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Drivers of rural land use in New Zealand: Estimates from National Data

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Abstract

Rural land-use decisions have direct impacts on many environmental issues, including greenhouse gas emissions, erosion, and water quality issues. By studying the relationship between rural land-use decisions and economic returns, we take a step toward understanding what New Zealand's future land-use path is likely to be, and how land-use may respond to differing environmental policies. In this paper, we study the responsiveness of four major rural land uses (sheep/beef, dairy, forestry, and abandoned land reverting to native bush) to exogenous shocks in commodity prices. We derive a theoretical model of land-use choice in terms of a portfolio decision, consistent with an "Almost Ideal Demand System". We estimate a long-run relationship between land-use area for and prices, using 29 years of data. We then use an error-correction model to explore the timing of adjustment of rural land-use to price shocks.

JEL classification
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1 Introduction

Agricultural and forestry products, even excluding horticulture, made up 8% of New Zealand's exports in 2003 (Statistics New Zealand, 2004). In 2001, approximately 60% of New Zealand land was used for agriculture or forestry. Another 30% is conservation land. Many of New Zealand's major environmental issues relate to land use: greenhouse gas emissions, water quality, water use, protection of habitat for biodiversity and maintenance of the landscape that attracts tourists. Agricultural land use is of key importance both economically and environmentally.

Despite this, we have relatively little understanding of the drivers of land use change. This paper is the first step in a project to address this gap. Here we use data for four key land uses at a national level over 29 years to create a model that simultaneously estimates the drivers of each land use and begin to gain insight into those drivers.

Our model is in the tradition of 'revealed preference' models (Stavins and Jaffe 1990) where rather than trying to model the physical and economic processes that drive land use change explicitly using agronomy models and economic estimates of profitability, we use a statistical approach where we relate historical patterns of land use to historical patterns of their economic drivers. Our model is an extension of this literature because we deal with multiple land uses. Other modelling approaches have dealt with multiple land uses (e.g. (Antle and Capalbo 2001) but using different methodologies and not in New Zealand.

In New Zealand several models have studied agricultural output. The Lincoln Trade and Environment Model is an international partial equilibrium model that covers all pastoral agriculture (Cagatay and Saunders 2002). The New Zealand Ministry of Agriculture and Forestry runs a Pastoral Supply Model which is a structural model estimated in part from historical data (Gardiner and Su 2003).

We find that dairy land and sheep/beef land respond predictably to their own prices. They adjust to a price shock over a period of two to three years.

Scrub is displaced by other uses, particularly sheep/beef and forestry, as their output prices rise. Forestry is a curious sector. Forested land shows a strong upward trend over the entire 29-year period that does not relate to output prices. Forested land does not consistently respond to any prices including interest rates. Forestry prices on the other hand appear to affect both scrub and sheep/beef land, negatively and positively respectively.

Our analysis is limited by the time series nature of the data, which cannot allow for variation in land conditions, by the short time series and by some limitations in data quality. The next stage of our research will break the data down into small geographical areas and explicitly control for land quality as well as including data on costs and changes in physical productivity.

The paper begins with a brief historical overview of the key factors affecting New Zealand land use since 1974. We then outline a heuristic model of land use and discuss our estimation approach. We discuss the data in section four and give results in section five. Section 6 suggests some direction for our future work.

2 Brief economic background with respect to rural land

In this section we discuss some important structural changes that have affected rural land use in New Zealand since the 1970s.

2.1 General Macroeconomic conditions

The 1973-1977 oil shock and subsequent devaluation of the New Zealand dollar raised costs (while also increasing commodity prices in NZ dollars). Following poor economic growth, high inflation and growing unemployment in the late 1970s and early 1980s New Zealand underwent significant economic reforms from 1984, including floating the exchange rate, financial sector deregulation, removal of many subsidies including those on agriculture and on exports, removal of import licensing, reductions in tariffs, extensive privatisation and public sector reform.[1]

The real exchange rate appreciated considerably following the float, leading to low real prices for exporters until the early 1990s. It fell sharply around 1993 and has since risen again. Possibly as a result of financial sector deregulation and structural reform, New Zealand suffered heavily in the wake of the stock market crash in 1987. Economic growth continued to be poor until around 1993. Inflation stabilised after 1990. Since 1993, economic growth has been positive and unemployment has fallen.[2]

2.2 Plantation Forestry

Until 1987, the New Zealand Forest Service dominated New Zealand forestry. Nearly all planting, management and harvesting decisions were made by this government agency. Labour costs in forestry were subsidised in this period. In 1987 the Forest Service was disestablished and its functions were divided between a new Department of Conservation and a Ministry of Forestry. The forestry assets to be sold were included in the 1988 government budget. Since 1990, most forest concessions have been in private hands even when the forests are on public land.

Tax and superannuation changes have also been significant for forestry. Forests are a long-term investment and are often a substitute for pension funds. In 1988, tax concessions on contributions to private and occupational pension or superannuation schemes were abolished, as were tax concessions to the

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[1] For discussion of the New Zealand reforms see Evans, L., A. Grimes, et al. (1996). "Economic Reform in New Zealand 1984-95: The Pursuit of Efficiency." Journal of Economic Literature **34**(4): 1856-1902.

Between 1984 and 1995 New Zealand changed from a closed and centrally controlled economy to one of the most open countries in the OECD. The reforms liberalizing the economy were notable for their very comprehensive coverage and innovations that included: performance contracts for senior civil servants and the central bank, legislated constraints on fiscal expenditure decisions backed by accrual accounting, tax neutrality, subsidy-free agriculture, and no industry-specific regulation of competition. Modern microeconomics contributed much to policy design. Economic growth has been vigorous since 1991, but a different sequencing of reforms may have enhanced outcomes..

[2] For more information on New Zealand's macroeconomic performance see Dalziel, P. and R. Lattimore (1999). The New Zealand Macroeconomy: A briefing on the reforms. Auckland, Oxford University Press.

superannuation funds themselves.[3] Since 1988 contributions to pension and superannuation schemes are taxed as they are made. In 1987, as forests were privatised, their tax treatment was changed. Rather than being able to expense the costs of establishing or managing a forest against other income (even from other forestry plots) as the costs are incurred, these costs are put in a 'cost of bush' account and used to offset the forest revenue on harvest. This is less advantageous than an immediate write off. This 'cost of bush' provision was removed in 1991. In the wake of Cyclone Bola, a major storm that destroyed large areas of land, a government forestry project on the East Coast of the North Island was created in 1992 to establish forests on erosion prone land. This planting is probably significant on a local scale but not nationally.

2.3 Sheep/beef and Dairy

Just before our period of analysis, 1974 – 2002, Zealand benefited from a world commodity price boom driven by a mix of supply and demand side factors. On 1 January 1973 however, Britain entered the European Economic Community, with major negative impacts on demand for New Zealand agricultural products.

