Nitrogen Management under Uncertainty: An Investigation of Farmers' Decision Processes

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DES MOINES Water Works has recently threatened a lawsuit against three upstream Iowa counties they claim are responsible for excessive nitrate loading in the Raccoon and Des Moines rivers. Excess nitrate loads, which must be reduced before water is safe to drink, is reported to have cost Des Moines taxpayers upwards of $1 million in 2013. The cost of nitrate removal, which could include investment in new treatment capacity, will continue, and may grow, unless steps are taken to reduce nitrate runoff from agriculture. While such water treatment is costly, yield losses may be more costly if rates are capped by regulations. The problem is complicated because of uncertainty over weather and soil conditions producers face when making their nitrogen use decisions. Furthermore, weather largely dictates how much of the applied nitrogen leaves the fields.

Our research is, in part, motivated by a crucial question in the nutrient management challenge: what steps can and should be taken to address nitrate runoff from Iowa's agricultural fields? Economists have studied pollution in agricultural-based economies for decades, typically attacking the problem by positing a model of fertilizer application practices and from this model designing policies that provide incentives to either lower application rates or adopt management practices that reduce nitrogen and phosphorous fertilizer runoff. Earlier research has relied on strong assumptions about the decision processes used by farmers when making fertilizer choices. The reason for doing so is that no one has asked farmers how they choose application rates, methods, and/or timing of application. The potentially serious problem is that if assumptions for underlying decision processes are wrong, it is likely that the policy recommendations derived from the model will also be wrong, or at least less effective than if the actual decision processes were known.

Our work turns the standard approach on its head. In fall 2014, our research team designed and implemented a survey that focuses directly on understanding the real-world decision processes used by central Iowa farmers. The survey asked several rather unorthodox, but revealing, questions about the nature and extent of the uncertainty that producers face, their subjective beliefs about the yields they expect on the field that they manage, the impact of different nitrogen application rates on yields, the role of weather variability, and a host of other questions all geared toward developing a clearer picture of the thought process behind nutrient management decisions.

Why is this important? We suspect—and our survey results seem to show—that real-world fertilizer decisions are impacted to some extent by judgmental bias, use of decision heuristics, and various other deviations from the decision models that have been used in previous research. That is, farmers' decisions do not necessarily conform to the often-assumed benchmarks based on models that do not incorporate such biases. This is not surprising given what is found in a wide body of research into real-world decision making under uncertainty and complexity of the decision. We are now developing economic models to inform policy that build on what we have learned, with real-world decision processes at their core. We are confident these models will identify better avenues for reducing the negative impacts on Iowa's valuable water resources, in a way that allows Iowa's agriculture industry to continue to thrive.

In the cab of a corn harvester, a technician checks readings on a digital yield monitor. Photo by Scott Bauer (USDA).

Survey of farmers and study findings

In an effort to understand how producers form their nitrogen decisions, we examined what they believe about the relationship between nitrogen and yields and how that relationship changes as weather and nitrogen are varied. Using a web-based survey delivered to members of a central Iowa cooperative, we elicited producers' beliefs based on their individual experiences and situations. The survey was designed to allow each producer to characterize his/her belief

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function about how yield responds to nitrogen. The survey responses were then used to develop a structural model of farmer-level nitrogen management decision-making.

Studies by psychologists and behavioral economists almost invariably find that people are overconfident. A form of overconfidence relevant to agricultural production is unrealistic optimism—the belief that really good outcomes (e.g., exceptional yields) will occur despite objective evidence to the contrary. Our survey does not indicate overconfidence is prevalent among the central Iowa farmers surveyed. However, we do find some evidence of unrealistic optimism regarding yield expectations among a subset of the farmers we surveyed. A roughly equal-sized group of respondents are pessimistic about yield expectations, that is, they expect lower yields than those estimated by independent data sources. On average, the farmers we surveyed expect to harvest only slightly more bushels per acre than is predicted by historical data.

Preliminary analysis suggests that farmers overstate the impact nitrogen has on corn yields. Using data from Iowa State research farms, which have been used to study the role of nitrogen on corn yields for decades, we estimate the actual impact of an increase in nitrogen on average yield. Our survey asked farmers their perceptions about the yield response to added nitrogen on the fields that they managed, and the results show farmers believe that the decline in expected yield due to a nitrogen reduction is generally larger than the rise in expected yield due to a similar increase in nitrogen applied.

A crucial question we seek to answer is, do farmers' subjective beliefs about nitrogen-corn yield relationships match the objective data or the agronomic models and advice that they receive? Our preliminary findings suggest the answer to this question is no. For approximately 30 percent of the farmers in our survey, the expected incremental increase in yield from an increase in nitrogen applied exceeds the objective estimate that was attained from the research farm data.

Implications for managing nitrogen

In summary, the early indication is that there may exist stark differences between farmers' subjective beliefs about nitrogen's effect on yield and the assumed relationships that underlie current nitrogen recommendation systems.

For example, we find that farmers may perceive yield and profit gains from added nitrogen that simply do not exist based on past data. If our results hold, this finding could have important implications for designing policies to manage nutrients. For example, perhaps an effective first policy step toward improving water quality is to provide farmers with better information about the impacts of nitrogen on yields and on their bottom line. More generally, understanding the fertilizer-yield relationship as perceived by producers can help inform nutrient policy design and also the extension services provided to producers. As state leaders, farmers, and other stakeholders begin to address the issues surrounding nutrient management and reductions of agricultural runoff, having a clear understanding of the decision processes used by producers will be key. Evidence-based policymaking needs to take into account the behavior and attitude of farmers to be effective, and designing policies without such information could result in policy that is not only inefficient but also ineffective. ■

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at this juncture. First, new label information would inevitably crowd other facts and claims already present, thereby competing for limited consumer attention. Consumers inevitably deal with information overload in many ways, including rule-of-thumb decision processes. If they are accustomed to seeing mandatory disclosures only when their need is unquestionable (e.g., tobacco packaging warning messages), consumers may rationally infer that if a GMO label is required it must be because these products are objectively risky. In other words, a mandatory GMO label may end up stigmatizing products carrying it, regardless of the objective truth, and turn off consumers. Somewhat paradoxically, precisely because GE products remain somewhat controversial despite the ample scientific evidence, the need-to-know perspective is of paramount importance vis-à-vis the right-to-know argument.

Other economic considerations are also in order. Mandatory GMO labeling would be costly to society. Such costs take a number of forms. Food manufacturers, conscious of the stigma of GMO labeling, might reformulate many of their products, substituting GE ingredients with less desirable yet non-GMO alternatives (e.g., palm oil instead of soybean oil). This costly process would be exacerbated if GMO labeling were mandated by some states and not others, requiring the food system to implement identity preservation and segregation activities currently unnecessary. Such costs could add up to nontrivial amounts. A University of California study in 2012 concluded that Proposition 37 could have increased food manufacturing costs by more than