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Analysis

Are Ecosystem Services Complementary or Competitive? An Econometric Analysis of Cost Functions of Private Forests in Vietnam

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ABSTRACT

Forest ecosystem service (FES) provisioning and management in Vietnam is a priority in the Vietnamese environmental agenda. The main rationale of private forest management is to maximise profits from timber and non-timber forest product (NTFP) production. From a social point of view an under-supply of positive forest externalities (or non-marketed ecosystem services) exists. This paper therefore contributes to the ecosystem service (ES) literature by assessing the production cost structure, in other words, the cost of marketed production and provision of carbon and biodiversity, based on a survey of private forest owners in Hoa Binh Province in Vietnam. The econometric analysis was carried out using a dual cost function approach to analyse the trade-off between forestry costs and ecological performance. This is, to our knowledge, the first time such an approach has been used to estimate the production relationship between marketed outputs and non-marketed ES in the forest sector. This approach appears to be appropriate for handling the multiple joint outputs of forest production and allows us to estimate marginal costs and other cost measures such as cost complementarities in the production of multiple ES. Our results indicate that there is complementarity in the provision of timber and carbon sequestration and, consequently, policies that enhance carbon sequestration in private forests in Vietnam can be implemented without additional costs for the forest owner. We also found that keeping deadwood (to favour biodiversity) had no significant cost and was complementary with NTFP (also an indicator of biodiversity in our study), but could increase the marginal cost of producing timber. This means that biodiversity can be enhanced at no additional cost, provided that the quantity of deadwood does not significantly increase.

1. Introduction

Forest ecosystem services (FES) play an important role in forest management and ecosystem service research, involving the conceptualisation of externalities, methodologies for assessment of their (physical and economic) values and the cost of their provision, as well as the design of policy instruments that regulate their supply and demand. FES, like carbon sequestration and biodiversity, can be seen as public goods associated with forest management.[1] In this paper, we focus on the positive externalities associated with forestland use and notably address the impact of their provision on production costs. Ecosystem services (ES) provided by forests have become increasingly important in the recent forest economics literature as a result of the multifaceted relevance of forests to society, including their global contribution to climate change protection (Costanza et al., 1997; De Groot et al., 2002). The ecological and economic benefits of these services to society are often still undervalued and the methods for valuation are arguably limited and incomplete. Furthermore, this field is faced with problems of defining ecological functions and services, lack of reliable data, spatial aspects and multiple scales, all of which complicate the assessment. Moreover, the link between biological indicators and the costs of supplying ES is still unclear. This is why the development of approaches to the estimation of the marginal cost of ES provision is important. We show in this paper that the estimation of a cost function based on forest property data may be a powerful tool to analyse the structure of multi-output forest production and management.

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[1] In this paper, we use the terms ecosystem services, amenities, environmental services and externalities interchangeably.

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Imperfect knowledge concerning the impact of forest management activities such as harvest strategies on ecosystems and service provision represents an important challenge for ecosystem management (Ninan and Inoue, 2013). However, it is important to understand the jointness in production, i.e., the interdependences in the provision of different ES from the same ecosystem when designing ecosystem management strategies and policies (Caparrós and Jacquemont, 2003; Boscolo and Vincent, 2003; Peerlings and Polman, 2004; Wossink and Swinton, 2007; Hodge, 2008; OECD, 2001; Ruijs et al., 2015). Knowledge of the cost structure offers the basis for setting efficient targets for provision of externalities and for cost-effective management strategies to meet such targets. Furthermore, the design of appropriate policy instruments, including market-based ones, relies on an understanding of the factors that have an impact on provision costs (Robert and Stenger, 2013). Nevertheless, very few empirical studies have investigated the cost of provision of FES as of this time.

However, one must be cautious when dealing with multi-output cost functions and production sets, together with "particular goods" such as ES. First, ES are the outputs of ecological production functions described by complex ecological processes with multiple interactions between ecological elements and human intervention, including, for example, timber harvest (Brown et al., 2011; Tschirhart, 2012). Examples can be found in species population dynamics in the standard predator–prey framework in which non-convexities appear in harvest production functions (Tschirhart, 2012). Furthermore, non-convexities in the production possibility set can arise from positive forest externalities along with a timber production function. Indeed, in the case where forest owners devote a part of their land to non-timber ES and the other part to timber production, this latter part also produces ES (e.g., water regulation, habitats). Hence, Brown et al. (2011) show that the production of ES over the total land could increase with an increase in land specialised in timber production. Secondly, as reported by Boscolo and Vincent (2003), fixed logging costs and administrative constraints on logging regulations can create non-convexities in production sets. In the case of road building, for example, high fixed costs exist, followed by increasing marginal costs, thus creating a non-convex forest production set. It has also been shown that administrative constraints can also create (even more) important non-convexities in the forest production set.[2] Recently, Ruijs et al. (2015) addressed these problems by presenting a method that does not require convexity assumptions. They estimate a transformation function with multiple ES by using a semi-parametric two-step approach that is flexible with regard to assumptions on the convexity of the production possibility set.

