Climate Change and Farm Use of Weather Information[1]

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Rapid global climate change as represented by rising temperatures and more erratic and severe weather events has heightened the interest in how farmers use weather information. Due to the food supply being so essential, it behooves us to pay attention to this phenomenon, and especially to put effort into understanding how farmers will respond and adapt to information about climate generally and forecasts in particular. To reduce the negative effects of climate on crop production and enhance field operations, the best weather information needs to be influencing farmer decisions.

According to Solow et al., estimated net society welfare from the use of ENSO (El Nino Southern Oscillation)-based improved climate forecasts (ICF) will range between $230 and $232 million (1995 dollars) annually for the U.S. agriculture. Better forecasts could drive a rightward shift in the supply curve, when coupled with a more inelastic demand curve, can generate surplus that will go to the consumer. This also raises the issue of surplus distribution between agricultural consumers and producers (Mjelde et al. 1998). On the farm level, the studies in climate forecasts indicate that its use improves farmers' net returns, under the assumption of no changes in the final product price. For example, Mjelde et al. (1997) reported that for the east-central Texas

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the value of ENSO-based forecasts were near zero for grain sorghum and for corn the values ranged from $1.08 to $2.15 per acre, depending on price.

A major impediment to the use of climate forecasts appears to be a lack of knowledge about users by the provider-scientist as well as about the characteristics of weather information as seen by users (Hartmann et al., Mcnew et al., Sonka and Mjelde). For example, Letson et al. reports that users have incomplete knowledge of climate effects and confusion of forecast time scales. He states, this "poses an obstacle to greater use of climate information" (2001, p.57) and calls for shifting the research and outreach to user communities "to close the gap of expectations between forecast user and provider" (2001, p.57). Providers also have little understanding of users, and what drives the influence of forecasts. The issue of improved use of weather and climate forecasts requires consideration of the issue at the interstice of various fields of sciences and needs an application of the models that can integrate across various disciplines.

Our search for the literature that would apply and compare behavioral theories in the field of weather and climate information and forecasting yielded no results. This paper, then, draws from a larger study (Artikov, 2005) that does this comparison. We highlight the main findings supporting a call for a more all-encompassing approach to understanding the influence of weather information and forecasts. In particular, we propose in a metaeconomics (after Lynne, 1999; 2002) approach that farmers are not only as rational producers, but also at base are far more emotional than usually considered. It is a real possibility that farmers not only seek profits (driven by an underlying feeling about the need for material goods, wealth) but also want to feel they are in unity with the community (and perhaps with nature, the place in which they farm, itself) with its values and norms. Cognitively conscious and rational choice involves finding the best integration and orientation in pursuit of both individual profit and unity with community, seeing farmers as seeking a kind of peace of mind in the pursuit of these oft times conflicting interests.

Findings of this study will help in assessing the validity and strengths of the various behavioral sciences, including traditional economic approaches found in the scientific literature for better understanding the general influence of weather forecast and information on decision-making. From the weather and climate information and forecasts providers' standpoint, this will serve as a way to target and enhance farmer attitudes and ambitions in relation to the use of weather and climate products.

Premises for a New Behavioral, Metaeconomics Theoretical Model

Sober and Wilson argue that people have both egoistic-hedonistic and empathetic-altruistic tendencies. Etzioni proposes the idea of people pursuing at least two irreducible utilities (cited in Kruse). There is also evidence of farmers pursuing other interests besides self-interest, for example, Willock et al. discovered that farmers ranked their job satisfaction over profit maximizing incentives in production behavior and tended to perceive themselves in unity with the environment and community that he/she resided by complying with the rules or norms. Lynne et al. (1995) concluded that farmers displayed characteristics of both, as he calls, *homo economicus* and *homo sociologicus.* The complexity of human nature, including actions going beyond a single interest motive, requires a more elaborated model that explicitly displays all the interests behind a human action, to in effect make "the invisible hand" visible.

Metaeconomics proposes to accomplish this task by bringing the phenomenon of empathy into the egocentric production economics model and thus, goes beyond standard microeconomic concepts while still maintaining most of its main precepts. Metaeconomics centers attention on balancing and integrating ego and empathy, the "I" and the "We," the self-interest and the "other"-interest, in production as well as capacity or potential of both interests at work. It stays close to the original idea in standard microeconomics *by positing both of these interests as arising within the individual*; metaeconomics is not about going outside the individual to account for interdependencies with others such as in the interdependent utility idea. Rather, the notion of an "other"-interest arises from empathizing with others, and internalizing the result of this empathy process to condition one's own sense of well-being represented in the integration and balancing of two competing interests that arise jointly and are internalized within the individual decision-maker. As a result, attention shifts to focusing on how the interests are oriented, toward the self-interest or the other-interest, with this orientation the driving force in how much influence weather information forecasts have on decisions. The focus is on testing the hypothesis of *joint pursuit of both the egocentric self-interest (Q_G) and the empathetic other- interest (Q_M), both internal to the self.*

