The Value of Information

Ramanan Laxminarayan • Molly K. Macauley
Editors

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Methodological Frontiers and New Applications in Environment and Health

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Abbreviations (Chapter numbers in parentheses)

ACT	artemisinin combination therapy (antimalarial drugs) (7)
AHA	American Hospital Association (6)
AIC	Akaike information criterion (5)
ARC	Africa Rainfall Climatology (1)
AWiFS	Advance Wide Field Sensor (10)
BAU	business as usual (2, 4)
BBN	Bayesian belief net (2)
BSE	bovine spongiform encephalopathy (9C)
CABG	coronary artery bypass graft (6)
COP	conference of the parties (of UNFCCC) (8)
CRRA	constant relative risk aversion (2)
DICE	model Dynamic Integrated model of Climate and the Economy (2)
EMR	expected mortality rate (6)
EO	Earth observation (4)
EPA	Environmental Protection Agency (10)
ESA	European Space Agency (8)
EVPI	expected value of perfect information (8)
FAO	Food and Agriculture Organization (4, 8, 9)
FeliX	Full of Economic-Environment Linkages and Integration dX/dt (4)
FFS	fee for service (6)
FTC	Federal Trade Commission (5)
GEO	Group on Earth Observation (4)
GEOBENE	Global Earth Observation—Benefit Estimation: Now, Next and Emerging (4)
GEOS	Global Earth Observation System (10)
GEOSS	Global Earth Observation System of Systems (4, 8)
GHG	greenhouse gas (2, 4, 8)
GLOBIOM	Global Biosphere Management Model (8)
GWP	gross world product (4)
HARITA	Horn of Africa Risk Transfer for Adaptation (1)
HMO	health maintenance organization (6)

IAA	integrated assessment approach (10)
IAM	integrated assessment model (2)
IIASA	International Institute for Applied Systems Analysis (8)
ICU	intensive care unit (6)
IFPRI	International Food and Policy Research Institute
IIA	independence of irrelevant alternatives (5C)
ILRI	International Livestock Research Institute (1)
IPCC	Intergovernmental Panel on Climate Change (8)
IPCC	4 Fourth Assessment Report of the Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society (1)
IT	information technology (3)
IV	instrumental variables (5)
LULC	land use and land cover (10)
LULUCF	land use, land-use change, and forestry
MCL	maximum contamination level (10)
MRLI	moderate-resolution land imagery (10)
MSL	maximum simulated likelihood (5)
NDVI	normalized difference vegetation index (9)
OIE	Office International des Epizooties (9)
OLS	ordinary least squares (5)
OMR	observed mortality rate (6)
PHC4	Pennsylvania Health Care Cost Containment Council (6)
RAMR	risk-adjusted mortality rate (6)
RDT	rapid diagnostic test (for malaria) (7)
REDD	Reducing Emissions from Deforestation and (forest) Degradation (8)
RTE	ready-to-eat (cereal) (5)
RVF	Rift Valley fever (9)
SBA	societal benefit area (4)
SBSTA	Subsidiary Body for Scientific and Technological Advice(8)
USDA	US Department of Agriculture (10)
USGS	US Geological Survey (10)
VaR	value at risk (1, 2)
VOI	value of information
VSL	value of a statistical life (3)
WHO	World Health Organization (9)
WIIET	Weather Index Insurance Education Tool (online software)
WTP	willingness to pay
UNFCCC	United Nations Framework Convention on Climate Change (8)

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Introduction

Ramanan Laxminarayan and Molly K. Macauley

Although the idea that information has value in both a statistical and a pragmatic sense dates back at least to the 1950s, in recent years, interest in the economic value of information has taken center stage. 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. Companies face the problem of what types of information best inform consumers of their products, and how to ascribe value to that information. The chapters in this volume explore innovative methodologies and applications of value of information research.

The chapters focus on applications in two disparate fields linked by the importance of valuing information: public health and space. Our selection of these two topics follows from several opportunities. Researchers in the health field have developed some of the most innovative methodologies for valuing information. These applications range from the value of diagnostics in informing decisions to treat patients to the value of private information on health insurance plans when some information is already publicly available. We seek to highlight these innovations in this volume, but broader challenges remain. How much should developing countries that spend less than $10 per person per year on the health of their citizens invest in gathering information to improve that resource allocation decision? How do individuals choose to respond to information, which in turn has an enormous impact on the value of that information?

