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Post-Reform Substitution and Cost Efficiency in the New Zealand Agricultural Sector

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Abstract

A recent study suggested that output composition rather than technical efficiency changes were the primary result of dramatic regulatory reforms imposed on the New Zealand sheep and beef farming sector in the 1980s. These results raise important questions about the substitutability and cost efficiency patterns underlying these changes. Although standard measures of returns and biases do not reflect these production characteristics, indicators can be developed, based on marginal rates of transformation and technical substitution, to facilitate such an analysis. We compute such measures and find that output substitutability, even given the product jointness inherent in pastoral production, supported cost efficient output compositional changes in response to reform. However, limited substitutability and rigidities for inputs restricted input responses and imposed significant costs on farmers in their attempts to adapt to the post-reform economic incentives.

Key words: cost efficiency; allocative efficiency; agriculture; regulatory reform

JEL classification: O0; Q1

1. Introduction

Dramatic economic reforms were initiated in New Zealand in the mid-1980s in an attempt to deal with a massive and rising international debt burden, which had outpaced the economy's agricultural product-based export sector. The regulatory reforms removed expensive governmental intervention programs, which had failed to expand pastoral production and earnings sufficiently to cover the nation's debt. The economic environment and incentives for farmers thus changed rapidly from

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being distorted by government assistance to more closely approximating a market orientation. Since wool and lamb were a primary focus of the original support programs, sheep farming operations in particular were dramatically and immediately impacted by the reforms.

Paul, Johnston, and Frengley (1999) (henceforth PJF) used an output distance function model to show that technical efficiency in this sector was not affected in any clear or substantive manner by the reforms, although financial difficulties may have constrained short-term responses to changing incentives. The reforms instead led to adaptations in output composition, toward beef and deer and away from traditional wool and lamb production. These findings raise questions about the underlying (output and input) substitutability and cost (allocative) efficiency patterns that might have generated such adjustments.

The returns and bias measures used by PJF to represent technological production processes for this sector do not capture, and thus do not permit analysis of, such patterns. However, insights about substitutability and cost (allocative) efficiency may be obtained from computing and evaluating absolute and relative shadow value measures from distance function estimation.

Such measures represent slopes of production possibility curves (marginal rates of transformation, $MRT_{m,n}$, for outputs y_m and y_n) and isoquants (marginal rates of technical substitution, $MRTS_{j,k}$, for inputs x_j and x_k). Although these types of indicators do not derive naturally from the translog function used for the PJF analysis, relative (value) measures may be constructed from the estimates both to further the analysis of substitutability patterns and to evaluate cost efficiencies by comparing them with market value ratios. Computing the associated Morishima elasticities may generate additional information about substitution patterns.

In this study we use the output-oriented multi-output and -input distance function approach of PJF, with farm-level determinants of technical inefficiency incorporated, to compute and analyze such measures. The results from empirical analysis of panel data for sheep and beef producing farms in the New Zealand agricultural sector (1969-1991) emphasize that the primary impact of changing economic incentives was to induce cost-efficient adaptations (subject to adjustment costs) in output composition. These responses are supported by some output substitutability, even with the inherent jointness involved in lamb and wool production. By contrast, changes in input use appear severely limited by lack of substitutability, which caused farmers' adaptations to changing economic conditions to fall short of those implied by cost efficiency, at least in the short term. However, direct input responses that are evident, such as a dumping of sheep livestock on the market and low and falling returns to (quasi-fixed) inputs such as labor, capital, and land, appear to reflect significant adjustment costs resulting from the speed and extent of the reforms.

2. The Model and Estimation

An output-oriented stochastic production frontier (SPF) model based on a distance function was used by PJF to represent production and technical efficiency in

New Zealand sheep and beef farming. The output distance function $D_O(\bullet)$ represents best practice production for a multi-output production process. It indicates the maximum amount of output (given composition) technically possible for a given input vector, and thus can be thought of as a multi-output production function. More formally, this function can be defined as in Lovell et al. (1994) as $D_O(\mathbf{x},\mathbf{y},t) = \min\{\Theta: (\mathbf{y}/\Theta) \in P(\mathbf{x},t)\}$, where **x** and **y** are input and output vectors, t is a vector of external production determinants, $P(\mathbf{x},t)$ is the production possibility set, and $D_O(\bullet) = 1$ implies technical efficiency.