Theoretical Model Development

Assuming that an idea of sub-selves is valid, then the symbolic (Q_M) as the other (empathetic)-interest along with an established self-interest (Q_G) emerge as substantial factors in producer decisions. The choice and mix of inputs is described by the attributes of inputs Xj. X_f is presumably an individualistic technology which is oriented to the more self-directed farmers that mainly pursue profit maximizing goals and X_o is a community-related technology that is oriented to a more other-directed farmer who is more oriented to being in unity with environment and community, and being concerned for the sustainability of the larger community. The latter might be manifested in ensuring fertilizer does not enter an adjacent waterway or in sharing water with neighbors during a drought, both perhaps better ensured by closely following weather and climate forecast and information. The choice and mix of these inputs is represented in two jointly occurring interest or production functions:

(1) $$Q_G = Q_G(X_f, X_o)$$

(2) $$Q_M = Q_M(X_f, X_o)$$

The equations described in (1) and (2) are identical in form to the multi-ware production processes described by Frisch (1965, pp. 269-278 cited in Hayes and Lynne), where he uses an example of wool and mutton production in sheep as joint and nonseparable outputs, the sheep (and the environment within which the sheep is confined) determines the proportion of each output. The major feature of multi-ware, multi-output joint and nonseparable production processes is the little to no possibility to affect the balance of these outputs. In other words, the inputs are nonallocable in contrast to being allocable, the latter generally assumed in multiple output production in standard microeconomics (Lynne 1988).

To illustrate the possibilities (and many other forms of this function could be used), we adopt a metaeconomics model derived and explained in detail by Hayes and

Lynne with the objective function:

(3) $$\Phi = \iota p Q_G(X_f, X_o) + \tau Q_M(X_f, X_o) + \gamma(Q_G)(Q_M) + \lambda(R - \kappa_f r_f X_f - \kappa_o r_o X_o)$$

where the (r_j) refer to the input prices paid for the attributes (X_j) by this firm; and (p) is the market generated price for the egoistic interest in providing this product, e.g., in producing corn or soybeans; κ_f, κ_o are subjective elements added to cost and input prices because farmers see costs in more complex ways than the monetary value of the item alone (Hayes and Lynne).

The following is observed from (3). As the value of (ι) increases, the farmer is orienting the internal self toward the egocentric self-interest. Unlike the objective price, (Q_M) function carries a subjective element (τ) which reflects the degree of the farmer's orientation toward the empathetic other-interest, such as having strong tendencies toward building social capital in the community, i.e., building unity with others through building networks with these others (including other creatures beyond *H. sapiens* in the biotic system) based on common and shared norms leading to trust. Jointness between the interests, synergy and interdependence is illustrated in the term $\gamma(Q_G)(Q_M)$.

After taking partial derivatives with respect to the perceived attributes of the inputs, we determine the least-cost expansion path that satisfies and suggests the orientation in the interests (and Fig. 3 in Hayes and Lynne)

(4) $$\frac{(\iota p + \gamma Q_M)\frac{dQ_G}{dX_f} + (\tau + \gamma Q_G)\frac{dQ_M}{dX_f}}{(\iota p + \gamma Q_M)\frac{dQ_G}{dX_o} + (\tau + \gamma Q_G)\frac{dQ_M}{dX_o}} = \frac{\kappa_f r_f}{\kappa_o r_o}$$

When $\iota = \kappa = 1$; $\tau = 0$; $\gamma = 0$, the equation in (4) is the standard microeconomics expansion path. However, this egocentric path ignores the orientation and interdependence in the interests and empathy is ignored as an underlying factor in driving interests. The expansion path equation from (4) is,

(5) $$X_o = X_o(Q_G, Q_M, \kappa_o r_o, \kappa_f r_f, p, X_f)$$

Equation (5) indicates that product and input prices as well as the values of (Q_G) and (Q_M) variables affect the expansion path. Under the assumptions of two symbiotically oriented interests, the derived demand function for weather information and forecasts becomes, with the (D) meaning a "disciplined" (by the integration of the two interests) demand is:

(6) $$X_f^D = X_f^D(\kappa_f r_f, \kappa_o r_o, p, Q_G, Q_M, R)$$

along the path 0Z.

Constraint (R) is asked to carry the load represented in natural capital (i.e. climate zone, such as easting or northing); social capital (i.e. constraints on volition; extent of control over the individual; perceived control, and preferences for control, by the individual) as well as the traditional financial capital. Another major focus of metaeconomics is on the derivative dQ_G/dQ_M that reflects the trade-off or balance between self and the "other"-interest along the frontier for a particular R. We derive the trade-off equation from using (6) and the objective function in (3)

(7) $$dQ_M / dQ_G = -\frac{d\Phi}{dQ_M} \Big/ \frac{d\Phi}{dQ_G} = -\frac{\tau + \gamma Q_G}{\iota p + \gamma Q_M} = T_{GM}$$

Please note that when $\gamma = 0$, $T_{GM} = -(\tau/\iota p)$, which displays the ratio of subjective element of the empathetic attributes of the decision to the objective market based ones.

