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The Value of Information

*Methodological Frontiers
and New Applications
for Realizing Social Benefit*

Molly Macauley and Ramanan Laxminarayan

June 28–29, 2010

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The Value of Information: Methodological Frontiers and New Applications for Realizing Social Benefit

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Molly Macauley and Ramanan Laxminarayan¹

This report highlights the major conclusions and outcomes from a workshop held June 28–29, 2010 at Resources for the Future in Washington, DC, on methodological frontiers and new applications of valuing information and its social benefit. The participants provided answers to a series of questions: What is meant by “value of information”? When does information have value? What are state-of-the-practice methods to ascribe value to information? Participants also identified steps to ascribe, measure, and communicate value. The workshop included identification of five discrete approaches at the frontier of methodological advances: price- and cost-based derivation; Bayesian belief networks; regulatory cost-effectiveness evaluation; econometric modeling and estimation; and simulation modeling and estimation.

The workshop was distinctive in serving as the first multi-day, in-depth meeting to convene experts in the two disparate communities of social science and Earth science to identify and critique state-of-the-practice methods for ascribing value and societal benefit to information.² The workshop outputs include specific recommendations and actions to enhance and further demonstrate the value of information from public investments, particularly those in Earth science applications.

Background and Workshop Organization

Although the idea that information has value in a statistical and a pragmatic sense dates back at least to the 1950s, interest in the economic value of information has taken center stage in recent years. Policymakers face the burden of justifying large public investment in data on climate and air quality, public health, ecosystems, water, and other natural and environmental resources, including those gathered from the unique vantage point of space.

In all cases, information potentially will create value in the form of a variety of societal benefits, including enhanced scientific understanding, but certainly will create costs. Often information suppliers

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² A group of social scientists and experts in the application of Earth science to problem solving met in 2009 at a panel session of the annual meeting of the American Geophysical Union. Discussion at that session provided input into the workshop.

pay little attention to the form in which information is communicated to decisionmakers, information processing costs that decisionmakers face, and their ability to use the information in a timeframe that makes the exercise worthwhile.

This workshop consisted of a series of invited papers from senior researchers, primarily from the academic community, exploring innovative methodologies and applications of value-of-information research for realizing societal benefit. The papers focused on applications in two disparate fields linked by the importance of valuing information: public health and space. The selection of these two topics follows from several opportunities. The health field has led some of the most innovative methodologies for valuing information. The Earth science field is using an increasingly large number of Earth-observing satellites and other platforms to collect data about climate and other natural and environmental resources. In this field, applications of value-of-information methods are nascent but critically important in informing investment in the observing instruments and platforms

Invited discussants from government and the academic community led critiques of the papers and provided written commentary. Workshop participants included 120 people from government, the private sector, universities, and other nongovernmental organizations. The workshop was organized and led by Dr. Molly K. Macauley, senior fellow and research director at Resources for the Future, and Dr. Ramanan Laxminarayan, senior fellow and director of the Center for Disease Dynamics, Economics, and Policy at Resources for the Future.

The authors and their affiliations are:

- Daniel Osgood, Columbia University;
- Roger Cooke and Carolyn Kousky, Resources for the Future;
- Luther Martin, Voltage Security;
- Michael Obersteiner and Steffen Fritz, International Institute of Applied Systems Analysis;
- Ginger Jin, University of Maryland;
- Jonathan Kolstad, Wharton School, University of Pennsylvania;
- Jessica Cohen, Harvard School of Public Health;
- David Hartley, Georgetown University Medical Center; and
- Richard Bernknopf, U.S. Geological Survey.

Discussants and their affiliations are:

- Michael Toman, World Bank;
- Timothy Brennan, Resources for the Future and University of Maryland, Baltimore County;
- Adam Finkel, University of Pennsylvania and UMDNJ School of Public Health;
- Molly Macauley, Resources for the Future;
- Mead Over, Center for Global Development;
- Kenneth Leonard, University of Maryland;
- Anup Malani, University of Chicago Law School;
- Scott Farrow, University of Maryland, Baltimore County;
- Joshua Michaud, Johns Hopkins University; and
- Catherine Shelley Norman, Johns Hopkins University.