Before 1984, a series of programmes subsidised the New Zealand farming sector. The Marginal Lands Board was established in 1950 to encourage farming on small or undeveloped land through loans. Farmers also received priority access to credit for development (in otherwise controlled financial markets) at preferential interest rates through the Rural Bank, which was established in 1974. Land Development Encouragement Loans that aimed to encourage further development of land into pastoral use began in 1978. Fertiliser (since 1978) and other inputs were subsidised, and firms in agriculture and forestry had special tax treatment. Supplementary Minimum Prices (SMPs) were paid from 1978 for some agricultural production. By 1984, the subsidies reached 90% of sheep farmers' market returns. Table 5 shows the levels of producer equivalent subsidy in each agricultural sector.

[3] Prior to 1988, superannuation funds were not taxed at the standard company tax rate. http://www.goodreturns.co.nz/article.php?ArticleID=976486067 Accessed June 2004

The government announced the termination of the SMP scheme 27 June 1984 ((Organisation for Economic Cooperation and Development 1985). Some subsidies were removed overnight and others were rapidly phased out. Removals of subsidies began in 1985. Since 1984, pastoral agriculture has experienced significant fluctuations in the exchange rate and a gradual adjustment to an unregulated environment.

In combination, the range of subsidies probably meant that some land was cleared that would otherwise have stayed in native vegetation. As regulation was removed, some of this land may have reverted to native scrub or been converted to forestry.

3 Theory

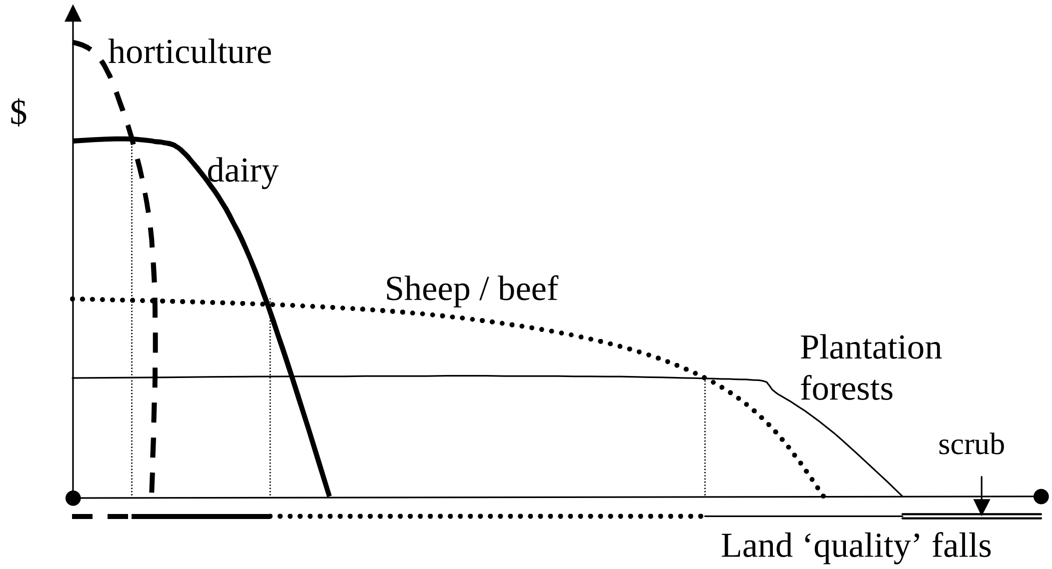
Our underlying theoretical model is based on that of (Stavins and Jaffe 1990). We assume that landowners solve a dynamic optimisation problem and choose the land use that brings them the highest net present value of expected utility. In the underlying model landowners care about expected net returns, conversion costs from one use to another and relative uncertainty. Land is heterogeneous so different land yields different returns. At any point in time there is a distribution of potential returns in each land use.

We are considering multiple land uses in contrast to Stavins and Jaffe who consider only two: forest and agriculture. The total land area available to 'rural' land uses is exogenously determined but not fixed over time. Our econometric model is based on (Deaton and Muellbauer 1980) simply because of the parallel between a fixed budget with declining marginal utility of consumption and a fixed land area with falling returns as each land use is extended.

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. In reality, land quality is not one-dimensional and plantation forests may in some instances compete with dairy land while in others they compete with sheep/beef or scrub land.

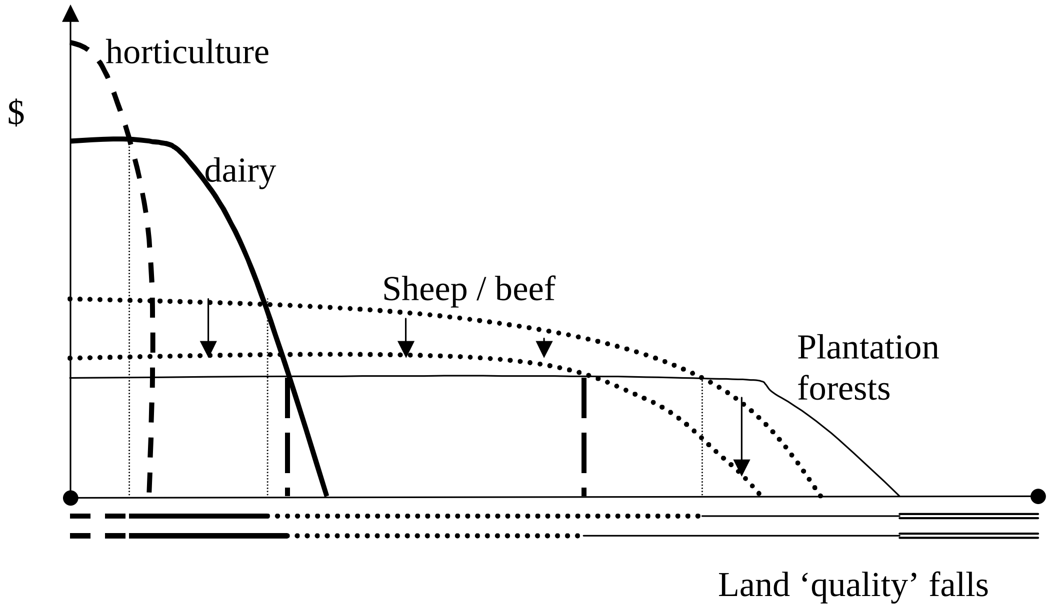
The y-axis indicates the expected return to the landowner from each hectare of land. Each curve represents the possible return on that land in one particular use. This curve depends on the potential yield of that crop on that land, current technology, current costs and current output and transport costs. 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.

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 land is converted to dairy, while the worst 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) and in fact has almost never been converted back in New Zealand's history. Planting costs are a major investment that should be sensitive to real interest rates and may be sensitive to cash flow when farm foresters are involved. Timing of harvest is sensitive to the interest rate at the time of maturity and also prices at maturity.

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 are relatively quickly reversible.

