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Farmer's decision parameters on diversification and supply responses to dryland salinity - *modelling across the Australian wheat-sheep zone*

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Abstract

Dryland salinity has resulted from clearing of deep-rooted plant species for farming. Farm diversification with trees and perennial pasture species may therefore reverse this problem. However, current opinion is that existing land uses are close to economic optimum and therefore changes involving perennials may not be viewed as desirable. Socially there is a trade-off between the opportunity cost of changing existing land use with the perennials and the current salinity reduction targets. In this context, this paper investigates the economic implications of key decision parameters of farmers on their response to achieve farm diversification involving farming with the perennials. This research aims to model diversification and supply responses of, in particular, wheat across the Australian wheat-sheep zone, and between the regions of NSW and Western Australia.

Keywords: diversification, supply response, farmer's decision parameters, wheat.

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1. Introduction

Dryland salinity is regarded as the most serious environmental and resource management problem in Australian agriculture in recent decades. It is expected that large-scale preventive impacts on salinity could be achieved by changes to the management of traditional annual crops and pastures. This strategy implies that the large proportion of land in threatened catchments would need to be revegetated with deep-rooted perennial plants such as shrubs, perennial pastures or trees. However, the attempts to prevent salinity by revegetation are complicated by the impacts of perennial vegetation on surface water flows and the possibility of negative responses from farmers. This situation creates some difficulties in devising efficient policies to promote prevention of salinisation by revegetation with perennials (Panell 2001).

It has been assumed that, even if perennials are not directly profitable in terms of their harvested products and farming system benefits, their ability to prevent salinity would make them financially attractive in long-term planning horizon. But some evidence suggests that the financial benefits to farmers from salinity prevention are unlikely to be high, particularly, with respect to the short-term opportunity cost of traditional (annual) crop or pasture production on the land in question. Even though the agricultural benefits are not deemed to be promising in short-run there are potential non-agricultural benefits (both private and social) associated with reducing saline discharges by revegetation with perennials. Example of these benefits include carbon sequestration, bio-diversity protection, reductions in wind and soil erosion, diversification of farm income, farming systems benefits in relation to weed control, regional development and employment creation (with respect to wood processing industries in rural areas) and aesthetic and amenity values that are related to the preservation of land and water salinisation (Pannell 2001).

Farm diversification, in particular, has benefited in several ways because of the multifunctional aspects of agriculture, such as improving land and water quality and providing environmental amenities. There are ample examples and case studies in

literature on the positive aspects of diversification in agriculture, as well as the resulting supply responses of farmers. For instance, it has been suggested that farm specialisation (or conventional farming system in agriculture) might not be an environmentally desirable practice due to negative externalities such as soil and water pollution caused by some farming systems in Norwegian agriculture (Culas 2003). Further, any changes leading to farm diversification from farm specialisation have also economic implication for supply responses with respect to relative prices (Vatn 1989). There are also factors, other than the environmental related and the relative prices, such as farm size and socioeconomic factors, which influence diversification choices in farming (Pope and Prescott 1980).

Only few studies have employed econometric models to analyse aspects of farm diversification and/or supply responses of farmers in agriculture with respect to those parameters. For example, Sanderson *et al* (1980) have cited few of such studies with respect to supply responses of Australian wheat growers. Although results from analyses of those econometric models could give some useful information on how supply responses are influenced by (or related to) key economic decision parameters of farmers, an extended version of such econometric models can further help to project the economic impacts of diversification and supply responses to dryland salinity and the current nature of farming systems. Such an analysis can help farmers to improve decision making under varying agronomic, environmental and technological conditions.

Thus the objective of the paper is to investigate economic implications of key decision parameters of farmers on diversification and supply responses to dryland salinity. This investigation proposes a model of supply responses of a major annual crop such as wheat for activities involving perennial pasture, mainly wool (or beef-meat) production in wheat-sheep zone across Australia. This analysis will also compare the regional differences between NSW and Western Australia to differentiate the impact of dryland salinity in wheat production. The paper is organised as follows. Section 2 discusses a farm management model of diversification. Section 3 details the model specification for

supply responses. Section 4 briefs data and methodology. Section 5 concludes with implications and future direction of this study.

2. Farm management model of diversification

Farming systems are often characterized by positive interactions or complementarities between the enterprises, and that any external costs of devoting a given area to wheat (in terms of negative externalities such as salinity) can be off-set over time by having perennial pastures and trees in the rest of the farmland for sheep (or cattle herd) production.[2] However, when such off-set is negative, it has impact on the expected economic returns from the wheat. This negative impact may reflect through low wheat yield and gross margins, or poor quality of wheat and low prices. Thus diversification in farm activities and the supply responses to area could be explained with these key economic variables.

