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Risk, reward, and payments for ecosystem services: A portfolio approach to ecosystem services and forestland investment

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ABSTRACT

This study examines the risks and returns associated with payments for ecosystem services (PES) for private forestland using modern portfolio theory. PES schemes for biodiversity conservation and climate change mitigation were considered. Pricing data for European carbon emissions offsets and the Finnish biodiversity conservation scheme 'Trading in Natural Values', and Finnish forest inventory data were used to model ex-post empirical results. The forest owner's portfolio could be comprised of either current forest management or a PES scheme with postponed harvesting; considerations for investing harvest income in equities and bonds were included. The correlation between a PES scheme's return series and timber returns was higher for the biodiversity scheme leading to relatively limited financial diversification benefits under current prices. Increasing the biodiversity conservation price level reduced this effect. For the climate scheme, removing the declining linear trend from the pricing data did not reduce the relatively greater diversification benefits. Overall these benefits were also greater on fertile forest site types than lower quality sites. These results indicate that the policy implications of designing socially efficient PES pricing include an important trade-off between increasing price risks for private landowners and decreasing marginal costs for society.

1. Introduction

The ecosystem services (ES) approach is a conceptual means of analyzing the anthropocentric valuation and utilization of both natural and semi-natural ecosystem functions to meet the demands of human well-being (de Groot et al., 2002; MEA, 2005; Turner and Daily, 2008; Jack et al., 2008; Fisher et al., 2009; Harrington et al., 2010). Land use management decisions applied on privately owned land affect the quality and quantity of ES that are provided to society, and can result in externalities when provisioning levels are socially suboptimal. One policy solution for regulating private land use decisions is Payments for Ecosystem Services (PES), which aims to address these misalignments between socially and privately optimal levels of ES provisioning (Engel et al., 2008; Pagiola et al., 2008; van Noordwijk et al., 2012). Monetizing ES to promote minimum levels of ES provisioning can help internalize the social value of those services (Engel et al., 2015). Thus, numerous public and private PES schemes have been developed for improving ES provisioning in forest ecosystems (Xu et al., 2005; Pagiola et al., 2008; Muñoz-Piña et al., 2008; Lopa et al., 2012).

PES schemes are voluntary or compliance-based, and usually for one well-defined service or a bundle of services (Pagiola and Platais, 2007; Engel et al., 2008). Prices are set through governments or other authorities, markets, or private bids, and are a reflection of the contract duration and expected management outcomes (Engel et al., 2008; Espinola-Arredondo, 2008). Although PES schemes can provide an opportunity for increased non-timber income to non-industrial private forest (NIPF) owners, there are also potentially undesirable consequences (Jack et al., 2008). The length of a contract could negatively affect the liquidity of the forestland in re-sale markets and shift new unsystematic risks to owners (i.e. risks specific to a certain asset or land use decision that could be diversified away through a portfolio of uncorrelated assets or decisions). Therefore, developing PES schemes that are concurrently socially efficient and considerate of the risks for NIPF owners requires understanding and quantifying the associated price and contract risks.

The portfolio diversification benefits of forestland have

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previously been noted to include the ability to hedge against inflationary pressures and the low or negative systematic risk (i.e. undiversifiable risk inherent to all assets or decisions), despite being seen as a relatively illiquid asset class (Redmond and Cubbage, 1988; Wagner et al., 1995; Ilmanen, 2011). Even with the considerable research on the diversification benefits of private forestland using financial methods, Hildebrandt and Knoke (2011) noted that research into the relationships between regulating ES and financial diversification are limited.

Some authors, including Benitez et al. (2006), Castro et al. (2013), Engel et al. (2015), and others, have explored the uncertainty and risk associated with PES schemes by using a Stochastic Dominance approach[1]. Knoke et al. (2011) used an "Optimized Land-Use Diversification[2]" approach to evaluate the cost of compensation to land owners for avoiding tropical deforestation at an aggregated landscape level. However, the average NIPF owner usually does not possess a forest with the size or ecological diversity found at the landscape level. Additionally, Engel et al. (2015) concluded that socially efficient PES schemes should aim to increase the correlation between PES payments and the opportunity costs of conservation. That aim could have adverse consequences for NIPF owners' ability to achieve maximum financial diversification benefits from forestland ownership and management. This is an especially important consideration for subsistence smallholders who rely in income diversification to hedge against unsystematic risks (Barrett et al., 2001).

These shortcomings highlight the need for further research on the benefits of PES schemes using financial portfolio methods in a land use diversification approach[3]. These benefits include diversifying price risks by including alternative sources of income and increasing ecosystem resilience through higher provisioning of a wider number of ES.

