Economic Value of Weather Forecast Information and Use of Forecast Information in Decision Making (Theme 3)

Philip Ganderton
University of New Mexico
Economics Department
MSC05 3060
Albuquerque, NM 87131
gandini@unm.edu

Prepared for the North American THORPEX Societal and Economic Research and Applications (NAT SERA) Workshop
August 14–16, 2006
Boulder, Colorado

August 1, 2006

DRAFT: Please do not cite or quote.

Theme 3: Economic Value of Weather Forecast Information and Use of Forecast Information in Decision Making

1. Defining high-impact (HI) weather events and HI weather forecasts

The meteorological definitions of these terms emphasize extreme weather phenomena (e.g., temperatures, winds, and precipitation). An economic perspective on HI weather would focus on weather that had extreme consequences, whether they were physical, economic, social, or psychological. Similarly, a weather forecast has high impact because of the economic consequences of the weather. A discontinuity could emerge between these definitions if a forecast of small changes in weather (perhaps an error of 2 or 3 degrees) has large economic consequences (e.g., energy companies cut back production and suffer excessive demand).

Clarifying the relationship between HI weather and HI forecasts is critical, yet easily beyond the scope of this theme paper. For current purposes I will define HI weather as having large or severe economic and social consequences, even if the weather itself is not particularly extreme. Weather forecasts, on the other hand, by providing information relating to the nature of temperatures, winds, and precipitation, have a value derived from the use made of the forecasts (a forecast that everyone ignores, or that cannot be acted on, has no value).

At some point in our research we must define, identify, and relate three concepts to each other: (1) HI weather, (2) forecasts of HI weather, and (3) HI weather forecasts.

The value of HI weather forecasts is defined by better decision making in advance of extreme weather or weather with extreme consequences. Accuracy, timeliness, relevance, and accessibility are the dimensions of forecasts that would lead to improved decisions. To employ the terminology of the natural hazards community, forecasts have the potential to improve decisions before events occur (*mitigation* and *preparedness* phases), as well as during and after the event (*response* and *recovery* phases).

2. Research on and understanding of the value of improved weather forecasts

The seminal work in this area is *Economic Value of Weather and Climate Forecasts,* edited by Richard Katz and Allan Murphy (1997). In the literature and in studies of valuing weather forecasts, a distinction has traditionally been drawn between *prescriptive* approaches (in which forecasts generate actions consistent with some specified optimization problem) and *descriptive* approaches (in which actual responses to forecasts are evaluated using decision and information science methods). Lazo and Chestnut's (2002) study reveals the weakness in this distinction because their work merges aspects of both approaches. Without fear of adding just another unnecessary taxonomy, I would divide previous work in forecast valuation into two general categories: (1) studies that deduce the value of improved forecasts using idealized scenarios; and (2) studies that derive the value from observed or stated preferences (called "economic welfare studies" in this paper). Idealized scenario studies tend to have the following characteristics:

- Agents (providers and users) are stylized with assumed preferences over utility and risk.
- Weather information is simple and perfect with categorical or point values and known probability distributions.
- Decision environments are simplified.

In contrast, economic welfare studies tend to have the following characteristics:

- Agents are identified and sampled for observed or stated behavior.
- Risk preferences are deduced, not assumed.
- Measurements are made in real contexts.

Although the two methods should produce similar measures of the value of the same forecast improvement, there are many reasons to anticipate divergence of results. Disparities emerge from simplifications, assumptions, errors, and approximations. The strength of idealized studies lies in removing the many distractions, covariates, and errors that plague direct observations, allowing us to focus on fundamental decisions and outcomes. The strength of economic welfare studies comes from recognizing the complex interactions among multiple factors when agents make decisions. Ultimately these two methodologies are not competing but complementary.

The existing literature includes many studies that simulate value by making assumptions about the risk preferences of forecast users in an expected utility framework, assuming the availability of perfect categorical or point value weather forecasts, then calculating optimal actions for stylized users under various weather and climate conditions (Adams et al., 1995; Hill et al., 2002; Britt et al., 2002). This method makes it possible to calculate the value of forecasts under idealized conditions. Some studies use economic welfare as the measure of the economic value of forecasts. Instead of simulating user preferences, Lazo and Chestnut (2002) use a stated preference choice model to assess the value of weather forecasts to U.S. households. Their study estimates the economic value of forecasts by the—unobserved, but stated—willingness to pay for changes (reductions or improvements) in forecasts. Rollins and Shaykewich (2003) use a similar method to estimate the value of various numerical weather forecast products, including an automated telephone service in Toronto that allows users to obtain a forecast.

In future research, we must develop models of decision making—similar to the idealized scenarios—that can highlight critical decisions and outcomes affected by improved forecasts. We must also parameterize and calibrate these models with estimates from observed behavior in both hypothetical and actual conditions.

