**Linking Farmers' Nutrient Management Choices with Downstream Environmental Quality**


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## Abstract

Excessive agricultural nutrient runoff has substantially degraded water quality and ecosystem services in many freshwater and marine ecosystems around the world, including Lake Erie and the Gulf of Mexico (Hudnell, 2010). Changes in management practices, which are needed to improve environmental outcomes will incur fundamental trade-offs by imposing costs on farmers and generating benefits by improving ecosystem services. However, these economic trade-offs of nutrient management policies are largely unknown due to the complex economic and ecological linkages. In particular, these trade-offs are dependent on ecological and economic spatial processes and the distribution of heterogeneous farmer and land characteristics. The existing literature shows that farmer heterogeneity is crucial in determining best management practice adoption (Norris and Batie 1987) and spatial heterogeneity is important in both farmer decisions and ecological damages (Wu et al. 2004). However, the relative importance of these sources of heterogeneity is unknown.

This paper aims to fill this knowledge gap by developing a farmer decision-making model that incorporates both individual and spatial heterogeneity. Specifically, we estimate an econometric model of farmers' heterogeneous derived demand for phosphorus fertilizer that varies by both farmer and field characteristics using data from an extensive survey of 7,500 farmers in the Maumee River watershed of Lake Erie – the largest in the Great Lakes Region (Reutter et al. 2011). In addition, this research is part of a larger, multidisciplinary NSF-funded project (Martin et al. 2010), and we account for the influence of space on ecological outcomes by explicitly representing factors like distance from field to lake or stream, and by making use of estimates from existing hydrological model – the Soil and Water Assessment Tool, and statistical ecological models (Gebremariam et al. 2013) that translate predicted land use and management outcomes into phosphorus loadings and water quality variables.

Using estimates of anglers' willingness-to-pay for water quality improvements based on a choice experiment (Zhang and Sohngen 2014), we are able to quantify the benefits of improved ecosystem services in Lake Erie due to changes in farmers' actions. We will then construct an efficient frontier to quantify the ecological and economic trade-offs among predicted changes in agricultural profits, phosphorus loadings and associated economic damages under a uniform fertilizer tax versus one

that is targeted either spatially or based on farmer characteristics. We focus on fertilizer tax policy because previous studies have shown that additional conservation is needed beyond current voluntary adoption by some farmers (e.g. USDA-CEAP, 2011), and several economists have argued that fertilizer tax should be the most effective and efficient form of policy (e.g. Lichtenberg, 2004; Sohngen et al., 2013).

This research makes at least two important contributions to the literature on modeling of agricultural production and its environmental impacts. First, by analyzing both farmers and anglers, we could directly compare upstream costs and downstream benefits resulting from nutrient management policies, and this analysis of ecological and economic trade-offs could help optimal policy design. Second, this model allows us to assess the relative importance of both spatial and farmer heterogeneity in driving farmer decisions and the provisioning of ecosystem services.

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