3.1.1 Perceptions of price changes

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. As we will see in section 4.3, output prices are highly variable. In the literature there is considerable debate about whether commodity prices (which the key output prices in our model are) are random walks or if they exhibit mean reversion. 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 log prices will be directly translated into a change in expectations about log prices at the time of harvest – 27 years away. One exception to this in New Zealand is the removal of subsidies. These were a large and permanent change in farmer returns and were understood to be so at the time.

New Zealand farm-gate prices are also heavily influenced by fluctuations in the exchange rate. These do not affect relative output prices except those for scrub where the price is fixed in New Zealand dollars. Farmers may regard changes in price that reflect exchange rate changes differently from other price changes. New Zealand's exchange rate does have a long-term cycle and thus these price changes can be expected to be reversed, though after some years.

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. Responses to permanent price shifts, or to policy changes (that may be regarded as more or less temporary than other price movements) may be quite different to responses to historical price series. In future work, when we have cross section variation we will attempt to isolate different causes of price variation to see if farmer responses vary.

3.2 Econometric Specification

Our econometric specification is based directly on an 'Almost Ideal Demand System' (AIDs) structure (Deaton and Muellbauer, 1980). For each of four land uses, i, we assume that the share of rural land in use i, s_i, depends linearly on a constant, the share of 1974 land not used for the four major land uses, OL, the output prices for each of the major land uses, p_i, and the nominal interest rate r.

$$s_i = \alpha_i + \beta_i \, OL + \Sigma_j \, \gamma_{ij} \log p_j + \delta_{1i} r + \delta_{2i} time + \varepsilon_i \quad (1)$$

We exclude other factors that are likely to affect land use shares such as costs, productivity, costs of conversion, and other measures of macroeconomic conditions simply because we are currently working with a small dataset with few degrees of freedom.

If we sum (1) across all four land uses we get (2).

$$1 - OL = \Sigma_i \alpha_i + \Sigma_i \beta_i OL + \Sigma_i \Sigma_j \gamma_{ij} \log p_j + \Sigma_i \delta_{1i} r + \Sigma_i \delta_{2i} time + \Sigma_i \varepsilon_i \quad (2)$$

This implies a series of adding up constraints on the model. If all prices are zero, and there is no 'other land' (i.e. it is 1974), the land use shares must add to one.

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

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

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

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

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

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

We do not include all prices (e.g. wages) in our model, and in particular have only an artificial output price for scrub which really yields only an option value, so do not expect homogeneity to hold. In the long run we might expect Slutsky Symmetry ($\gamma_{ij} = \gamma_{ji}$) to hold for small changes in prices. In the short run, fixed costs of investment and other partial irreversibilities make movements between uses asymmetric. If price changes are large, the non-linearities in the real model will make the effects of prices asymmetric. This is easily seen from the shapes of the curves in Figure 1 and Figure 2.

4 Data

4.1 Dependent Variable: Rural Land-use Categories

We create four major land use categories: sheep and beef, dairy, plantation forest, and scrub. These are our four dependent variables; in our model all other land-uses are assumed exogenous. We have 29 years of national land-use area data spanning 1974 to 2002.

We use data from the Statistics New Zealand's Agricultural Production Surveys carried out from 1974-1996, and 2002, and the Economic Service's Farm

Surveys for 2000 and 2001.[4] We interpolate the missing years 1997-1999 using production data for each of the land-uses (described in detail in Appendix A).[5]

We calibrate all land-uses to match the 1996 satellite-based land-use information from the Land Cover Database (LCDB1). We do this partly for data integrity and partly so that we can simulate spatial changes in a consistent way (see Hendy and Kerr 2004). The Agricultural Production Census data we use separates rural land-use into 'pasture', 'plantation', and 'other'.[6] The 'pasture' category also includes lands for crops. To separate land for crops from true pasture we assume land for crops land is fixed over time at the LCDB1 level in 1996 and subtract it from Census 'pasture'. LCDB1 includes the rural categories 'pasture', 'plantation forests', and 'scrub'. We scale the corrected 'pasture' from Census so that in 1996 it equals 'pasture' in LCDB1. We also scale plantation forests so their area is equal to the LCDB1 level in 1996.

The Economic Service (Meat and Wool Innovation) provided us with a breakdown of the Census 'pasture' category into pasture for dairy, pasture for sheep/beef, and pasture for other agriculture (lifestyle blocks, government farms – e.g. pastoral leases, deer, and goats) based on Census data.[7] We applied this split proportionately to the LCDB1-calibrated Census "pasture" area to give us a time series of sheep/beef area, dairy area and 'pasture for other agriculture'.[8]

The Census "other" category includes mature native bush, native scrub and regenerating native bush, and all other land (including building area, shelter belts etc). We used the Census "other" category to represent changes in scrub

[4] The land-use data is as at June 30 of the year listed.
[5] Andrew Maclaren from SNZ recommends not including 1999 survey data.
[6] In SNZ publications, pasture generally includes grassland, lucerne, and tussock. In some years, the SNZ pasture category includes land for crops and in others it does not (it was generally separated out after 1983). Economic Service has provided us with a consistent series back to 1980; this includes land for crops for the entire series.
[7] Sheep and beef are combined because they often share the same land. The pasture areas for dairy, sheep/beef, and other pasture were estimated using Economic Service Survey data on average farm sizes and farm numbers.
[8] Economic Service provided us with a "sheep/beef", "dairy", and "other pasture" split of the SNZ pasture category area, back to 1980. To create a split for the 1970s, we extrapolate the relationship back using animal numbers from the Statistics New Zealand Agricultural Production Census.

land-area over the period, and calibrated this to the 1996 measure of scrub from the LCDB1.[9]

We set total 'rural' land equal to the sum of dairy, sheep/beef, plantation, and scrubland area in 1974. We then defined an exogenous land-use category as the difference between the 'rural' land area at time *t* and the 'rural' land area in 1974. This variable, OL, encompasses the net change in all land-uses other than sheep/beef, dairy, plantation forestry, and scrub. This includes changes in urban area, horticulture, and pasture for other agriculture that infringe on land that in 1974 was in one of our four major uses. Its inclusion allows us to study a constant area of land by acting as the balancing item.[10]

4.2 Explanatory Variables

As explanatory variables, we include prices for sheep/beef, dairy, and plantation production, a real 5-year interest rate, and the exogenous land-use area described in section 4.1.

All our price data are based on data provided to us by the New Zealand Ministry of Agriculture and Forestry (MAF), from the database compiled for estimation of their Pastoral Supply Response Model(Gardiner and Su 2003). All prices are deflated using the CPI excluding GST and including interest rates (source Reserve Bank of New Zealand), in 2002 NZ$.[11]

We created a composite sheep/beef price that is a weighted average of the price for prime beef (cents/kg), price for wool (cents/kg clean wool), price for sheep/beef (cents/kg, itself a weighted average of lamb and mutton prices). We

[9] In 1987, a significant amount of rural land was reclassified as conservation land, so that some land that had been administered by the Department of Lands and Survey was passed over to the Department of Conservation (Agricultural Statistics, 1996). This land was all in the SNZ "other" category (Personal communication with Andrew McLaren, SNZ, 2004). We smoothed this out by subtracting the total change in the "other" category between 1986 and 1987 from all the previous years.

