Estimating the drivers of regional rural land use change in New Zealand

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We present a new econometric methodology for estimating the responses of multiple land uses to economic driving forces at a Territorial Authority level. The model is based on a microeconomic model of landowner decision-making scaled to a wider spatial scale and is loosely based on an AIDS model framework. The model uses a publicly available data set that Motu has complied from a variety of sources including Agricultural Censii and Surveys, population census, Land Cover Database (LCDB) and agricultural and productivity indices produced by Landcare Research for the project. This work builds on earlier Motu work estimated at a national level.

Keywords: rural land use, forestry, pastoral farming, regional, econometric model

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1 Introduction

Almost 60% of New Zealand's total land area is used for agricultural purposes including plantation forestry (Statistics New Zealand, 2006). Thus, the agricultural sector plays a significant role in the New Zealand economy, with export receipts of NZ$14.1 billion, or 47% of the total export receipts, in 2005-2006 (ABARE and MAF, 2006). But the sector also supports many small communities across the country. However, this is not a homogenous sector and landowners need to make choices regarding how they will use their land. These decisions will affect the level of profitability of their farm and will be constrained by the characteristics of their land and surrounding community. Each land use will be possible only on particular types of land and will require different things from the surrounding area such as infrastructure. Changes in the types of land use within an area can alter the infrastructure demands, population and local economies, as well as the direct effects on the landowners.

The land use profile of New Zealand has important environmental implications, as different land uses will affect the environment in different ways. For example, while plantation forestry will sequester carbon from the atmosphere, dairy and sheep/beef farming emit greenhouse gases. Thus, shifts in rural land use from pastoral activities to plantation forestry may reduce New Zealand's greenhouse gas emissions. Additionally, different land uses have local effects. For example, nutrient run-off from fertiliser use is more pronounced in fertiliser-intensive land uses like dairy farming and may have greater impacts in some catchments than others. Alternatively, individuals may prefer areas to be maintained in a particular land use to preserve the aesthetic value of an area. For example, some people object to the idea of large areas of plantation forestry over rolling hills that are currently in pastoral farming. Thus, local changes in land use can be as important as national level changes for particular environmental effects.

By understanding the drivers of rural land use change, we are better able to predict, and prepare for, changes in the future and the economic and environmental implications associated with them.

The drivers of rural land use change at a national level have been estimated previously by Kerr and Hendy (unpub.). They used four key New Zealand land uses (dairy farming, sheep and beef farming, plantation forestry and scrub) over 29 years of data to estimate the relationships between the shares of rural land in each land use type and prices, interest rates and the area of non-rural land. This work generated coefficients that are consistent with the underlying economic theory. For example, increases in the dairy price led to an increase in the share of total land used for dairy while an increase in forestry price led to a decrease in the share that is left for scrub. However, due to the small number of data points, the power and the number of variables able to be included in the model specification were limited.