Our "space" topic refers to innovations in the technologies that collect information; this is the new information provided by the growing number of Earth-observing satellites that collect data about air quality, freshwater supplies, climate, and other natural and environmental resources that affect our health and our overall quality of life. In this field, recent applications of value-of-information methods are critically important for informing investment in the satellite networks. As of 2010, 79 satellites were circling Earth to observe, measure, and monitor the natural dynamics of freshwater, the oceans, land, the atmosphere, and climate, together with human interactions with these resources and consequent implications for human and environmental health. The satellites represent an investment made by more than 40 countries and totaling an estimated $40 billion.

A common theme in this book is that information is often, although not always, a public good. Once the information has been gathered and provided for people to use, one more person can use the information without reducing its value to others or imposing costs on them. This attribute of information—additional use at very low additional cost, or widespread benefit beyond that accruing to just one individual—also justifies public investment in collection and supply of many types of information. For example, testing individuals for a disease will benefit not only the individuals in caring for their own health, but contributes to public information about disease prevalence and in turn informs public health investment in disease prevention. The information collected by an Earth resource observing satellite may benefit all of society, although it may not be optimal for a single individual to launch the satellite.

As the examples in this book show, investment in information has the potential to deliver valuable societal benefits, including better-informed citizens, companies, and governments. But this value has seldom been measured or expressed in ways to ascertain whether the investment is paying off. Worse, suppliers of the information often pay little attention to the form in which information is communicated to decisionmakers, the information-processing costs that decisionmakers face, or their ability to use the information in a time frame that makes the exercise worthwhile.

The chapters are based on papers commissioned for a workshop hosted by Resources for the Future and held in Washington, DC, on June 28–29, 2010. Workshop participants included 120 people from government, the private sector, universities, and other nongovernmental organizations. A steering committee assisted in planning the workshop. Discussants drawn from the government and academic communities were selected to lead the conversation about each paper; these commentaries follow their respective chapters. The discussant chapters were written based on versions of the papers presented at the workshop. Some of the papers have evolved since the workshop.

What Is Distinctive About This Volume?

This volume is the first to present research by experts in two disparate communities—social scientists and experts in the use of satellite data about natural and environmental resources—to identify and critique state-of-the-practice methods for ascribing value and social benefit to information. The findings offer answers to important questions: What is meant by *value of information?* When does information have value? What are the state-of-the-practice methods to ascribe value to information? The contributors identify 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. They advance terms to describe what is meant by "value" (which need not be expressed in monetary terms) and identify steps to ascribe, measure, and communicate value.

Overview of the Chapters

In Chap. 1, Daniel Osgood and Kenneth Shirley describe index insurance, a relatively new approach to providing climate risk protection to low-income farmers in developing countries. The success of index insurance hinges critically on the climate information: What weather pattern can be expected over the long term and with what degree of certainty? Osgood present this concrete component of the value of information by quantifying the value of improved data in the reduction it allows for insurance prices.

Continuing a focus on climate but broadening the discussion, Roger Cooke and Carolyn Kousky in Chap. 2 propose a way for society to manage risk in light of the possibility of cataclysmic damages if climate changes abruptly. This concern shifts the policy question to how much risk of catastrophe society is willing to accept. Using the value-at-risk management approach from the banking and insurance sectors as an analogy for managing the risk of climate change catastrophes, Cooke and Kousky provide rough estimates of the value of improved information in these areas. They offer the important observation that knowing when not to wait for more information is just as important as knowing when to seek additional information.

Luther Martin asks in Chap. 3 whether one can infer the value of business information by observing how much companies spend to protect this information. Many businesses claim that information is their most valuable asset. Martin finds that unless protection is required by regulation or legislation, businesses appear unwilling to invest heavily in technologies to protect information—say, from unauthorized access, use, or disruption. Part of the reason may be that in many cases, huge amounts of information flow through a company, and “at the margin,” the value of information is quite low. On this basis, the benefit of increasingly large efforts to protect information may not justify the cost. Another explanation may be that businesses perceive the probability of hacking or other breaches of security to be quite low and thus have low incentives to invest in information protection. Martin explores these and other reasons why efforts to secure information may be imperfect measures of information’s value.

Martin’s point of view is that of the business sector. In Chap. 4, Michael Obersteiner, Steffen Fritz, Ian McCallum, and Felicjan Rydzak characterize the value of investment in information made by the government sector. In particular, they consider the case of investment by European governments in satellites to observe natural and environmental resources. Different governments have each invested in these satellites, leading to the possible opportunity for global coordination of satellite investment to enhance the value of the information. Obersteiner and his colleagues present an engineering approach drawn from the field of systems dynamics to assess the effect of such integration in improving the value of information.