A farm management model is considered where a farmer allocates homogenous farmland to two alternative enterprises A and B (Fraser 1990, cited in Kingwell 2004). It is assumed that A is an activity based on annual crop such as *wheat* and B is another activity based on perennial pasture and trees such as *wool* (or, it could be *beef-meat*). These enterprises generate returns without interaction and with economies of size absent.

Expected farm returns $E(\Pi)$ are:

$$E(\Pi) = E\ (\alpha\ a + (1- \alpha)\ b - g\ (\alpha) + f\ (\alpha)$$

where:

a = uncertain net return from wheat,

b = certain net return from wool, for that $E(a) > b$.

α = the proportion of farmland allocated to wheat,

[2] Other examples include nitrogen supplied by leguminous pastures to following grain crops or windbreak benefits of agro-forestry or disease and pest cycle breaks bestowed by rotation phases.

$g(\alpha)$ = the internalized cost of negative externality by wheat (e.g. salinity),
$f(\alpha)$ = an incremental net return by complementarities with perennial pastures.

The farmer's decision is choice of α to maximize expected profit.

The first-order condition for optimal level of α is:

$$Max\ E(\Pi):\ a - b + f'(\alpha) - g'(\alpha) = 0$$

where:
$f'(\alpha) < 0,\ g'(\alpha) > 0$ and $a-b = g'(\alpha) - f'(\alpha)$.

From the first-order condition, the optimal level of α can be expressed as a function of net return for the wheat and the return for the wool:

$$\alpha^* = f(a - g'(\alpha) + f'(\alpha), b)$$

For this functional relationship, an optimal (desired) level of land allocated to wheat in time t can be studied as an area response (supply) function as derived in Section 3.

Figure 1 illustrates possible farm diversification decisions of joint inclusion of negative externalities and enterprise complementarities for enterprises A and B (see Appendix 1).

3. Model specification for supply responses

The general model takes the form

$$Y_t^* = a + bX_t + cR_t + dZ_t + v_t \qquad (1)$$

where Y_t^* is the desired wheat area for the proportion of land α_t^* allocated to wheat in period t. X_t is the expected relative value of the net returns from wheat and wool.

The other possible explanatory variables to decide the level of land allocation are R_t and Z_t, where R_t is a vector of net returns from other activities and Z_t is a set of exogenous shifters. An error term is defined as v_t with the classical properties.

To allow for the possibility of adjustment lags, a Nerlovian partial adjustment model is specified,

(2) $$Y_t - Y_{t-1} = \gamma (Y_t^* - Y_{t-1}),\ 0 \leq \gamma \geq 1,$$

where γ is the coefficient of adjustment.

The expected relative value of the net returns X_t is defined in (3) by the parameters following the function $\alpha^* = f(a - g'(\alpha) + f'(\alpha), b)$

(3) $$X_t = (a - g'(\alpha) + f'(\alpha)_t / b_t)$$

Substituting (1) and (3) into (2), and readjusting gives the model

(4) $$\begin{aligned} Y_t &= a\gamma + b\gamma X_t + c\gamma R_t + d\gamma Z_t + (1-\gamma) Y_{t-1} + \gamma v_t, \\ &= \beta_0 + \beta_1 X_t + \beta_2 R_t + \beta_3 Z_t + \beta_4 Y_{t-1} + u_t. \end{aligned}$$

Thus, in (4) testing the null hypothesis that $\beta_4 = 0$, which means γ = 1.0, can be used to assess a significant adjustment lag.

In (4) the expected relative value of the net returns (X_t) can be measured as a ratio of the gross returns for the enterprises wheat (A) and wool (B)

(5) $$X_t = (P_t^A * Y_t^A - \sum Ø_{n\,t}^A * C_{n\,t} - g'(\alpha)_t + f'(\alpha)_t) / (P_t^B * Y_t^B - \sum Ø_{n\,t}^B * C_{n\,t})$$

where Y_t^A and Y_t^B are, respectively, production of wheat and wool. P_t^A and P_t^B are expected prices of wheat and wool. *C* is the cost of inputs *n* in period *t,* and $Ø_{n\,t}^A$ and $Ø_{n\,t}^B$

are respectively the coefficients denote use of the inputs *n* in period *t* in the production of wheat and wool.

However, value of the variables $g'(\alpha)$ and $f'(\alpha)$ can not be known in practice, and also it is difficult to measure accurately some of the other parameters involved in estimating X_t.

Studies of models of supply responses suggest employing expected relative prices instead of expected relative net returns (for example, Sadoulet *et al* 1995; Sanderson *et al* 1980). In which case the variables X_t and R_t can be employed as expected relative prices.

Although it is difficult to figure out the actual impact of $g'(\alpha)$ and $f'(\alpha)$ on the net returns of wheat, the model (4) could be analysed across the regions for comparison. Thus the model estimates across the regions along with some qualitative information such as historical perspectives on impact of salinity on agriculture, farming systems development and structural changes in agriculture could shed light on discussing the model estimates for any policy options across the regions.