For empirical implementation, PJF approximate this technological relationship by a translog functional form, with homogeneity of degree one in outputs and symmetry of cross-effects imposed. Writing the resulting function with $\ln D_{Oit}$ as a one-sided inefficiency error u_{it} in addition to the standard "white noise" error term v_{it} results in:

$$\begin{aligned}-\ln y_{1i} &= \alpha_0 + \Sigma_m \alpha_m \ln y^*_{mit} + .5\, \Sigma_m \Sigma_n \beta_{mn} \ln y^*_{mit} \ln y^*_{nit} \\ &+ \Sigma_m\Sigma_b \gamma_{mb} \ln y^*_{mit}\, t_{bit} + \Sigma_j \alpha_j \ln x_{jit} + \Sigma_j\Sigma_b \gamma_{jb} \ln x_{jit}\, t_{bit} \\ &+ .5\, \Sigma_j \Sigma_j \beta_{jk} \ln x_{jit} \ln x_{kit} + \Sigma_j \Sigma_m \beta_{jm} \ln x_{jit} \ln y^*_{mit} + v_{it} - u_{it}, \\ \text{or } -\ln y_{1i} &= TL(x_i,y_i/y_{1i},t,\alpha,\beta,\gamma) + v_{it} - u_{it}\,,\end{aligned} \tag{1}$$

where the left hand side of the expression is negative (so input marginal products will be negative and output shadow values positive), m and n enumerate M-1 normalized output levels, j and k identify J input levels, b represents B external factors, *i* denotes the farm, *t* signifies time period, and the combined error term v_{it}-u_{it} puts this model in the SPF form.

The netputs recognized in PJF include four outputs (wool (y_1), lamb (y_{LMB}), mutton or sheep (y_{SO}), and beef and deer (y_{BDO}), where "O" denotes output), and seven inputs (labor (x_{LAB}), capital (x_K), land area (x_{LND}), aggregated materials (x_M), aggregated purchased services (x_{PS}), sheep livestock (x_{SI}), and beef and deer livestock (x_{BDI}), where "I" signifies input stocks). The t vector for the final specification includes only R, a dummy variable representing the onset of economic reform in 1986, because the inclusion of a technical change (or trend) term was invariably insignificant when substitution effects and reform impacts were accommodated in the distance function.

PJF estimated this model by maximum likelihood methods, while simultaneously representing factors affecting (in)efficiency by assuming the u_{it} are distributed as truncations at zero of the $N(m_{it},\sigma_U^2)$ distribution, where $m_{it}=z_{it}\delta$, z_{it} is a vector of farm-specific environmental variables, and δ a vector of parameters [as in Battese and Coelli (1995)]. For their final specification, the efficiency determinants (z_{it} variables) included a time trend, T, a financial (debt/equity) variable, DE, and the reform variable R. Instruments were initially used to accommodate potential endogeneity issues from the inclusion of output ratios (with the dependent variable in the denominator) on the right hand side of the estimating equation, but this approach was rejected because the results were too sensitive to the choice of instruments. The overall results were, however, very robust across alternative specifications of the multiple output technology explored in preliminary estimation, so this issue did not seem empirically substantive.

3. Measures of Returns, Substitutability, and Efficiency

The productive contributions of outputs, inputs, and exogenous factors were represented in PJF by $\varepsilon_{DO,m} = \partial ln\ D_O/\partial ln\ y_m$, $\varepsilon_{DO,j} = \partial ln\ D_O/\partial ln\ x_j$, and $\varepsilon_{DO,b} = \partial ln\ D_O/\partial t_b$ elasticities, computed as $-\varepsilon_{y1,m} = \partial ln\ y_1/\partial ln\ y_m$, $-\varepsilon_{y1,j} = \partial ln\ y_1/\partial ln\ x_j$, and $\varepsilon_{y1,b} = -\partial ln\ y_1/\partial t_b$ to facilitate conceptually linking the results to the more familiar production function framework. So, for example, a (negative) $\varepsilon_{DO,j}$ measure is interpreted as the "returns" to input x_j, or its contribution to production, similar to the (positive) coefficient of a Cobb-Douglas production function. Bias measures indicating the adaptations in these returns from deregulation – such as $B_{jR} = \partial\varepsilon_{DO,j}/\partial R$ – were also constructed.