[10] In future work we will include each of these categories separately as they infringe on different types of land use. For example, urban expansion often happens on productive land that could have been used for dairy, while goat and deer farming will tend to dispace scrub or sheep.

[11] All prices are averaged over the year ending June 30.

weight by volume of product (kgs) in 2002.[12] As our dairy price we use cents per kg of milksolids.

The plantation price is cents per m^3 of round-wood equivalent. To take some account of the likelihood that current price does not reflect expected price, we use the average of the last three years' prices as our price measure. As our interest rate variable we used the RBNZ 5-year government bond yield series.

We adjusted these prices to include measures of the subsidies that were received by farmers during the 1970s and early 1980s. We used Producer Subsidy Equivalents to adjust prices to include subsidies.[13] These measure the extent to which border and domestic output-related policies increase gross income to firms (Lattimore 2003). Table 5 gives PSE estimates from 1970 - 1990.

4.3 Descriptive Stats

Table 1 shows the land-use area in 1996, distinguished by conservation and non-conservation land.

Table 1 Land-use distribution, 1996

	GIS		*Census/Survey*
Land-use Type:	*DOC Land Area (ha)*[14]	*Non-DOC land area (ha)*[15]	*Rural Land area (ha)*[16]
Dairy	-	-	1,683,781
Sheep/beef	-	-	9,234,180
Other pasture	-	-	2,399465
Pasture	1,183,025	12,813,300	**13,265,426**

[12] See 0 for details of the composition of the sheep/beef price.
[13] Sourced from MAF. For the 1970s, we only have PSE estimates for 1970 and 1975. We linearly interpolated between these points.
14 This is derived from an overlay of the Department of Conservation Land Register Database with the LCDB1. Both the layers were gridded to a 25ha cellsize before the cross-tabulation was calculated. The land in the Conservation Land *Register includes* land of the Crown which the Department administers.
[15] This is derived from an overlay of the Department of Conservation Land Register Database with the LCDB1. Both the layers were gridded to a 25ha cellsize before the cross-tabulation was calculated.
[16] This is based on the Agricultural Production Census in 1996, with Economic Service estimates of the breakdown into dairy, sheep/beef, and other pastoral land.

(sum of above) [17]			
Plantation	59,000	1,549,150	**1,683,217**
Scrub/other[18]	944,975	1,736,925	**1,475,484**
Horticulture	175	45,050	**122,986**
subtotal	***2,187,175***	***16,144,425***	***16,547,113***
Urban[19]	4,175	181,750	-
Indigenous Forest	4,774,625	1,441,250	-
Other[20]	1,001,150	1,002,225	-
Total	7,967,125	18,769,650	-
Total NZ	26,736,775		-

As we can see in

Table 2, New Zealand land use changed dramatically over the 29 years we studied. Price variability is also significant.

Table 2 Variables used (29 observations)

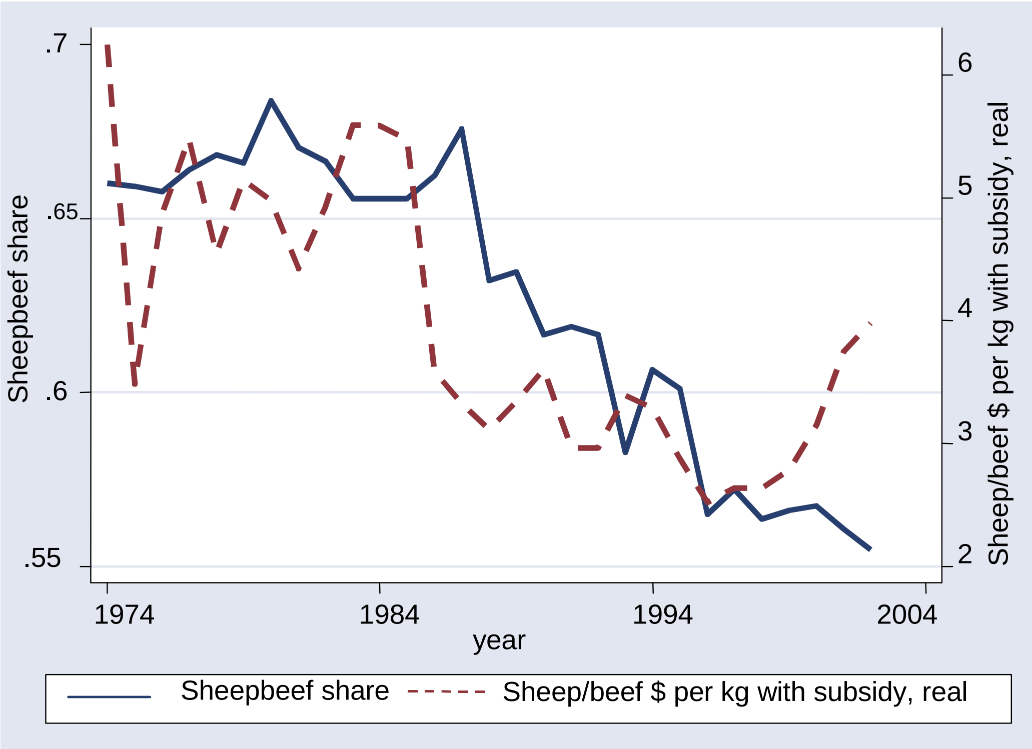
Variable		Mean	Standard Deviation	Minimum	Maximum
Areas	Total land included	12.6m ha	0.54m	11.7m	13.5m
	Sheep and beef	7.98m ha	0.55m	7.07m	8.71m
	Dairy	1.15m ha	0.15m	1.03m	1.54m
	Plantation forest	1.15m ha	0.39m	0.53m	1.83m
	Scrub	2.36m ha	0.51m	1.56m	3.12m
Shares	Sheep and beef	0.63	0.043	0.56	0.69
	Dairy	0.091	0.012	0.081	0.12
	Plantation forest	0.091	0.031	0.042	0.14
	Scrub	0.19	0.040	0.12	0.25
	Other	0.0046	0.043	-0.064	0.075
Prices	Sheep and beef	$3.95	$1.09	$2.52	$6.25
	Dairy	$4.79	$0.98	$2.96	$7.14
	Plantation forest (average of last 3 years)	$141.19	$19.54	$106.99	$178.78
	Scrub	$1	0	$1	$1
Log(price)	Sheep and beef	5.94	0.27	5.53	6.44
	Dairy	6.15	0.21	5.69	6.57
	Plantation forest	9.55	0.14	9.28	9.79
	Scrub	0	0	0	0

[17] This is the sum of the LCDB1 categories: primarily pasture and tussock.
[18] This is the area of scrub for the LCDB1 sourced data, and the area of "other land" for the SNZ data.
[19] This is the sum of the LCDB1 categories: urban and urban open-space.
[20] This is the sum of the LCDB1 categories: mangrove; inland water; inland wetlands; coastal wetlands; mines-dumps; coastal sands; bare ground.