A statistical model could thus be defined as follows:

$$Y_{it} = \beta_i + \beta_1 X_{it} + \beta_2 R_{it} + \beta_3 Z_{it} + \beta_4 Y_{i\,t-1} + \beta_5 T + u_{it} \qquad \text{for } i = 1,\ldots,N. \tag{6}$$

where T is time-trend as proxy for technological development over the period.

Following the model (6), the estimated coefficients of variables β_1, β_2, β_3, β_4, and β_5 can be interpreted both statistically and economically as the respective farmers' decision parameters for diversification and supply responses.

4. Data and methodology

Panel data of a quantitative and qualitative nature from various sources are sought. Production, land area and financial related data are available form ABARE for an average

farm basis for various regions over a period of 1990 - 2004. For reality check it would be useful to test the model parameters with individual farm level data focusing on a particular area in a region.

Econometric estimation with fixed-effects and random-effects formulation could further help to evaluate the impact of variables $(g'(\alpha) + f'(\alpha)$ in the model because of the location and the time related effects that can be fixed (separated).

5. Implications of the study and future direction

The proportion of farm area allocated to cropping relative to livestock, in particular, wool production has increased by the mixed crop-livestock producers in the Australia's wheat-sheep zone. Although economic conditions which favoured wheat prevailed for more than a decade influenced this trend, farmers have rarely switched *completely* out of livestock production in the regions. Historically the enterprise diversity within the wheat-sheep zone has been for farmers growing a variety of crop species with reducing their sheep flocks or boosting their cattle numbers.

Recent economic conditions driven by the demand for meat and rising costs of cropping have shifted to favour more livestock production than cropping. Conditions such as from salinity, water scarcity, weeds and pest control, etc. could further influence the shift. A shift in a farm's enterprise mix ultimately depend on the differences in profit due to the adjustment costs and the investment decisions related to farm infrastructure and so forth (Ewing *et al* 2004).

The farming systems in the wheat-sheep zone also depend on various climatic, biological, economic and social influences, most of which are taken into consideration in this study for comparison across the zone and between the regions for policy analysis. Future research from this study would be directed towards econometric models of Australian broadacre agriculture, with a focus on *interactions* between the wheat, beef meat, sheep meat, wool and grains industries and applications to the analysis of agricultural policies.

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Appendix 1

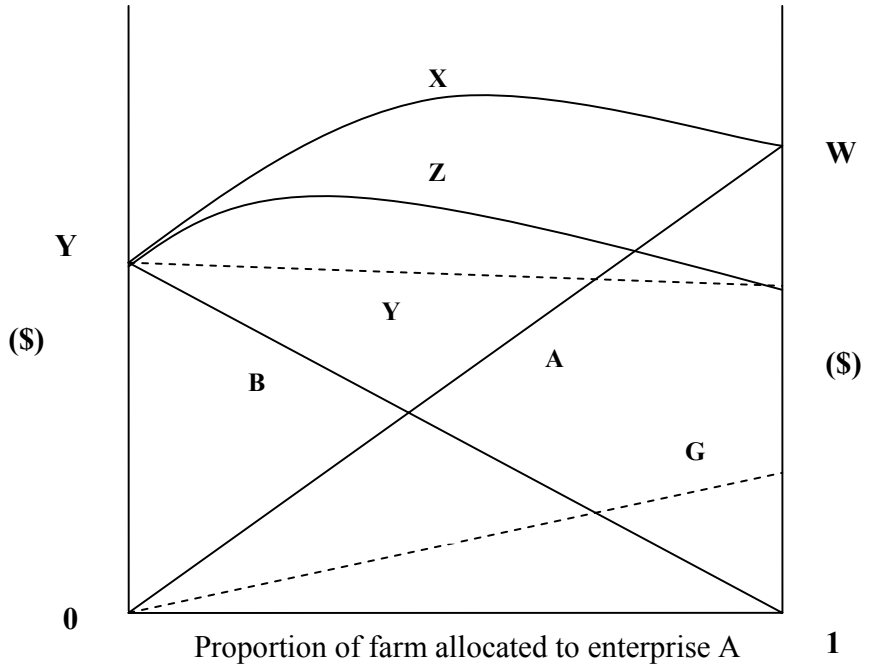

Figure 1: Representation of impacts on diversification of internalizing negative externalities and enterprise complementarities (source: Kingwell, 2004)

A = enterprise based on annual crop (wheat)

B = enterprise based on perennial pastures and trees (wool) (or, beef-meat)

W= optimal with all land allocated to enterprise A

Y = optimal with all land allocated to enterprise B

G = Negative externalities (e.g. salinity)

Y = optimal with negative externalities

X = optimal with complementarities

Z = optimal with complementarities and negative externalities.