These measures cannot directly be used to analyze substitution patterns, or to infer cost efficiency in the output and input markets. However, indicators to accomplish these tasks may be developed from shadow values of outputs and marginal products of inputs, computed with respect to D_O. These measures can then be used to represent the slopes of product transformation curves and isoquants (i.e., marginal rates of transformation, MRT, and technical substitution, MRTS) that with profit maximization would be equated to the associated output and input price ratios. Second-order derivatives can also be constructed to reflect the curvature of these relationships and thus output and input substitutability.

That is, for inputs, the elasticities $\varepsilon_{DO,j}$ are proportional versions of the distance function-based "marginal products," MP_j^{DO}, which can be recovered from $\varepsilon_{DO,j}$ as:

$$MP_j^{DO} = D_{O,j} = \partial D_O/\partial x_j = \partial ln\ D_O/\partial ln\ x_j \bullet (D_O/x_j) = \varepsilon_{DO,j} \bullet (D_O/x_j). \quad (2)$$

Such measures represent the implicit (relative shadow) value of x_j, and thus have implications for x_j demand, since in profit-maximizing equilibrium $VMP_j^{DO} = MP_j^{DO} \bullet p_{y1} = p_j$, or $MP_j^{DO} = \partial D_O/\partial x_j = p_j/p_{y1}$ (where VMP_j^{DO} is the value of the marginal product, p_{y1} is the price of the normalizing output, and p_j is the market price of x_j). They are thus conceptually more consistent with measures from a more familiar production function than are the associated output measures developed below.

Further, MP_j^{DO}/MP_k^{DO} captures the marginal rate of technical substitution $MRTS_{j,k}$, which, if farms are cost-efficient, will reflect relative input prices p_j/p_k. Thus, cost efficiency can indirectly be considered from a distance function model that directly represents only technological processes. However, $MRTS_{j,k}$ is more interpretable as in indicator of substitutability if expressed as a *relative* contribution in terms of output production or shares, as noted in Grosskopf et al. (1995). Such a measure also more naturally derives from a translog form since it becomes a ratio of the $\varepsilon_{DO,k}$ elasticities:

$$sub_{j,k} = (MP_j^{DO}/MP_k^{DO})/(x_k/x_j) = \varepsilon_{DO,j}/\varepsilon_{DO,k}\ , \qquad (3)$$

where $sub_{j,k} > 1$ (<1) indicates more difficult (easier) substitution. So optimization can be assessed by comparing $sub_{j,k}$ with $V_j/V_k = p_jx_j/p_kx_k$.

In turn, Morishima elasticities of substitution for inputs may be computed to capture the second-order effects between x_j and x_k, thus more clearly representing the curvature of the isoquant (in either absolute or relative terms):

$$\begin{aligned} M_{j,k} &= -d\ln (D_{O,j}/D_{O,k})/d\ln (x_j/x_k) = x_j\bullet[(D_{O,jk}/D_{O,k})-(D_{O,jj}/D_{O,j})] \\ &= (x_j/D_{O,k})\bullet\partial D_{O,k}/\partial x_j - (x_j/D_{O,j})\bullet D_{O,,j}/\partial x_j = \varepsilon_{k,j} - \varepsilon_{j,j}\ , \end{aligned} \qquad (4)$$

where the subscripts refer to the derivatives with respect to j and k, $D_{O,j} = \partial D_O/\partial x_j = MP_j^{DO}$, and $D_{O,jk} = \partial D_{O,j}/\partial x_k = \partial MP_j^{DO}/\partial x_k = \partial^2 D_O/\partial x_j\partial x_k = \partial^2 D_O/\partial x_k\partial x_j = D_{O,kj}$. These elasticities more appropriately represent asymmetry in the substitutability relationship than Allen-Uzawa substitution elasticities when the number of inputs (or outputs below) exceeds two, as shown by Blackorby and Russell (1989). The $\varepsilon_{k,j}$ elasticities are, however, closely related to both Allen-Uzawa elasticities and the bias terms developed in PJF since the Allen elasticity $\sigma_{k,j}$ is $\varepsilon_{k,j}/\varepsilon_{DO,j}$ for the distance function specification, or $D_{O,kj}D_O/D_{O,k}D_{O,j} = (\beta_{kj}+\varepsilon_{DO,k}\varepsilon_{DO,j})/\varepsilon_{DO,k}\varepsilon_{DO,j}$, and cross-effects between x_k and x_j are reflected in the bias measure $B_{k,j} = \partial\varepsilon_{DO,k}/\partial \ln x_j = \varepsilon_{DO,k}(\varepsilon_{k,j}-\varepsilon_{DO,j}) = \beta_{kj}$.

