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Review

Real options analysis for land use management: Methods, application, and implications for policy

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ABSTRACT

Discounted cash flow analysis, including net present value is an established way to value land use and management investments which accounts for the time-value of money. However, it provides a static view and assumes passive commitment to an investment strategy when real world land use and management investment decisions are characterised by uncertainty, irreversibility, change, and adaptation. Real options analysis has been proposed as a better valuation method under uncertainty and where the opportunity exists to delay investment decisions, pending more information. We briefly review the use of discounted cash flow methods in land use and management and discuss their benefits and limitations. We then provide an overview of real options analysis, describe the main analytical methods, and summarize its application to land use investment decisions. Real options analysis is largely underutilized in evaluating land use decisions, despite uncertainty in policy and economic drivers, the irreversibility and sunk costs involved. New simulation methods offer the potential for overcoming current technical challenges to implementation as demonstrated with a real options simulation model used to evaluate an agricultural land use decision in South Australia. We conclude that considering option values in future policy design will provide a more realistic assessment of landholder investment decision making and provide insights for improved policy performance.

1. Introduction

New markets and policies are emerging which are exerting transformational pressure on land use (Bryan et al., 2013). Diversification of land use—moving away from production agriculture to multifunctional land uses—has been recognised globally as being important for remediating environmental problems and enhancing the sustainability of food and fibre production (Crossman and Bryan, 2009; Lovell and Johnston, 2008; O'Farrell and Anderson, 2010). Many studies worldwide have examined the financial profitability of alternative land uses and the attractiveness of economic incentives through mechanisms such as payments for ecosystem services and agri-environment schemes (Connor et al., 2008; Hein et al., 2013; Wunder et al., 2008). Carbon forestry (Paterson and Bryan, 2012), biodiversity plantings (Polglase et al., 2013), the production of biofuels (Bryan et al., 2010a; Fischer et al., 2010) and bioenergy (Bryan et al., 2010b; Schneider and McCarl, 2003) feedstock may all potentially provide economically viable alternatives to conventional agriculture under the right policy settings. However, the widespread uptake of these alternatives faces many challenges. Psychological inertia, the sunk cost fallacy (Ross and Staw, 1993), the status quo bias (Burmeister and Schade, 2007), along with other factors have all been invoked to explain the reluctance to change. While the decision to adopt an alternative land use or management regimes involve more than purely economic considerations—financial competitiveness is a key component (Lambin et al., 2001; Lubowski et al., 2006).

Capital budgeting is an established process by which organisations evaluate long term investment decisions, typically in new plant and machinery, new products, and in research and development. Discounted Cash Flow (DCF) analysis is one way of evaluating investments using the concept of time value of money. The value of an investment depends on its propensity to generate cash flow. A

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measure of DCF—net present value (NPV)—has been used widely to assess investments (Bryan et al., 2008; Harper et al., 2007; Paterson and Bryan, 2012; Walsh et al., 2003). However, NPV often has limited ability to account for the value landholders place on managerial flexibility, or the option to wait for further information in the face of uncertainty and risk (Arya et al., 1998)—important considerations in typical land use investment decisions.

A more recent capital budgeting method—real options analysis (ROA)—has been proposed as a better model for valuing investments and describing investment behaviour in the presence of uncertainty (Isik and Yang, 2004; Schatzki, 2003; Song et al., 2011). ROA is applicable when investment decisions are irreversible and where there is the opportunity to delay decisions until more information is gained (Fenichel et al., 2008). This review examines the use and limitations of DCF techniques in evaluating land use and management decisions. We review the application of ROA to land use management and consider the potential for ROA to provide insights into the response to land use change incentives in uncertain contexts. A simulation based real options model is applied to a land use change problem and the implications for policy makers and land holders are discussed.

2. Discounted cash flow

2.1. Concepts

DCF analysis and the calculation of NPV is a practical and widely used method for evaluating agricultural and other investments (Cocks, 1965; Marra et al., 2003). It is based on a fundamental principle of finance—due to inflation, economic growth and risk, a dollar today is worth more than a dollar tomorrow (Homer and Leibowitz, 2013). In DCF analysis, future income streams are discounted and expressed in present value terms (Johnson and Hope, 2012). NPV is the sum of the discounted annual cash flows (inflows and outflows) and is a widely used indicator of an investment's profitability. Numerous metrics have been used in capital budgeting problems to evaluate investments based on DCF analyses and NPV including: Internal Rate of Return (IRR), Benefit–Cost (B/C) ratios, and payback periods (Arya et al., 1998; Baker and English, 2011). However, in its simplest application, a project is regarded as economically feasible if the NPV is positive as this indicates positive cash flow compared to a targeted rate of return over the life of the project.