Other	Nominal interest rate	9.96%	3.73%	5.18%	18.47%

Figure 3, Figure 4 and Figure 5 show the relationship between changing land use shares and changing prices. For sheep/beef land, both shares and prices are relatively stable up until 1984 (after the price fell from the earlier commodity price boom). Prices fall sharply from 1985 with the removal of the subsidies and continue a downward trend until the late 1990s. The share of land in sheep and beef falls dramatically with a slight lag after the price drop and continues to fall throughout the period. Some of the year-to-year variation in the share of land in sheep/beef may simply be measurement error. It seems easy to posit a relationship between price and land use for sheep/beef.

Figure 3 Share in sheep/beef vs. sheep/beef price



In contrast, the dairy price and dairy share show little relationship. Dairy prices more or less fall until the late 1990s though with significant variability. Since the early 1990s the share of land in dairy has exploded.

Figure 4 Share in Dairy vs. Dairy Price

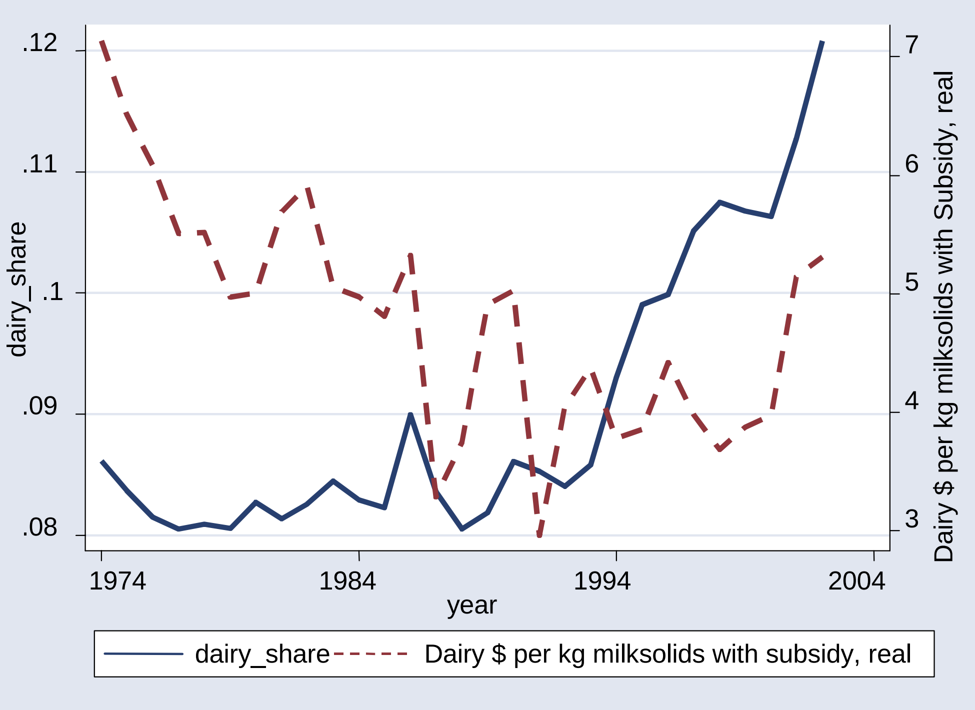
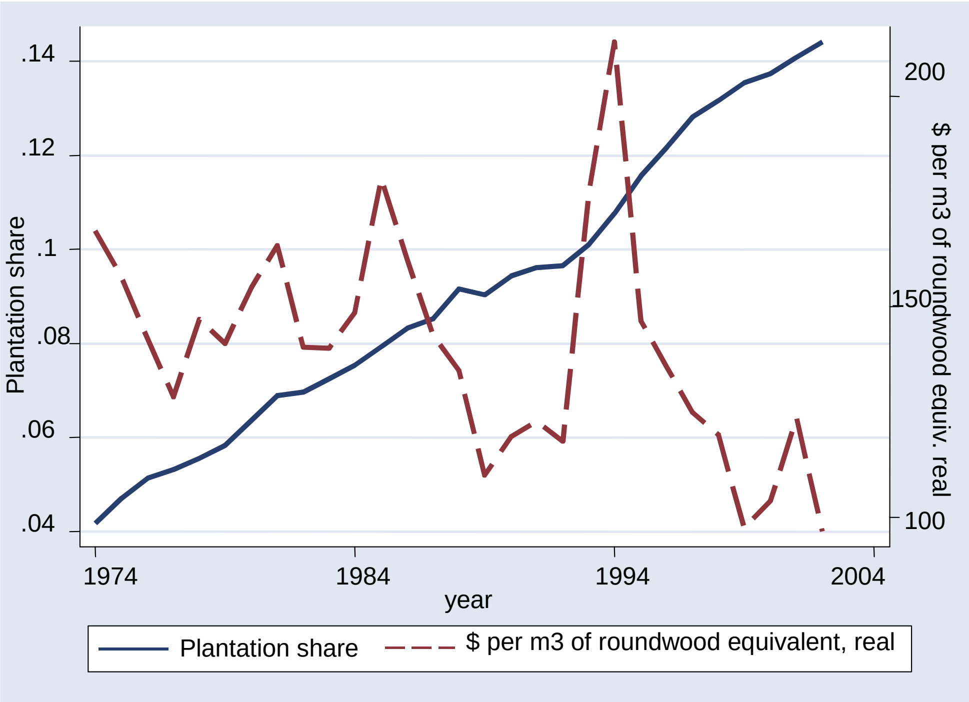
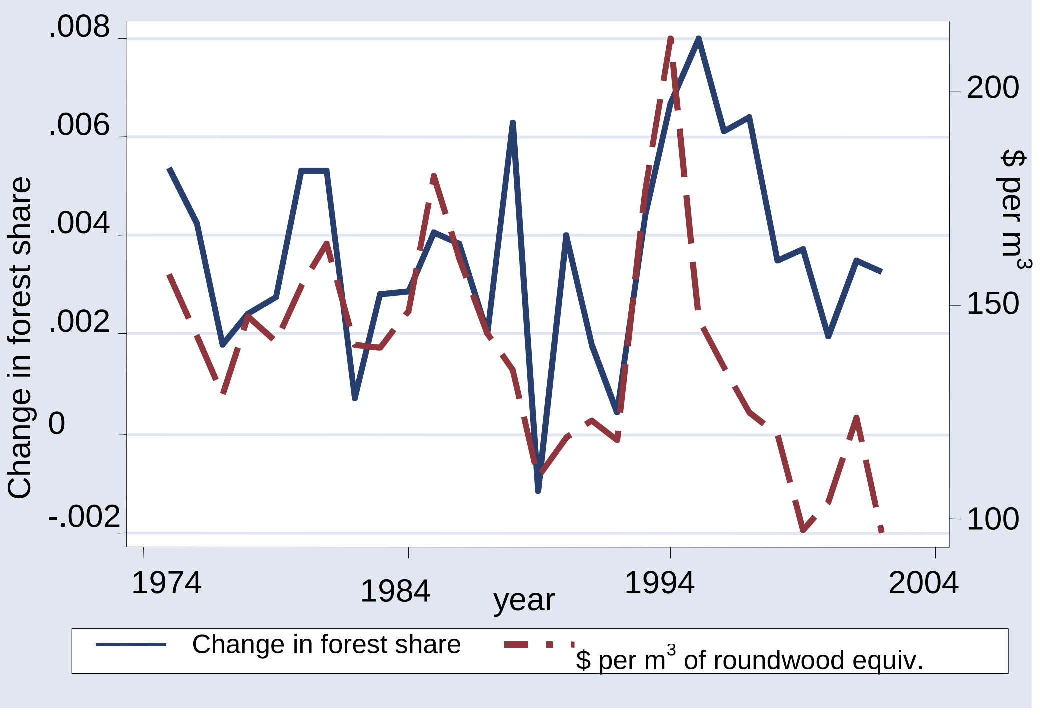