The components of $M_{j,k}$ are thus elasticities of MP_k^{DO} and MP_j^{DO} with respect to x_j. For example, $\varepsilon_{k,j} = \partial \ln MP_k^{DO}/\partial \ln x_j$ captures the absolute change in the productivity or value of x_k with a change in x_j, and $\varepsilon_{j,j} = \partial \ln MP_j^{DO}/\partial \ln x_j$ represents the impact of a change in $(\ln x_j)^2$, providing information about the curvature of the function in x_j-y space. $M_{j,k}$ thus reflects the relative adaptation of MP_k^{DO} and MP_j^{DO} to a change in x_j given x_k (so $M_{j,k}$ and $M_{k,j}$ elasticities are not symmetric since the latter reflects x_k changes holding x_j fixed). Also, elasticities similar to $\varepsilon_{k,j}$ can be defined in terms of the shift variables t_b. In particular, we can define $\varepsilon_{k,R} = \partial \ln MP_k^{DO}/\partial R$ as the reform impact on MP_k^{DO}.

Interpretation of the output-oriented coefficients and elasticities is less familiar than for the inputs but is the primary focus of our analysis due to the PJF finding that output composition changes comprised the primary adaptation to reform. To explore the output patterns, measures analogous to those for the inputs can be constructed [as developed in Grosskopf et al. (1995)]. In this context the first-order derivatives $\partial D_O/\partial y_m$ (or $-\partial y_1/\partial y_m$) are typically motivated in terms of (relative) shadow values:

$$r^*_m = D_{O,m} = \partial D_O/\partial y_m = \partial \ln D_O/\ln y_m\bullet(D_O/y_m) = \varepsilon_{DO,m}\bullet(D_O/y_m). \qquad (5)$$

Färe et al. (1993) and Färe and Grosskopf (1990) show that this definition of the y_m shadow value stems from the distance function duality with the revenue function, which is used to support a distance-function-oriented Shephard's lemma. Such a definition represents the shadow value *relative* to the price of the normalizing output. That is, r^*_m is the revenue-deflated relative output shadow price, $Z_m/R(p,x) = Z_m \bullet(\partial D_O/\partial y_1)/p_{y1}$ (where Z_m is the un-normalized shadow value that in equilibrium would be equal to the output price with profit maximization), R(p,x) is the revenue function, and p_{y1} is assumed equal to the shadow value (since otherwise r^*_m depends on other shadow prices we wish to define). This is similar in spirit to the idea that, for an input, $MP_j=p_j/p_{y1}$; in this case $r^*_m = (p_{ym}/p_{y1})\bullet(\partial D_O/\partial y_1)$ in equilibrium.

The important implication is that *ratios* of these shadow values are analogous to the input MRTSs; $MRT_{m,n} = r^*_m/r^*_n$ will be equal to the output price ratio p_m/p_n with profit maximization. In turn, a *relative* $MRT_{m,n}$ measure, constructed as

$$sub_{m,n} = (r^*_m/r^*_n)/(y_n/y_m) = \varepsilon_{DO,m}/\varepsilon_{DO,n}\,, \tag{6}$$

can be compared to the relative values $V_m/V_n=p_m y_m/p_n y_n$ to assess output cost efficiency.

In addition to the $MRT_{m,n}$ or $sub_{m,n}$ measures reflecting the slopes of production transformation curves, Morishima elasticities reflect the curvature or extent of substitutability between outputs, as represented by the *change* in the $MRT_{m,n}$:

$$\begin{aligned} M_{m,n} &= -d\ln (D_{O,m}/D_{O,n})/d\ln (y_m/y_n) = y_m\bullet[(D_{O,mn}/D_{O,n})-(D_{O,mm}/D_{O,m})] \\ &= (y_m/D_{O,n})\bullet\partial D_{O,n}/\partial y_m - (y_m/D_{O,m})\bullet\partial D_{O,m}/\partial y_m = \varepsilon_{n,m} - \varepsilon_{m,m}\,, \end{aligned} \tag{7}$$

where the subscripts refer to first and second partial derivatives of the $D_O(x,y)$ function; $D_{O,m} = \partial D_O/\partial y_m = r^*_m$, $D_{O,mn} = \partial D_{O,m}/\partial y_n = -\partial r^*_m/\partial y_n$, and $\partial \ln D_n/\partial \ln y_m= \partial \ln r^*_n/\partial \ln y_m = \varepsilon_{n,m}$.

