick Macchione, director, San Diego Health and Human Services Agency*
Group 4: *Louise Russell, Rutgers University*

2:15 p.m. **Barriers and opportunities for using models to inform population health interventions and policies**
Moderator: Bobby Milstein, director, ReThink Health

Model validation and decision making
Michael Weisberg, associate professor, Department of Philosophy, University of Pennsylvania

Improving communication with policy makers on the use and usefulness of models
Karen Minyard, director and associate research professor, Department of Public Management and Policy, Georgia Health Policy Center
Representative Sharon Cooper, chair, health and human services committee, Georgia State House of Representatives

3:00 p.m. **Discussion of barriers and opportunities**

3:30 p.m. **Break**

3:45 p.m. **Future Directions**
Moderator: Steven Teutsch, former chief science officer, Los Angeles County Public Health

Preventive and Population Health Models Group at the Centers for Medicare & Medicaid Services Center for Medicare & Medicaid Innovation
Darshak Sanghavi, director, Preventive and Population Health Models Group, Center for Medicare & Medicaid Innovation/ Centers for Medicare & Medicaid Services

Lessons for using modeling in assessing health impact
Rajiv Bhatia, director, The Civic Engine

4:30 p.m. **Discussion with all workshop attendees on future directions and capacity building**
Facilitator: Steven Teutsch

5:00 p.m. **Reflections on and reactions to the day**
George Isham, senior advisor, HealthPartners, senior fellow, HealthPartners Institute for Education and Research; co-chair, Roundtable on Population Health Improvement

5:30 p.m. **Adjourn**

C

Biographical Sketches of Workshop Speakers

Rajiv Bhatia, M.D., M.P.H., the founder and director of The Civic Engine, is an internist and social medicine practitioner with two decades of experience in advancing population health needs, including environmental quality, economic opportunity, and political inclusion. He has broad experience and expertise in the generation, analysis, and communication of data and information to inform public policy, catalyze civic engagement, and monitor governmental accountability.

Representative Sharon Cooper, M.A., M.S.N., is the chairman of Health and Human Services for the Georgia House of Representatives. Born in Houston, Texas, Rep. Cooper is proud to have called Georgia home for more than 38 years. She was married to the late Dr. Tom Cooper for more than 33 years. She was first elected in 1996 as the state representative for the 41st District of Georgia (now 43rd district). In 2000 Rep. Cooper was chosen as legislator of the year by the Georgia Republican Party, and in 2002 she was elected caucus chairman by her Republican colleagues. In 2004 she was elected majority caucus chairman, making her the highest ranking woman in the Georgia House. In 2007, in response to her ever-increasing committee responsibilities, Rep. Cooper assumed the role of caucus chair emeritus. Currently Rep. Cooper chairs the Health and Human Services committee, one of the busiest committees in the House. She was also appointed chairman of the Special Committee on Certificate of Need as well as chair of the Special Committee on Grady Hospital. Rep. Cooper is also a member of the rules, judiciary non-civil, and regu-

lated industries committees. Rep. Cooper holds several degrees, including a B.S. in child development, an M.A. in education, and an M.S.N. in nursing. Rep. Cooper has written two textbooks on psychiatric nursing, and in 1994 she authored *Taxpayer's Tea Party*, a how-to book that encouraged the average citizen to become politically active. Recently she was asked to update this book, available now in e-book format. A graduate of the first class of the Coverdell Leadership Institute, Rep. Cooper was able to pass a major revision of the state's stalking law while still in her freshman term. In 2002, A. G. Ashcroft appointed her to the president's 30-member National Advisory Committee on Violence Against Women. In 2006 Cobb County Commission Chairman Sam Olens credited Rep. Cooper as being the major catalyst behind the creation of Cobb County Police Department's Domestic Violence Unit. She has also served on Georgia First Lady Mary Perdue's Advisory Committee on Foster Care. Rep. Cooper continues to author and foster legislation that promotes improved health care for Georgians such as the HIV Screening Bill for Pregnant Women, Georgia Smoke free Air Act, and the "Health Share" Volunteers in Medicine Act. Rep. Cooper has earned the reputation of being one of the hardest working legislators at the Capitol as well as being honest, straightforward, and committed. Former governor and U.S. Senator Zell Miller still calls her "the little legislator that tells it like it is."