Microeconomic theory directly presumes $\iota = 1$, $\tau = 0$ and $\gamma = 0$. As a result market prices of strawberries and the inputs (Lynne et al. 1995); or corn/soybeans

(Cutforth et al., Lynne et al. 2001, Kruse) are the only substantial attributes of the farm decisions. This is to say, $TG_{/M} = 0$: There is only a self-interest driving the decision, the Q_G. This reflects the path of the egocentric, profit-maximizing individual who is not concerned with the community at all, at least not in any significant or substantive way. In contrast, if weather and climate forecast information is to be primarily used as a shared public good (i.e. shared "other"-interest), the farm firm is to subdue the self-interest and use input combinations in the "other"-interest along some… not necessarily profit maximizing… expansion path where $T_{GM} = -\infty$, and, in the extreme, even where $T_{GM} > 0$, the irrational zone.

The solution provided by metaeconomics is less drastic. The outcome depends on the reasoned, synergetic… perhaps even symbiotic, sum greater than sum of parts… and joint interest orientation at work, which is reflected in the ratio $-\infty < T_{GM} < 0$. This allows the determination of a joint and unique mix of the weather information using practices at some point on their production frontier where they do not maximize their well being as in T = 0, rather they satisfice in both self and "other" interest domains. Satisficing is equivalent to the behavior that Simon (1957) relates to the capacity of the individual to make decisions, which yields the possibility of multiple outcomes rather than a single outcome in point of maximization. Also, in his writings (Simon, 1997, esp. pp. 39-43), the author emphasizes the role of altruism in finding satisfactory rather than necessarily maximum outcomes (cited in Kruse). As Wight suggests, Adam Smith had in mind a broadened more all encompassing version of self-interest, representing it being human nature to seek peace of mind at point B, such that the maximization is about reducing and managing the internal conflict between the interests. The individual satisfices in each domain while maximizing the joint interest arising from resolving the conflict resolution within self and with others.

Having compared components of (4) and (7), we can see that the resource price ratio ($\kappa_f r_f/\kappa_o r_o$) influences $T_{G/M}$ making farmers orient their interests. By and large, the orientation between the egocentric and the empathetic interests (influenced but not completely revealed by the market) is demonstrated by resolving the conflict. In other words, the interdependence of the individuals in the community whose relatedness goes beyond the market, which economics generally dismisses as irrelevant, does play a significant role.

The supply of product (Q) and the price (p) is similarly affected, as demonstrated in the supply function $Q_G = Q_G(\kappa_f r_f, \kappa_o r_o, p, Q_M)$, where Q_G is the production of corn or soybeans for profit. As with the demand for inputs, the subjective element represented in Q_M, i.e. the empathy, also now is a force in commodity supply. Overall, in metaeconomics, the reaction to *price and price ratios is influenced by subjective measures of value reflecting how the egoistic and empathetic forces are symbiotically integrated and oriented by the disciplined decision maker.* In the absence of the discipline a farmer may act as an unbalanced, non-integrating maximizer oriented completely to only the self(ish) interest. The same is true about those who pursue solely their own internalized other-interest without much concern for profit. In this application, we focus on the third integrated, balanced and satisficing path where farmers are maximizing the extent to which conflict in the interests is being resolved by the orientation each rationally chooses.

Empirical Model Specification, Variable Development and Hypotheses

In this application, the objective is to estimate (6) which represents the disciplined (i.e. conflict has been resolved within self), derived demand for weather information and forecasts using the metaeconomic approach. For practical reasons, we recognize the probabilistic dimension of the decision choices that a particular farmer will choose in integrating and orienting his interests. With this in mind, a Tobit type probability model (McDonald and Mofitt) is selected. The method estimates the probability of whether farmers' decisions are influenced or not, and, when influenced, to what extent they are influenced (0, X where X is the extent) by weather and climate forecasts and information. According to McDonald and Mofitt, the Tobit method generally produces more robust and consistent results on censored data than the Ordinary Least Squares (OLS).

The empirical model that represents interdependence, synergy or symbiosis ($\gamma \neq 0$) in Q_G and Q_M as represented in Q_{GM} (which is the second partial derivative of the frontier expression in (3) after substituting back in the expansion path and demand equations, see Hayes and Lynne) and the orientation in the interests represented in T_{GM} is:

(8) $$Pr(0,X_f) = \beta_0 + \beta_1(T_{GM}) + \beta_2(Q_{GM}) + \beta_3(C) + \beta_4(P) + \beta_5(R) + \beta_6(L) + \varepsilon$$

