GETTING REAL:

Real Options Analysis of land use change in a world of price, yield and climate uncertainty.

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Table of Contents

ABSTRACT

The de-carbonisation of electricity generation systems will be vital in mitigating the worst effects of global climate change. This will involve the substitution of fossil fuel based generation with renewable and carbon neutral energy sources such a photovoltaics, wind and biomass. Internationally, the use of biomass to produce electricity has maintained a market share of approximately 2% of total global generation over the past 20 years (Evans et al., 2010). However, for the biomass share of electricity generation to increase, dedicated biomass crops will likely be necessary on land currently used for traditional agricultural production. Understanding the returns required by landholders from alternative land uses such as biomass is an important first step in determining a) the viability of such an industry in any particular region and; b) how policy setting can facilitate new industries and land use change.

The economics of land use change from agriculture to agro-forestry based biomass production has been broadly examined in Australia. However, these studies have largely employed discounted cash flow analysis (DCF) to determine the profitability of biomass enterprises. Discounted cash flow analysis 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 (ROA) has been proposed as a better valuation method under uncertainty and where the opportunity exists to delay investment decisions, pending more information. When uncertainty and flexibility are considered, the rates of return required for investing in a new land use can be substantially higher than suggested by DCF calculations. This has obvious implications for investors and policy makers alike. However, while investments in biomass agro-forestry are characterised by uncertainties, risk and large upfront (mostly sunk) costs, the application of ROA to this land use change question in Australia has been scarce.

A previous limitation to the uptake of ROA has been model complexity and dimensionality. Established analytical methods demand advanced mathematical skills of the practitioner and can only be applied to limited range of problems, as solutions only exist for rather simple situations considering limited sources of uncertainty. However, investments in alternative land uses, unlike investment questions in financial markets (to which established analytical methods were designed to be applied), will involve multiple sources of uncertainty such as commodity prices, spatially varying risks like crop yields and emerging risks such as climate change. This poses challenges to the application of ROA to these types of investment questions. Newer Monte Carlo simulation methods

provide opportunity to investigate land use change problems where investment decisions are likely to involve multiple sources of uncertainty, spatially variable risks such as crop yields and long investment horizons.

This research aimed to adapt a Monte Carlo based ROA simulation model to investigate [1] the effect of multiple uncertainties on the investment decision to switch land use from agriculture to biomass agro-forestry in a climatically diverse region of southern Australia, [2] Understand the effect of spatially varying yield uncertainty across the study area, [3] explore the role potential climate change may have on the returns required to encourage land use change to biomass agro-forestry and [4] provide mapped estimates of viable areas for biomass agroforestry at a range of price points across the study area.

The results show that the consideration of price and yield uncertainty adds substantially to the returns required to trigger land use change from wheat to biomass when compared to results from the DCF analysis. Results indicate that uncertainty over returns to agroforestry, high upfront (largely sunk) costs, and loss of flexibility associated with agroforestry provide the landholder with a valuable option to delay reforestation and wait for uncertainties to resolve. Our results showed that for the lower Murray study area, the value of this option can be substantial, ranging from 1.45 – 2.32 times the present value of expenditures (DCF break-even point).

Landholders often cite the lack of certainty of government policies, and the longevity of incentive schemes as barriers to investment in reforestation. This research investigated the effect of incentive payments and incentive payment uncertainty on returns required to trigger land use change. This research found that a \$25/t CO_2-e carbon payment reduced the trigger price substantially but that this impact varied spatially. While the effect of an uncertain carbon payment policy was to increase the conversion trigger returns when compared to a fixed carbon payment, the effect of added uncertainty was found to be small. The small effect of payment uncertainty reflects that the additional payment acted more as an additional top up payment, not a main source of revenue from conversion to biomass. This highlights a need to understand the role of incentive payments in the overall revenue stream created from any land use change. For example, when a large proportion of revenue from land use change is reliant on government policy, not market demand, policy risks are higher.

Future climate change is anticipated to be the principal source of risk affecting long term economic viability of rain-fed agricultural systems. This research specifically modelled land use change from agriculture to biomass production in a spatially explicit framework across a broad region accounting for impacts of climate change on yield variability. The effect of climate change on trigger returns shows substantial spatial heterogeneity not only between high and low rainfall areas as one would intuitively expect, but within similarly classified areas. In broad terms climate change reduced returns required for land use change to biomass in low and medium rainfall zones (-76%) and increased them in the higher rainfall areas (25%). The results of this research show that even under severe climate change comparatively small areas are economically viable for conversion to biomass under $200/ DM t (930,986 ha), and it is not until prices exceed $200/DM t that significant areas become profitable for conversion to biomass (up to 2,738,463 ha).

On an energy equivalence basis, to be competitive with an oil price of AU$41/barrel (current at the time of writing) biomass would have to be priced at less than AU$130/DM t. Similarly, to be competitive with coal at AU$68/t, the energy equivalent price of biomass would have to be less than AU$52/DM t. Whether or not these prices are ultimately achievable is speculative, however, for substantial biomass industry development to occur in the study area, the synchronisation of products and services derived from mallee (oil, biomass, charcoal and carbon) and the development of markets will be paramount.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Courtney Regan

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When I first started along this road it was hard to believe I would ever be at the point where I was writing this section. But after chipping away little by little I find myself, obligatory coffee in hand, sitting at my computer (who I affectionately call old Bertha; a fine example of artificial intelligence who has tried to give me a heart attack on more than one occasion) wanting to thank all of those people that have helped me in my continuing journey to become an educated and enlightened human being. I hope the following does you all justice.

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LIST OF PUBLICATIONS

Regan, C.M., Bryan, B.A., Connor, J.D., Meyer, W.S., Ostendorf, B., Zhu, Z., Bao, C., 2015. Real options analysis for land use management: Methods, application, and implications for policy. Journal of Environmental Management 161, 144-152.

Regan, C.M., Connor, J.D., Bryan, B.A., Meyer, W.S., Ostendorf, B., 2016. Spatial real options analysis: informing better incentive policy for motivating biomass agroforestry in agricultural land. Land Use Policy. Submitted, manuscript ID LUP_2016_139.

Regan, C.M., Connor, J.D., Raja Segaran, R., Meyer, W.S., Bryan, B.A., Ostendorf, B., 2016. Climate change and the economics of biomass energy feedstocks in semi-arid agricultural landscapes: A spatially explicit real options analysis. Journal of Environmental Management. Submitted, manuscript ID JEMA-S-16-01136.

List of Tables

List of Figures