Ross Hammond, Ph.D., is a senior fellow in economic studies at the Brookings Institution, where he is the director of the Center on Social Dynamics and Policy. His primary area of expertise is modeling complex dynamics in economic, social, and public health systems using mathematical and computational methods from complexity systems science. His current research topics include obesity etiology and prevention, food systems, tobacco control, behavioral epidemiology, crime, corruption, segregation, trust, and decision making. Dr. Hammond received his B.A. from Williams College and his Ph.D. from the University of Michigan. He has authored numerous scientific articles, and his work has been featured in *New Scientist*, *Salon*, *The Atlantic Monthly*, *Scientific American*, and major news media. Hammond was a member of the authoring committee of the Institute of Medicine (IOM)/National Research Council report *A Framework for Assessing Effects of the Food System*, and he is a public health advisor at the National Cancer Institute, an advisory special government employee at the Center for Tobacco Products of the Food and Drug Administration, and an advisory council member at the National Institute for Minority Health and Health Disparities. He also currently serves on the editorial board of the journals *Behavioral Science & Policy* and *Childhood Obesity* and has been a member of the National Institutes of Health (NIH)-funded research networks MIDAS (Models of Infectious Disease Agent

Study), ENVISION (part of the National Collaborative on Childhood Obesity Research), NICH (Network on Inequality, Complexity, and Health), and SCTC (State and Community Tobacco Control). Dr. Hammond has been a consultant to the World Bank, the Asian Development Bank, the IOM, and NIH. He has taught computational modeling at the Harvard School of Public Health, the University of Michigan, Washington University, the National Cancer Institute, and the NIH/CDC Institute on Systems Science and Health. He currently holds appointments at the Harvard School of Public Health, the Santa Fe Institute, and Washington University in St Louis, and he previously held positions as the Okun–Model Fellow in Economics, a National Science Foundation fellow in the Center for the Study of Complex Systems at the University of Michigan, and a consultant at PricewaterhouseCoopers LLP.

J. T. Lane currently serves as the assistant secretary for public health in Louisiana. As head of the chief public agency charged with promoting and protecting the health of all Louisiana residents and visitors, Mr. Lane has prioritized making environmental and place-based policy changes to promote healthy lifestyles and building a new Center for Population Health Informatics to increase transparency and better equip and empower communities to make healthy changes. Lane has served in consulting and full-time roles for a variety of organizations, including Fortune 500 companies, start-ups, nonprofits, and government agencies in the higher education, human services, health, and technology sectors across the country. He currently serves on the board of directors for the Association of State and Territorial Health Officials and has chaired several of its national policy committees. He received his master's degree from the University of California, Berkeley, School of Public Health, has completed the Robert Wood Johnson Foundation's New Health Leaders program certification at the Harvard Kennedy School for Government, and received his bachelor's degree from Louisiana State University.

Nick Macchione, M.P.H., F.A.C.H.E., is the agency director of the County of San Diego's Health and Human Services Agency. In that role Mr. Macchione manages one of the nation's largest health and human services networks at the local level, supporting the public health, safety, and well-being of the more than 3.2 million residents of San Diego County. With an annual budget responsibility of $2 billion, Mr. Macchione oversees a workforce of 6,000 employees, hundreds of volunteers, 1,000 service contractors, and 162 citizen advisory boards and councils that collectively provide direct services to more than 1 million clients annually. With a focus on innovation and service integration, he works closely with local, state, and federal elected officials on advancing evidence-based policy

for population health and directs the delivery of health and social service safety net programs, including public health services, behavioral health services, Medicaid managed care and other safety net health insurance programs, nutrition assistance for the indigent, child and adult protective services, and early childhood development programs. Mr. Macchione implements operational policy direction of an elected county board of supervisors and oversees the operations of the county's psychiatric hospital; the Edgemoor Skilled Nursing Facility (2014 winner of a Silver Achievement in Quality Award by the American Health Care Association and the National Center for Assisted Living); the Polinsky Children's Center, a 24-hour facility for the temporary emergency shelter of children; and San Pasqual Academy, a first-of-its kind residential campus for foster youth. Under Mr. Macchione's leadership, in 2010 the Health and Human Services Agency and the rest of County government embarked on a bold and ambitious county-wide health and wellness movement known as Live Well San Diego. This groundbreaking, data-driven strategy is now being implemented throughout the entire region through public–private partnerships in building better health, safer living, and economic vitality for all San Diego County residents. Live Well San Diego is a collective impact model that has received numerous awards and recognitions and is being replicated in other jurisdictions in California and throughout the country. He is a fellow of the American College of Healthcare Executives, having previously served a 3-year term as the elected regent for San Diego and Imperial Counties. He is a public health leadership scholar alumnus with the federal Centers for Disease Control and Prevention and a Creating Healthier Communities fellow alumnus of the American Hospital Association's Health Forum. He is a commissioner of the First Five Commission of San Diego and serves on numerous regional and national boards, including serving as vice chair of the National Association of Counties' Healthy Counties Initiative Advisory Board and of the steering committee for Harvard University's Human Services Summit. Mr. Macchione holds dual master's degrees from Columbia University and New York University, where he specialized in health services management and health policy. For the past 18 years he has been an instructor and faculty member at San Diego State University's Graduate School of Public Health. In 2007 he was appointed as the school's John Hanlon Executive Scholar for the division of health management and policy.

