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Profit efficiency and habitat biodiversity: The case of upland livestock farmers in Ireland

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ABSTRACT

This study evaluates the private economic value of biodiversity using original farm habitat data and farm household survey data from livestock farms in the hills and uplands of Ireland. Profit efficiency and biodiversity efficiency are estimated using a stochastic translog production frontier model. Results indicate that biodiversity plays a beneficial role in farm profitability but the effect is non-linear. Stocking rate and the perimeter to area ratio are found to have a negative effect on biodiversity while the number of plots per farm has a positive effect. Biodiversity efficiency is influenced by the number of livestock, habitat quality, spatial habitat patterns and arrangement, perimeter to area ratio, the number of plots, profit efficiency and farmer's education and age.

1. Introduction

Although considerable economic attention has been attributed to the genetic (Weitzman, 1992), recreational (Yadav et al., 2013a,b), existence (Hanley et al., 1995; Montgomery et al., 1994) and productive (Tilman et al., 2005) value of biodiversity, far less is known about the effects of habitat biodiversity on farm income or how the private value of biodiversity might influence household decision making in livestock systems. In managed landscapes farm households are thought to benefit directly from habitat biodiversity but are also involved in the costs of its provision. By habitat biodiversity we mean grazing areas, hedgerows and their margins, buffer strips, ponds and woodland on farmland not crop diversity—crop species and varieties; or livestock diversity (species and breeds). Biodiversity can be depicted as a stock or economic asset that may benefit farmers directly by maintaining or enhancing agricultural productivity and farm gate sales. In this regard the determinants of biodiversity and its impact on productivity has been the subject of a growing body of empirical literature in recent years. Empirical studies typically use cross section or panel data and an index of biodiversity in the estimation of a production function where biodiversity is modelled as an input in the production process. Early studies focussed exclusively on domesticates rather than what we refer to as habitat biodiversity and on the realised productivity and farm income gains associated with intra-crop diversity (Smale et al., 1998; Di Falco and Perrings, 2005; Jin et al., 2008).

More recent work reveals how intra-crop diversity could reduce crop variability (Di Falco and Chavas, 2008) and Di Falco et al. (2010), Ofori-Bah & Asafu-Adjaye (2011) and Bangwayo-Skeete et al. (2012) have since demonstrated how multi-crop diversity can affect productivity. All of the studies discussed above with the exception of Ofori-Bah & Asafu-Adjaye (2011) focus on crop diversity. The papers by Ofori-Bah & Asafu-Adjaye (2011) and Sauer and Abdallah (2007) represent a new departure from earlier work on crop diversity because the subject of interest is productivity and income gains (affecting coffee or tobacco respectively) related with 'habitat biodiversity'. We argue that the private source of diversity value in grazing systems arises from the interactions between species on the whole farm. Crop or genetic diversity[1] only captures a subset of the potential complementary effects arising from ecosystem services on a farm (McMahon et al., 2010) and therefore the value of diversity may be understated, compared with habitat diversity.

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[1] Genetic diversity is variously termed sub specific (below the species level) or intraspecific (within the species).

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Empirical studies that investigate the effects of habitat biodiversity on productivity, income and efficiency in regions where high levels of agricultural subsidies are the norm are rare. We are aware of only one study—Omer et al. (2007) that employs a stochastic production frontier approach to consider the effects of 'habitat biodiversity' on the supply of a marketable product in this case cereal crop output for a biodiversity poor intensively managed agricultural system in the UK. Omer et al. (2007) compiled a biodiversity index based on measures of plant species richness in adjacent non-cropped field margins and hedgerows.

To our knowledge there is no study that employs a similar approach to Omer et al. (2007) applied to livestock grazing systems and there are very few papers on this topic in a developed country setting. In terms of the private economic value of biodiversity the reasons for conserving 'planned' or *in situ* biodiversity (*e.g.* crop and genetic livestock diversity) in less developed regions are reasonably well understood (Hoffman, 2011). Productivity gains to the farm household from biodiversity may be more obvious in semi-subsistence systems where access to capital inputs (agrochemicals) is constrained and where crop diversity is employed to regulate pests and diseases and enhance nutrient recycling (Altieri, 1999). However, the private role of biodiversity in livestock systems in developed countries is less clear. Our analysis helps fill this gap in the literature because it represents one of the few papers that considers the private effects of habitat biodiversity on livestock productivity, farm income and efficiency in a developed region where high levels of agricultural assistance are the norm. The study examines the role of biodiversity as an input to production by investigating the relationship between biodiversity and profitability and evaluates if biodiversity has an impact on farm household income. A further objective of the work is to explore the role of biodiversity as a farm output by evaluating the variation in biodiversity and its determinants. We measure habitat biodiversity using a Shannon Weaver index which is particularly suited to this study since it can discriminate between sites with respect to habitat biodiversity (Magurran, 2004) and is widely used and understood in the literature concerned with agricultural production functions and biodiversity (Di Falco and Perrings, 2005; Béné & Doyen, 2008; Di Falco and Chavas, 2008). The Shannon Weaver index is defined in more detail in Section 4.1 below. Hereafter we use the term biodiversity to refer to habitat biodiversity as previously defined.