Lawrence Friedl of the US National Aeronautics and Space Administration provided vision and leadership for the workshop. A steering committee assisted the planning and has remained engaged in the workshop outputs and outcomes, helping to disseminate findings. The steering committee and their affiliations are:

- Richard Bernknopf, U.S. Geological Survey;
- Robert Chen, Columbia University;
- William B. Gail, Microsoft;
- Kass Green, Kass Green and Associates;
- William Hooke, American Meteorological Society;
- Charles F. Kennel, University of California;
- Michael Obersteiner, International Institute for Applied Systems Analysis; and
- Lea Shanley, National Research Council.

The organizers established a SharePoint document library during the workshop planning period. The steering committee, authors, and discussants contributed more than 50 documents including peer-reviewed, published articles; reports; magazine articles; and PowerPoint presentations. All these related to valuing information; managing information to enhance its value; and using new technology, community remote sensing, and other wiki tools to enhance the value of information. The appendices to this report include the workshop agenda and abstracts of the papers. The papers and commentaries will be published in an edited volume forthcoming in late 2011.

Valuing Information: What to Value, When, and How?

The workshop findings and results provide answers to three questions:

What is meant by “value?” In general, participants agreed that value connotes a quantitative measure, although not necessarily one expressed in monetary terms. In some papers, the authors derived monetary values. In other papers, the authors derived such nonmonetary values as additions to number of lives saved, improvements in environmental quality, or enhanced regulatory efficiency. The choice depended on the context of the applied problem and the data available for empirical evaluation. By emphasizing a quantitative dimension in expressing the value of information, the participants sought to provide a metric that would be relevant for decisionmaking. In the absence of such measures, it is difficult to gauge the relative usefulness of information, distinguish among types and sources of information that can substitute for one another but may differ in acquisition cost, or inform investment decisions in information collection and use.

When does information have value? All papers and discussant commentaries agreed on the criteria by which “information” has value, with the corollary that information has little or no value in some circumstances. These criteria can provide a set of guidelines for policymakers, program managers, and other leadership in guiding the nation’s investment in information collection and in demonstrating the value of the information.

The criteria follow:

- Information has the most value when decisionmakers are indifferent to the alternative choices to be made in light of the information

- Information has the most value when action can be taken in response to the information. If action cannot be taken, information has less value.
- Information has the most value when the consequence of making the wrong decision is large.
- Information has the most value when the constraints on using the information are few, and the cost of using the information is small.
- The value of “perfect” information may not be commensurate with the cost of its acquisition.
- Information has value even if it introduces more uncertainty. In this case, it reveals that what was thought to be certain may not be.³
- Certain attributes of information may confer more value than other attributes.⁴

What are the state-of-the-art methods to ascribe value to information? The papers illustrated five methodological approaches.

- *Price- and cost-based derivation.* An example of this approach is the use of satellite weather and climate data in weather index insurance in developing countries. In this context, the value of the satellite data is expressed in monetary terms derived directly from the insurance premia and value-at-risk. Another application of this approach illustrates the value of information in terms of losses averted from having the information, expressed in economic costs. This application attributes value to Earth observation data for forecasting vector-borne disease outbreaks. The avoided loss estimate includes avoided control costs, reduced morbidity and mortality, and averted disruption of international trade.
- *A Bayesian belief network.* One application uses this formulation to derive the value of Earth observation data about expected temperature mean and variability in a changing climate and a monetary value for these data. The Bayesian framework is a conventional statistical approach in which people update their expectations when given new information. The belief network allows decisionmakers to bring other information to bear. In this application, the other information is the economy’s output (gross domestic product) and damages associated with climate change. This information “conditions” the value of the Earth observation data. The network also provides an efficient computational approach and a means of visually displaying results to show the determinants of the information value.
- *Regulatory cost-effectiveness.* One application of this framework allows demonstration of direct cost savings enabled by Earth observation data products in implementing land use and water quality regulation. Another application demonstrates peoples’ willingness to pay to avoid the loss of information as a means of informing business decisions to maintain and protect information databases.
- *Econometric modeling and estimation.* Several approaches include econometric estimation of hypothesized relationships between information and people’s decisions. In these cases, the coefficient on the explanatory variables in the estimated equations serves as a quantitative measure of the value of information. These econometric equations also allow the researcher to control for, or hold constant, other variables that influence the value attributable to the information.
 - For example, an application to identify the value of diagnostic tests for malaria estimates quantitatively the size and statistical significance of the information from the tests on behavioral responses of patients in their decision to seek additional treatment.