David Mendez, Ph.D., is an associate professor in the Department of Health Management and Policy (HMP) at the University of Michigan School of Public Health, with training in operations research and system science. His research focuses on the analysis of population health problems through the use of computational models. He has published

in the areas of tobacco control, residential radon mitigation, and human papilloma virus vaccine uptake, among others. Dr. Mendez is also actively involved in promoting online education and is currently the director of the executive master's program in HMP.

George Miller, Ph.D., M.S.E., has served on the technical staff of Altarum Institute and one of Altarum's predecessor organizations, Vector Research, Inc., since 1972. He is currently affiliated with Altarum's Center for Sustainable Health Spending, where he participates in the center's efforts to track national health spending, understand the drivers of spending growth, and quantify a sustainable spending growth rate. In other efforts, he has supported Altarum in applications of operations research to modeling and analysis of health care issues that have included the value of prevention, disease management, medical responses to demand surges, cost-effectiveness of clinical interventions, beneficiary population forecasting, telemedicine, graduate medical education, medical logistics, medical staffing, medical facilities planning, and collections forecasting. His work has been published in journals such as the *New England Journal of Medicine*, the *Journal of the American College of Cardiology*, *Health Affairs*, *Medical Decision Making*, *Health Care Management Science*, *Infection Control and Hospital Epidemiology*, *Interfaces*, and *Management Science*. He frequently serves as a reviewer for several of these journals. Dr. Miller has chaired numerous sessions at national meetings of the Institute for Operations Research and the Management Sciences (INFORMS), served on INFORMS's long-range planning committee, and served for 7 years (3 years as chair) on its committee to select the recipient of the Bonder Scholarship for Applied Operations Research in Health Services. Dr. Miller received his B.S.E., M.S.E., and Ph.D. degrees in industrial and operations engineering from the University of Michigan, where he subsequently served as an adjunct assistant professor.

Bobby Milstein, Ph.D., M.P.H., directs ReThink Health's work in dynamics, systems strategy, and sustainable financing. An expert in health system dynamics and policy, Dr. Milstein oversees the ongoing development of the ReThink Health Dynamics Model. He spent 20 years at the Centers for Disease Control and Prevention, where he founded the Syndemics Prevention Network and coordinated planning and evaluation activities for a number of public health initiatives. Dr. Milstein has a Ph.D. in public health science from Union Institute and University, an M.P.H. from Emory University, and a B.A. in cultural anthropology from the University of Michigan Honors College.

Karen Minyard, Ph.D., has directed the Georgia Health Policy Center (GHPC) at Georgia State University's Andrew Young School of Policy

Studies since 2001. Dr. Minyard connects the research, policy, and programmatic work of the center across issue areas including community and public health, end-of-life care, child health, health philanthropy, public and private health coverage, and the uninsured. Prior to assuming her current role, she directed the networks for rural health program at the GHPC. She has experience with the state Medicaid program, both with the design of a reformed Medicaid program and the external evaluation of the primary care case management program. She also has 13 years of experience in nursing and hospital administration. She is an advocate for the importance of community in national, state, and local policy and for the power of communities to improve health. Dr. Minyard maintains her connection with communities by working directly with local health collaboratives and serving on the boards of the National Network of Public Health Institutes, Physicians' Innovation Network, and Communities Joined in Action. Dr. Minyard's research interests include financing and the evaluation of health-related social policy programs; the strategic alignment of public and private health policy on all levels; the role of local health initiatives in access and health improvement; the role of targeted external facilitation and technical assistance in improving the sustainability, efficiency, and programmatic effectiveness of nonprofit health collaboratives; and public health systems and financing. Dr. Minyard frequently makes presentations and acts as a neutral convener and facilitator for groups and organizations. She often provides testimony for the state legislature and recently presented to congressional and executive agency staff at the National Health Policy Forum. Currently, she is spearheading a team of faculty and staff at Georgia State University dedicated to translating national health care reform. She received a bachelor's degree in nursing from the University of Virginia, a master's degree in nursing from the Medical College of Georgia, and a doctoral degree in business administration with a major in strategic management and minor in health care financing from Georgia State University.