The *response variable* (X_f) consisted of questions that asked farmers to rate the extent to which weather and climate information and forecasts a) influenced current decisions and b) intentions to use forecasts in future similar decisions. The list of decisions consisted of agronomic decisions (e.g. crop type, seed variety, tillage, planting density and date), purchasing crop insurance, summer growing season decisions (e.g., pesticides, herbicides, fertilizer and water applied), harvest and post-harvest decisions (e.g. fall tillage), crop marketing, and an other decisions category the respondent could specify. The respondent could also indicate "does not apply." All responses were elicited on a 7-point scale, ranging from *No, it did not influence my decision,* starting with *a little,* following 4-point descriptors in the middle, and ending with *a great deal*, in the *Yes, it did influence my decision* range. The option *does not apply* was treated as *does not influence* because when estimated with and without the *does not apply* data, no considerable difference in the significance of model parameters were found while gaining a substantive increase in the number of observations with this data included. Principal component (PC) analysis (Kim and Mueller) was used to assure that the dependent variable was distinctive and represented a complete and inclusive set in the farmers' decision framework. Three significant distinctive groups of decisions, leading to three distinctive groups of the response variable reflecting current behavior and future intentions being identified: agronomic decisions (agronomic through planting, summer growing season, harvest and post-harvest decisions); crop insurance decisions; and marketing decisions. The influence of short-term forecasts in concert with farmer's current and recent past experience was different from the influence of the long-term forecasts for agronomic (spring, summer, and fall) decisions due to the variety of field decisions and was further segmented. Among the literature that supports such a proposition is the study by Ziervogel et al. (p. 10) where he states, "Decisions might be short-term tactical decisions, such as changing crop management or input supply choice, or long-term strategic decisions." In contrast, farmers considered the influence of their current and recent and past experience, short-term and long-term forecasts on insurance and crop marketing decisions equally important, so that the temporal dimension of the forecast information for these two decision types were handled as one kind of influence. As a result, analysis of the final set of models included four probability behavioral/intention models, with two in the agronomic decisions area (with different time frames on the forecasts, basically the short-term vs. the long-term), and one each in the decision making arenas of crop insurance and marketing.

Four forecast period-related proxies are developed for T_{GM} (balance-joint and nonseparable balancing and integration at work of both the private (self) and public (other) interests – $dQ_M/dQ_G=T_{GM}$) and Q_{GM} (synergy-interdependence and jointness of the interests,with the Q_G*Q_M being a proxy for the Q_{GM}) variables, in that they are not directly observable. Components of *Balance* and *Synergy* variables (Q_is) were constructed according to the recommendations in Ajzen and Fishbein. Measures of Q_is can be interpreted as measures of "experienced utility" (Kahneman et al.) or equivalent to the notion of utility in economics (Vodopivec). In this application, they are treated as "indexes of expected utility" computed by multiplying probability and value parts of Q_i (Q_M represents farmer's empathetic utility index of sustaining rural communities and Q_G is the sum of the profit-oriented attitude attributes addressing a) lower possible costs and b) reduced financial risk when forecasts used). Both parts are evaluated on a corresponding 7-point scale from "0=extremely unlikely"/ "0=outcome has a low value to me" to "6=extremely likely"/ "6=outcome has a low value to me" with an option "does not apply" in response to the question: "In your experience, how likely is it that these weather forecasts and information are any good at producing the following outcomes?".

In addition, calculation of the *Balance (again, as noted earlier, representing the*

Orientation) and *Synergy* variables required additional rescaling. Initially, components of the *Balance* and *Synergy* variables were scaled from 0 to 7. Scale values were used to determine the farmers' degree of perception and marked numbers by themselves do not bear any value. This is why, to retain the sample size and remove possible algebraic errors such as dividing or multiplying 0 by any scale value that results in 0 or dividing by 0 that yields infinity, a number of 10 was added to the denominator and numerator of the *balance* variable and a number of 0.001 was added to the multipliers of the *synergy* variable. We selected these numbers out of several other numbers because these numbers yielded the least variance of the sample.

Cost of the inputs (C) carries the price information κr_1, κr_2 as represented in the costs of weather and information as well as that for all other inputs. This cost information as well as the price (P) of the commodity(s) being produced need not be considered in that all eastern Nebraska farmers (the focus of this study) essentially face the same price(s) for the commodity, and pay the same costs for the weather and climate information as well as for other inputs.

Also, an expanded version of just what is meant by (R), the capital constraint, is also needed. As noted earlier, (R) represents human, social, and natural as well as financial capital, where (R) is carrying a large load in (8) representing not only financial constraints (*capital*), but also the extent to which the farmer is influenced by the community (*social norms*) that he needs to comply with; also this variable represents the farmers' preference for the full volition to choose (PBC), i.e. *R = f{Capital, Norms, PBC}*. *Capital* in R is a logarithmic transformation of the farmer's household gross farm sales ($10,000 increment) in a typical year (*Farm Sales* variable in Results and

Discussion section). Similar to Q_is, the *Norms* variable was constructed from the probability and value parts in the answer to the question: “How likely is it that each of these groups believes that weather forecasts and information should influence your crop-related decisions?” The Bagozzi test identified influential groups represented in friends and neighbors, bankers and lending agencies, chemical and fertilizer dealers, government agencies, university cooperative extension, TV and radio, magazines and newspapers.