3. The most critical research need

Simply put, we need models of the impact of weather on economic activity. These models must allow us to measure the value of improved weather forecasting, including HI weather forecasts. Economic activity is a very general term to describe all activities by individuals, groups (organizations), and institutions (usually governments) that produce or have value. The economy of the United States, for example, could be described by an incredibly complicated system of relationships and interactions between individuals. Even when simplified considerably, these models would describe many relationships between inputs, technology, the environment, outputs, and consumers/users of the models (outputs). The problem that economists face is not one of too few models of the production process, consumer behavior, and markets. Instead, we lack models that explicitly include weather as an input into objective and constraint functions and that recognize the separate role played by weather forecasts. We do not have models comprehensive enough to be used for a regional or national assessment of changes in weather forecasts.

Weather forecasts are information, and relatively little is known about how economic agents—producers, consumers, and governments—use information to make economic decisions. Two areas are of interest here: the economic value of information (Lawrence, 1999), and the way in which economic agents use information. (Hilton, 1981) Although the two are clearly related, it is possible to observe an economic value of information without understanding how that information generated value. More can certainly be learned about the decision process than is observed about the outcomes of those decisions (the economic choices people make). The role of information is generally deduced in controlled experimental settings by holding everything constant, changing information, and observing choices. There are just too many variables in nonexperimental data to allow us to isolate the effect of different information on economic choices. This is one of the reasons why experimental economics has become so closely associated with behavioral economics (Camerer and Loewenstein, 1997; Mullainathan and Thaler, 2000). In research on the value of information, few studies have considered weather forecasts, and more research must be done to characterize the informational content of weather forecasts compared to other forms of information. Although many similarities may exist, the specifics of how users respond to weather forecasts can inform the valuation research agenda. In pursuing a research agenda dealing with behavioral issues, relevant research questions include

- Who are the decision makers who use weather forecasts?
- Who values weather forecasts (by their demand for and use of weather forecasts)?
- Who wants to know the value of forecasts (governments, private groups)?

4. Types of analysis suitable for measuring HI weather forecast value

Essentially, there are two broad categories of analysis: theoretical and empirical. These relate, albeit weakly, to the previous distinction between idealized models and economic welfare models. Although the very practical nature of weather forecasts suggests that development of theory is unlikely and perhaps unnecessary, a potential exists to develop game-theoretic models of user decision making. These models could be checked for internal consistency and performance using simulated data. Empirical models, especially of the use of forecasts and the decisions they generate, offer the most fertile opportunities. Note that when mentioning agent behavior, I do not refer to agent-based models, which are ultimately very complex systems built from very simple agent behavior. I do not currently see much potential application for these models in a forecast valuation research agenda.

Two types of research programs fall under the empirical model banner—those using field data and those using experimental data. Any behavioral model must be parameterized and tested using data. Because of the nature of HI weather and the associated forecasts, collecting relevant data is difficult for many reasons. For example, meteorological systems generate a plethora of data, much of which is unnecessary for economic analysis. In addition, real-time data generation makes identifying all extraneous influences (which must be controlled for in economic analysis) extremely difficult.

Although considerable meteorological and physical data are collected, little emphasis is placed on gathering response and decision data. This is true whether the data are collected and used by private organizations or public entities. Although HI weather occurs almost constantly around the globe, data on specific events at a particular location is sporadic. Even if such data were available, we must deal with the many influences that are conflated within the data. To isolate the influences of the improvements in HI weather forecasts, we must remove or control for these influences. The distinctions among HI weather, weather with large or extreme economic consequences, and HI weather forecasts alter the relative importance of some of these issues, yet they remain critical. In general, the current data relating to HI weather forecasts does not lend itself to economic analysis and measurement of value. Once economic models of value for weather forecasts are designed, requesting the relevant data from meteorological experiments and real-time event monitors could become a priority.

The alternative to collecting field data is generating data in controlled hypothetical settings. In economics, there is now a considerable body of experimental designs and methods that can be applied to analyzing the value of HI weather forecasts in improving decision making under uncertainty (see, for example, Roulston et al., 2005). Considerable potential exists for using economic experiments or simulated environments to develop, test, and refine models of decision makers who use HI weather forecasts. Some elements of these experiments follow.

- Stylized problems faced by users of HI forecasts can be designed to capture the essential elements of decisions without the burden of too much detail.
- Actual decision maker groups can be identified and sampled to form subject pools for the experiments.
- Although hypothetical, the experiments are salient in that subjects are compensated for their efforts and rewarded through clearly defined performance incentives.
- "Time" can be accelerated in experimental settings to expose subjects to more events than could be observed naturally.
- All design parameters—including measuring the risk aversion of subjects and other exogenous factors—can be tested.
- Behavioral experiments can be incorporated into other elements of HI forecast research, especially the development of user interfaces and data presentation.

5. Dimensions of an experimental economics research agenda

Experiments analyzing the role of improved forecasts in decision making can be incorporated into a larger research program that uses demonstration projects to gather field data on actual events, systems, users, and outcomes. An experiment-based research program could generate a range of questions and answers:

- What aspects of HI weather forecasts are important to decision makers?
- What is the relative importance of each forecast dimension to users?