An improved knowledge of the factors that affect biodiversity efficiency may be important in aiding land managers and policy makers with land use and biodiversity conservation decisions.

The structure of the paper is as follows; the first section reviews the literature on the productive role of biodiversity in livestock systems and highlights the relevant empirical literature on the topic, second; a description of the survey data and methodological approach is provided; fourth empirical results are discussed and finally conclusions and recommendations are drawn.

2. Literature review

2.1. Irish uplands

We use commonage hill farmers in the Irish uplands as a case study (Di Falco and van Rensburg, 2008; van Rensburg et al., 2009). Commonage is land held in common ownership on which two or more farmers have grazing rights. There are an estimated 426,124 hectares of commonage in the Republic of Ireland managed by 11,837 farms (Central Statistics Office, 2002). The Land Law (Commission) Act of 1923, transferred shares in the commonage land to Irish tenant farmers and formally granted them grazing rights (Lafferty et al., 1999).

The Irish uplands are rich in biodiversity, they represent a major recreational resource and they are included in Annex I of the European habitats directive and are of international conservation significance (European Commission, 2008; Yadav et al., 2013a,b; Kelley et al., 2016).

The uplands are traditionally managed using extensive grazing systems that maintain the semi-natural plant communities that provide income to farms in the hills and uplands. Production based payments under the EU's Common Agricultural Policy (CAP) have led to a steady intensification of farming systems and provided an incentive for farmers in Ireland to increase sheep and cattle numbers which gave rise to severe overgrazing in some areas (Bleasdale, 1995). To counteract these trends, the European Union introduced significant reforms including the agri-environment schemes such as the Rural Environment Protection Scheme (REPS), the commonage framework plans and a number of initiatives in support of biodiversity provision in agriculture (Commission of the European Communities, 2006) to encourage farmers to reduce livestock numbers. REPS was introduced in the Republic of Ireland in 1994 under EU Council Regulation 2078/92 in order to encourage farmers to carry out their activities in a more extensive and environmentally friendly manner (Emerson and Gillmor, 1999). REPS consists of 11 basic measures and farmers must incorporate at least two biodiversity undertaking options (BUs) on their farms from a list of 24 BUs. However, despite these policy reforms, farmers remain reliant on subsidies such as the Less Favoured Areas (LFA) (introduced in 1975) scheme, the single farm payment[2] and agri-environment schemes and there is a dearth of knowledge on the role of biodiversity on the productivity and income of upland hill farms. The single farm payment is based on the number of premium claims made in the historical 3 year reference period from 2000–2002. At the present time it is still not clear what effect agri-environment schemes have on biodiversity in livestock systems at the farm scale in Ireland or elsewhere (Feehan et al., 2005; Murphy et al., 2011).

2.2. Biodiversity and livestock

In livestock systems there are a number of factors that are considered to affect biodiversity. It is generally thought that grazing has a positive effect on biodiversity (Fraser et al., 2014). Defoliation by domestic herbivores maintains an open landscape, may also promote plant diversification (Marriott et al., 2009; Reinhammar, 1995) and pastoral systems are acknowledged as a means of maintaining and restoring open managed landscapes, preventing natural succession to woodland and a decline in herbaceous diversity (DeGabriel et al., 2011; Mavromihalis et al., 2013). Species rich Machair habitats are thought to be strongly associated with agriculture, particularly grazing (Mate, 1992; Edwards et al., 2005). However, the level of disturbance appears to be important and stocking rates are considered to influence biodiversity and productivity (Dumont et al., 2009; Marriott et al., 2009; Mavromihalis et al., 2013). Hulme et al. (1999) found that high levels of grazing resulted in the replacement of productive *Agrostis-festuca* grassland by less desirable species such as *Nardus stricta* and *Molinia caerulea*. Animal breeds and mixed grazing may also have an effect on diversity (Bignal and McCracken, 2000; Rook et al., 2004). Upland grassland areas in Ireland have traditionally been maintained through the use of mixed livestock farming systems and Dunford & Feehan (2001) suggest that biodiversity tends to decline in areas where mixed grazing has been replaced by single species livestock management.

[2] Details of the single payments scheme are available from:http://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/singlepaymentsscheme/2006_booklet.pdf.