A recurrent theme in the value of public information is how information alters economic choices and thereby influences societal welfare. Often the value of information is in changing consumer behavior—altering decisions on what health insurance to buy, which hospital to go to, or how energy-efficient a washing machine to buy. The expectation is that publishing information, whether about environmental indicators or hospital infections, will alter demand-side behavior, which in turn will result in higher quality. However, does information truly alter consumer behavior? What is its effect in the case of "experience goods," where a single experience with the good could be important in adoption and habit formation?

In Chap. 5, Yan Chen and Ginger Jin study how consumers choose among brands when they have limited information about the product and its quality (even if they know that the product or brand exists). How does information derived from two distinct sources of information—purchase experience and brand advertising—influence consumer purchase decisions? Using Nielsen Marketscan data, they find that advertising does inform consumers about the existence and quality of a product. Incorporating information about the existence of a product increases price elasticity, they find, because informative advertising increases consumer choice set. We can infer from this that in a range of spheres, public information about choices can improve consumer welfare. So an effort by government to provide information on energy-saving appliances could inform consumers about their choices for lowering their energy bills. Indeed, informative advertising may be underprovided by private firms, if part of the value of this advertising is public. Public information can help consumers make a smarter choice of first-time experience and have a lasting effect on consumer welfare through habit formation.

In Chap. 6, Jonathan Kolstad tackles the related theme of the relative value of public and private information. Public information is often justified in its role to correct market failures generated by asymmetric privately provided information. For instance, a hospital may advertise the need for an expensive surgical procedure even if such a procedure has questionable health value. Kolstad looks at how consumers respond to hospital rankings provided by *U.S. News and World Report* hospital reputation before and after the release of report cards on surgeon quality in Pennsylvania's market for cardiac bypass surgery. Kolstad addresses two questions. First, how much do market-based learning and private information (such as that provided by a physician in choosing a specialist) alter consumer choices in the absence of public reporting? And second, does the prior existence of privately provided public data (such as by *U.S. News*) alter the value of public reporting? He finds that privately reported data are a substitute for publicly provided information. There are two main lessons to take away from this study. Researchers must consider existing sources of information on quality available to consumers when deciding on investments in public information. Not accounting for these existing sources could lead to underestimates of the value of public information. Public information could have important distributional consequences that depend on consumers' *ex ante* knowledge of provider quality. Public information, in this case, could have large effects among those who do not have access to privately provided information.

But how likely is information to be provided by private sources? On the one hand, private sources can charge for the information. On the other hand, their profits could be influenced by the information they provide, if they are attempting to sell a bundled good of both information and a commodity or service. Take the case of small drug sellers in Africa who sell antimalarials, including expensive artemisinin-based combinations (ACTs). Use of ACTs when the patient does not have malaria can lead to wasted resources, loss of an opportunity to treat for the true underlying condition that is making the patient sick, and sometimes drug resistance and side effects because of inappropriate use of the drugs. Given the right incentives, small drug sellers (where the majority of Africans seek treatment for malaria) who make money from ACT sales could also sell rapid diagnostic tests (RDTs) that could quickly inform the patient whether he or she has malaria. In Chap. 7, Jessica Cohen and William Dickens find that with symmetric information about the likelihood that patients have malaria, and no subsidies for treatment, drug shop owners will provide RDTs at a socially optimal level. But if ACTs are subsidized and there are external costs associated with the misuse of antimalarials, drug shops will likely underprovide RDTs. This underprovision can be corrected through a wholesaler level subsidy for RDTs; educating customers about the true prevalence of malaria can also help.

Additional questions about how best to characterize the value of information to inform investment are addressed in the remaining chapters. In Chap. 8, Steffen Fritz, Sabine Fuss, Petr Havlík, Ian McCallum, Michael Obersteiner, and Jana Szolgayová evaluate the value of improved global data about land. They develop and then illustrate 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 data set to evaluate policies influencing land use.

The case for greater investment in satellite data is often made on the back of public health. More precise information on weather patterns could help improve our ability to predict disease outbreaks and thereby reduce loss of life and economic damage by allowing local authorities to take preventive action. Emerging understanding of the spatiotemporal determinants of disease emergence and transmission indicates that such prediction is possible, although there is no guarantee that the information will actually be used to prevent disease. As David Hartley notes in Chap. 9, data on the economic payoff from investments in information aimed at reducing health risk are sparse to nonexistent. He discusses economic returns in the context of Rift Valley fever, a disease for which there has been significant investment in weather-based predictive modeling.