The underlying shadow value elasticities $\varepsilon_{n,m}$ indicate how the valuation of y_n adapts as y_m changes, implying output demand and composition changes. The Morishima elasticities thus indicate the extent of substitutability through *relative* shadow values; high (low) values of $M_{m,n}$ reflect low (high) substitutability [as discussed further in the context of relative input demand elasticities in Blackorby and Russell (1989) and Huang (1991)]. Finally, reform impacts can be represented analogously as $\varepsilon_{n,R} = \partial \ln r^*_n/\partial R$.

4. The Results

The model was estimated using data from the *New Zealand Meat & Wool Boards' Economic Service* (now called the Meat and Wool Economic Service of New Zealand), which is an unbalanced sample of 32 geographically and economically similar farms over the 1969-91 time period. The model is based on a translog function with no time trend or cross x-y terms (since they were statistically insignificant). The results in PJF showed virtually no technical inefficiency (and the minimal evidence of inefficiency found seemed linked to debt/equity ratios) and that the primary impact of reform was to drive output composition changes. Our focus is thus on these changes.

The output production patterns from the data are summarized in Table 1. For outputs, only y_{BDO} (beef and deer) increases over the whole time period, with a 1.5

percent average annual growth rate for 1969-91 (computed by constructing logarithmic growth rates per year, $\text{dln}\ y_m/dt = \ln(y_{mt}/y_{mt-1})$, and then averaging the yearly rates). After deregulation, wool (y_W) and lamb (y_{LMB}) production declined by 3-6 percent per annum (p.a.) during 1985-91, whereas y_{BDO} increased by 9.1 percent p.a. This is in contrast to the 1975-79 period where y_W and y_{LMB} increased by 8-13 percent p.a. and y_{BDO} production dropped from previous levels. In between it seems some adjustment may have occurred, either in preparation for anticipated regulatory shocks or simply in response to apparent demand for products. Note also that y_{SO} appears to be dropping in the last period, although this is somewhat misleading due to a significant increase in y_{SO} in 1985, reflecting reform-induced stock reduction, and a large drop in 1991, likely due to farmers reaching lower desired sheep stocks.

Table 1. Average Annual Growth Rates, Output and Input Levels and Prices

Levels	y_W	y_{LMB}	y_{BDO}	y_{SO}	x_L	x_K	x_M	x_{PS}	x_{LND}	x_{SI}	x_{BDI}
1969-91	-0.005	-0.005	0.015	-0.004	-0.026	0.103	0.067	0.079	-0.001	-0.006	-0.003
1969-74	-0.058	-0.117	-0.050	-0.076	-0.104	0.141	-0.043	0.020	-0.026	-0.061	-0.024
1975-79	0.078	0.128	-0.020	0.049	0.013	0.188	0.263	0.196	0.008	0.069	-0.063
1980-84	0.009	0.058	0.039	0.054	-0.021	0.072	0.130	0.108	0.001	0.021	0.011
1985-91	-0.030	-0.056	0.091	-0.025	0.016	0.020	-0.038	0.018	0.013	-0.037	0.057
Prices	p_{yW}	p_{yLMB}	p_{yBDO}	p_{ySO}	p_{xL}	p_{xK}	p_{xM}	p_{xPS}	p_{xLND}	p_{xSI}	p_{xBDI}
1969-91	0.076	0.058	0.078	0.006	0.086	0.049	0.006	-0.003	0.068	0.032	0.037
1969-74	0.058	0.004	-0.016	0.051	-0.003	0.060	0.000	0.009	0.065	0.015	-0.008
1975-79	0.240	0.199	0.256	0.210	0.238	0.076	0.002	-0.011	0.194	0.114	0.117
1980-84	0.060	0.092	0.089	0.194	0.125	0.048	-0.005	0.000	0.107	0.002	0.048
1985-91	-0.028	-0.035	0.015	-0.366	0.014	0.017	0.026	-0.010	-0.067	0.004	0.007

Note: y_m and p_m = output levels and prices; x_j and p_j = input levels and prices; W=wool, LMB=lamb, BDO=beef and deer output, and SO=sheep output; L=labor, K=capital, M=materials, PS=purchased services, LND=land, SI=sheep input, and BDI=beef and deer input.