In this study, we look at how price dynamics and the structures of economic returns for different PES schemes affect the level of financial diversification benefits available to owners and investors. We considered two different PES schemes using a modern portfolio theory (MPT) applied in an empirically based optimization of forest management regimes. We use stand inventory data from Finland, PES pricing data from the Finnish biodiversity conservation scheme Trading in Natural Values (TNV), and carbon prices from the European Union Emissions Trading Scheme (EU ETS) futures market. A biodiversity conservation (biodiversity for short) PES scheme was modeled based on the TNV scheme, and a climate change mitigation (climate for short) PES scheme was constructed similar to the New Zealand ETS scheme (Jain et al., 2009). Scenarios considered the continuation of business-as-usual (BAU) management and management for the postponing the harvest decision for the duration of one or two consecutive PES contracts. These scenarios were run for three different forest site types and three starting age classes.

[1] The Stochastic Dominance approach is a stochastic ordering method for decision-making problems.

[2] Knoke et al. (2011) define Optimized Land-Use Diversification as the consideration of an optimal risky portfolio made up of different simultaneous land-use options that are seen as risky natural assets and controlled by financial forces.

[3] A diversified portfolio approach aims to decrease unsystematic risk by including of other uncorrelated assets or land uses in the optimal risky portfolio. This idea can be transferred into ecological terms, where increased diversity in an ecosystem can lead to greater resilience on the basis that each element of diversity in the ecosystem will respond differently to environmental shocks (Elmqvist et al., 2003).

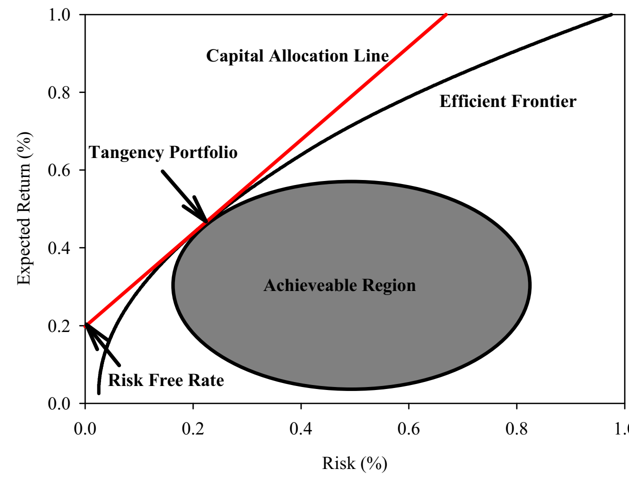

Fig. 1. Example of the efficient frontier and tangency portfolio.

2. Methods and data

2.1. Portfolio asset allocation model

Modern Portfolio Theory (MPT) (Markowitz, 1952, 1959) implies that diversification of capital over different assets usually leads to portfolios with lower variance and greater expected returns compared to single-asset investments. Thus, uncertainty can be addressed by extending portfolio diversification so that capital is allocated over multiple asset classes (or land use decisions) to diversify and reduce exposure to unsystematic risk. A fully diversified portfolio is left with a trade-off between the expected return and the unsystematic risk, resulting in a frontier of efficient risky portfolios of assets (Fig.1).

Following the assumptions[4] of MPT, an optimal portfolio of risky investments preferred by all rational investors, regardless of their risk aversion, can be identified (the tangency portfolio) (Bodie et al., 2011). All investors choose this optimal risky portfolio and differ only in the amount that they allocate to the risk-free rate and the tangency portfolio. A change in the risk-free rate of return can mean a shift in the optimal portfolio of risky assets. To model optimal asset allocation the Sharpe ratio, the slope of the capital allocation line, is maximized to achieve the maximum excess return possible for a given risk-free rate (See Eq. (A.1)) (Sharpe, 1964).

Following Iyengar and Kang (2005, p. 323) and using the notation of Jobson and Korkie (1982) we selected the weights. for all asset classes with μ returns and r_f risk-free rate, including the $n-m$ forest stands and m alternative investments, where:

$$\max Z = \frac{w`\mu - r_f}{\sqrt{w` \sum w,}} \tag{1}$$

$$\text{s. t.} \quad 1`w = 1 \tag{1a}$$

$$w \geq 0 \tag{1b}$$

$$w_j \leq \bar{w}_j, \; j = m-1, \; \ldots, \; n. \tag{1c}$$

The model is subject to: (1a) the budget constraint (the investment assets' weights in the portfolio sum to 1), (1b) restriction for short sales, and (1c) the buying constraint for purchasing

[4] Riskless lending is always possible, input data is identical for all investors, and borrowing at the risk-free rate of return is unlimited.