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The potential to reduce the risk of diffuse pollution from agriculture while improving economic performance at farm level

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ABSTRACT

Within the constraints of the EU Nitrates and Water Framework Directives, controlling and managing nutrient transfers to water from excessive nutrient use on agricultural land is a significant environmental policy challenge. This paper assesses whether there is room to reduce inorganic nitrogen and phosphorus fertiliser applications and imported feeds by exploring the extent to which application rates may have exceeded optimum levels using data envelopment analysis methodology. The investigation concentrates on specialist dairy and tillage farms in the Republic of Ireland stratified by land use potential as these agricultural systems are the most intensive and may pose the greatest risk in terms of managing nutrient transfers from agricultural land to water bodies. Results demonstrate inefficiency in the utilisation of nitrogen and phosphorus fertilisers across these systems. Second stage regression analysis indicates significant return to efficiency from agricultural education. Average over application of chemical fertilizers ranged from 22.8 to 32.8 kg N ha^{-1} and 2.9 to 3.51 kg P ha^{-1} in 2008 which research has shown is at least similar and greater than losses to leaching and runoff for N and P, respectively, from similar intensive agricultural land uses. Potential cost savings on chemical fertilisers across all systems on average ranged from €38.9 ha^{-1} to €48.5 ha^{-1}. Additionally, potential cost reductions on imported feeds of €65–84 per livestock were indicated for dairy farms versus efficient cohort benchmark farms. Average excess of imported feedstuffs equated to 5.82–7.44 kg LU^{-1} of N and 0.92–1.17 kg LU^{-1} of P. Such reductions have the potential to deliver a double dividend by reducing the risk of diffuse nutrient losses from agricultural land while improving economic margins at farm level.

1. Introduction

Compliance with environmental legislation in the context of intensive, productivist agriculture is a significant policy challenge (Sutton et al., 2011). Much political and commercial pressure has been brought to bear on the agricultural sector to improve environmental performance while maintaining economic efficiency and competitiveness in a global marketplace (Jay, 2007). Consequently eco-efficiency has become a prevalent theme in the agricultural and environment literature (Asmild and Hougaard, 2006; Ebert and Welsch, 2007; Lauwers, 2009; Picazo-Tadeo et al., 2011). This is especially so in the European Union (EU) where member states are committed to management (mitigation or maintenance) of all water bodies to good

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ecological status by 2015 under the Water Framework Directive (OJEU, 2000).

Over application of chemical nitrogen (N) and phosphorus (P) in intensive agricultural regions of Europe, and throughout the developed world, has lead to excessive accumulations of these nutrients in soils, groundwaters and surface water bodies (Volk et al., 2009). It has been estimated that as much as 55% of non-point water pollution of eutrophic surface waters in the EU is attributable to agriculture (Kersebaum et al., 2003), with the majority linked to losses of nitrogen (N) and phosphorus (P) nutrients from soil surfaces which can lead to eutrophication (Vörösmarty et al., 2010; Sutton et al., 2011). In the UK, DEFRA (2006) reported that around 70% of N and 40% of P pollution of inland waterways was derived from agriculture with the balance from industrial and municipal sources. Nutrient pollution from agriculture is acknowledged as one of the major sources of water quality impairments in the United States (Morgan and Owens, 2001; Ribaudo et al., 2001; Sharpley et al., 2008). The problem of eutrophication in Irish watercourses has been an issue since the 1970s (Flanagan and Toner, 1972, 1975; Inland Fisheries Trust, 1973, 1974). Recently 18% of river channel across the Republic of Ireland was found to be slightly polluted; 10% moderately polluted and 0.5% seriously polluted. Agricultural sources were associated with 32% of cases of slight and moderate pollution (EPA, 2008).