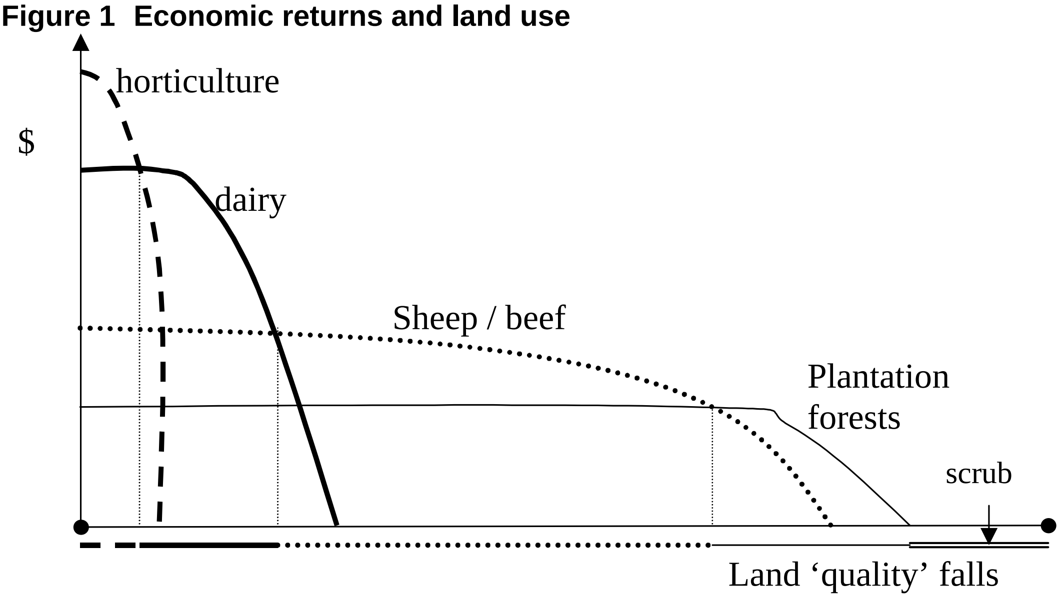
This paper will detail an extension of Kerr and Hendy's work to estimate rural land use drivers at the Territorial Authority (TA) level. Disaggregating the analysis required the construction of a panel dataset, models additional variables, and allows us to investigate their relationship with land-use change. By estimating the model at a finer spatial scale, patterns in land-use change are less likely to be obscured by aggregation at the national level and the local variation in land use change can be explored. This paper will outline the theoretical background behind the model followed by a brief description of the data available to estimate the model at the Territorial Authority (TA) level. The adaptation of Kerr and Hendy's model to estimation at the TA level is then discussed. Finally, additional enhancements to the model are suggested.

2 Theoretical Model

The following discussion of the underlying model is adapted from the discussion provided in Kerr and Hendy (unpub). The underlying theoretical model used in this paper is based on that of Stavins and Jaffe (1990) and assumes that landowners solve a dynamic optimisation problem and choose the land use that brings them the highest net present value of expected utility. Thus, we assume that landowners respond to expected net returns, conversion costs from one land use to another, and relative uncertainty in returns. Since land is heterogeneous, different land will generate different returns.

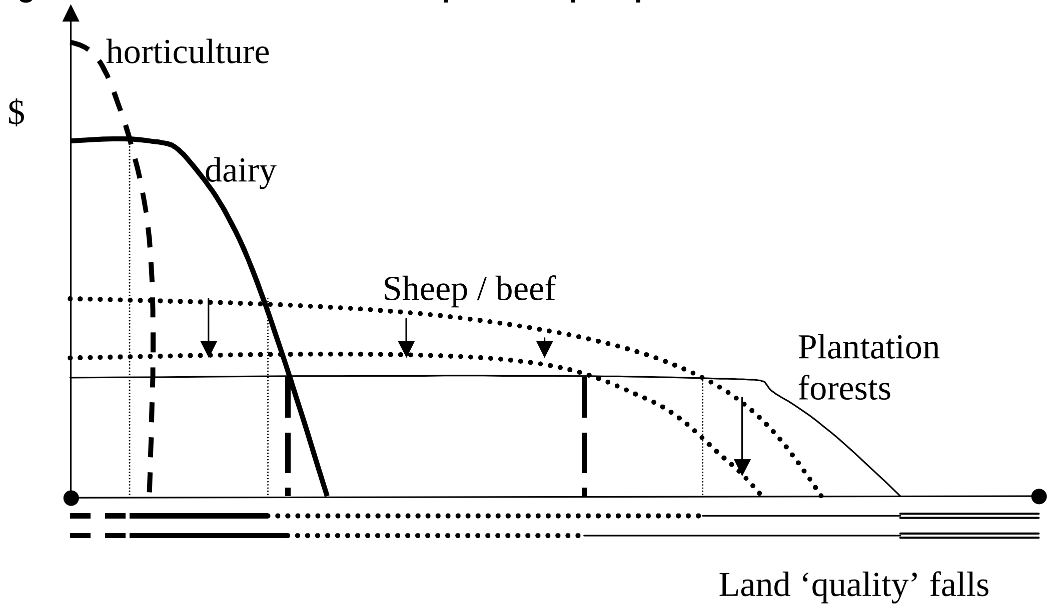
Our heuristic model is presented in Figure 1. The x-axis represents the hectares of rural land in New Zealand. They are ranked in a one-dimensional way from left to right in terms of land quality. The y-axis indicates the expected return to the landowner from each hectare of land. Each curve represents the possible return on that land in one particular use. This curve depends on the potential yield of that crop on that land, current technology, current costs and current output and transport costs. The landowner will optimally choose the land use with the highest return. Thus at the point where each curve intersects we can drop a line to the horizontal axis to indicate a change in land use at that level of land quality. The returns achievable will be reflected in the value of the land so that the farmer gains only normal profit even in the optimal land use. Since in reality land quality is not one-dimensional, in some places plantation forestry may compete with dairy land while in others it competes with sheep/beef or scrub land.