The perceived behavioral control (Ajzen) consisted of two components. The first component (controllability) focused on limitations from forecasts, such as the accuracy of forecasts, reliability of the source making the forecasts, availability of forecasts for the farming area, and the timeliness of the forecasts information. Respondents scoring high on the 0-6 scale for these limiting factors are likely to be those who are working hard to build self-efficacy, working to better understand the forecast and to enhance personal abilities in applying the forecast. The second component assisted in understanding the personality influence on the controllability, by asking the question: “How important is it to you, personally, to have complete control over all your farming decisions?” (in contrast, e.g., to decisions being controlled by landlords and bankers). Answers to this question, on the 7-point scale from “0=extremely unimportant to me” to “6=extremely important to me,” would reflect a personal desire to gain more control in the operation (drawing on the theoretical model of Lynne and Casey, Lynne 1999).

The biophysical setting (longitude in the *Easting* variable and latitude in the *Northing* variable) shows how far east or north the farm is located, which is a proxy for the weather and climate zone within which the farmer is operating. This is to say, the physical setting at work in this situation could be constraining, forcing the farmer onto some path rather than the path being freely chosen.

With the model in (8), we seek to estimate the probability that the farmer will be influenced (and, thus, indirectly, demand) climate and weather forecast information X_f and the extent to which the information is in demand, again measured indirectly by the extent to which it will be influential. We expect that a) the *Synergy* variable will complement the *Balance* variable and display the individual's point on a expansion path and motive "potential", b) the *Balance* variable will identify the extent to which the balance in empathy relative to egoism motivates farmers' climate forecast demand decisions, c) measures of social, financial and perceived by individual constraint (R) will complement *Balance* and *Synergy* variables in explaining farmers' demand for climate forecasts, and d) farmers operating further to the east and north where the climate is somewhat stable and has higher precipitation will be less influenced than those to the west and south (closer to the Great Plains) with dominating longer dry seasons and volatile climate.

Survey Area and Design

Three counties located in different climatic regions of Nebraska were selected for this study in order to encompass various farm decisions that depend on the farm locations, specializations, and specific microclimate. Since weather and climate forecasts affect almost all farm related decisions including the economic, social, and agronomic, the research team that designed the questions to be used in the focus groups consisted of various scientists with backgrounds in social psychology, agronomy, meteorology, and agricultural economics. Sessions with focus groups consisting of 15-18 farmers were held in each of the three areas in order to design the survey instrument, as well as to obtain qualitative information about what was driving the use of weather and climate information and forecasts. The final survey form focused on the relationship of farmers` personal beliefs, values, as well as social influence/norms and importance exerted by the farmer's community on the use and influence of weather and climate information and forecasts within three forecast timescales: current and recent past experience, short term, and long term forecasts.

In January 2003, 2100 farm operators (in contrast to owners and operators no longer farmers who are still owners) from Seward, Otoe, and Fillmore counties received mailed surveys. Each county was believed to be representative of the three major agroecozones in eastern Nebraska, western Corn Belt region of the U.S.A. In order to increase the response rate, optional payments in the amount of $25 were made at their request. Also, a reminder post card was sent to non-respondents after two weeks, again offering the $25. Overall, 724 or 33% of the sampled farmers responded. A total of 630, or 87%, requested the payment, the less than 100% request for payment perhaps suggesting the reasons for taking actions may be especially empathy related for those not requesting the payment, like in "if I was doing this survey (walking in the shoes of the researchers), it sure would be nice if farmers would fill it out and send it back." The response rate was better than in most survey-based studies (e.g. see Cutforth et al., Willock et al.). Cutforth et al. in a study of the agrodiversity on Saunders county farms in Nebraska used a payment of only a token $2-bill; the response rate was substantively lower, in part due to not offering the $25. Of the 724 responding farmers, 26 were excluded because they did not fully complete the survey. The final usable dataset contained 698 valid observations across the three counties.

Results and Discussion

Results of the econometric analysis of the models reflecting farmers' demand for weather and climate forecasts indicate that the metaeconomics adds useful new insights into explaining the influence of various forecasts in all the types of farming decisions. As expected, the *synergy* variable is highly significant across all the farming decisions at $p<0.001$ (Table 1). Interestingly, change in normalized slope coefficients per 1-unit change in the response variable ranges from 0.023 to 0.028, which is fairly small range (Table 1), suggesting that farmers jointly pursue self- and other-interests across all the farming decisions. Analysis of elasticities and marginal effects gives more insight into the effect of the *synergy* variable on demand for forecasts reflected in the influence of forecasts. The probability of the forecast influence both for new and current forecast users (E1, E2) goes up by 0.11% as the *synergy* variable increases by 1% for the current and recent past conditions and short term forecasts; 0.15% for the long term agronomic; 0.24% and 0.13% in insurance and marketing decisions (Table 2). For current users, the marginal effect (ME1), at mean values, reflects an absolute change in probability of 0.031 and 0.034 for the short term and long term forecast influence on the agronomic decisions as we move up the *synergy* variable scale by one unit; and 0.04 and 0.032 in the insurance and marketing decisions (Table 2). The marginal effects of overall influence

(ME2) are extremely small and near zero. As defined earlier, the *synergy* variable enables measuring farmers' overall capacity or potential for decision making. Small and near zero values of ME2 (elasticity of influence) indicate that this potential is least sensitive to changes in overall performance of forecasts (Table 2).