The associated price patterns suggest that price changes drove these adaptations in output composition. The reported average annual decline in wool prices, for example, was nearly 3 percent, and for y_{LMB} was 3.5 percent after 1985. But these averages mask volatile changes, especially for p_{yLMB}. The most dramatic price decline appears for p_{ySO}, which dropped by over 35 percent per year in the post-reform period, after average annual increases of about 20 percent in the previous decade (but significant fluctuations).

Table 2. Substitution and Morishima Elasticities, Outputs

	1969-1991	1969-1974	1975-1979	1980-1984	1985-1991
$\varepsilon_{DO,yW}$	0.358	0.367	0.378	0.372	0.327
$\varepsilon_{DO,yLMB}$	0.148	0.162	0.169	0.172	0.103
$\varepsilon_{DO,yBDO}$	0.282	0.265	0.265	0.266	0.320
$\varepsilon_{DO,ySO}$	0.212	0.205	0.188	0.190	0.251
$sub_{W,LMB}$	2.424	2.264	2.232	2.159	3.186
$sub_{W,BDO}$	1.270	1.385	1.426	1.397	1.021
$sub_{W,SO}$	1.688	1.793	2.003	1.954	1.301
$sub_{LMB,BDO}$	0.524	0.612	0.639	0.647	0.321
$sub_{LMB,SO}$	0.696	0.792	0.898	0.905	0.409
$sub_{BDO,SO}$	1.329	1.294	1.405	1.398	1.275
V_{yW}/V_{yLMB}	2.183	1.799	2.445	2.220	2.681
V_{yW}/V_{yBDO}	1.298	0.948	1.573	1.966	1.079
V_{yW}/V_{ySO}	7.539	2.494	5.939	6.117	16.358
V_{yLMB}/V_{yBDO}	0.625	0.558	0.646	1.070	0.409
V_{yLMB}/V_{ySO}	3.321	1.553	2.395	3.303	6.431
V_{yBDO}/V_{ySO}	7.008	2.773	3.820	3.701	17.824
$M_{W,LMB}$	0.878	0.881	0.884	0.882	0.870
$M_{W,BDO}$	0.762	0.758	0.761	0.760	0.762
$M_{W,SO}$	0.783	0.784	0.779	0.778	0.784
$M_{LMB,BDO}$	0.881	0.892	0.897	0.899	0.827
$M_{LMB,SO}$	0.784	0.792	0.788	0.791	0.746
$M_{BDO,SO}$	0.878	0.871	0.869	0.870	0.893
$M_{LMB,W}$	0.883	0.893	0.898	0.900	0.829
$M_{BDO,W}$	0.803	0.799	0.801	0.800	0.809
$M_{BDO,LMB}$	0.893	0.885	0.885	0.885	0.908
$M_{SO,W}$	0.760	0.755	0.739	0.740	0.784
$M_{SO,LMB}$	0.675	0.681	0.668	0.672	0.645
$M_{SO,BDO}$	0.803	0.796	0.779	0.781	0.833

The first question to address is how these output compositions and price patterns relate to those for the shadow values r^*_m or the (relative) ratios of these shadow values $MRT_{m,n}/(y_n/y_m) = sub_{m,n} = (r^*_m/r^*_n)/(y_n/y_m)$. These measures are presented in Table 2, along with the underlying $\varepsilon_{DO,m}$ and $\varepsilon_{DO,n}$ elasticities. The reported values are slightly different in magnitude than those reported in PJF, as well as being of the opposite sign, since they are based on the distance function itself rather than in terms of y_1. Also, standard errors are not presented because all measures are combinations of elasticities, which are in turn combinations of coefficients, each with their own standard error.Substitutability is most evident for the meat categories. In particular, it seems that substitution away from lamb toward other meat products is relatively easy, and this substitutability is increasing over time. This contrasts with the apparent difficulty of substituting away from wool, as evident from the corresponding $sub_{m,n}$ elasticities. It is consistent, however, with rising $\varepsilon_{DO,BDO}$ and $\varepsilon_{DO,SO}$ measures and y_{BDO} and y_{SO} output levels, particularly in the late 1980s when the $\varepsilon_{DO,LMB}$ measures were dropping.