Figure 1 Economic returns and land use



As output prices, costs etc. change, the shapes of the curves will change also. This will lead to changes in optimal land use. Figure 2 shows the possible effect of a fall in sheep/beef prices. The share of land used for sheep/beef falls. The best sheep/beef land is converted to dairy, while the worst sheep/beef land is converted to plantation forests.

Figure 2 Effects of a fall in sheep/beef export prices on land use



The figure does not take account of conversion costs, which introduce hysteresis in land use and may also affect the timing of land use change. This will particularly affect plantation forestry land which tends to only be converted to other uses at the point of harvest (after around 27 years). Conversion costs affect dairy land also because of the considerable investments required in dairy sheds and equipment and also potentially in irrigation. Dairy land could be used for other purposes in the short term if relative returns shift significantly. It is still likely to respond more to perceived long-term price changes than to short-term changes. Sheep/beef farming and scrub require relatively little investment and shifts into them can be reversed relatively quickly.

Our theoretical model implicitly assumes that observed price changes are long-term shifts and that farmers perceive them that way, or at least perceive them to be an indicator of a long-term shift. However, since prices are highly variable, rational farmers may not alter their price expectations significantly in response to short term price changes. In particular, it is unlikely that a shift in timber prices will be directly translated into a change in expectations about timber prices at the time of harvest 27 years away. Thus, when we interpret the coefficients, we need to be conscious that we are estimating responses to factors that drive farmers' price expectations rather than to actual returns.

3 Data Available

To estimate regional land use drivers at the Territorial Authority (TA) level we require a panel dataset that contains information on the area of each land use throughout time as well as information on how potential drivers have changed over the same time period. We collected this data from a variety of sources.

3.1 Agricultural Production Surveys and Censii

The area of each land use by TA, or county prior to 1991, was obtained from information in the Statistics New Zealand Agricultural Production Surveys and Censii. This provided the total pasture, forestry, horticulture and other rural areas within each TA annually from 1991 to 1996 and 2002 to 2004 and each county from 1981 to 1990. In addition to not providing data for the years 1997 to 2001, this data had two other limitations. The proportion of the pasture that is dairy and sheep and beef farming needed to be identified and a concordance needed to be created to generate a consistent series at a single spatial scale.

Within the Agricultural Production Surveys and Censii, information is provided on the area of pasture, forestry, horticulture and other rural areas. However, in our model we are interested in the area of sheep and beef farming and dairy farming. Thus the pasture area needed to be allocated within each TA or county to each of these two land uses. To estimate land allocation, we used data from Meat and Wool New Zealand on maximum stocking rates for sheep/beef farming and annual national areas of dairy and sheep/beef farming and Statistics New Zealand data on sheep/beef and dairy stock units by TA (or county prior to 1991). We carried out an optimisation to calculate the dairy stocking rates in each TA/county, for each year, by minimising the difference between the TA stocking rate and the national stocking rate,[1] subject to

[1] National stocking rate was calculated as the sum of dairy stock units by TA/county divided by the national dairy area provided by Meat and Wool New Zealand.

area constraints. These area constraints ensured that there was sufficient land left for the sheep/beef animals, based on maximum stocking rates, and did not exceed the area available in the TA/county after allocation to dairy. We also ensured that the land allocated to dairy equalled the national dairy total. The area of pasture allocated to sheep/beef farming was allocated in the same way with constraints on the area allocated so as not to exceed the remaining area in the TA/county once dairy land had been allocated.

Prior to 1991 Statistics New Zealand collected regional data at the county level. However, since 1991 they collect data at the TA level. Thus the data that is provided in the Agricultural Production Surveys and Censii comes in two different data frames, with different spatial units. To create a consistent panel from 1981 to 2004 a concordance was developed. The concordance utilised information on population changes at the meshblock level from Population and Dwelling Censii and a satellite image of 1996 land use from LCDB1.