³ An example is the value of a second opinion in a medical diagnosis.

⁴ Attributes include, for example, timeliness, accuracy, precision, spatial resolution, and spectral resolution.

The coefficient shows by how much the information from the diagnostic test contributes to a patient's decision, controlling for other explanatory variables such as age and income.

- Other econometric applications illustrate the effects of information in situations where the value of information is expressed in added years of life expectancy or other quality-of-life dimensions.
- Simulation modeling and estimation. Other approaches use systems engineering to design flow charts characterizing multiple uses of the same information. For example, an application of this method illustrated how Earth observation data on land use provide information for land carbon assessment. The value of improved land carbon assessment can then be linked to the prices at which carbon is traded in the European Union Emissions Trading Scheme or voluntary exchanges such as the Chicago Climate Exchange.

Next Steps toward Realizing the Value of Information

The participants agreed on several next steps to increase the value of information:

- Focus on information requirements by asking people who use information what they need. Ascertain:
 - what attributes of the information are most useful; and
 - what quality (such as precision, accuracy) is most useful.
- Increase the sophistication of understanding of the usability and quality of information.
- Improve the usability of information, and reduce barriers to its use.
- Lower decisionmakers' constraints by:
 - enhancing the actions that can be taken in response to information;
 - enlarging the number of people who know about the information, including consumers of the information and policymakers; and
 - demonstrating that information has value and is valued.

The participants also agreed on the desirability of setting priorities for information investment in areas that have the ability to produce the greatest economic and nonmarket value. These areas include Earth science data and information that may significantly enhance fundamental knowledge—a social value itself.

Participants further agreed on the usefulness of investing in the development of standardized comparisons of the value of information across applications.

Workshop Outcomes: Short- and Long-Term Impacts

The workshop was seminal and unique in introducing experts in public health and Earth science applications for sustained, day-and-a-half interaction. The experts in both communities are nationally recognized, senior professionals who will carry forward the workshop results to additional communities of practice. The workshop also began to advance a common terminology across social and Earth sciences. The authors and discussants forged relationships, cutting across disciplines and institutions. In addition to their individual spheres of influence, these experts represent a new community of practice that can carry forward methods and applications of value of information to Earth science.

The workshop demonstrated that the value of information can be quantified in contexts that are appropriate to the applications. It is important to establish and communicate that values need not be

expressed in monetary terms, but that other measures, quantitatively expressed, are appropriate—particularly in some Earth science applications contexts. The workshop also provided a basis for valuing information to inform public investment. For example, going forward, the workshop provides the following basis for NASA managers:

- Value can inform the decision to invest in information infrastructure, including observing platforms, instruments, algorithms, validation/verification, and human capital.
- Value can inform the choice of data attributes, for instance, spatial, spectral, and temporal resolution.
- The value of information is unlikely to be, nor should it be, the only factor in these decisions, but the value of information has been an overlooked factor in these decisions.

Workshop discussion also addressed the usefulness of objective measures; for example, who carries out the valuation matters. The valuation must be objective in both perception and execution. Assumptions must be transparent and results must be replicable.

As immediate next steps, enhanced opportunities for convening economists and other social scientists, physical scientists, and program managers from the nation's science agencies would better enable the design and evaluation of value-of-information studies. Funding this line of research in pilot projects could serve to prototype and pave the way for more routine integration of value-of-information studies in science-based and applied-science research. In turn, these efforts would better enable realization of the social benefits of the research. Connecting these efforts within a working group could impart appropriate standardization of terms, approach, and presentation of findings to build a body of research, with practical import, to inform the nation's investment in information.