As hypothesized, the *synergy* variable allows us to view the dynamics of the elements of the farming decisions in a familiar economic perspective without compromising conventional economic assumptions. Besides tracing farmer's location on the expansion path similar to the budget constraint, the *synergy* variable has an advantage of measuring the overall capacity or potential of the egocentric and empathetic interests. By capacity or potential we infer the amount of farmers' general knowledge, experience, beliefs and values about ego and empathy within the context of the decision, so that the more knowledge or experience, the larger the potential and the more efficient tradeoff between inputs.

The *balance* variable supports the hypothesis of farmers' dual and joint interest. The probability of the expected influence, representing the marginal effect of reducing *balance* (ME1) variable, at mean values (i.e. moving toward more emphasis on self-interest), increases by 2.64, 2.01, 1.55 and 2.79 for 1-unit decrease in the balance ratio in all the decisions (Table 2). Across all the decisions, out of current users those more oriented toward the self-interest are also more likely to be influenced by weather information and forecasts, as indicated by the probability increasing by 0.89, 0.78, 0.88 and 1.1% for a 1% decrease in the balance ratio, meaning a shift toward being more egocentric, suggesting that the farmer puts more effort into pursuing the self over the community interest in all the decisions, except insurance decisions (E1, E2 in Table 2).

In the insurance decisions, the balance in private and public interests is far less a factor in the very personal, private insurance decision in contrast to "how one farms" and "how one markets."

In agronomic decisions, we suggest that the large significance of the *balance* variable is because farmers cannot capture the egocentric and empathetic parts of the decisions with the behavior inducing variables such as *social norms, perceived control,* and *farm sales.* The empathetic part of the forecast influence unlike the egocentric one is practically elusive in the agronomic decisions; therefore, a new factor measuring a psychological inner balance, such the *balance* variable is required. The role of the balance and orientation of interests in the insurance and marketing decisions is smaller compared to the previous decisions; this can be due to the fact that first, these decisions are more profit-oriented and reflect the farmers' intentions to maximize profit from crop production and, second, both the empathetic and egocentric parts of the inner balance might be already embedded into other parameter constructs such as social norms, perceived behavioral control, and farm sales.

In the set of agronomic decisions, *norms* significantly intensify the influence ($p<0.001$) of weather and climate forecasts (Table 1). The probability of the influence goes up by 0.25% as measure of *norms* variable increases by 1% for the current and recent past conditions and short term forecasts; 0.27% for the long term agronomic; 0.26 and 0.27% in insurance and marketing decisions where it is a less factor ($p<0.05$) (Table 1). For current users, marginal responses, at mean values, reflect an absolute change in probability of .31 for the short term forecast influence on the agronomic decisions as we move up the *norms* variable scale by one unit; 0.29 in long term forecast influence on the agronomic decision, 0.19 and 0.16 for insurance and marketing decisions (Tables 1, 2).

It is clear that farmers are buying into norms for use of weather information in the communities of interest, and are being influenced by others. For example, a farmer may consult with his friends, family, or bankers to make a final decision of planting certain type of crop or selecting a planting date. The positive sign on the *norm* variable infers that as the social pressure becomes larger the more forecast influence farmers perceive in the agronomic decisions. The *social norms* variable is statistically strong in the agronomy decisions; at the same time, this effect disappears in the insurance and marketing decisions (Table 1). This suggests that these kinds of decisions seem to be more individualized, more profit-oriented, with the influence of others quite minimal at least during the time when the decision is made.