Figure 5 Share in forest and forest product price



Similarly, the area of forestry land seems unrelated to the price of forest products. The defining pattern is a steady upward trend in forestry land throughout the period. As we can see more clearly in Figure 6, the growth accelerates around 1992 when log prices rose and the tax treatment of forests was made more favourable. This boom lasts until around 1996. Changes in plantation forest appear to track levels of prices much more than levels of forest do particularly if you consider that the large fluctuations (whether statistical artifacts or real changes) in changes in forest in the late 1980s are a consequence of the movement from state to private forestry. The changes in forest level are always positive however. Could this close relationship reflect lagged planting responses to high forestry prices? The significant irreversibilities in forestry mean that levels of forest cannot quickly respond but planting can.

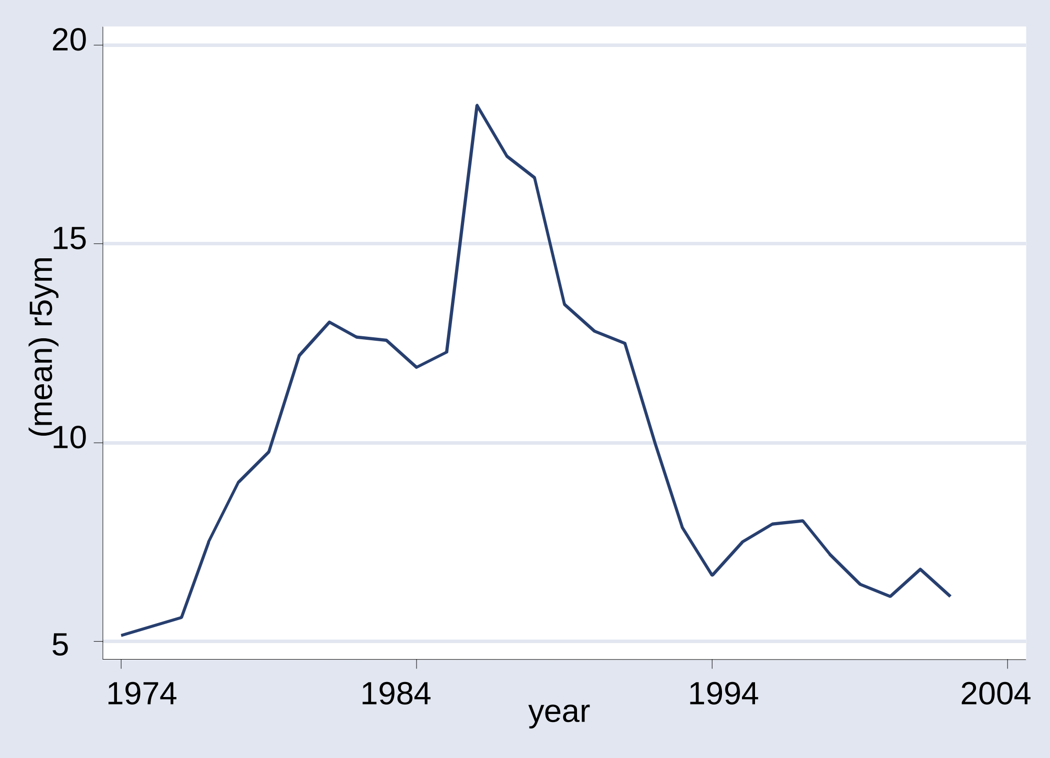
Figure 6 Changes in the area of plantation forest



We use the nominal interest rate as a broad indicator of macroeconomic conditions. It rises through the late 70s and early 80s and then peaks during the period of rapid structural reform. It returns to moderate levels in the mid 1990s when inflation is stabilised and New Zealand has come out of recession.[21]

Figure 7 Nominal interest rates

[21] We experimented with different measures such as the real interest rate and the real per capita GDP growth rate. Given that we have only time series variation and only a relatively short time period, none shows a very strong relationship with land use change. We hope to control for these conditions more effectively in future work.



4.3.1 Time series properties of data

We have 29 years of annual data. This means that most tests for the time series properties of the data will be weak – they will tend to fail to reject the null simply because of lack of power. This said, we tend to find that while prices appear to be stationary in both levels and changes, land uses may not be, even when a trend is included.[22]

Of more concern, we can observe from Figure 3 that sheep/beef prices and land both have strong trends. This likely to make separating the effect of price from the simple effect of a time trend difficult.

[22] We used both a standard Augmented Dickey Fuller unit root test for each series individually and the panel unit root test of Im, K. S., M. H. Pesaran, et al. (2002). "Testing for Unit Roots in Heterogeneous Panels." Journal of Econometrics **115**: 53-74.
for the sets of prices and land uses respectively.

5 Analysis and Results

5.1 The 'long-run' relationship between land use and prices

We estimate the model first in levels using OLS with cross equation restrictions (3) – (7). This 'long-run' model is an estimate of the long-term equilibrium relationship among the variables. Table 3 shows the results for each of the four equations.