3.2 Independent Variables

Additional variables have been collected from a number of sources to include in the model specification. This dataset includes a variety of variables which may contribute to landuse change, such as land quality indices, prices, and interest rate data.

4 Adaptation of Kerr and Hendy (unpub.)

As a first step in estimating the drivers of rural land use change at the regional level, we replicated the model specification used by Kerr and Hendy (unpub.) by adapting the model specification for use at the Territorial Authority level.

4.1 Long Run Estimation

The econometric specification used in this paper and Kerr and Hendy is based directly on an ‘Almost Ideal Demand System’ (AIDS) structure (Deaton and Muellbauer, 1980). Four rural land uses are considered – dairy farming, sheep/beef farming, plantation forestry, and scrub. Each of these land uses are calculated as a share of the total rural land in 1981. The share of land in each land use, s_i, in each TA, m, is assumed to depend linearly on a constant, the share of 1981 rural land in non-rural land uses in TA m, NR,[2] the output prices for each of the major land uses, p_i, and the nominal interest rate, r.

$$S_{i_{mt}} = \alpha_i + \beta_i \, NR_{mt} + \Sigma_j \, \gamma_{ij} \log p_{jt} + \delta_{1i} r_t + \delta_{2i} time_t + \varepsilon_{imt} \quad (1)$$

i,j = dairy, sheep/beef, plantation forestry, scrub

m = territorial authority

t = time

Each of the four equations are estimated simultaneously with constraints in place to ensure that the total land area does not change through time. If we sum (1) across all four land uses we get (2)

$$1 - NR_{mt} = \Sigma_i \, \alpha_i + \Sigma_i \, \beta_t NR_{mt} + \Sigma_i \, \Sigma_j \, \gamma_{ij} \log p_{jt} + \Sigma_i \, \delta_{1i} r_t + \Sigma_i \, \delta_{2i} time_t + \Sigma_i \, \varepsilon_{imt} \quad (2)$$

This implies a series of adding up constraints on the model. If all prices are zero, and there is no ‘non-rural land’ (i.e. it is 1981), the land use shares must add to one.

$$\Sigma_i \, \alpha_i = 1 \quad (3)$$

When more land is converted out of the four major uses relative to 1981 (i.e. the share of non-rural land increases), the sum of changes in rural land shares must offset it

$$\Sigma_i \, \beta_i = -1 \quad (4)$$

When one price or the interest rate or time changes, the changes in all shares must offset each other

$$\Sigma_i \, \gamma_{ij} = 0 \quad (5)$$

$$\Sigma_i \, \delta_{1i} = 0 \quad (6)$$

$$\Sigma_i \, \delta_{2i} = 0 \quad (7)$$

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[2] Non-rural land includes urban land, conservation land and reserves. By assigning the dependent variable as share of 1981 land we may in come cases get a negative value for the share of 1981 land in non-rural land uses. This result indicates that the area of rural land within the TA has increased.

4.2 Short Run Estimation

While the above model provides estimates of a long run equilibrium relationship among the variables, the short run responsiveness to shocks and the speed of adjustment may also be of interest. To estimate the short run response (assumed to be a single year), we include the same variables as the model above, but in their differenced form. The estimated residuals from the long run equation are also included to provide an estimate of the degree to which land use is out of equilibrium at the beginning of the period. Thus we estimate the following equation.

$$\Delta s_{imt} = \alpha_i + \beta_i \Delta NR_{mt} + \Sigma_j \gamma_{ij} \Delta \log p_{jt} + \delta_{1i} \Delta r_t + \Sigma_j \delta_{2j} \varepsilon_{imt-1} + \mu_{imt}$$

The cross equation restrictions in the long run estimation are also included in this model specification. In addition, we add a constraint ensuring that the coefficients on the lagged residuals sum to one across equations.