These measures can be compared to the market value shares to assess cost efficiency. The $sub_{m,n} = r^*_m y_m / r^*_n y_n$ and $V_{ym}/V_{yn} = p_m y_m / p_n y_n$ ratios are very similar for the y_W-y_{LMB}, y_W-y_{BDO} and y_{LMB}-y_{BDO} relationships but are not even close for ratios associated with y_{SO}. This provides evidence of adjustment costs. The estimated valuation (or contribution to output) of y_{SO} is large relative to its market price, suggesting farmers were dumping sheep on the market to get rid of it even given the exceedingly low prices resulting from this behavior across farms.

Consideration of the output Morishima elasticities $M_{m,n}$ generates further insights about substitutability. The $M_{m,n}$ measures all fall short of 1, suggesting a limited amount of substitutability across outputs. Greater values for, say, $M_{W,LMB}$, reflect the complementarity or jointness of wool and lamb outputs. None of the measures are low enough to suggest substantive substitutability, emphasizing the difficulties and costliness of adjustment to reform. The measures are also quite consistent across time, suggesting that farmers were not able to substitute products more easily after reform than before.

Turning to the inputs, note from Table 1 that input use also adapted significantly from 1969-91. Purchases of x_M, x_{PS}, and particularly x_K increased during this period, whereas x_{LND}, x_{SI}, and x_{BDI} stayed virtually constant and x_L dropped slightly. The primary increases in input use occurred in the strong growth period of 1975-79, although x_M and x_{PS} growth remained relatively buoyant in the early 1980s. Post-reform patterns indicate declines in both x_M use and x_{SI} stocks and a clear x_{BDI} growth trend, likely due to the lack of financial capital to pay for x_M inputs and an attempt to bring down sheep and increase beef livestock levels to facilitate adjustment to the new economic conditions.

The price patterns show that farm (especially labor) values declined post-reform. The prices of materials inputs and purchased services changed little during this period, with x_{PS} actually decreasing by about 1 percent per year. The remaining input prices increased more significantly. In particular, for farm assets, great price increases (and thus capital gains) are evident for land from the mid-1970s to the reform period, with the late 1970s average growth rate reaching nearly 20 percent p.a. However, after deregulation (1985-1991), land values declined by about 7 percent p.a. Capital value growth also fell, dropping from 7.6 to 4.8 to 1.7 percent p.a. in 1975-79, 1980-84, and 1985-91. And the value of livestock changed significantly, although somewhat surprisingly; the prices of both beef and sheep stocks were depressed post-reform. The substantial post-reform decline in cattle prices was possibly due to low farm value and thus liquidity, so prices stagnated even with the desire to augment cattle stocks.

Table 3. Substitution Elasticities, Inputs

	1969-1991	1971-1975	1976-1980	1981-1985	1986-1991
$\varepsilon_{DO,xL}$	-0.048	-0.150	-0.104	-0.027	0.065
$\varepsilon_{DO,xK}$	0.277	0.316	0.284	0.282	0.234
$\varepsilon_{DO,xM}$	-0.012	0.044	-0.012	-0.051	-0.031
$\varepsilon_{DO,xPS}$	-0.002	-0.007	0.002	0.028	-0.023
$\varepsilon_{DO,xLND}$	1.418	1.247	1.390	1.486	1.535
$\varepsilon_{DO,xSI}$	-0.815	-0.885	-0.841	-0.790	-0.754
$\varepsilon_{DO,xBDI}$	-0.118	-0.147	-0.112	-0.089	-0.119
$sub_{L,K}$	-0.173	-0.474	-0.368	-0.094	0.279
$sub_{L,M}$	4.036	-3.382	8.599	0.515	-2.074
$sub_{L,PS}$	20.425	22.186	-68.632	-0.946	-2.834
$sub_{L,LND}$	-0.034	-0.120	-0.075	-0.018	0.042
$sub_{L,SI}$	0.059	0.169	0.124	0.034	-0.086
$sub_{L,BDI}$	0.404	1.016	0.934	0.298	-0.549
$sub_{K,M}$	-23.398	7.137	-23.374	-5.484	-7.437
$sub_{K,PS}$	-118.403	-46.815	186.559	10.063	-10.160
$sub_{K,LND}$	0.195	0.254	0.204	0.190	0.152
$sub_{K,SI}$	-0.339	-0.358	-0.337	-0.357	-0.310
$sub_{K,BDI}$	-2.340	-2.145	-2.538	-3.175	-1.967
$sub_{M,PS}$	5.060	-6.559	-7.982	-1.835	1.366
$sub_{M,LND}$	-0.008	0.036	-0.009	-0.035	-0.020
$sub_{M,SI}$	0.015	-0.050	0.014	0.065	0.042
$sub_{M,BDI}$	0.100	-0.301	0.109	0.579	0.264
$sub_{PS,LND}$	-0.002	-0.005	0.001	0.019	-0.015
$sub_{PS,SI}$	0.003	0.008	-0.002	-0.035	0.030
$sub_{PS,BDI}$	0.020	0.046	-0.014	-0.316	0.194
$sub_{LND,SI}$	-1.740	-1.409	-1.653	-1.882	-2.035
$sub_{LND,BDI}$	-11.993	-8.455	-12.443	-16.730	-12.926
$sub_{SI,BDI}$	6.894	5.999	7.529	8.890	6.351