As highlighted by Fuss and Waverman (1981, p. 280), a dual cost function exists for every transformation function as long as the product transformation function satisfies normal regularity conditions such as convex isoquants. We thus based our cost function approach on the result of Briec et al. (2004) on non-convex technologies, revealing the existence of corresponding non-convex cost functions and establishing a local duality between non-convex technologies and cost functions. As a result, we chose a translog specification for the estimation of the cost function that is both flexible and has good local estimation properties since it is a second-order approximation, making the tests depend on the point of approximation.

In our empirical section, we use the cross-sectional data obtained from a survey of forest owners in Hoa Binh Province in Vietnam. Vietnam has undergone a transition from net deforestation to net reforestation. In 1943, under the French colonial administration, the national forest cover was very low. After several decades of separation, the country was unified in 1975, but the forest cover decreased to 33.8% in 1976 (Nguyen et al., 2014; Lambini and Nguyen, 2014). This trend continued until 1990 when the forest cover reached its lowest level of 27.8% (Wil et al., 2006). During the period 1980–1995, Vietnam lost approximately 110,000 ha of natural forests annually (Nguyen et al., 2010). In addition to the loss in forest areas (deforestation), forest quality also decreased (forest degradation). The forest area with rich and medium timber stock had declined, whereas the area with poor stock (timber volume < 80 m3/ha) had rapidly increased and reached 7 million ha in 1990. Due to the steep terrain in most forest areas and the concentration of rainfall in summer, poor forest sites were further degraded because of water and soil erosion (Vu et al., 2014).

FES provisioning and management in Vietnam is a priority in the Vietnamese environmental agenda. For example, several private afforestation programmes and programmes for the transition of forest ownership have been implemented. The Forest Protection and Development Plan for the period 2011–2020 includes targets on afforestation, regeneration and improvement of the quality of natural forests (FSDR, 2013). The main objective of the public forest programmes is to increase profits in timber and non-timber forest product (NTFP) production. However, at the same time, the supply of non-marketed FES is considered to be lower than the social optimum. Therefore, an assessment of the provision cost of FES (both marketed and non-marketed) provides relevant information for policy makers who design forest regulations and subsidy schemes.

In this article, we aim at modelling the production structure of FES by applying a dual cost function approach that appears to be appropriate for dealing with the multiple joint output production in forests. To do this, we quantify the cost of FES by estimating the marginal cost of service provision and assessing potential complementarity or competitiveness relationships between timber, NTFPs, the quantity of deadwood in the forests (taken as an indicator of biodiversity) and forest carbon storage.

This article seeks to fill several research gaps by: (1) contributing to the forest economics literature by assessing the production cost structure, i.e., the cost of marketed goods (timber, non-timber forest products) and non-marketed goods (biodiversity, carbon storage) with data from Hoa Binh Province in Vietnam; (2) developing and estimating a cost function where market and non-marketed goods are modelled as joint outputs; and (3) suggesting important policy implications for cost-efficient FES provision by accounting for cost synergies and competitiveness between these outputs. Although the cost function approach has been proven useful to analyse multiple output technologies and used in the analysis of joint production in agriculture (Nilsson, 2009; Gullstrand et al., 2014), this study is the first application of the analysis of joint production of market and non-market services in forestry.

The paper is organised as follows. After this introduction, Section 2 reviews the literature relevant to FES cost drivers and variables that influence the supply of multiple outputs. Section 3 focuses on the theoretical cost function framework relevant to the study. Section 4 presents and describes the empirical model specification for the cost estimation, introduces the study design and presents the data. Econometric results are presented in Section 5. Our findings are discussed in Section 6.

2. A Brief Review of the Literature About the Costs of Ecosystem Service Provision

Assessments of the provision costs of FES have generally been based on the so-called engineering approach (Mäntymaa et al., 2014). In this case, provision costs are based on the opportunity cost of restrictions on timber production (Olschewski and Benítez, 2010; Ahtikoski et al., 2011).

Household models where forest management is integrated into the forest owners' consumption decisions have also addressed the production of amenity values (Newman and Wear, 1993; Pattanayak et al., 2002). However, these studies have focused on the impact of the household's amenity consumption on forest management decisions.

[2] See Chavas (2009), who illustrates several cases of non-convexities of the production set when considering an ecological system as a production sub-system involving various private and environmental goods.