5 Benefits of Estimation at TA Level

The model created by Kerr and Hendy (unpub.) was limited in its model specification because of the small number of data points. Our new estimation at the TA level makes this constraint is less binding. As a result, we are able to include additional variables and further explore the model specification. Estimation at the TA level also has other benefits. The national patterns in land use are not necessarily representative of the patterns in individual TAs. Thus, the drivers of land use change in particular areas may be obscured when the model is estimated at the national level. By estimating at the TA level, we may reveal the effect of more localised drivers. The remainder of this paper will discuss some possible enhancements to the model specification.

5.1 Inclusion of Asymmetric Price Responses

Landowners are unlikely to respond equally to price increases and decreases. As the relative returns from one land use increases, landowners should be more likely to move into that land use. However, once they have moved into that land use and made the investment required to do so, they may be less likely to move back out of the land use due to the investment that they made previously. This fixed cost of conversion may play a major role in preventing the landowner from changing land use as fluidly as they might like. Thus we would like to include asymmetric prices into the short run equation to investigate whether the landowners do make different land use decisions in response to increases and decreases in price. The short run equation would then be as follows.

$$\Delta\, s_{imt} = \alpha_i + \beta_i\, \Delta\, NR_{mt} + \Sigma_j\, \gamma_{ij}\, \Delta \log \text{ pos } p_{jt} + \Sigma_j\, \gamma_{ij}\, \Delta \log \text{ pos } p_{jt} + \delta_{1i}\, \Delta r_t + \Sigma_j\, \delta_{2j}\, \varepsilon_{imt-1} + \mu_{imt}$$

5.2 Explaining TA Specific Variation

Different TAs have quite different land use profiles. While at the national level, we see all of the land use types represented, at the TA level this is not the case. For example, some TAs such as those in the Waikato have a large amount of dairying while other TAs such as Queenstown have a large amount of scrub and no dairying. Thus we would like to include variables into the model specification that allow us to identify what is contributing to the different patterns of land use within each of the TAs. The remainder of this paper will discuss some variables which we have the data for and are considering including in the model specification.

5.3 Varying Yield

The yield that a landowner is able to achieve from his land is unlikely to be constant across the country. For example, high quality land is able to support more animals than lower quality land and thus higher quality land is able to produce more yield. Consequently the return for a landowner for a particular land use is likely to vary across the country. In the national model by Kerr and Hendy this variation was not able to be considered due to a small number of degrees of freedom. However, at a TA level we can vary yields, such as milk production, biomass produced and timber, across the country based on land quality.

Being able to vary yields is especially important for sheep/beef farming where there is substantial variation in stocking rates. For example, stocking rates in the Waikato are higher on average than those in Marlborough leading to higher average returns per hectare. By incorporating this variation through differences in the prices obtained in different areas we may be able to further explain the differences in land-use patterns observed in different TAs.

Land quality not only affects the yield that is able to be had from a particular land use but also may prevent a land use being selected. If land is of a sufficiently low quality, no matter how high the price goes it will be impossible for the landowner to move into that land use. For example, dairy farming requires reasonably flat and fertile soils. Thus, landowners in the South Island high country with steep land will be unable to convert to dairying even if the price doubled or tripled its currently level. We have information on land quality from the Land Use Capability (LUC) index that we can include in our model. So by including a measure of the proportion of land in each of the quartiles of land quality into the long run equation, we will be able to assess the role that land quality is playing.

5.4 Varying Production Costs

The current model specification does not include production costs, which is equivalent to an assumption that the production costs are equal across all land uses. However, this is unlikely to be the case. Across the country, the cost of producing one unit of a good are likely to differ. For example, landowners closer to the market are likely to pay lower transportation costs than landowners further away. Other areas might pay different wages due to variations in living costs or the availability of workers in the area. Thus, by including spatially varying prices into the long and short run equations for each land use we are able to incorporate some of this variation. Spatially varying production cost datasets have been collected from MAF for dairy production costs and Meat and Wool New Zealand for sheep/beef farming. Motu is currently in the process of creating a spatial dataset for forestry production costs, based on wood supply regions. Once this is complete, spatially varying production costs for each landuse will be included in the model specification.

6 Current Progress

We are currently in the process of finalising the dataset and running the first estimation of the model. In addition to the suggestions above, we are considering the benefits of fixed effects and fixed effect interaction terms in both the long and short run equations. Final datasets will be available, where possible, from www.motu.org.nz.

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