Perceived behavioral control (PBC) is a substantive factor in explaining the influence of weather and climate forecasts (Table 1). Farmers perceive control as a significantly limiting factor, which restrains their ability to control (Table 1). As expected and in support of Ajzen, controllability (accuracy, timeliness, and availability) and preference for control explains behavior well. Adding the general preference for control, in turn, enhances the controllability aspect; those wanting more control will be more likely to be influenced, and, for those already so influenced, will also be influenced to a larger extent. However, as noted, analysis of the elasticities of perceived control on the forecasts influence reveals that farmers are quite a bit less sensitive in insurance and marketing decisions. The largest response of 0.28% is associated with the influence of the long-term forecasts in the agronomic decisions (Table 2). The second largest elasticity is in the insurance decisions (Table 2). The very act of buying crop insurance is to take control through protecting oneself from uncertain weather. The perceived behavioral control reveals this by suggesting that farmers probably perceive uncertainties of forecast precision and desire to remove this uncertainty and sustain the control over their operations more acutely than that during their real-time decisions. In marketing decisions, the response to PBC is substantive, but again elasticities are not large at 0.16% (Table 2.). This suggests that in the marketing decisions, farmers perceive control for weather and climate information and forecasts to be substantively important, although its absolute effect is lower then that in the agronomic decisions. This seems reasonable; farmers still worry about the crop damage once it is harvested even if it is stored in ostensibly safe elevators and/or protected open storage areas, which ensures the crop is safe from an uncertain physical environment to a certain extent. Also, it is reasonable to suggest that farmers' effort to capture more control over production and controllability over the marketing decision is seen to be related to forecasts, suggesting that both the local forecasts and weather information (which is understandable once the crop has been harvested) and forecasts and information from other parts of the country or world might affect local markets and play a substantive part in marketing the crop.

The capital variable (*Farm Sales*) recognizes that farmers' behavior will likely be influenced by their financial capabilities. For each $10,000 increase in farm sales, the probability of the expected influence for current farmers' increases by 0.13, 0.08, 0.39, and 0.27% while the marginal effect of the capital on the probability that forecasts will influence decisions is 0.17, 0.09, 0.30, and 0.27 in the short term and long term agronomic, insurance, and marketing decisions, respectively (Tables 2). Similar changes are observed for farmers who already use forecasts.

Throughout the production cycle (agronomic decisions), farmers need to make short-term decisions like fertilizing, irrigating, or harvesting crops. Heavy rains may cause greater runoff of fertilizer or delay harvesting; alternatively, drought can stress a crop resulting in a lower yield. Negligence of climate information and forecasts in such short-term field decisions can be costly and affect farm crop sales. Farmers are aware of these costs, which prompt them to keep forecasts in mind. In the insurance decisions, negligence of forecasts can make the crop production quite costly too. This decision can be so important that farmers tend to rely upon their own judgment only, which explains the little significance ($p<0.05$) of the *norms* coefficient in the model. In the marketing decisions, farmers may follow weather and climate forecasts in other regions that demand or supply similar crops. Any adverse or favorable climatic changes in those regions will affect farmers' crop pricing and marketing strategies, and consequently, their profit. This may explain the importance of the capital variable in these decisions.

Analysis of *easting* and *northing* variables indicates that farmers perceive the influence of forecasts on all the decisions similarly as their farm locations change from the south to the north and the east to the west (Table 1). The fact that in most of the agronomic decisions, location appears to have no effect on the degree of forecast influence infers that sociological parameters of the metaeconomics model have been able to capture all other factors reflected in location variables. This supports analysis on land conservation practices where it has been found that attitude, norms, and control variables can mediate demographic and agronomic factors (Lynne et al. 1995, p. 590); it appears they also mediate location factors. In agronomic decisions, the degree of forecast influence rises as farm location shifts further to the west or areas with lower annual precipitations and highly volatile and drier climate suggesting that farmers pay more and more attention to weather and climate forecasts. In marketing decisions, the real-time marketing strategies differ as farmers move further to the east and north as well, with weather information and forecasts having less influence on these decisions. After harvesting, grain is usually stored both in the safe elevators and open storage area vulnerable to the precipitation and other natural weather events such as high winds. Further to the west, drier conditions can damage grain qualities by reducing its moisture content and weight and causing farmers to market faster and perhaps at lower prices while those to the east and north with stable humid conditions can store their grain much longer without any fear of reduced quality or weight.

Table 1. Estimated parameters and statistical significance of independent variables in the metaeconomics model.

Variables	Agronomic (Cur. Rec. Past Exp. & Short term forecasts) Decisions	Agronomic (Long Term Forecasts) Decisions	Insurance Decisions	Marketing Decisions
Synergy	0.026[c]	0.027[c]	0.028[c]	0.023[c]
Balance	-2.246[c]	-1.580[c]	-1.080[b]	-2.032[c]
Norms	0.261[c]	0.229[c]	0.133[b]	0.118[b]
PBC	0.141[c]	0.197[c]	0.094[b]	0.105[b]
Farm Sales	0.145[c]	0.071[a]	0.211[c]	0.223[c]
Easting	-3.15E-6[c]	-4.652E-7	1.181E-6	-2.069E-6[b]
Northing	3.183E-6	-3.019E-7	4.001E-7	-3.508E-6[b]
Constant	-3.481	2.514	0.051	9.164
R^2	0.41	0.38	0.27	0.31

Notes: Dependent variable is the degree of influence of climate and weather information and forecasts. PBC is represented by C (controllability).
[a] $p<0.10$, [b] $p<0.05$, [c] $p<0.001$.

Table 2. Elasticities and marginal effects of the significant independent variables in

the agronomic decisions under the current and recent past experience, short term forecasts, and long term forecasts in the metaeconomics model.