Pasky Pascual, M.S., J.D., is an environmental scientist and lawyer who works for the U.S. Environmental Protection Agency (EPA). He served as the director of the EPA's Council for Regulatory Environmental Modeling. His primary interest is in the area of regulatory decision making, and he has published papers on the judicial review of regulatory science. Pasky began his work at EPA with the Climate Change Division, during which he worked with nongovernmental organizations (NGOs) to help measure the greenhouse gases avoided through projects funded by the EPA. He followed this up with work on an initiative spearheaded by the Clinton Administration, leading stakeholders from industry, government, and the NGO sector to develop approaches to facility management that com-

bined environmental performance, regulatory flexibility, and economic efficiency. He led efforts within EPA's Research and Development Office to look at the emerging risks and opportunities associated with bio- and nano-technology.

Louise B. Russell, Ph.D., is a distinguished professor at the Institute for Health, Health Care Policy, and Aging Research and in the Department of Economics at Rutgers University. Her research focuses on the methods and application of cost-effectiveness analysis. Before coming to Rutgers, Dr. Russell was a senior fellow at the Brookings Institution in Washington, DC. Elected to membership in the Institute of Medicine (IOM) of the National Academies of Sciences, Engineering, and Medicine in 1983, she has served on several IOM committees, including the National Cancer Policy Board (2001–2005) and the Committee on Valuing Community-Based, Non-Clinical Prevention Policies and Wellness Strategies (2011–2012). Dr. Russell co-chaired the U.S. Public Health Service Panel on Cost-Effectiveness in Health and Medicine, which published recommendations for improving the quality and comparability of cost-effectiveness studies in a book (*Cost-Effectiveness in Health and Medicine*, Oxford University Press, 1996) and three articles in the *Journal of the American Medical Association* (October 1996). Since 2011 she has been one of a group of five leaders in the field who are organizing and facilitating the Second Panel on Cost-Effectiveness in Health and Medicine, which is working to bring the book and the recommendations up to date with the many advances in cost-effectiveness since 1996. She was deputy editor of the journal *Medical Decision Making* from 2011 to 2015 and has published many articles and seven books, including *Educated Guesses: Making Policy About Medical Screening Tests* (California/Milbank, 1994), *Is Prevention Better Than Cure?* (Brookings, 1986), and *Technology in Hospitals: Medical Advances and Their Diffusion* (Brookings, 1979). Dr. Russell received her Ph.D. in economics from Harvard University.

Darshak Sanghavi, M.D., is the director of the Population and Preventive Health Models Group at the Center for Medicare & Medicaid Innovation, where he oversees the development of large pilot programs aimed at improving the nation's health care costs and quality. Recently, he was the Richard Merkin Fellow and a managing director of the Engelberg Center for Health Care Reform at the Brookings Institution, where he directed efforts to better engage clinician in health care payment and delivery reform. Dr. Sanghavi is also an associate professor of pediatrics and the former chief of pediatric cardiology at the University of Massachusetts Medical School, where he was charged with clinical and research programs dedicated to children's heart defects. An award-winning medical

educator, he also has worked in medical settings around the world and published dozens of scientific papers on topics ranging from the molecular biology of cell death to tuberculosis transmission patterns in Peruvian slums. A frequent guest on NBC's *Today* show and a past commentator for NPR's *All Things Considered*, Dr. Sanghavi is a contributing editor to *Parents* magazine and is *Slate*'s health care columnist, and he often writes about health care for the *New York Times*, *Boston Globe*, and *Washington Post*. His best-seller, *A Map of the Child: A Pediatrician's Tour of the Body*, was named a best health book of the year by the *Wall Street Journal*. He speaks widely on medical issues at national conferences, advises federal and state health departments, and is a former visiting media fellow of the Kaiser Family Foundation and a winner of the Wharton Business Plan Competition. He previously worked for several years as a U.S. Indian Health Service pediatrician on a Navajo reservation.