Appendix: Agenda

**The Value of Information:
Methodological Frontiers and New Applications for Realizing Societal Benefit**

June 28–29, 2010

Resources for the Future

First floor conference room

1616 P Street NW

Washington, DC

<http://www.rff.org>

AGENDA

Day One

Monday, June 28

- 8:00 am Coffee, pastries
- 8:45 am Welcome and introductions
Dr. Ramanan Laxminarayan, RFF
Dr. Molly Macauley, RFF
Dr. Lawrence Friedl, NASA
- 9:30 am Session One
- Earth Observations and Weather Index Insurance*
Daniel Osgood, Columbia University
Discussant: Michael Toman, World Bank
- Information and Catastrophe*
Roger Cooke and Carolyn Kousky, RFF
Discussant: Timothy Brennan, RFF and University of Maryland, Baltimore County
- Understanding the Value of Business Information*
Luther Martin, Voltage Security
Discussant: Adam Finkel, University of Pennsylvania
- 12:30 pm Lunch Session
- Valuing the Potential Impacts of GEOSS: A Systems Dynamics Approach*
Michael Obersteiner, Steffen Fritz, Ian McCallum, and Felicjan Rydzak
International Institute of Applied Systems Analysis
Discussant: Molly Macauley, RFF
- 2:00 pm Break

2:30 pm Session Two

The Effect of Advertising on Consumer Choice and Ready-to-Eat Cereal

Ginger Jin, University of Maryland

Discussant: Mead Over, Center for Global Development

The Complementarity of Privately Supplied and Public Health Information

Jonathan Kolstad, Wharton School, University of Pennsylvania

Discussant: Kenneth Leonard, University of Maryland

Malaria Diagnostics

Jessica Cohen, Harvard School of Public Health

Discussant: Anup Malani, University of Chicago Law School

5:30 pm Wrap up
Adjourn

Day Two

Tuesday, June 29

8:00 am Coffee, pastries

8:30 am Session Three

The Value of Reducing Uncertainties in Global Land Cover with Respect to Climate Change Mitigation Policy Assessment

Steffen Fritz, Sabine Fuss, Petr Havlik, Ian McCallum, Michael Obersteiner, and Jana Szolgayova, International Institute of Applied Systems Analysis

Discussant: Scott Farrow; University of Maryland, Baltimore County

Space Imaging and Rift Valley Fever Vectors

David Hartley, Georgetown University Medical Center

Discussant: Joshua Michaud, School of Advanced International Studies, Johns Hopkins University

The Value of Earth Observations in Environmental Regulation: The Case of Land Use and Pollution

Richard Bernknopf, U.S. Geological Survey

Discussant: Catherine Shelley Norman, Johns Hopkins University

11:30 am Wrap up
Next steps
Adjourn

Appendix: Abstracts, Authors, and Discussants

Earth Observations and Weather Index Insurance

Daniel Osgood, Columbia University

Discussant: Michael Toman, World Bank

Index insurance is a relatively new approach to providing climate risk protection to low-income farmers in developing countries. Because this insurance is implemented in data-poor environments, information constraints and uncertainty pose substantial impacts on the products. Since insurance is a tool that can be used to exchange uncertainty in the market, the level of information available directly impacts prices, with insurance protection for climate risk and insurance protection for information uncertainties about climate risks both being components of the final price. The paper will present this concrete component of the value of information by quantifying the value of improved data in the reduction it allows for insurance prices. The paper uses data, methodologies, and contracts for index insurance applications in Africa. The paper also provides a brief overview of index insurance in developing countries and discusses the value of remote sensing in informing the index and in the role of climate trends.

Information and Catastrophe

Roger Cooke and Carolyn Kousky, Resources for the Future

Discussant: Timothy Brennan, Resources for the Future and University of Maryland, Baltimore County

The standard economic approach to analyzing the climate change problem has been to search for efficient abatement policies. The massive uncertainties and the possibility for cataclysmic climate damages, however, suggest that a risk management approach is more appropriate. This shifts the policy question to how much risk of catastrophe society is willing to accept. Risk management requires different information than economic efficiency. In particular, improved information on the nature of catastrophic impacts, their likelihood under differing emissions scenarios, the ability to detect tipping points before catastrophic impacts materialize, and the timeframe for response should we pass such tipping points, all become critical. Using the value-at-risk management approach from the banking and insurance sectors as an analogy for managing the risk of climate change catastrophes, we provide rough estimates of the value of improved information in these areas. We also note that knowing when not to wait for more information is just as important as when to wait for more information.