In Chap. 10, Richard L. Bernknopf, William M. Forney, Ronald P. Raunikar, and Shruti K. Mishra use a sample of satellite 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. They consider the case of corn production in the Midwest of the United States, where biofuels mandates, land and water protection, and crop production subsidies have both 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, they develop empirical estimates of the value of satellite data in evaluating decisions on the use of natural resources and agricultural output.

Findings and Results

What the chapters show is the array of methods for ascribing value to information and the desirability of bringing these methods to bear to inform public investment in information collection, dissemination, and use—whether one is a corporation, the government, or a private individual.

What is meant by "value?" In general, the authors agree that value connotes a quantitative measure even if it is not necessarily expressed in monetary terms. In some chapters, the authors derive monetary values. In other chapters, the authors derive nonmonetary values, such as number of lives saved, improvements in environmental quality, or enhanced regulatory efficiency. The choice depends on the context of the problem and the data available for empirical evaluation. By emphasizing a quantitative dimension in expressing the value of information, the authors seek to provide a metric that would be relevant for decisionmaking. In the absence of such measures, it is difficult for a company, the government, or a consumer 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 the authors agree on the criteria by which "information" has value, with the corollary that there are circumstances in which information has little or no value. These criteria can guide policymakers, corporate managers, and other leaders in making investments in information collection and in demonstrating the value of the information on behalf of consumers, shareholders, and the public. The criteria are as follows:

- Information has the most value when decisionmakers are more indifferent among their alternatives.
- 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.[1]

[1] An example is the value of a second opinion in a medical diagnosis.

- Certain attributes of information may confer more value than other attributes.[2] *What are the state-of-the-art methods to ascribe value to information?* The chapters illustrate five methodological approaches.
- Price- and cost-based derivation. The illustrations of this approach include the use of satellite weather and climate data in weather index insurance in developing countries. In this context, the value of the satellite data are expressed in monetary terms derived directly from the insurance premiums and the value at risk. Another example is the value of information in terms of losses averted from having the information, expressed in terms of economic costs associated with vector-borne disease outbreaks. The avoided loss estimate includes avoided control costs, reduced morbidity and mortality, and averted disruption of international trade.
- Bayesian belief network. This approach uses a Bayesian belief net to derive a monetary value for Earth observation data about expected temperature mean and variability in a changing climate. The Bayesian framework is a conventional statistical approach in which people update their expectations when given new information. The belief net allows other information to be brought to bear by a decisionmaker. In this example, the other information was the economy's output (gross domestic product) and damages associated with climate change. This information "conditions" the value of the Earth observations data. The net also provides an efficient computational approach and a means of visually displaying results to show the determinants of the information value.
- Regulatory cost-effectiveness. The illustration of this approach demonstrates direct cost savings enabled by Earth observation data products in implementing land-use and water quality regulation. Another application of this approach demonstrates people's willingness to pay to avoid the loss of information as a means of informing regulatory decisions to maintain and protect information databases.
- Econometric modeling and estimation. Illustrations of this method use statistical approaches involving 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, econometric evaluation of the role of diagnostic tests for malaria allows quantitative estimation of the size and statistical significance of the information from the diagnostic tests on behavioral responses of patients in their decision to seek additional treatment. The results show by how much the information (from the diagnostic test) contributes to a patient's decision, and the other explanatory variables show how much other factors (age, income, etc.) contribute to the decision. Other applications of this approach illustrate the effects of information in situations where the value of

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[2] Attributes include, for example, timeliness, accuracy, precision, spatial resolution, and spectral resolution.

information is expressed in added years of life expectancy or other quality-of-life dimensions.

- Simulation modeling and estimation. An example of this approach is use of systems engineering to design flow charts characterizing multiple uses of the same information. For example, 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 Trading System, for example. The common theme across all of those approaches is the goal of a quantitative expression for the value of information, although the value need not be in monetary terms.

Going Forward

The research presented here shows the dire need for those who invest in information collection to better understand the needs of those who use the information. What attributes of the information are most useful? What quality (how much precision or accuracy) is most useful? What are the barriers in using information? How can the constraints on decisionmakers be lowered, to enable them to make better use of information. For example, can we expand the solution set (i.e., enhance the actions taken in response to information)? Can we ease cognitive constraints (i.e., enlarge the number of people who know about the information, including consumers of the information and policymakers)? Can we change resource constraints (i.e., the budgets governing investment in information) by better demonstrating that information has value and is valued?

If we can begin to answer these questions, we can set priorities for information investment in areas that have the ability to produce the greatest economic and nonmarket value.