Steven Teutsch, M.D., M.P.H., is an independent consultant; an adjunct professor at the Fielding School of Public Health at the University of California, Los Angeles; a senior fellow at the Public Health Institute; and a senior fellow at the Leonard D. Schaeffer Center for Health Policy and Economics at the University of Southern California. Until 2014 he was the chief science officer for Los Angeles County Public Health, where he continued his work on evidence-based public health and policy. He had been in the outcomes research and management program at Merck since October 1997, where he was responsible for scientific leadership in developing evidence-based clinical management programs, conducting outcomes research studies, and improving outcomes measurement to enhance quality of care. Prior to joining Merck, he was the director of the Division of Prevention Research and Analytic Methods (DPRAM) at the Centers for Disease Control and Prevention (CDC), where he was responsible for assessing the effectiveness, safety, and the cost-effectiveness of disease and injury prevention strategies. DPRAM developed comparable methodology for studies of the effectiveness and economic impact of prevention programs, provided training in these methods, developed CDC's capacity for conducting necessary studies, and provided technical assistance for conducting economic and decision analysis. The division also evaluated the impact of interventions in urban areas, developed the Guide to Community Preventive Services, and provided support for CDC's analytic methods. He has served as a member of that task force and the U.S. Preventive Services Task Force, which develops the Guide to Clinical Preventive Services, as well as the Americas Health Information Community Personalized Health Care Workgroup and the Evaluation of Genomic Applications in Prevention and Practice Workgroup. He chaired the Secretary's Advisory Committee on Genetics Health and Society and

has served on and has chaired Institute of Medicine panels, Medicare's Evidence Development and Coverage Advisory Committee, and several subcommittees of the Secretary's Advisory Committee on Healthy People 2020. Dr. Teutsch joined CDC in 1977, where he was assigned to the Parasitic Diseases Division and worked extensively on toxoplasmosis. He was then assigned to the Kidney Donor Program and subsequently the Kidney Disease Program. He developed the framework for CDC's diabetes control program. He joined the Epidemiology Program Office and became the director of the Division of Surveillance and Epidemiology, where he was responsible for coordinating CDC's disease monitoring activities. He became chief of the Prevention Effectiveness Activity in 1992. Dr. Teutsch was born in Salt Lake City, Utah. He received his undergraduate degree in biochemical sciences at Harvard University in 1970, an M.P.H. in epidemiology from the University of North Carolina School of Public Health in 1973, and his M.D. from Duke University School of Medicine in 1974. He completed his residency training in internal medicine at Pennsylvania State University, Hershey. He was certified by the American Board of Internal Medicine in 1977, the American Board of Preventive Medicine in 1995, and is a fellow of the American College of Physicians and the American College of Preventive Medicine. Dr. Teutsch has published more than 200 articles and 8 books in a broad range of fields in epidemiology, including parasitic diseases, diabetes, technology assessment, health services research, and surveillance.

Gary VanLandingham, Ph.D., is the director of the Pew–MacArthur Results First Initiative, a joint initiative of the Pew Charitable Trusts and the John D. and Catherine T. MacArthur Foundation. He manages Pew's work to advance the use of cost-benefit analysis and to cultivate a climate for evidence-based decision making that can enable states to eliminate ineffective programs and shift resources to those that generate the best outcomes. As lead on Pew's efforts to improve the use of data on cost-effectiveness in state policy making, VanLandingham works with state partners to implement proven analytical tools that more accurately assess the true costs and benefits of public programs. He also helps policy makers use the findings to drive state dollars toward programs with the highest returns on taxpayer investments. Before joining Pew in January 2011, VanLandingham served for 7 years as director of the Office of Program Policy Analysis and Government Accountability, the Florida Legislature's policy research and evaluation arm. He has more than 30 years of experience conducting and leading policy studies at the state and local government levels. He has served as the staff chair of the National Conference of State Legislatures, chair of the National Legislative Program Evaluation Society, and president of the Southeast Evaluation Associa-

tion and the North Florida Chapter of the American Society for Public Administration. He also taught as an adjunct professor with the Askew School of Public Administration and Policy at Florida State University. VanLandingham has a Ph.D. and a master's degree in public administration from Florida State University and a bachelor's from the University of Florida.

Michael Weisberg, Ph.D., is a professor and chair of the philosophy department at the University of Pennsylvania. Dr. Weisberg is also a distinguished research scholar at the Annenberg Center for Public Policy and a faculty affiliate of the Institute for Research in Cognitive Science, the Center for Cognitive Neuroscience, and Penn Museum. His research focuses on the philosophy of science, especially modeling, trade-offs, robustness analysis, the nature of the chemical bond, the division of cognitive labor, and public understanding of science.

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