Understanding the Value of Business Information

Luther Martin, Voltage Security

Discussant: Adam Finkel, Executive Director, Penn Program on Regulation, University of Pennsylvania

The field of information security encompasses protecting information from unauthorized access, use, disclosure, disruption, modification, or destruction. At its core is the cost-benefit trade-off that businesses need to make when they decide how to invest in information security technologies. Applying traditional cost-benefit analyses to information security, however, can sometimes lead to very puzzling results. Many businesses seem to be conflicted when it comes to understanding the value of their

information. Many claim that it is their most valuable asset, yet they seem unwilling to invest in information security technologies to protect it. A closer look at a few different ways to understand the value of information suggests how to resolve this apparent paradox.

Valuing the Potential Impacts of GEOSS: A Systems Dynamics Approach

Michael Obersteiner, Steffen Fritz, Ian McCallum, and Felicjan Rydzak; International Institute of Applied Systems Analysis

Discussant: Molly Macauley, Resources for the Future

National governments and international nongovernmental organizations have joined together to build the Global Earth Observation System of Systems (GEOSS) to integrate the multitude of Earth-observing sensors flown in space to measure and monitor natural and environmental resources. How best to achieve this integration across institutions is far from clear, however. This paper presents a systems dynamics approach to assess the impact of improvements in Earth observations. The paper considers each of nine societal benefit areas (ranging from public health and natural disasters to biodiversity) that have been identified by the Group on Earth Observation, responsible for implementing the GEOSS. We find that the benefits from integrating the systems derive from economies of scope in the actual collection of observations as well as their application to interrelated benefits.

The Effect of Advertising on Consumer Choice and Ready-to-Eat Cereal

Ginger Jin, University of Maryland

Discussant: Mead Over, Center for Global Development

This paper models how consumers make brand choice when they have limited information. In an experience-good market with frequent product entry and exit, consumers face two types of information problems: first, they have limited information about product existence; second, even if they know a product exists, they do not have full information about its quality until they purchase and consume the product. In this paper, we incorporate purchase experience and brand advertising as two sources of information and examine how consumers utilize them in a dynamic process. Specifically, to address the awareness problem, we model the consumer choice set as a function of experience and advertising, which varies across consumers and evolves over time. In terms of quality, we allow a first-time consumer to infer product quality from advertising. Once she buys the product, she learns the quality perfectly. To better capture the dynamics, we incorporate habit formation conditional on each consumer's purchase history. The model is estimated using the AC Nielsen homescan data in Los Angeles, which records grocery-shopping histories for 1,402 households over six years. Taking ready-to-eat cereal as an example, I find that consumers learn about new products quickly and form strong habits. More specifically, advertising has a significant effect informing consumers of product existence and signaling product quality. However, advertising's prestige effect is not significant. We also find that incorporating limited information about product existence leads to larger estimates of the price elasticity.

The Complementarity of Privately Supplied and Public Health Information

Jonathan Kolstad, Wharton School, University of Pennsylvania

Discussant: Kenneth Leonard, University of Maryland

Information-based policy interventions have become increasingly common in health care markets. The rationale for such interventions is to correct a market failure in which consumers are asymmetrically informed about relevant attributes of a health care provider (e.g., quality). The magnitude of this market failure and the impact of public intervention on welfare depend on whether market-based information on quality alters consumer choice. To better understand such effects, I study consumer response to information provided by *U.S. News and World Report* hospital rankings and reputation before and after the release of report cards on surgeon quality in Pennsylvania's market for cardiac bypass surgery. I estimate a model of consumer demand for surgeon quality (mortality) that integrates market-based information and quality reporting while controlling for the role of insurers and referring physicians in consumers choice. The role of public versus market-based learning is identified using the interaction of the inter-temporal change in information induced by the release of report cards with differences across providers in market-based information on those providers' quality. I find that market-based mechanisms explain about half the response to quality prior to the release of report cards. After public release of information, the response to surgeon quality increases significantly. However, existing *U.S. News and World Report* rankings reduce consumer response to surgeon quality.