The input substitution patterns evident from the measures in Table 3 suggest that anticipatory investment as well as the effects of pre-reform price supports and investment incentives distorted input demand. Overall, these values are not indicative of clear substitution or cost efficiency. The $sub_{k,l}$ measures are volatile due to problems with signs and scale (for example, when $\varepsilon_{DO,PS}$ is in the denominator, the measures become very large). They all deviate from consistency with cost efficiency. Substitutability for inputs varies more dramatically across time than for outputs, and the only $\varepsilon_{DO,k}$ measures that indicate a higher value (marginal product) after reform are those for x_{BDI} and x_{PS}.

Although not tabled, it is worth noting that the Morishima elasticities for these inputs tend to be quite large; very few fall short of 1 (in absolute value). This suggests limited (but perhaps increasing over time) potential for substitution across inputs, which provides some indication why farmers do not appear to be cost efficient in terms of investment in stock inputs.

Finally, we can directly assess reform impacts on the valuation of the outputs and inputs through the $\varepsilon_{m,R}=\partial ln\ r^*_m/\partial R$ and $\varepsilon_{k,R}=\partial ln\ MP_k^{DO}/\partial R$ measures in Table 4. Due to the logarithmic form, a positive sign shows an increase in the valuation for either an output or input in response to reform. And the values for the pre-reform periods indicate what the impact of reform would have been, given economic conditions at that time.

Table 4. Reform Measures

		1971-1975	1976-1980	1981-1985	1986-1991
$\varepsilon_{yW,R}$	0.040	0.115	0.033	-0.028	-0.012
$\varepsilon_{yLMB,R}$	-0.320	-0.205	-0.274	-0.357	-0.562
$\varepsilon_{yBDO,R}$	0.279	0.362	0.278	0.213	0.218
$\varepsilon_{ySO,R}$	0.387	0.473	0.406	0.331	0.304
$\varepsilon_{xL,R}$	-0.169	0.118	-0.102	-4.260	0.301
$\varepsilon_{xK,R}$	-0.141	-0.037	-0.152	-0.206	-0.235
$\varepsilon_{xM,R}$	-0.886	0.675	-0.469	-0.169	-0.315
$\varepsilon_{xPS,R}$	11.766	2.781	-3.675	-2.606	1.371
$\varepsilon_{xLND,R}$	0.129	0.201	0.118	0.060	0.086
$\varepsilon_{xSI,R}$	-0.017	0.061	-0.021	-0.093	-0.070
$\varepsilon_{xBDI,R}$	0.122	0.195	0.111	0.052	0.080

For outputs, in the post-reform period there was a definitive drop in the shadow value of lamb and a smaller decline for wool. It seems the impact would not have been as severe for either output earlier in the sample (except for the early 1980s for wool) due to changes in substitution patterns. For inputs, reform reduced the value of sheep livestock and augmented that for cattle, as well as decreasing the value of farm capital.

5. Concluding Remarks

In this study we have further documented that output composition changes and adjustment difficulties driven by New Zealand economic reform in the 1980s were associated with limited substitutability and thus difficulties attaining cost efficiency. In particular, cost efficiency (subject to adjustment sluggishness) appears to have been closely attained for outputs, as farmers faced and responded to changes in economic conditions. However, very limited input substitutability and flexibility seem to have constrained input cost efficiency, and dramatically curtailed the returns to farmers.

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