Variables	Agronomic (Cur. Rec. Past Exp. & Short term forecasts) Decisions				Agronomic (Long Term Forecasts) Decisions			
	E1	**E 2**	**ME 1**	**ME 2**	**E 1**	**E 2**	**ME 1**	**ME 2**
Synergy	.11	.11	.031	.0007	.15	.15	.0342	.0017
Balance	-.89	-.90	-2.64	-.0564	-.78	-.78	-2.012	-.1003
Norms	.25	.25	.31	.0065	.27	.27	.292	.0145
PBC	.16	.16	.17	.0035	.28	.28	.251	.0125
Farm Sales	.13	.13	.17	.0037	.08	.08	.0904	.0045
Easting	.10	.10	-3.7E-6	-7.9E-8	NS	NS	NS	NS

	Insurance Decisions				**Marketing Decisions**			
	E 1	**E 2**	**ME 1**	**ME 2**	**E 1**	**E 2**	**ME 1**	**ME 2**
Synergy	.24	.22	.04	.0069	.13	.13	.0317	.0022
Balance	-.88	-.81	-1.55	-.2684	-1.09	-1.08	-2.787	-.1897
Norms	.26	.24	.191	.0331	.15	.15	.1614	.011
PBC	.22	.20	.135	.0233	.16	.16	.143	.0098
Farm Sales	.39	.36	.302	.0525	.27	.27	.3054	.0208
Easting	NS	NS	NS	NS	.09	.09	-2.8E-6	-1.9E-7
Northing	NS	NS	NS	NS	.13	.13	-4.8E-6	-3.27E-7

Notes: Dependent variable is the degree of influence of climate and weather information and forecasts. ME1 is the effect of the expected value for the weather and climate already influenced farmers; ME2 is the effect of the probability of being influenced by climate and weather information (elasticity of influence). E1 is the elasticity at the mean that represents the percentage change in the probability that the weather and climate forecast and information influences decisions at all, and; E2 is the elasticity at the mean for those who are being influenced, the percentage change in the degree of influence. NS - not significant.

Conclusions

This research explores the behavioral, metaeconomics dimension of the use and influence of weather and climate information and forecasts in farmer decision making. The most intriguing conclusion has the most implications for further development and application of weather information and forecasts. That is, the fact that the orientation in the interests of farmers is the underlying factor in decision choices regarding weather related information suggests that those providing such forecasts need to be aware of said orientation in order to better ensure there will be influence. In particular, this study suggests that only those more oriented to the self(ish)-interest will be likely 1) to be influenced at all by forecasts, and, for those willing to be influenced, 2) to use them to any extent. So, it follows that, the greatest payoff from limited resources expended to achieve more use of forecasts will come from trying to help those with a more "other-interest" orientation to see the benefit of applying forecasts. To expand the use and influence of forecasts, more effort needs to be put into helping those with a community and other-orientation to also see applying information and forecasts as being in their other-interest, and perhaps, then, to the extent this is a shared interest, in the interest of the community at large. A major thrust needs to be applied to help produce new users who see that it is in the greater interest of the entire community to use forecast information in individual decisions.

Another substantive improvement in use and influence of weather and climate forecasts will come from changing the individual's "collective attitude" of his/her community (the social norms), e.g., friends and neighbors, bankers, and university extension, towards his/her use of climate forecasts. The highly significant *social norms* variable in the decision-making underline the importance of the human dimension in production decisions, and indicate that a focus on changing both the farmers' and their societies' beliefs and values, and perceptions of weather and climate forecasts will greatly affect their use and influence.

A perceived behavioral control measure, representing controllability (timeliness, accuracy, availability) and general preference for control plays a significant role. In some ways, the perceived control can help us to understand the roles of norms in decision-making related to forecasts use. It appears that availability, reliability, timeliness, and accuracy of the forecasts interact with the desire for more control of farming operation. This signals that the forecast makers should focus on changing the farmer's perception of forecast accuracy (if not the actual accuracy itself) by making available more easy-to-understand forecasts through widely available and reliable media in a timely fashion. Thus, offering training programs to help farmers, *as well as those who influence farmers*, and enhancing their understanding and ability in applying the forecasts will improve the sense of control.

In addition, a farmer's financial abilities also directly affect that farmer's willingness to be influenced by weather forecasts. We observe that the influence increases as farm sales increase, because greater financial ability complements the control available to, and desired by, the farmer. Gaining more control in farming operations and outcomes is also a reason to increase the use of weather and climate forecasts, although such desire for control varies in magnitude farming population. Weather information and weather forecasts will likely carry an ever more important role following the trend toward industrializing the farms, with one of the main goals to have more effective control of farming operations and outcomes.

Overall, metaeconomics emerges as a promising theory and approach in adding further understanding of economic behavior. The metaeconomics model shows that farmers are dual and jointly-interested individuals who are influenced by the social context; also, it displays significance of internal decision elements by focusing on the interactive balancing and orientation in the nature of the interests and overall potential or capacity that drives behavior.

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