Table 3 Long run estimates: Adding up constraints only

	Share of 1974 'rural' land in given land use			
	Dairy	Sheep/Beef	Forestry	Scrub
Logged prices				
Dairy price	0.019** (2.75)	-0.017 (-1.58)	0.0077 (1.42)	-0.010 (-0.86)
Sheep/Beef Price	0.00050 (0.09)	0.022** (2.48)	-0.0016 (-0.37)	-0.021** (-2.16)
Forestry Price	0.0072 (0.81)	0.037** (2.71)	0.0020 (0.30)	-0.046** (-3.12)
Other land	-0.080 (-1.15)	-0.31** (2.93)	-0.017 (-0.33)	-0.59** (-5.06)
Nominal interest rate	-0.0012** (-2.54)	0.0017** (2.27)	-0.00033 (-0.88)	-0.00012 (-0.15)
Trend	0.0017** (5.02)	-0.0027** (-5.16)	0.0038** (14.27)	-0.0028** (-4.87)
Constant	-0.11 (-1.07)	0.28* (1.74)	-0.015 (-0.19)	0.85** (4.9)
RMSE	0.0050	0.0086	0.0037	0.012
F-Stat	24.30	162.61	338.34	114.98

** significant at 95% level. * significant at 90% level only.

We see that each land use shows a positive own-price elasticity. Sheep/beef and dairy land respond significantly to their own prices. The sizes of the responses are relatively small. A 1% rise in the dairy price leads to a 0.019% rise in the share of land in New Zealand in dairy. This is around 2,400 ha increase in dairy land. The sheep/beef response to price is on a similar scale. Because of the time series identification problems, the own-price coefficient in the sheep/beef equation may significantly underestimate the true responsiveness.

Dairy land responds negatively to nominal interest rates while sheep/beef farming responds positively. This could reflect cash flow issues – converting land to dairy involves considerable investment.

Curiously, sheep/beef land also responds positively to the forestry price. By comparing Figure 3 and Figure 5 we can see that, excluding the forestry price spike in the early 1990s, the forestry and sheep/beef prices track each other quite closely. Thus this result could simply be a problem of identification in the time series. It is also possible that sheep/beef farmers find that when forestry prices are high, they are able to sell wood that is on their land and use this income to cross-subsidise their farming activities, thus deferring a change in land use. During most of this period, however, farm forestry was not a significant feature of farming.

Scrub would be the major land use if all prices were zero (this makes sense!). Scrub area responds negatively to the prices of all other land uses and makes up nearly 60% of the response when the area of 'other land' changes. Sheep and beef land is the other category that responds strongly to expansion of 'other' land.

5.1.1 Test for cointegration of long run relationship

We test the system of equations for cointegration using the group mean panel test of (Pedroni 1999).[23] The test rejected non-stationarity at the 1% level suggesting that the system of equations is cointegrated.[24] Thus the estimates are consistent with a valid long run specification. This gives us some confidence in proceeding to the second stage of the error correction model.

[23] This parametric ADF-based test is analogous to the Im, *et al* (2002) unit root statistic applied to the estimated residuals of a cointegrating regression. The test allows for heterogeneity in both the long-run cointegrating vectors as well as heterogeneity in the dynamics associated with short-run deviations from these cointegrating vectors.

[24] When only a constant is included and the test is augmented with no lags, the t-bar value is 4.46 against a critical level of 2.44. With two lags, the test rejects at the 10% level.

5.2 The short-run dynamics of land use change

If we consider that the long run model estimated above represents the long run equilibrium relationship among the variables we might also be interested in the short run responsiveness to shocks and the speed of adjustment back to the long run equilibrium. Here we take the short run as one-year changes. Thus we look at the change in land use in one year in response to the change in output prices etc. in the same year. We include the same variables as above but in their differenced form. Thus the trend becomes a constant.

We also take the estimated residuals from each equation and use those as an estimate of the degree to which land use is out of equilibrium at the beginning of the period. If for example the forestry residual is positive, this means that there is more forestry land than the model predicts. If this is out of equilibrium we would expect that forestry land would reduce in the following period to reduce this residual.

$$\Delta s_i = \alpha_i + \beta_i \Delta OL + \Sigma_j \gamma_{ij} \Delta \log p_j + \delta_{1i} \Delta r + \Sigma_j \delta_{2j} \varepsilon_i + \mu_i$$

The coefficients in Table 3 and Table 4 should have the same signs. If dairy land will respond positively to the dairy price in the long run it should also do so in the short run. A comparison of the sizes of the coefficients and consideration of the coefficients on the residuals gives us an indication of the timing of adjustment back to equilibrium. The relative magnitudes of the coefficients may vary if the timing of adjustment of different land uses is different. We impose the same cross equation restrictions as before and also constrain the coefficients on the lagged residuals to sum to one across equations.

Table 4 Short run: Adding up constraints only

	Change in land-use share			
	Dairy	Sheep/Beef	Forestry	Scrub
Change in…				
Dairy price	0.0082** (2.24)	-0.012 (-1.55)	0.0020 (0.84)	0.0019 (0.24)
Sheep/Beef Price	-0.0022 (-0.55)	0.012 (1.40)	-0.00012 (-0.05)	-0.010 (-1.10)
Log Price	-0.00037 (-0.04)	0.10** (4.98)	-0.0080 (-1.29)	-0.092** (-4.46)
Other land	-0.066 (-1.43)	-0.34** (-3.4)	-0.013 (-0.43)	-0.58** (5.69)
Nominal interest rate	0.000015 (0.03)	0.00038 (0.40)	0.00058** (2.01)	-0.00097 (-1.00)
Lagged residuals				
Dairy	-0.73** (-2.91)	0.0034 (0.01)	0.30* (1.79)	0.43 (0.79)
Sheep/beef	0.41 (0.46)	-1.21** (-6.31)	0.07 (1.20)	1.10** (5.59)
Forestry	0.33 (0.82)	1.15 (1.33)	-0.72** (-2.72)	-0.76 (-0.86)
Constant	0.0013** (2.36)	-0.0019 (-1.60)	0.0036** (10.31)	-0.0031** (-2.57)
RMSE	0.0028	0.0075	0.0018	0.0089
F-Stat	3.28	18.09	2.09	10.02

** significant at 95% level. * significant at 90% level only.

As before we find positive own-price elasticities for dairy and sheep/beef though the latter are now insignificant. We find a negative but insignificant own-price elasticity for forests. It has been suggested that this might be expected because when log prices are high foresters have an incentive to harvest and there may be a lag between harvesting and replanting in which forest area falls. We continue to find the puzzling relationship between forest prices and sheep/beef land. We also find a puzzling positive relationship between nominal interest rates and forest area. The change in land use in response to incursion by ‘other’ land is almost identical in the short and long term. Scrub continues to respond negatively to sheep/beef and forestry prices but the sheep/beef effect is no longer significant.

5.2.1 Timing of adjustment

The short-run coefficients on the dairy and sheep/beef price are mostly half or less of the long-run coefficients. This suggests gradual adjustment to shocks. The responses to ‘other land’ incursion and the time trend / constant are almost identical in each model. The responses of sheep/beef land and scrub to forestry prices are much larger and more significant in the short run. The level of forest responds more strongly to short-run changes in the interest rate while dairy and sheep/beef show no short run response. The coefficients on the lagged residuals are all negative and significant, as we would expect.