Malaria Diagnostics

Jessica Cohen, Harvard School of Public Health

Discussant: Anup Malani, University of Chicago Law School

Increasing evidence is emerging that a large share of non-malarial illnesses are treated with antimalarials in Africa. Recent evidence from drug shop purchases in rural Kenya suggests that only 35 percent of older children and adults purchasing artmesinin combination therapies (ACTs) for malaria actually have the disease, and recent estimates of overtreatment from urban areas such as Nairobi and Kampala are even more striking. These studies are revealing that patients and caregivers seeking treatment for malaria are poorly informed about true malaria prevalence and the probability that their symptoms are being caused by malaria. Beyond the health consequences of inappropriate treatment, this lack of information can lead to many other inefficiencies, such as slow learning about the benefits of ACTs and bed nets, and negative externalities in the form of accelerated parasite resistance. In this context, an accurate and appropriately priced rapid diagnostic test (RDT) could be valuable to consumers, "social planners" or governments, and potentially pharmacists and other private-sector providers. We explore the value of a malaria diagnosis in the retail sector (pharmacies) to help provide structure to the current policy debate over subsidies for RDTs in that sector. We consider the value of RDTs from the consumer's perspective (what are consumers willing to pay for a diagnosis, and under what circumstances does a diagnosis change consumer behavior?), from the pharmacist's perspective (under what circumstances are RDTs profitable?), and from the social planner's perspective. We conclude with recommendations about policy tools such as RDT subsidies, pharmacist training, and consumer information/education campaigns that can potentially encourage more widespread use of malaria diagnostics.

The Value of Reducing Uncertainties in Global Land Cover with Respect to Climate Change Mitigation Policy Assessment

Steffen Fritz, Sabine Fuss, Petr Havlik, Ian McCallum, Michael Obersteiner, and Jana Szolgayova;
International Institute of Applied Systems Analysis

Discussant: Scott Farrow; University of Maryland, Baltimore County

In this paper, we evaluate the value of improved global land data. We first ask how models designed to help in policy design can be used to quantify the differences in policy implementation costs. By examining the differences in implementation costs, we are able to quantify the benefit of better information. We then develop a portfolio optimization model to find the optimal mix of mitigation options under different sets of information to estimate the benefit of having an improved land cover dataset. We illustrate the methodology by comparing portfolio outputs of the different mitigation options modeled within the GLOBIOM economic land use model with cropland data from different land cover databases.

Space Imaging and Rift Valley Fever Vectors

David Hartley, Georgetown University Medical Center

Discussant: Joshua Michaud; Johns Hopkins University

The ability to analyze the Earth's surface over large areas is tantamount to infectious disease transmission risk assessment. The value of this information must be known, though, if Ministries of Health and other public health agencies are interested in employing this technology. This paper provides an overview of the applications of remote sensing to public health, focusing on a case study of Rift Valley Fever, including remote sensing's impact across human and agricultural dimensions and the potential related avertable burden of disease.

The Value of Earth Observations in Environmental Regulation: The Case of Land Use and Pollution

Richard Bernknopf, U.S. Geological Survey

Discussant: Catherine Shelley Norman, Johns Hopkins University

Environmental data collected from the unique vantage point of space satellites offer a wholly new basis for economic analyses of public policy. We use a sample of these data to disentangle the cumulative regulatory-induced effects of agricultural production on the environment, a set of effects that at present is confounded by the concurrent implementation of agriculture, energy, and environmental policies. We consider the case of corn production in the U.S. Midwest, where biofuels mandates, land and water protection, and crop production subsidies have intended and unintended consequences on long-term economic output and environmental resources. By coupling space-derived data on spatial and temporal changes in land use with production and economic data, we develop empirical estimates of the value of satellite data in evaluating decisions on the use of natural resources and agricultural output.

About the Organizers

Ramanan Laxminarayan is a senior fellow at Resources for the Future, where he directs the Center for Disease Dynamics, Economics, and Policy, and a visiting scholar and lecturer at Princeton University. His research deals with the integration of epidemiological models of infectious diseases and drug resistance into the economic analysis of public health problems.

Molly Macauley is a senior fellow and research director at Resources for the Future. Her research interests include space economics and policy, the economics of new technologies, climate policy, and the use of economic incentives in environmental regulation.