NPV evaluations have advantages in that they: are relatively simple to explain and understand; have clear and consistent decision criteria; rely on quantitative data, and; account for time value of money (Mun, 2006b). Another great benefit of NPV is that it enables the comparison of investments that involve uneven costs and returns over time.

2.2. Application in land use and management

DCF analysis has been used to evaluate agricultural and conservation technologies and investment scenarios both in Australia and internationally including investment in conservation tillage (Stonehouse, 1997), precision agriculture (Robertson et al., 2007; Swinton and Ahmad, 1996), technology adoption (Marra et al., 2003), new crop varieties and rotations (Bell et al., 2008; Doole and Pannell, 2008), extension programs (Robertson et al., 2009), and the value of ecosystem services and environmental restoration (Birch et al., 2010; Bryan and Crossman, 2013; Kaiser and Roumasset, 2002; Sathirathai and Barbier, 2001). Land use studies using DCF methods have often incorporated a spatially explicit framework to estimate the profitability of land uses such as reforestation (Bateman, 2009; Burns et al., 2011; Crossman et al., 2011; Lawson et al., 2008; Paterson and Bryan, 2012; Polglase et al., 2011, 2013) and bioenergy feedstock (Bryan et al., 2010b, 2008) at a landscape level. Despite the widespread use of DCF methods, there are important limitations to the use of these methods in the analysis of land use and land use change.

2.3. A critique

A commonly cited weakness of NPV is that it only considers the opportunity to invest as a *now or never* decision (Dixit and Pindyck, 1995). NPV analyses make implicit assumptions concerning future cash flow scenarios and assume management's passive commitment to an investment strategy where a firm starts and completes a project without any contingencies (Trigeorgis, 1996). In reality an investment may become less risky into the future or the projected cash flows may differ from initial forecasts. For most capital budgeting decisions, which rarely go beyond twenty five years, this may not pose such a significant problem (Pindyck, 2007). However, many land use investments have significant time horizons over which decisions may be undertaken and benefits accrued (Ross, 1995; Van Der Werf and Peterson, 2009). A long time horizon exacerbates the uncertainty over an investment's costs and benefits (Pindyck, 2007). While firms sometimes find it wise to invest early, (e.g. to pre-empt investment by competitors), the cost of immediate investment must be weighed against the benefits of waiting for new information that will resolve or lessen uncertainties (Pindyck, 1991). The inability to evaluate returns to waiting to invest as new information becomes available, poses serious challenges to use of NPV for land use change investments with long time horizons.

A further critique of NPV is that it doesn't account well for risk when investments are not easily reversible and expenditures difficult to recovered should market conditions deteriorate (Ross, 1995). Yet, many investments in land management are not easily, cheaply or quickly reversible. Related plant and equipment are subject to considerable depreciation and resale values are often well below purchase costs (Pindyck, 1991). To compensate for risk, a premium can be added to the discount rate for all future cash flows, thereby creating a hurdle rate that investment return must exceed in order to be considered. However, risk-adjusted hurdle rates can be a blunt instrument which do not always adequately account for risk. In highly uncertain environments, hurdle rates have been seen to be three or four times the cost of capital (Dixit, 1992), resulting in investment inertia (the reluctance to invest) becoming the optimal investment strategy (Ross, 1995). To overcome inertia, excessively large project cash flows are required (Ross, 1995) which can lead to underinvestment (Baker and English, 2011).

As a result of these limitations, DCF and NPV calculations have often failed to explain landholder investment responses, often despite favourable NPV valuations (Musshoff, 2012). While NPV is a good starting point to analyse investments in land use, where there is uncertainty over future cash flows, long investment horizons and investment is irreversible, the NPV rule systematically undervalues the benefits of waiting (Kemna, 1993). Real options analysis can better capture the value of flexibility and the opportunity to update decisions with new information and consequently may provide better models of land use investment behaviour.

3. Real options analysis

3.1. Concepts

The concept of ROA derives from markets for financial options (Borison, 2005; Mun, 2006b). Financial options in commodity markets are derivative securities that take their value from other financial securities known as the *underlying asset*. In brief, an option