Taking dairy as an example, our model suggests that in the long run a 1% change in dairy price will lead to around a 2,400 ha change in dairy land (as discussed above). This might be made up of around 1,000 ha of change in the first year, 1,000 ha the second year (0.73 times the residual of 1,400 ha) and around 300 ha the third year. After three years more than 95% of the adjustment will have taken place.

6 Future work

Some of our coefficient estimates have plausible and easily understood directions, though their magnitudes may be incorrect. Others are puzzling. Still others are insignificant which may simply be a result of the small sample size. In the next stage of our research we plan to shorten our time period of interest to 1980 – 2002 but create a panel of data so that we can use cross sectional variation to better identify land use responses. We have collected data on land use and its drivers at the smallest spatial scale available.

Our land use data comes from a variety of sources, each of which has strengths and weaknesses. We will use satellite data from 1996 and 2001 (and ultimately around 1990) to give precise spatial detail for native forest, plantation forest, scrub, pasture and other land covers. We will use MAF / Statistics New Zealand Agricultural Census data at a territorial local authority level. We will use National Exotic Forestry Database information on plantation forests. We will complement these with data from Quotable Value New Zealand on optimal land uses at the mesh block level.[25]

We will add a number of variables that we were unable to include in this first stage simply because of shortage of degrees of freedom. We will include a wider range of macroeconomic and regulatory controls. We will include data on physical productivity trends and changes in input costs.

At a spatial level we will include data on actual yields and costs. We will use distance measures combined with data on cost per km to control for transport costs to processing plants and ports. We will control for the governance of land. Not only do we exclude conservation and government controlled land (as in this paper) but we will also control for Maori land with multiple owners. We will use geophysical measures including soil fertility and drainage, slope, land use capability, and climate as indicators of land quality for different potential uses. Currently we use these data to create rules to predict spatial land use (Hendy and Kerr 2004). With these data we plan to develop and test an econometric, spatially specific, multiple-land-use model that we can use as a firm basis for simulations of agricultural and environmental scenarios.

[25] For description and analysis of these data see Stillman et al (2004).

Appendix A Land-use Variables

Summary of Land-use Data

	Sources	Years*	Inter/extrapolations
Sheep/beef (ha)	Original data was sourced from the Agricultural Production Census **Pasture** category (and ES farm surveys for 2000/01). This was split into sheep/beef, dairy, and other pasture by Economic Service using Economic Service Survey data on average farm sizes and farm numbers. We have scaled these areas, so that the sum is to equal the LCDB pasture category in 1996.	1980-1996, 2000-2002.	1974-1979 extrapolated the sheep/beef area backwards using stock unit numbers. 1997-1999, interpolation using stock units numbers.
Dairy (ha)	Original data was sourced from the Agricultural Production Census **Pasture** category. This was split into sheep/beef, dairy, and other pasture by Economic Service using Economic Service Survey data on average farm sizes and farm numbers. We have scaled these areas, so that the sum is to equal the LCDB pasture category area in 1996.	1980-1996, 2000-2002.	1974-1979 extrapolated the dairy area backwards using stock unit numbers. 1997-1999, interpolation using stock units numbers.
Scrub (ha)	Original data was sourced from the Agricultural Production Census **Other** category. Includes mature native bush, native scrub and regenerating native bush, all other land (including building area, shelter belts etc) We have scaled the SNZ **other**, so that the sum is to equal the LCDB scrub category area in 1996.	1974-1996, 2000-2002.	1997-1999 linearly interpolated.
Plantation (ha)	Original data was sourced from the Agricultural Production Census **Plantations** category. We have scaled the SNZ **Plantations**, so that the sum is to equal the LCDB plantations category area in 1996.	1974-1996, 2000-2002.	1997-1999 interpolated using National Exotic Forestry Description data
Total Rural	This is sum of sheepbeef, dairy,		

Land (ha)	scrub and plantation land area in 1972.		
Exogenous Land-use Area (ha)	Difference between "Total Rural Land" and the sum of sheepbeef, dairy, scrub and plantation land area. This will include changes in urban, horticulture, other pasture (goats, deer etc).		

* Years of actual data

Appendix B Exogenous Variables

Summary of price data

Variable	Description
Sheep/beef Price (cents/kg composite product)	Derived weighted average of price of prime beef per kg, price for wool per kg clean, and price of sheep meat per kg (itself a weighted average of lamb and mutton prices). Weighted by total volume of each product (kgs) in 2002. See below for derivation. Components sourced from MAF (PSRM model data, original source Economic Service, based on schedule and auction prices). Converted to 2002 real cents using RBNZ CPI excluding gst and including interest rate
Dairy Price (cents/kg milksolid)	Cents per kg milksolids. Converted to 2002 real cents using RBNZ CPI excluding gst including interest rate Sourced from MAF (PSRM model data, original source Livestock Improvement Corporation, farmgate price).
Plantations Price (Cents/m3 round wood equivalent)	(F.o.b. value)/(m3 of exported rwe). Rwe created using conversion factors for each forestry product. Converted to 2002 real cents using RBNZ CPI excluding gst inc interest rate Sourced from MAF (PSRM model data). Originally from SNZ export data.
Real Interest Rate	5 year government bond yield Converted to real using RBNZ CPI excluding gst including interest rate Sourced from RBNZ
Year	Year ending June

Derivation of Sheep/beef price

Q_{beef} = total hot weight of slaughtered beef cattle (excluding bobby calves) (kgs).
P_{beef} = prime beef shedule price (cents/kg)

Q_{lamb} = total hot weight of slaughtered lambs (kgs).
P_{lamb} = lamb schedule price (cents/kg)

Q_{mutton} = total hot weight of slaughtered adult sheep (kgs)
P_{mutton} = mutton schedule price (cents/kg)

Q_{wool} = total quantity of clean wool (kg)
P_{wool} = clean wool price at auction (cents/kg clean)

$$P_{sheep} = \left(\frac{P_{lamb} Q_{lamb} + P_{sheep} Q_{sheep}}{Q_{lamb} + Q_{sheep}} \right)$$

$$Q_{sheep} = Q_{lamb} + Q_{sheep}$$

$$P_{sheepbeef} = \frac{P_{beef} Q_{beef}(2002) + P_{wool} Q_{wool}(2002) + P_{sheep} Q_{sheep}(2002)}{Q_{beef}(2002) + Q_{wool}(2002) Q_{sheep}(2002)}$$

Appendix C

Table 5 Producer Equivalent Subsidies

	PSE (% increase in farmer returns)			
	Sheep	Wool	Beef	Dairy
1970	5	5	5	-1
1975	24	11	10	40
1980	15	10	5	32
1981	15	10	17	40
1982	36	26	24	32
1983	84	30	19	10
1984	90	19	13	17
1985	80	10	9	18
1986	75	14	16	13
1987	16	11	13	11
1988	14	11	12	16
1989	8	5	5	14
1990	5	3	3	12

Sourced from MAF. The estimates from 1982 – 1989 come from (Tyler and Lattimore 1990). The other figures are from the OECD.

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