Much attention has been paid to controlling nutrient enrichment of watercourse by means of traditional command and control regulatory methods. Less emphasis has been placed on measuring nutrient management efficiency at farm level from an economic loss perspective (Huang et al., 1996; Brown et al., 2005; Picazo-Tadeo and Reig-Martínez, 2007). The optimum fertiliser rate is not always the rate at which maximum crop yield is achieved but must produce a satisfactory level of crop yield for profit; covering its costs while minimising nutrient losses to the environment. Excessive fertiliser applications over the optimum may often be attributed to such factors as risk aversion to lower yields, information asymmetry or incentive incompatible fertiliser pricing. However, over application of nutrients may have both economic and environmental consequences. Economic costs are incurred in two ways; the cost of wasted nutrient inputs at farm level and the cost of clean up associated with pollution caused as a result of such losses. In the absence of effective control, the cost of eutrophication is external to the farm, therefore the rational farm level decision is often to apply fertilisers up to the point of maximum private gains including some coverage for risk and uncertainty. The lower the relative price of fertiliser the greater the incentive to apply it to excess to offset potential risk and uncertainty. If asymmetric information is prevalent on crop nutrient requirement, soil fertility and farm level nutrient balances, then over application of fertiliser equalises the need to ascertain precise information and offsets risk while using the wider environment as a sink at no internal cost to the farm (Scott, 2005).

Chemical fertiliser prices in the Republic of Ireland reached record levels in 2008 (CSO, 2009a). Average prices increased by over 140% between 1999 and 2008. Fertiliser consumption among farmers was seen to react to price as N fertiliser sales to farmers declined by 24% and P by over 48% during this period (DAFF, 2009). Hence, farmers had significant economic incentives for efficient fertiliser input usage.

Farmers apply chemical fertilisers because a benefit is derived through either increased output, income or both. However, plants absorb fertilisers only up to their requirements. Nutrients in fertilisers (principally N, P and potassium (K)) promote plant growth but application in excess of plant requirement can be exposed to leaching and runoff transfers from land to water where these hydrological pathways coincide with intensive agricultural landuse (Sharpley et al., 2003; Tunney et al., 2010).

While the analysis of exact proportions of N and P required for optimal growth in grassland or tillage systems is outside the scope of this paper, productivity analysis techniques can measure farm nutrient management efficiency by examining farm inputs to output ratios across a sample of farms. Such an approach was adopted by Fraser and Cordina (1999), Reig-Martınez and Picazo-Tadeo (2004), Theodoridis and Psychoudakis (2008), Barnes et al. (2009) and Uzmay et al. (2009). Nutrient accounting systems have been proposed as a means of managing nutrients at farm level. These measure the nutrient inputs onto the farm (through feedstuffs and fertilisers) and subtracts quantities exported from the farm through outputs such as milk, meat and cereals with a view to achieving a nutrient balance (Breembroek et al., 1996; Ondersteijn et al., 2002, 2003; Berentsen, 2003; Nevens et al., 2006; Bassanino et al., 2007; Treacy et al., 2008; Ghebremichael and Watzin, 2011; Huhtanen et al., 2011; Nousiainen et al., 2011). Where nutrient inputs do not closely match nutrient offtakes then nutrients are potentially available for loss to the system, for example, via leaching and/or runoff to water.

The negative impacts of nutrient loss to receiving watercourses can be highly site specific due to the varying potential interactions of hydrology, soil type, atmospheric chemistry and farm level fertiliser practices (Doody et al., 2012). However, all other things being equal, the most intensive agriculture systems may pose the greatest risk due to the magnitude of the nutrient load into the farming system and especially when considering those systems with accumulating nutrient surpluses, above farm nutrient balances. With this background, this paper seeks to investigate the level of nutrient management efficiency across intensive agricultural systems in the Republic of Ireland. As soil types may influence the means of nutrient accumulation and the mode of transfers from land to water (Jordan et al., 2005), the analysis further uses a novel land use potential metric based on soils class as a basis for stratification and benchmarking.

2. Methodology

Farm level efficiency in the literature (Ahmad et al., 2002; Lohr and Park, 2007; Theodoridis and Psychoudakis, 2008) is generally measured using one of two methods; either stochastic frontier analysis (SFA) or data envelopment analysis (DEA). Stochastic frontier analysis is a parametric approach to measuring farm efficiency where a set of explanatory variables can be estimated. However, SFA necessitates assumptions regarding functional form and the inefficiency disturbance term which may bias results.