- Do different users place different relative importance on forecast dimensions?
- Do different users require different user interfaces and presentation modes?
- How do decision makers use forecasts?
- Do better forecasts reduce or increase user risk aversion?
- Are forecasts used alone, or in concert with other sources of information?

The value of improved forecasts along various dimensions can be inferred in the experimental settings by observing the trade-offs and marginal decisions made under given situations (or sets of parameters). The type of conjoint-based analysis performed by Lazo and Chestnut (2002) provides a good example of the method that can be used with both experimental and survey data to value attributes or dimensions. Multiple margins could be valued using empirical models based on observed trade-offs, including a marginal change in HI weather, a marginal improvement in HI weather forecasts, and a marginal change in response to the forecast. Although expressed in experiment currency, they represent relative values that can be translated into prices. If calibrated using field data, these relative values can be used to calculate dollar values comparable to system costs within a benefit cost analysis (BCA). It is notable that all these calculations can be done with field-generated data (Lazo and Chestnut, 2002), because the estimation method is general and not just specific to experimentally generated data. Consequently, the estimation of the value of incremental changes in weather forecast dimensions (e.g., timeliness, accuracy, coverage, relevance, and accessibility) is a method that can be used to request and collect real-time data that are not currently being gathered.

6. The role of BCA

BCA offers an assessment tool for evaluating alternative projects that can improve HI weather forecasts. BCA is a general framework for identifying costs of improvements in forecasts and benefits from those improvements. Estimates of benefits derived from experimental, simulated, or survey-based (revealed preference) studies are increasingly being used in BCA. Consequently, BCA is a general program evaluation tool, not to be confused with behavioral models or other valuation models of the kind discussed previously.

Individual estimates can be aggregated by simply multiplying mean values with numbers of agents or by applying distributions of characteristics to sets of estimates. Benefits can be hard to identify and measure, and although some cost estimates present problems (e.g., when forecasts are jointly produced with other information or services), system development, deployment, and maintenance costs are relatively easy to measure or predict. Although not exhaustive, the type of valuation methods I discuss in this paper offer the potential to measure the benefits of improved HI weather forecasts.

I believe that building models of decision making using weather forecasts must precede measurement of value and subsequent BCA of alternative forecast improvements. Without an understanding of how and why certain individuals and organizations use HI weather forecasts, we cannot hope to measure the value of improvements in forecasts or evaluate programs that offer specific bundles of improvements.

To summarize the major points to emerge under Theme 3, the following tasks are necessary:

- Clarify HI weather forecast dimensions to assist valuation studies.
- Develop models of user decision making in both hypothetical and real-world environments.
- Encourage the gathering of data relevant to, and in a form usable by, economic researchers.

- Clarify the nature of the information contained in HI weather forecasts, which may be user dependent.
- Coordinate the development of research studies to use field-experiment (real) data, survey data, and experimental/hypothetical data.
- Apply existing stated and revealed preference methods to weather forecast data, regardless of the origin.

7. References

Adams, R., K. Bryant, B. McCarl, D. Legler, J. O'Brien, A. Solow, and R. Weiher, 1995: Value of improved long-range weather information. *Contemporary Econ. Pol.*, **13**, 3, 10–19.

Britt, M. L., O. A. Ramirez, and C. Carpio, 2002: Effects of quality considerations and climate/weather information on the management and profitability of cotton production in the Texas high plains. *J. Agr. Appl. Econ.*, **34,** 3, 561–583.

Camerer, C., and G. Loewenstein, 1997: Progress in behavioral game theory. *J. Econ. Perspect.*, **11,** 4, 167–188.

Hill, H., and J. Mjelde, 2002: Challenges and opportunities provided by seasonal climate forecasts: A literature review. *J. Agr. Appl. Econ.*, **34,** 3, 603–632.

Hilton, R. W., 1981: The determinants of information value: Synthesizing some general results. *Manage. Sci.*, **27**, 1.

Katz, R. W., and A H. Murphy, Eds., 1997: *Economic Value of Weather and Climate Forecasts*. Cambridge University Press, 222 pp.

Lazo, J. K., and L. Chestnut, 2000: Economic value of current and improved weather forecasts in the U.S. household sector. US-NOAA 2002.

Lawrence, David B. *Economic Value of Information* Springer Verlag NY, 1999.

Mullainathan and Thaler, "Behavioral Economics" MIT Economics Dept working paper series, Sept. 2000.

Rollins, K., and J. Shaykewich, 2003: Using willingness-to-pay to assess the economic value of weather forecasts for multiple commercial sectors. *Meteorol. Appl.* **10,** 1, 31–38.

Roulston, M. S., G. E. Bolton, A. N. Kleit, and A. L. Sears-Collins, 2005: A laboratory study of the benefits of including uncertainty information in weather forecasts. *Weather and Forecasting*, 21:116-122 2006.